A Methodology for Measuring the Property Flood Resilience (PFR) of Households at the Risk of Flooding

Taiwo Adedeji

A thesis submitted in partial fulfilment of the requirements of Birmingham City University for the degree of Doctor of Philosophy

June 2022

Faculty of Computing, Engineering and Built Environment,
Birmingham City University.

A METHODOLOGY FOR MEASURING THE PROPERTY FLOOD RESILIENCE (PFR) OF HOUSEHOLDS AT THE RISK OF FLOODING

TAIWO J. ADEDEJI

Doctor of Philosophy
2022

A METHODOLOGY FOR MEASURING THE PROPERTY FLOOD RESILIENCE (PFR) OF HOUSEHOLDS AT THE RISK OF FLOODING

TAIWO JOHN ADEDEJI (B.Sc., MSc.)
(STUDENT NO: 16147278)

A thesis submitted in partial fulfilment of the requirements of Birmingham City University,
Computer Engineering and Built Environment, Birmingham for the degree of Doctor of Philosophy (PhD)
June 2022

This work or any part thereof has not previously been submitted in any form to the University or to any other body whether for the purpose of assessment, publication or for any other purpose. Save for any express acknowledgements, references and/or bibliographies cited in the work.

Signature ……………………………………

Date ……23/06/2022……………………………

ABSTRACT

The risks of flooding have been ever present for homes located in flood plains or close to coastal areas. Surface water flooding and flash flooding in urban areas means that homes located away from flood plains and coastal areas may also be exposed to flooding. While some of these homes have developed a level of resilience over time, many have very poor, inadequate or lack any level of resilience to flooding. This raises the questions as to what level of resilience is appropriate; how best to quantify flood resilience at the level of the individual homes; and what steps to take to improve resilience. However, despite the current focus on resilience within UK flood risk management policy and strategy, no accepted definition for the term exists and, more significantly, there is a lack of a general measurement framework for determining the level of flood resilience for an individual home. Hence, the aim of this research is to develop a model for reliably measuring the level of resilience present in individual homes at risk of flooding.

In order to establish the framework for this research, a comprehensive literature review was conducted on the concept of resilience and flood risk management in the context of households. Based on a synthesis of the literature, a conceptual framework of Property Flood Resilience (PFR) at the household level was developed which comprises both building and human components. A quantitative research methodology was employed towards testing the design and validity of the PFR framework, with data collected through a questionnaire survey of homeowners who have experienced flood events on their properties.

Different sets of analyses were performed on the data collected, including the normality test, analysis of variance (ANOVA), correlation analysis, and regression analysis. The overall PFR was modelled with the building and human resilience using multiple linear regression, and from this model it can be inferred that building and human resilience significantly predicts the level of the overall PFR. Further, building resilience were found to be positively and significantly associated with human resilience (at $r = 0.407$). This implies that increases in the resilience of the building component will result in an increase in the human resilience and ultimately increase in the overall resilience of the individual household.

The PFR model developed provides valuable information on the flood resilience levels currently present in the home for the benefit of homeowners. It also provides property experts and surveyors with a tool to estimate resilience levels within a property, enabling them to provide impartial and professional advice on risk exposure and measures that can be adopted to help further protect properties. The model also serves as an evidence based tool to inform insurers on the levels of resilience present within a given property and to consider how this might affect insurance premiums and excesses which will in turn improve the role of flood insurance as a market-based incentive, and to complement Government‘s effort in encouraging homeowners to invest in PFR.

ACKNOWLEDGEMENTS

Thanks be to God almighty who always gives us victory through our Lord Jesus Christ!

Many individuals and organisations deserve my gratitude for their tireless efforts and active support, which included contributing their time, ideas, and talents, granting or enabling access to participants, and offering prayers.

Firstly, my appreciation goes to my Director of Studies, Doctor Hong Xiao for his tireless effort in providing guidance, support and comments as supervisor. Your extreme commitment to the success of the research and your great support and encouragement during tough times is second to none. Also, a huge thank you for the constructive criticisms and valuable inputs through the various phases of the research.

My profound gratitude and respect go to Professor David Proverbs for instigating this research, and for granting me this unique opportunity to work with you. I started this research journey with you as my Director of Studies and your belief in me from the start of the study, ongoing reassurance, steadfast support, and encouragement during the difficult periods of writing my thesis were vital in keeping me going and bringing this endeavour to fruition. Your phrase "keep writing" was a big motivator in and out of the research.

I likewise extend my sincere appreciation to Professor Victor Oladokun, my second supervisor, who saw this opportunity and believed that I am capable of carrying out research of this magnitude. Thank you for this platform and I hope I have made you proud. I am grateful for your consistent support and guidance which helped shape the direction of the research.

I'd also like to convey my gratitude to those flood victims who took the time to fill out the questionnaire survey. Your responses have made a significant contribution to the research project's success.

I am grateful to Birmingham City University for providing me with funded postgraduate research, as well as the chances and support I received during my time there. I would like to thank the research, teaching, and administrative staff of the Faculty of Computing, Engineering, and the Built Environment, as well as the Doctoral Research College, for their kind assistance throughout my PhD journey. I also want to thank Sue Witton, the Doctoral Research College Programme Administrator, for your assistant.

I am also grateful to the academic and non-academic staff of the department of Industrial and Production Engineering, University of Ibadan, Nigeria where I had both my BSc and MSc. Prof A.E Oluleye, Prof. Akanbi, Prof. Anyaeche and Dr. Kolawole just to mention a few thanks for faithfully building the blocks.

Furthermore, my sincere appreciation goes to Engr. Oluwakemi and Fatimah Mustapha for financially supporting my coming to the UK and ensuring that I did not miss this PhD opportunity. Also, a very big thank you to Dr Okunribido for your financial support and Dr. Ajisegiri for the advisory role you play. Thank you so much!

Of course, none of this would have been possible without the unwavering support of family: mostly my dad Pastor J. Adedeji, and my siblings Kenny Adedeji, Gabriel Adedeji, Tosin Ayoola and Mrs Gloria Adedeji; and friends: Oluseye Adebimpe, Bismark Aha, Varsha Radhakrishnan, Oluwayemi Oladunjoye, Akinola Siyanbola, Ugochukwu Chibuisi, Kudirat Ayinla.

I am also grateful for the families here in the UK; Engr Isaac and Mrs Joy Olanipekun; Mr Oyefunsho and Taiwo Oshowole; Pastor and Mrs Tolani-Atanda, Mr and Mrs Agbaje and the Liberty Church family, you have all made my stay in the UK a warm one.

To my beautiful wife, Grace, and my adorable daughter, Peace. I thank you both from the bottom of my heart for your patience, kindness, and encouragement as I worked on this thesis. You were an incredible source of inspiration for me, and I couldn't have done it without you. Indeed, Grace and Peace have been multiplied!

DEDICATION

This thesis is dedicated to God who rules over the floodwaters and who reigns as king forever. To my beautiful daughter Peace, you are priceless, and to my gorgeous wife, you are the best. Finally, to my mum of blessed memory, keep resting and singing.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATIONS AND ACRONYMS

ABI	Association of British Insurers
ANN	Artificial Neural Network
ANOVA	Analysis of Variance
CDRM	Community Disaster Risk Management
CIRIA	Construction Industry Research and Information Association
CoP	Code of Practice
DEFRA	Department of Environment, Food and Rural Affairs
DV	Dependent Variables
EA	Environment Agency
EAD	Expected Annual Damage
FRA	Flood Risk Assessment
FRM	Flood Risk Management
GAR	Global Assessment Report
HFA	Hyogo Framework for Action
ICC	Intra-Class Correlations
IV	Independent Variables
KMO	Kaiser-Meyer-Olkin

MRA	Multiple regression analysis
NaFRA	National Flood Risk Assessment
NFF	National Flood Forum
NPD	National Property Dataset
PFR	Property Flood Resilience
PTE	Potentially Traumatic Events
RFCC	Regional Flood and Coastal Committee
R_{wg}	Inter-Rater Agreement Index
SEM	Structural Equation Model
SPSS	Statistical Package for the Social Sciences
VIF	Variance Inflation Factor

CHAPTER ONE: GENERAL INTRODUCTION

1.1 INTRODUCTION

This chapter, which is an overview of the thesis, presents the research background and context of the study. The background information, rationale and the research context are presented. Subsequently, the aim and objectives are presented followed by a summary of the research methodology adopted. Thereafter, a statement of the scope, and contribution of the study are described. The chapter concludes with an explanation of the organisation of the thesis.

1.2 RESEARCH BACKGROUND

The Global Assessment Report (GAR) on Disaster Risk Reduction, a key report based on global analysis, finds that disasters have deep and devastating impacts on development, the performance and economy of a nation (UNISDR, 2013). Disasters do this by undermining long-term competitiveness and sustainability which in turns hamper growth and development. Floods are the most common natural disaster in both developed and developing countries. Meanwhile, floods are not only the most common but also placed among the most devastating natural disasters in the world, claiming more lives and causing more damage to properties, both residential, commercial and critical infrastructure, than any other natural phenomena (Etuonovbe, 2011). According to Fay et al (2009) floods currently account for half of the losses across the world arising from natural disaster. Globally, it is estimated that floods constitute about 43% of the total number of natural disasters, 47% of all weather-related disasters, and has affected over 2.3 billion people within 1995–2015 (CRED, 2015). While the damage caused to properties is usually obvious, the impacts on people can be more subtle, particularly in cases where drowning and serious injury is absent during a flood event. There is always potential to damage the physical and mental health of households who are affected by them which can be even more devastating (Tunstall et al., 2006; Ranger et al., 2011). On a global scale, the numbers of people affected by floods and the financial, economic and insured damages have all increased (Ranger and Surminski, 2013). This is due to the rapid increase in the frequency and consequences of these extreme flood events in recent decades (Bouwer et al., 2007; Zevenbergen et al., 2013). The worldwide increase in frequency of extreme weather events has been reflected in the UK. The primary cause of concern for this increase in the UK would seem to be the warmer, wetter winters resulting to higher prior wetness and increase flooding together with more intense summer rainfall causing more summer pluvial flooding (Lamond, et al., 2012). Over the past two decades there have been several severe flood events recorded such as the Boscastle in 2004; Carlisle and North Yorkshire in 2005; winter and summer flooding of 2007; Northumbria in 2008; Cockermouth flooding in 2009; Cornwall flooding in 2010; Newcastle pluvial flood of 2012; the Cumbria flooding of 2016; among other flood events which have become very topical in the UK and moved up on both political and research agendas. These flood events have caused considerable damage to properties and lives, with millions of homes affected. While some of the affected properties experienced a fairly shallow flooding that took several months to repair, others were immersed in deep water flooding with extensive damage to the structure and contents demanding significant financial sums for repairs and replacements.

1.2.1 Increasing Flood Risk In The UK

Consequently, flood risk in the UK is on the increase (Environment Agency, 2011). According to figures from the Environment Agency (2014), it is estimated that there are around 5.4 million properties at risk of flooding in England. Of these, 2.4 million are at risk from rivers or the sea, 3 million from surface water and 600,000 are at risk from both. Estimates suggest that in England and Wales over £220 billion worth of property is potentially at risk of flooding, from rivers, groundwater, sewers and coastal excesses (Kenney, et al., 2006). In the UK, annual flood damage is estimated at £1.1 billion and expected to rise to as much as £27 billion by 2080 under a worst-case climate change scenario (Foresight, 2004). And with this growing flood risk, the need to address these challenges becomes more apparent (Adedeji et al., 2018).

1.2.2 Mitigation Approaches

A number of innovative approaches have been developed towards reducing the impacts of floods on homes (Oladokun et al., 2017). At the outset, structural measures such as flood defences, dams and levees were put in place to provide protection against flooding (Proverbs and Lamond, 2017). While these traditional flood defences may be available to provide protection against coastal and river flooding for large communities, there will always be some properties that would not benefit from these schemes. Also, such defences are not likely to deal properly with localised pluvial, surface water or groundwater flooding. Sources of flooding, such as blocked drains, surface water run-off and groundwater flooding, may also pose a residual risk and must be properly managed (Department for Communities and Local Government, 2009). These forms of floods are seen by many as an invisible hazard, which can often strike with little warning in areas with no recent record of flooding (Houston, et al., 2011). It is also difficult to predict (Houston, et al., 2011). Consequently, there will always be a residual risk which could occur as a result of the failure of flood management infrastructure such as a breach of a raised flood defence, a severe flood which causes a flood defence to be overtopped, floods outside the known flood risk areas, blockage of a surface water sewer or failure of a pumped drainage system (Department for Communities and Local Government, 2007). It is not economically viable to protect all of these properties from the threat of flooding. Despite the huge investment in structural approaches and engineering measures, flood still remains a big threat to buildings and the wellbeing of humans (DEFRA, 2016).

In recent years, UK flood risk management policy has shifted towards recognising that it is no longer considered feasible to prevent all flooding, and instead, efforts should be towards improved management as captured under the *living with water* philosophy (DEFRA, 2005). This approach entails recognising that some flooding will occur and adopting approaches that help to reduce the impacts and improves resilience (Oladokun et al., 2017). More recently, the concept of flood resilience has gained wide recognition in the domain of flood risk management (FRM) (Oladokun et al., 2017). However, in the context of property level flood protection, the concept focuses on the development and adaptation of buildings to the risk of flooding (Wingfield et al., 2005; Kazmierczak and Connelly, 2011). This involves constructing buildings that are resilient to flood risk using features that prevent flood damage to the components of a building, such as the sub-structure and super structure, services, fixtures and fittings and the effect that flood water has on them (Jha et al., 2012). It also captures adapting existing buildings to flood risk by retrofitting the buildings to become resilient to floods. Resilient design also ensures that items such as electric sockets and service meters are raised above expected flood levels and the use of resilient materials that do not deform or disintegrate on contact with floodwater.

1.3 RESEARCH RATIONALE

Much has been done and put in place to ensure the quick recovery of buildings from the impact of flooding through the use of property level flood protection (Lamond et al., 2016). Meanwhile, as important as these measures are, their efficacies to a large extent depends on the characteristics (such as socio-economic factors) of the residents. Humans will continue to interact with buildings and so it becomes essential to recognise the human factors that promote resilience against the impact of flooding within the building. For example, a homeowner's decision to choose a lower flood insurance scheme or exclude content insurance based on their financial capacity will impact the household resilience. Therefore, factors such as financial capacity, level of flood awareness, exposure rate and previous flood experience will influence decisions taken on the level of resilience in the building. That is, the residents have roles to play in determining the degree of resilience present in a building. Much of the research on property flooding is focused on either making the building or the human components resilient (ODPM, 2003; Joseph et al., 2015; Lamond et al., 2019). Most of these considerations tends to focus only on the physical structure, that is, the building (ODPM, 2003), however, the human component also merits consideration and it is essential to consider both components concurrently in order to improve the resilience of the household.

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 a system (Carpenter et al., 2001; Walker et al., 2002). Therefore, as important as it is to have a resilient property, it's 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 property flood resilience (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 the PFR, considering both the building and human components.

The foregoing discussions have highlighted the significance of the PFR measures in minimising flood impacts. The conclusion drawn from these discussions are 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 its capacity. There is a lot of support for this conclusion in the literature (Lamond, et al., 2017). The FRM has for instance demonstrated that the typical range of the PFR measures for properties have 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 human, is enormous and almost immeasurable (Joseph, 2014). It is against this background that this research undertakes to shed new light on FRM by applying the concept of resilience as a fresh perspective for evaluating the effectiveness of the 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 against flood impacts in individual homes exposed with significant flood risk exposure.

1.4 RESEARCH CONTEXT

Flood related research is multidisciplinary in nature (Lamond, 2008; Joseph, 2014). In the last two decades, much research has been conducted in the FRM field which cut across several disciplines, each of them focusing on different aspects of flood risk. For instance, the physical sciences focus on short term flood prediction, engineering discipline on flood damage protection, and social science considers aspect of vulnerability and economic damage assessment. The current study is placed broadly within the socio-technical domain of FRM but more specifically placed within the scope of PFR. Therefore, the primary focus is the design intervention applied for flood prevention (resistance) and flood damage reduction (resilience) (Tagg, et al., 2016) to safeguard both lives and properties. Combining both components, buildings and humans, falls in line with the CIRIA definition of the term property flood resilience (PFR), in their publication *the Code of Practice for Property Flood Resilience* which encapsulates the measures applied to ensure that both people and buildings are less susceptible to the impacts of flooding (Kelly, et al., 2019).

However, to understand the flood mitigation approach, a deep understanding of the full impacts of flooding on properties and lives is required. This is necessary to gain insight into the operations of the mitigation measures which will in turn helps to offer a reliable contribution to the flood management policies in the best interests of all (Green et al., 1994). Damage to property, infrastructure and human lives has been studied in some detail and is well dispersed across the literature (Penning-Rowsell and Wilson, 2006; Penning-Rowsell et al., 2010). Meanwhile, concerning property level protection, the focus is not on flood defences like flood embankments, dykes, levees and other hard engineering structures. It has been acknowledged that flood risk can no longer be totally prevented, so the attention is on the use of flood resistance and resilience measures in both new and existing buildings. There are a lot of researches on flood protection within the UK particularly ones with less reliance on hard engineering measures and extensive research on householder experience (EA/DEFRA, 2005; Joseph et al., 2011; Rose, 2019). Most of these researches claim that a residual risk will remain after these engineering measures have been put in place. Examples of residual flood risk include: i.) the failure of flood management infrastructure; or (ii) a severe flood event that exceeds a flood management design standard. Therefore, the focus is on these residual risks. It is in response to this form of risk that the PFR was designed (Department for Communities and Local Government, 2009). According to *the Code of Practice for Property Flood Resilience*, the PFR is taken as any measures that can be applied at a property level to make people and their property less vulnerable to flood impacts (Kelly, et al., 2019). These PFR measures have been classified into two main categories, the resistance measures (designed to keep water at bay) and the recoverability measures (required to minimise floodwater impacts (both direct and indirect) when water enters into the property).

1.5 STUDY AIM AND OBJECTIVES

The aim of this research is to develop a model for reliably measuring the level of resilience present in individual homes at risk of flooding. To achieve this aim, the research will have the following objectives:

i. To establish from theoretical perspective the nature of flood risk, their causes and impacts, with particular reference to impacts on households and to identify measures that are available to reduce or eliminate the identified flood impacts.
ii. To discuss the concept of resilience and its applicability to the study of PFR measures, with the aim of incorporating it in the PFR model.
iii. To develop a conceptual framework, specific to domestic property in the UK, for estimating the property level resilience based on a synthesis of the extant literature.

iv. To elicit information, from homeowners in the UK with flood experience, on the PFR measures installed in their properties and their effectiveness during flood events.

v. To explore appropriate statistical analysis to the level of PFR with a view to exploring the relationship between the building, the human and the overall resilience.

vi. To test, refine and validate the PFR model towards its predictive accuracy and potential relevance for practical application in flood risk management at individual home level.

vii. To draw conclusions from the findings of the study to provide a basis for proposing implications for flood risk management at household levels and make recommendation for further studies.

1.6 RESEARCH APPROACH

According to Creswell (2009), the driving forces for the choice of a research methodology in any study are not the advantages or disadvantages associated with a particular method but the nature of the research problem or the objectives of the study. Therefore, based on the research aim geared at developing a model to measure the level of flood resilience present in individual homes at the risk of flooding, a quantitative approach to this study was considered appropriate. Such approach implied that the study presumes that the “truth” is a measurable fact that exists in the real world and that quantitative dimensions of PFR can be objectively and independently measured using specific quantitative methods and frameworks (Creswell, 2003). Evidence from the literature on similar studies also supports the adoption of a quantitative approach (Lamond, 2008; Joseph, 2014).

The quantitative data was collected from the UK household in flood risk areas. In order to collect empirical data from the target population, a self-administered questionnaire via mail was considered to be the most appropriate data collection method. The reasons for using the self-administered questionnaire are: it addresses the issue of reliability of information by reducing and eliminating differences in the way in which the questions are asked (Comford and Smithson, 1996); it involves relatively low costs of administration; it can be accomplished with minimal facilities; it provides access to widely dispersed samples; respondents have time to provide thoughtful answers; it assists with asking long questions or complex response categories; it allows asking of similar repeated questions; and also the respondents do not have to share answers with interviewers (Fowler, 2002).

The quantitative data were analysed using both descriptive and inferential methods such as regression models. The research adopted statistical softwares (e.g., Statistical Package for the Social Sciences (SPSS) and GPower in analysing the research data. Inter-rater agreement tests were carried out on the questionnaire data to confirm that there is significant agreement among the respondents in terms of their judgements on the issues being assessed. Statistical analysis techniques including correlation analysis, ANOVA, and multivariate regression analysis were used to make inferences and draw conclusions on the data. Appropriate statistical analysis methods were used resulting in the development of PFR model.

1.7 SCOPE OF THE STUDY

The study will focus on fluvial flooding, surface water flooding and coastal floods, but will not consider any form of water system failure such as fault in private drainage. The UK will form the context for the study during the literature review stage.

This study was set out to develop model for measuring PFR for individual homes in the UK by incorporating both the building and human resilience measures in the model. Only domestic residential property was considered, owing to residential buildings representing a large part of the built environment and playing a vital role in meeting one of the basic human needs of providing shelter (Sirochmanova et al. 2016). Also, most of the research relating to the adaptation of buildings to flood risk has concentrated almost exclusively on residential properties as compared to other kind of properties (Pottinger and Tanton, 2011).

For the purposes of the empirical analysis, only properties that have been directly or indirectly affected by flooding will be included. Data for the study will be taken from the archived information on flood events reported in news, the Environment Agency web-based flood risk map and a survey of homeowners' experience. However, it is not possible to guarantee the veracity of the responses even though efforts have been made to reduce the potential for wrong responses by ensuring that questionnaires were only sent out to homeowners who would have experienced minimum of one flood event to ensure they have access to the information required.

The research is centred on the property owner; for example, in homes with multiple occupants, the survey will be completed by the person who knows the most about the property. In other words, he or she speaks for the entire household and responds to questions about the entire household. He will also be in charge of ensuring that the questionnaire is completed and returned.

In addition, the householder is responsible for answering general household questions such as household size, household income, and number of children, among others. The implication of this is to ensure that the response obtained is specific and accurate to the property, as well as to avoid conflicting and confusing responses from any member of the household who does not know much about the technical features of the property.

It has not been possible in this research to test whether these results will hold true for another international location. However, a simple and comprehensive conceptual framework developed for this research can allow for similar analysis to be carried out in another country.

1.8 BENEFICIARIES

The current state of knowledge in the purview of disaster risk reduction in relation to flood risk research consists of varying dimensions. However, in the context of property flood resilience, most researches focus on the development and adaptation of buildings to the risk of flooding. Also, it was discovered that several resilience frameworks have been developed to measure systems' resilience to flood, however from extensive literature research on the flood resilience on households, it appears that no previous research has focused on the development of a framework to measure property level flood resilience with respect to both the resilience of the building and the humans. This research aims to make a contribution within this clear gap in understanding. By focusing on this particular gap, this study is building on the existing body of knowledge on FRM by opening up a new area of research through the application of the concept of resilience to PFR measures.

In order to increase understanding it has been necessary to develop a framework for analysis that will combine elements for both human and building resilience and quantifies the property level flood resilience. This research offers a framework, which could be used by homeowners, flood management stakeholders and researchers to systematically determine the level of flood resilience in individual homes. This, therefore, represents a significant contribution to knowledge.

The following are the potential implications of the PFR framework that the study aims to develop:

i. The call for the homeowners to take responsibility for FRM at household levels and the recent publication of the Code of Practice (CoP) for PFR has made this study timely as it is expected to provide useful information on the level of flood resilience present in domestic property. It is anticipated that the PFR model developed in this study can be used by homeowners to make informed decisions on improving the flood resilience measures.

ii. The result of this study is a contribution to academic research through the development of a new methodology for quantifying the flood resilience at household level. Therefore, the model can be used by flood risk assessment companies, property experts and surveyors in the UK to estimate the level of PFR, thereby enhancing the insurability of their clients' home.

iii. Often, it can be difficult for insurers to know how to quantify the benefits of any existing resilience measures, particularly those that needs to be proactively deployed (May et al., 2015). Insurers can use the information from this research to advise any potential customer on the benefits of adopting PFR measures and also provides insurers with the means of assessing the level of flood resilience present. This will in turn enable insurers to consider how this might affect insurance premiums and excesses which will in turn improve the role of flood insurance as a market-based incentive.

iv. It is envisaged that the benefits from this research work will be wide-ranging as the findings have the potential to be used by many FRM stakeholders. The key significance to the public at large is that the research has the potential to eliminate the barrier of information in the decision making process on PFR measures. Therefore, it supplements Government policy in encouraging homeowners in flood risk areas to take-up PFR measures.

1.9 ORGANISATION OF THE THESIS

Chapter 1 presents the research context that is undertaken and the justification, and then sets out the aim and objectives. The final sections of the chapter discuss the limitation of the study and the implication in terms of contribution to knowledge.

The literature review for the study was broadly sectioned into two parts which make up the next two chapters. Chapter 2 presents a critical review of the literature on the flood risk, its impacts and the mitigation approaches with larger focus on the UK and particular attention to property level flood protection.

In chapter 3 the concept of resilience is considered. The chapter presents the application of the concept of resilience in different fields of study and also investigate the different dimensions of resilience. Thereafter, it explores how this concept may be adapted for application in the context of the study.

Chapter 4 presents the conceptual framework that brings together, in a logical manner, the appropriate parameters and points of reference to protect both buildings and lives and also show how these variables are helping to minimise flood impacts.

Chapter 5 provides a detailed outline of the research methodology adopted for undertaking this research; in this case a quantitative research methodology was adopted. Arguments are presented justifying this choice of approach and the specific research methods applied to collect data. The data collection and analysis methods are also detailed in this chapter.

Chapter 6 presents the descriptive analysis and findings of the primary data collected through the questionnaire survey. Also, it discusses the empirical issues that have been reported from the survey findings. This chapter first discusses the appropriateness of response rates in the light of existing work. Exploration of the questionnaire data is carried out by using an interrater agreement tests and relative importance index. Then it discusses the instrument validation process by reflecting upon issues such as content validity, reliability and construct validity.

Chapter 7 presents the Pearson's correlation coefficients and analysis of variance (ANOVA). The ANOVA is used to identify key indicator variables that promote the implementation of the PFR model at the household level in the UK.

Chapter 8 is devoted exclusively to the development of the PFR model designed to measure the level of resilience in individual homes. Regression analyses, multicollinearity tests, and residual analyses are employed in the development of the model.

Chapter 9 concludes with discussions of the findings and highlight keys to improving the PFR model designed. It also outlines the potential recommended applications.

Chapter 10 provides the results of the validation of the PFR model. The chapter describes the validation process, which includes both the external and internal validations. In carrying out external validation, academic validation will be established through publication of the research findings.

Chapter 11, presents the conclusions and recommendations drawn from the entire study. A review of the research objectives is presented and the contribution to knowledge arising from the study is stated. The practical implications of the developed model are described with particular emphasis on the potential for the findings to be developed into an expert system. The research was brought to an end by making recommendations for future research.

1.10 SUMMARY

This chapter shows that flooding is an important issue, not just for the UK but across the globe. Flood risk is an increasing phenomenon which has attracted a lot of attention in terms of increased research in this area. Flood related research has included a substantial body of work relating to flood risk management and the concept of resilience which has been embraced as a way to minimise residual flood risk to properties in flood prone areas. It has also been shown that whilst there has been a lot of research on the development and adaptation of new and existing properties to the impact of flooding, there is scope to explore the means of measuring the level of resilience present in such property, which has remained unexplored.

The aim and objectives for this investigation are clearly stated and well-structured to move towards a fuller understanding of the concept of resilience and the property level flood resilience. The scope of the study and the implications of the study were stated.

This chapter has laid the foundation on which the thesis is developed. On this foundation, the thesis continues with the detailed discussion of the research. The following two chapters constitute the critical literature review section of the thesis. The next chapter presents the critical review of the flood risk with the UK, its impacts on properties and lives and the mitigation approaches.

CHAPTER TWO: A REVIEW OF FLOOD RISK MANAGEMENT IN THE CONTEXT OF HOUSEHOLDS

2.1 INTRODUCTION

The chapter presents the review of the extant body of literature on flood risk, the impacts of floods on humans and residential properties and the mitigation approaches. The chapter therefore addresses the first key objective of this research, which sought to critically review the literature on the different forms of flood impacts on households with the view to understanding the necessary measures, which have been put in place to minimise these flood impacts. The review explores the impacts of flooding on households in the UK. Publications were identified based on key words including flooding, flood damage, resilience, adaptation, recovery, flood risk management.

Thus, various features of the literature were structured starting with a review of flood risk and the different types of flooding; the flood impacts to properties and humans; flood mitigation measures that have been put in place; and the flood mitigation approaches adopted in property flood resilience (PFR).

2.2 UNDERSTANDING FLOOD RISK

Whether and to what extent flood protection measures are necessary will depend on the degree of flood risk, and the vulnerability of the property and its occupants (Dhonau, et al., 2016). Before exploring the attributes of the mitigation approaches, this section introduces a number of important concepts that underlie the understanding of risk, and describes how these are used to inform the process and context of the mitigation approaches.

2.2.1 The Make-Up Of Flood Risk

The term risk is understood in different ways by different people (Kron, 2005). While this variety in usage may often be of no significance, it is still essential to define risk, at least for the purpose of scientific discussions, in an unambiguous and consistent manner. Therefore, in the scientific community, it is widely accepted that risk has two components, the chance of an event occurring, otherwise referred to as hazard, and the impact associated with that event (Sayers, et al., 2015). This is usually expressed as the product of these components; the hazard and its consequences (Kron, 2005). However, this is only true for situations where there are people or values that can be affected by a natural phenomenon. Just as a disaster can only occur when people are affected and/or their belongings damaged (Kron, 2005). For instance, a very strong flood in an uninhabited region without human property cannot result in disaster. Similarly, a strong flood in a well-prepared region may not be catastrophic. However, in a poorly prepared region, even a moderate flood event may have a devastating impact. Though the flood hazard is clearly highest in the first case but the consequences are the least, while, the flood risk is highest in the third case. Therefore, what substantiates a flood risk is the presence of lives and properties.

Therefore, in the context of flooding, flood risk is generally defined as the function of hazard, exposure and vulnerability, where the hazard is referred to as the probability of a flood event; exposure is the population and value of assets subject to flooding; while vulnerability is the capacity to deal with the flood event (Kron, 2005; IPCC, 2012). Consequently, damage is only recorded when hazard and exposure combine and the amount of damage suffered by the receptor is a function of its vulnerability.

2.2.2 The Source Pathway Receptor Model

To further understand flood risk, it is important to consider how flood is categorised, the ways in which floods can cause damage to humans and buildings and, equally, the way these damages can be minimised. In the flood risk management literature, there are many ways of categorising floods. The Flemings source pathway receptor model which is adopted by many authors (Fleming, 2001), is an example of a useful depiction for capturing the elements which differentiate between different flood incidents (refer to Figure 2.1). This becomes particularly important as the rationale behind flood risk management in the UK is based on the principle of source-pathway-receptor (Bowker, et al., 2007). This approach has placed greater emphasis on addressing the actual hazard posed by a severe flood rather than the impacts or consequences experienced by the receptors (people, buildings and infrastructure). It is a risk based approach. A source might be heavy rainfall or high tides, while a pathway can be a river or overland flood and a receptor could be a house, field or factory. Figure 2.1 illustrates the source pathway receptor model with the key components clearly shown.

Sayers et al (2015) relates the components of flood risk to the source pathway receptor model. According to them,

- The probability of occurrence of inundation reflects both the probability of the occurrence of the initiating event (which relates to the source of the flood such as rainfall or a marine storm) and the probability that flood waters will reach a particular location in the floodplain, taking account of the performance of the intervening system of wetlands, channels, dams, levees, floodwalls and other structures (the pathway of the flood water).
- While the consequences in case of flood event, reflects both the vulnerability of the receptors and the chance that a given receptor will be exposed to the flood.

For instance, a flood caused by heavy downpour of rain might lead to overflow of river above its banks which might eventually cause damage to lives and properties. This model will be described in subsequent sections, with source discussed in section 2.2, as causes of flooding; pathway discussed in section 2.3 as flood type; and receptor discussed in section 2.4 as flood impacts.

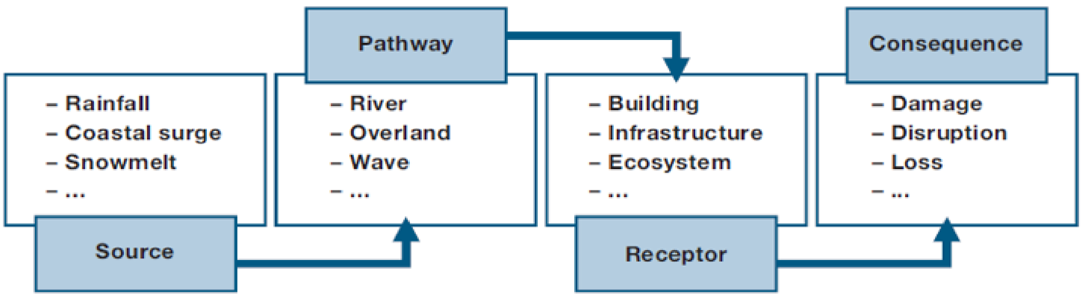


Figure 2.1: The Source, Pathway, Receptor Model

Source: (Jha, et al., 2012)

2.3 CAUSES OF FLOODING

While flooding is a natural event (UNECE, 2000) there are still a number of factors responsible for its occurrence around the world. These factors however, represents the variety of sources from which floods can originate, such as climate change and global warming, population growth, unsustainable development, and changes in land-use patterns which have raised human vulnerability to floods (Kundzewicz, 2000; IPCC, 2007; Doocy et al., 2013; Barsley, 2020).

Mandych (2009) asserted that the specific characteristics of floods are basically determined by a combination of two key factors. The first is the physical process that produces the change in the interaction of the lithosphere, atmosphere and water masses (Mandych, 2009). These entail activities such as deforestation, drainage of wetland and urbanization, expansion of human settlement in floodplains which has resulted to a higher number of homes located at risk areas (Kropp, 2012). Floodplains are natural ecosystems that serve as cushion to the effects of heavy rainfall by providing protection to communities located downstream. According to the EEA (2016), in Europe, about 90% of these floodplains have been lost during the last centuries or have lost their ability as a natural ecosystem to reduce flood risk as a result of urban sprawl, infrastructural development and agriculture. These factors have increased the vulnerability of both human and properties to floods. Also, with respect to this factor, floods may be caused or exacerbated by failure of natural drainage (Du, et al., 2010). Reduced absorption of water occurs when the natural landscape is replaced with non-absorbent infrastructure, e.g., urban expansion or the replacement of wetlands (Du, et al., 2010). Impaired drainage may be associated with poorly planned or inadequate drainage systems in new constructions or drainage systems which become blocked with debris or trash (Poole and Hogan, 2007).

The second key factor depends on the geographic situation in the area where the flood takes place, and this to a large degree, determines the scale of a flood, such as the area and depth of inundation, and its duration (Mandych, 2009). These conditions entail the amount of precipitation and storminess and increased rainfall activity of storms. Precipitation is the generic name given to all kinds of moisture that falls from the atmosphere on to the ground. It includes rainfalls, snow, sleet, glaze and hail. This can have both immediate and longer-term impacts (Du, et al., 2010). Of all these forms of precipitation, rainfall is the most common cause of flooding in the UK. Heavy rainfall can cause localized flash flooding or downstream (riverine) inundation (Du, et al., 2010). In December 2015, as a result of the storms Desmond and Eva, some parts of the UK, experienced a record-breaking month for rainfall, with exceptional amounts of rain falling onto already saturated ground. According to Mandych (2009), the geographical situation plays a critical role in giving rise to floods. However, as the geographical situation combines with the physical process, flood events can occur with huge potential consequences.

2.4 FLOOD TYPES

The nature and consequences of floods vary with respect to its cause (Du, et al., 2010). In order to lay a good foundation for this research work, it is important to review different categories of flooding, which are currently being experienced particularly in the UK. It is believed that for residential property in the UK, all types of flooding are normally covered by domestic house insurance. Lamond (2008) holds that the distinction between flood types is not of critical importance to the householder since their insurance cover is not dependent on it. However, she agreed that it is essential for a researcher, to be aware of this distinction in definition of flooding particularly when comparing estimates of the cost of floods. Simply because some types of flooding are more controllable or preventable than others which in turn influence resilience. Therefore, for the purpose of this research, a much simplified grouping of flood types is practical. Also, it is essential to recognise that several flood events may be a combination of more than one type of flooding for instance, during the 2007 summer flood events, some locations experienced more than one type of flooding (ABI, 2009).

Flooding across the country in 2007, 2009, 2013 and 2014 and even more recently highlights the various forms of flooding that the UK faces (Cabinet Office, 2015). However, in the UK, the three common types of flooding are from the sea (coastal or tidal), from rivers and streams (fluvial), and from surface water (pluvial) (Cabinet Office, 2015). All three forms of flooding could occur during a single storm (Cabinet Office, 2015). According to Sayers et al., (2015), groundwater flooding, became an addition to the list provided by the Cabinet Office on the ground of Expected Annual Damage (EAD). With regards to the best analysis of the underlying data provided by the lead authorities in each country, the most significant source of flooding today is fluvial (river), contributing £560m (40%) of total UK EAD; Coastal flooding contributes £320m (24%), surface water £260m (20%) and groundwater £210m (16%) (Sayers, et al., 2015). All of these sources are projected to increase risk in the future (Sayers, et al., 2015). Therefore, these four types are covered in this study. These categorisations are important because the effectiveness of property level flood protection measures depends on the types of flood risk in a particular location (Joseph, 2014).

2.4.1 Coastal Flooding

Coastal floods are amongst the most dangerous natural hazards. Simply put, a coastal flood is when the coast is inundated by the sea. Coastal floods are driven by extreme water levels, which arise as combinations of four main factors: (1) waves (especially setup and runup); (2) tides; (3) storm surges; and (4) relative mean sea level (Pugh and Woodworth, 2014). The most common cause of coastal flooding in the UK is storm surges, where the storm wind pushes the water up and thereby creates high waves. These storm surges are often the greatest threat to life and property along the coast. Therefore, coastal flooding is one of the top priority risks for the UK (Cabinet Office, 2015). In England, it is estimated that around 520,000 properties are located in areas with a minimum of 0.5% annual risk from coastal flooding (Committee on Climate Change, 2018).

Furthermore, coastal flooding continues to grow in threat due to the rapidly increasing mean sea-level, possible changes in tides and storminess associated with climate change, population growth, urbanisation and development in low-lying coastal areas (Sayers et al., 2015; Stevens et al., 2016; Palmer et al., 2018). Meanwhile, engineering solutions put in place to mitigate coastal flooding are limited, simply because of the huge volumes of water involved and because it is not contained or channelled (Dhonau and Rose, 2016).

2.4.2 Fluvial Flooding

River flooding, also known as fluvial flooding, occurs when the capacity of a river channel is exceeded as a result of intense or prolonged rainfall (Doswell, 2003). River floods typically unfold over days, or even months until a watercourse cannot cope with the water draining into it from the surrounding land (Dhonau and Rose, 2016). The resultant runoff engulfs the natural water courses and exceeds their capacity for transmitting water downstream. River floods can be slow, in the case of a sustained rainfall, or fast, as a result of rapid snowmelt or heavy downpours (Jha, et al., 2012). However, within a river flood event, several flash flood events can occur. Flash floods are those flood events where the rise in water is either during or within a few hours of the rainfall that produces the rise (Doswell, 2003). While fluvial flooding is often predictable during periods of prolonged rainfall, flash flooding may occur too fast for monitoring systems to generate warnings especially when intense rainfall for a wide catchment is directed into a narrow watercourse.

2.4.3 Surface Water Flooding

Surface water is rainwater which is on the surface of the ground and is yet to move into a watercourse, drainage system or sewer (Chapman, et al., 2013). Surface water (pluvial) flooding arises when heavy rainfall overwhelms the drainage capacity of the local area (Dhonau and Rose, 2016). In this case, the volume of rainwater is unable to drain away through the drainage systems or percolate into the land and instead stays over land. The risk of surface water flooding can be increased due to blocked drains and sewers, impervious surfaces, as the water has nowhere to go. It can occur almost anywhere but is most likely to be of particular concern in topographical low spots (Lancaster, et al., 2004). It is difficult to predict exactly when and where it will occur, much more so than river or coastal flooding (Dhonau and Rose, 2016) and this has made this form of flooding a major source of concern to flood risk managers.

2.4.4 Groundwater Flooding

Just as river flooding, groundwater flooding tends to occur after long periods of continuous rainfall. The continuous rainfall results in more water permeating into the ground and causing a rise in the water table above normal levels (Adedeji, et al., 2019). Therefore, groundwater flooding occurs when the water table rises up to the surface during a prolonged wet period. Low lying areas, areas near aquifers and properties with cellars or basements are more likely to experience this type of flooding. Groundwater flooding is most likely to be a problem in areas that are low-lying and have water-bearing rock strata at the ground surface (Sayers, et al., 2013).

2.5 FLOOD IMPACTS

Floods have always presented both benefits and challenges to mankind (Sayers, et al., 2013). The benefits have been in form of flood-prone areas being attractive for human settlements. This attraction is due to a variety of reasons such as transportation, readily available water supplies, power production, improved soils fertility for agriculture, and for the simple beauty of the surrounding areas. According to Eleuterio (2012) people populate the flood-prone areas largely for human convenience. However, most of the effects of floods on lives and properties is adverse. The growing flood risk has resulted into greater concern towards the impacts. Flooding is a major problem for many people in the United Kingdom, posing a risk to health, safety and wellbeing, and resulting in widespread damage to property (Garvin, et al., 2005). The catastrophic impacts to the built environment can include bridges being washed away, roads becoming rivers, raw sewage flowing among the contaminated mix that makes up flood water and damage to infrastructure and property (Barsley, 2020). While there is a wide-ranging opinion that flooding only causes damage to property (Wingfield, et al., 2005), it can also have a devastating impact on lives too. The impacts on lives could be direct mortality and morbidity and indirect displacement from homes (IPCC, 2007; Doocy *et al.*, 2013).

This section reviews the various impacts of flooding on buildings and human lives both during and after flood events. This is important as it further emphasises the relevance of improving resilience.

2.5.1 Impacts On Buildings

Flood damage can range from being relatively minor where very limited volumes of water enter a building, to severe cases of deep water flooding where extensive damage occurs to the building and its contents (ODPM, 2003). During floods, water can gain entry into property causing damage to structures, electrical installations, floors and walls, and partial or total destruction of any other items that comes in contact with the water. Flood water will always find its way through a path of least resistance into a building. Mostly, floodwater can gain entry through the weakest points in the construction, particularly through masonry and construction joints, and any voids and gaps (Bowker, et al., 2007). When water penetrates the walls of a property, it can rise through capillary action, causing salt deposition to occur. Also, it can damage or inundate loose-fill insulation in cavity voids (Barsley, 2020). The hydrostatic and hydrodynamic loads can cause huge structural failure, particularly when accompanied with impact from debris (Bowker et al., 2007; Barsley, 2020). However, once the floodwater is inside a property, it will damage and contaminate any contents it comes in contact with that are not water compatible or resistant (Barsley, 2020).

There is now a significant body of research that has been carried out on the impact of floods on buildings in the UK (BRE Scottish laboratory, 1996; Penning-Rowsell and Green, 2000; Soetanto et al., 2002; Netherton, 2006; Tagg, 2006). However, in the review by Soetanto and Proverbs (2004), it was identified that little or no attention was given to flood characteristics when assessing flood damage to properties. They pointed out that in assessing flood damage to domestic properties just as the characteristics of the property (such as physical location, materials of construction, and ability to withstand floodwater forces) is essential, it is equally important to consider the flood characteristics (e.g., velocity of flow, time duration, and nature of any suspended contaminants) (Soetanto & Proverbs, 2004). This was echoed by Garvin et al. (2005) as they opined that the amount of damage caused to buildings will depend, upon factors, such as flood depth of exposure, water velocity, flood duration and presence of contaminants. However, flood water depth and the flood duration vary proportionately to the potential damage to buildings (Wingfield, et al., 2005).

Meanwhile, the three most commonly damaged household contents during flood events are: furniture, carpets and electrical goods (Elliott & Leggett, 2002). However, in the case of electrical good and furniture, the incidence of damage is expected to increase significantly as the depth of flooding increases. Meanwhile, in terms of cost of damage, one part of the domestic property that stands out as most expensive based on 'like for like' replacement when affected by flood is the kitchen (Joseph et al., 2011). According to DEFRA report on *Repairable and Resilient Kitchen Design*, the kitchen remains the costliest item to replace when a flood happens (DEFRA, 2020).

2.5.2 Impacts On Building (After Flood Event)

Once flood waters have retreated (which can take weeks or months), the residue and deluge that remains is often contaminated, and seemingly all-pervading (Barsley, 2020). In the event of coastal flood, the presence of saltwater from coastal floods can promotes corrosion to metal components while water containing sewage may require extensive cleaning and decontamination (Garvin, et al., 2005). Properties that have flooded may suffer from mould, damp and fungal decay. Also, materials affected by flood water will often swell, distort, delaminate, slump or lose structural integrity (Barsley, 2020). Even while some furniture, fittings and personal possessions may dry out after exposure to floodwater they may be permanently stained (ODPM, 2003).To fully address flood damage to a building, it may need to be stripped back to its most basic form with the affected contents removed (Barsley, 2020). Also, in some case, buildings may require further cleaning or extended drying times following a flood, leading to increased costs and delays in re-occupation (Bowker, et al., 2007).

Another aftermath impact is that the property prices can also be affected, and homes may be damaged beyond repair (or in which residents are unable to afford recovery works) which might lead to abandonment (Barsley, 2020). During this time residents may be housed in temporary accommodation, some distance from their work, family and friends (Barsley, 2020). Another key effect of flooding is the financial aspect of the occupants. Much literature pointed towards the financial impacts of flooding at a property level, with widely reported decreases in house value (Yeo, 2003; McKenna, 2010; Richards, 2011). Yeo (2003) reported that form of impact can last for several years after the flood; with typical losses reported at around 25% - 60%, while McNulty and Rennick (2015) asserted that this impact is easy to quantify and attribute. There have been a number of studies detailing the long term impact of floods on property markets, property prices and values (Eves, 2002, 2004; Lamond, 2009; Daniel et al., 2009), which have established that property values decrease immediately after a flood but usually recover within 3 to 4 years. These studies have also shown that in the 12 months following the flood event the differences in value between flood affected and non-flood affected properties in the same location can be up to 35%.

2.5.3 Impacts On Humans (During Flood Event)

During a flood, the risks to life can be significant and the experience itself traumatic to endure (Barsley, 2020). Flood events can damage people's health and on occasions result in loss of life. It can also have significant physical and emotional effects on human health; both during the event and after the victims have recovered from it (Kenney, et al., 2006). The effect on health has been widely regarded as an important dimension of the human impact of flooding (Tapsell et al., 2002; Tapsell, 2001). Meanwhile, McNulty and Rennick, (2015) have split the effects on health into physical and psychological for easy differentiation with 39% of people suffering from physical effects and 67% on their emotional health (Pitt, 2008).

The physical impacts are mostly experienced during the flood event. In a study carried out by Few et al. (2004), the physical health impacts were recognized as fatalities, injuries and the occurrence of disease. In the UK, fatalities and serious injuries are relatively rare with just 183 fatalities recorded between 1985 and 2008 (Burningham et al., 2008). Likewise, few incidents of post-flood disease outbreaks such as gastrointestinal illnesses, has been reported in the UK (McNulty & Rennick, 2015). Some other valuables, such as food and drinking water source, can be contaminated which can lead to a variety of illnesses (Barsley, 2020). Also, within the property heating may be affected, leaving residents feeling damp, cold and tired, which holds greater risk for the elderly and more severe if flood happens in the winter season (Barsley, 2020).

Residents may be trapped in their building as the flood level rises. Barsley (2020) pointed out that prior to and during a flood event, residents may be required to relocate to temporary accommodation in areas of lower flood risk. He noted that in some cases, residents may decide to remain in their properties after such announcement, out of fear that their home will be burgled if left uninhabited. However, in taking such decision, the residents stand the risk of being trapped inside as flood water levels rises.

2.5.4 Impacts On Human (After Flood Event)

Just as the physical impacts are mostly associated with damage caused during the flood event, psychological health impacts are mostly experienced as an after-effect. In the aftermath of a flood, feelings of frustration can permeate the mind of victims (Barsley, 2020). Many of those affected will suffer post-traumatic stress disorder (PTSD) and anxiety around safety and security in their home or community (Barsley, 2020). Meanwhile, a study by Tapsell (1999) identified that the psychological health effects of flooding can be as a result of the actual physical damage to the property, the loss of memorabilia and the anxiety that is held in respect to future flooding. Therefore, during any period of continuous and/or heavy rainfall, the stress level increases. Further, McNulty and Rennick, (2015) identified clinical depression and post-traumatic stress disorder as an addition to the list of the psychological health issues. Lamond (2008), believed that the discomfort caused due to the disruption to domestic life where essential services such as electricity and water supplies are cut off is something to reckon with.

The interim guidance for improving the flood resistance of domestic and small business properties published by the Office of the Deputy Prime minister reports that the most important aspect to remember is that the damage to property is only a minor part of the true human cost of a flood (ODPM, 2003). It emphasised on the stress that accompanies losing personal belongings, and having to live in temporary accommodation while repairs are being done, and also the trauma of cleaning up and restoration. While most residents would prefer to be back in their home immediately, though the initial clear-out can be quick, the reinstatement (by traditional means) is rarely a quick process (Barsley, 2020). Therefore, the resettling of those affected can be disruptive and traumatic.

In addition to the list of the post-flood impacts on humans is the financial impact (Lamond, 2008). This comprises of the extra transport costs, and increased living expenses incurred when victims are not able access the normal amenities of their homes. However, this impact is hard to quantify and will probably be borne by the flood victim (Lamond, 2008). The impacts upon economic well-being are huge and it emanates from a combination of the negative impacts on an individual's financial situation – including material losses, increased insurance premiums and declining house values (McNulty & Rennick, 2015). Decreases in economic well-being have been shown to have a strong negative correlation to the psychological health and well-being of those affected (Green et al., 1985). More widely, the literature pertaining to economic impacts speaks of increasing costs, outlays, and arrears; all of which have the potential to impact on the ability of individuals to respond and recover (McNulty & Rennick, 2015).

2.5.5 Classification of Flood Impacts

Flood losses, both to property and lives, have been categorized as direct and indirect losses, with further classification as tangible and intangible losses, based on whether or not these losses can be assessed in monetary values (Smith & Ward, 1998). Direct consequences are those resulting from direct exposure to the water and the flooded environment, while indirect damage refers to the losses that occur due to the disruption of some activity by the flood, referred to as damage caused by secondary effects. Smith and Ward (1998) argued that direct losses to floods occur immediately after the event as a result of the physical contact of the flood waters with humans and with damageable property. However, indirect losses are induced by flooding, but occurs, in space or time, outside the actual event (Thieken, et al., 2008). Therefore, indirect losses usually result as a consequence of direct losses.

The physical damage to buildings and their contents is a direct impact which is considered tangible because it can be measured in terms of replacement or reinstatement cost (Queensland Government 2002). Some of the key direct costs of flooding such as loss of human life or the consequent ill health of the survivors, loss of irreplaceable items like memorabilia and also the economic losses are intangible.

Meanwhile, the other forms of tangible but indirect impacts include the loss of building value, loss of utility supplies like electricity, water and gas which could be fixed. Also, the rise in insurance premium, increased travel cost and cost of reinstating the property are indirect, tangible impacts. Much of the indirect impacts of a flood for a residential property owner will be intangible as it affects their quality of life (Lamond, 2008). These indirect, intangible impacts include the disruption caused to daily life and normal activities, being upset about damage caused to buildings or psychological disorder in the case of recurrent flooding. Table 2.1 shows the classification of flood damage to buildings and humans as direct and indirect impacts with further distinction into tangible and intangible impacts.

Table 2.1: Classification of the flood impacts to the building and human components

	Building		Human	
	Tangible	Intangible	Tangible	Intangible
Direct	Physical damage to building and contents	Loss of irreplaceable items Loss of memorabilia		Injuries and fatalities Hypothermia Ill health
Indirect	Loss of house value Loss of utility supplies (like electricity, gas, water)		Increased travel cost Increase in insurance premium Repair costs	Stress Anxiety Disruption of daily life and normal activities Inconvenience of post flood recovery

Source Adapted from Joseph (2014)

2.6 THE EVOLUTION OF FLOOD RISK MANAGEMENT

The evolution of flood risk management approaches was captured and described across five major periods of development which are a willingness to live with floods, a desire to utilize the floodplain, a need to control floods, a need to reduce flood damages and a need to manage risk (Sayers, et al., 2013). According to Sayer at al. (2013), the earliest civilizations identified the necessity of living alongside floods and hereby engaged in different practices to help them live well and safe. The benefits that ensued from this form of interaction between the human and the natural environment (such as the enrichment of land and ecosystems located on the floodplain by the river; the utilisation of the abundant fish and wildlife populations supported; and serves as means to maintain trade and communication links) propelled them to find a means of living in harmony with water (Jha, et al., 2012). Throughout this period of history, the strategy was to keep water at bay from people and property, and to control water to agricultural areas through the construction of levees, dykes and diversions or irrigation (Sayers, et al., 2013). For centuries, therefore, it has been necessary to protect these areas from flooding, by building defences that supplement natural features such as river banks (Jha, et al., 2012).

However, as the development level increased, the need and the possibilities for flood control increased (de Bruijn, 2005). Consequently, the pressure produced as a result of preventing floods and retaining a natural sediment regime concurrently marked the start of an enduring challenge (Sayers, et al., 2013). Therefore, in an attempt to control flood waters for the convenience of humankind, the scale of the engineered responses continued to increase, but failed to prevent catastrophic floods and continued to bring problems of resources, maintenance and ecosystem destruction.

At the dawn of the twentieth century, the universally preferred strategy was still aimed at controlling floods. However, the intense period of flood events during the 1930 to 1950s compelled governments to rethink their flood management approach. Consequently, academics and practitioners analysed the effectiveness of structural flood control measures and widely recommended that such measures were, in fact, exacerbating the consequences of floods (Sayers, et al., 2013). In recent years, strategies for the mitigation and prevention of flood disasters have shifted from a ‘flood defence’ approach, aimed at controlling the hazard by means of structural measures, to a flood risk management approach, based on comprehensive risk assessment studies and costs and benefits analyses (Merz et al., 2010; Fuchs et al., 2011).

Flood management measures are broadly divided into structural and non-structural approaches according to whether engineering or administrative methods are employed (Thampapillai and Musgrave, 1985; Smith, 1996). These two categories are further discussed in the next two sections with their strengths and weaknesses.

2.6.1 The Structural Approach

The structural measures range from the heavily-engineered interventions, such as floodways and reservoirs, to more natural approaches like wetlands and greening measures (Jha, et al., 2012). According to Li et al. (2016), structural measures are based on "hard" infrastructure such as dykes, detention basins, drainage channels, floodgates, dams, and reservoirs that help in containing or controlling water. These flood defences are intended to reduce the risk of flooding to people, the built environment and the natural environment and to sustain economy. They are constructed to protect against flood events of a particular magnitude, expressed as risk in any one year (Jha, et al., 2012). In many parts of the world, flood risk management has focused primarily on the implementation of structural engineering solutions, favouring large-scale infrastructure systems, such as flood embankments and channelization (Brown and Damery, 2002; Ashley and Brown, 2009).

However, where buildings are situated in the floodplain, even if they are protected to some extent by structural flood defences, there will still remain some residual risk of flooding.

Meanwhile, Jha et al (2012) believed that when walls and embankments (levees or dykes), are strategically located around settlements or adjacent to water courses, ingress of water can be prevented into inhabited areas. Although, heavily-engineered structural measures can be highly effective when used appropriately, they tend to transfer flood risk from one location only to increase it in another (Jha, et al., 2012). This may be acceptable in some circumstances, while in others it may not be based on cost-benefit analysis.

Another shortcoming is that the engineered solutions are usually designed with defined limits of disturbance they can accommodate. Once the disturbance is more than the specified threshold capacity of the engineered solutions, it is overtopped and lives and properties again become susceptible. However, because these traditional approaches have not been designed for failure, the consequence of extreme floods can be disastrous (IRGC, 2016). Furthermore, poorly designed defence systems can result in even more damage due to what is known as the ‘levee effect’ (Jha, et al., 2012). This is where development proceeds behind a flood protection system in what is believed to be a safe area (Jha, et al., 2012). In 1953, Europe experienced devastating coastal floods where many flood defences were overtopped and breached in England, the Netherlands and Belgium (Sayers, et al., 2013). The net effect of these flood events emphasized the fragility of structural defences and the need to adopt a more flexible approach. Although the response taken to address the challenge at that period was to increase the investment in levees, floodwalls, floodways and other structures, because it was believed that a flood defence strategy could protect communities and individuals, and their property. Nowadays as climate change and increasing urbanisation create greater exposure to flooding, the traditional approach of building barriers against flooding is becoming less effective to tackle the increasing flood risk. This called for the need to introduce another approach to flood management which will focus on reducing the risks and the damage caused to the built environment.

2.6.2 Non-Structural Approach

Non-structural approaches on the other hand involve “soft” measures, such as flood forecasting, flood insurance, flood risk analysis, land use planning and zoning, policy response, flood awareness programmes, flood emergency planning and response, and post-flood recovery (Li et al. 2016; Zhou et al. 2017). These have been classified into four parts which are increased preparedness, flood avoidance, emergency planning and management, *and* speeding up recovery and using recovery to increase resilience (Jha et al., 2012). *The* contributions of this approach to flood risk reduction are mostly through a process of influencing behaviour, usually in the form of building capacity in all stakeholders. This capacity building is achieved through active learning and appropriate and effective engagement between the stakeholders (Taylor & Wong, 2002). Therefore, the effectiveness of the *non-structural measures* rely on a good understanding of flood hazard and adequate forecasting systems (Jha, et al., 2012). Although the non-structural approaches have recently emerged as an effective method of risk management and they can be seen as a first step to protecting people in the absence of more expensive structural measures. However, their effectiveness to a degree depends on the presence of the structural measures (Jha, et al., 2012). Therefore, in addition to flood control structures and wise use of the floodplain, the non-structural measures are required to help manage residual risk where such schemes have been constructed (Sayers, et al., 2013).

Another key factor to enhance the effectiveness of the measures is the proper education of the stakeholders involved and adequate cooperation between the residents who are exposed to flood risk and related government authorities. This is because the implementation of measures alone does not guarantee their effectiveness, residents in flood risk areas must acquaint themselves with the measures in order to be able to deal with flooding effectively, thereby minimize the impacts.

The advantages of non-structural approaches consist of improved organisational relations in the area, no significant environmental changes, and it is a more effective approach to deal with the dynamic nature of flood risk. Some of the drawbacks with this approach are the increase in property value where they are applied, lead to the invasion of floodplains, and higher levels of insurances coverage is needed (Petry, 2002).

2.6.3 An Integrated Approach to FRM

In 1945, Gilbert Fowler White, popularly referred to as the “father of floodplain management,” published his notable thesis, titled Human adjustment to floods: A geographical approach to the flood problem in the United States, which criticized the reliance on engineered flood defences and request for a change to these approaches (White, 1945). He claimed that the overreliance on the development of structural flood defence schemes were actually going to result to increased losses when levees and dams are overtopped.

The early part of the 21st century birthed the ‘living with water’ and ‘make space for water’ philosophy, which has resulted in the renewed understanding of flood resilience at household level (Proverbs and Lamond, 2017). The change in flood risk philosophy coupled with the experience of flood events and the prolong recovery process has led to research and investment geared in this area.

Flood risk management is now generally accepted as a sound basis for managing the competing needs of people, economies and the environment (Sayers, et al., 2013). The modern FRM recognizes that there is hardly a single solution to managing flood issues. Instead, collections of FRM measures and instruments are utilized. According to Jha et al. (2012), it is the proactive approach that entails the effective combination of both the structural and non-structural measures with the intention of keeping people and properties safe from floods through better planning and management of urban development. Nowadays, with FRM, the risks to people and property are the central emphasis, and thus not only water management measures are considered, but also measures to reduce the society's vulnerability (de Bruijn, et al., 2009). Therefore, FRM requires the holistic development of a long-term strategy balancing current needs with future sustainability (Jha, et al., 2012).

Sayer et al. (2013), outlined the portfolio from which a range of actions could be drawn to develop an FRM strategy in order to reduce risk in an efficient and sustainable manner. This is classified as:

1. 'hard' structural measures (such as construction of dykes, levees and dams)
2. 'soft' structural measures (such as wetland storage)
3. Non-structural measures (such as improved flood forecasts and warnings)
4. policy instruments (such as land use planning, insurance and other funding incentives, such as homeowner grants for flood proofing).

2.6.4 Property flood Resilience (PFR)

Property flood resilience is a component of an integrated approach to FRM. According to the Construction Industry Research and Information Association (CIRIA) *Code of Practice for Property Flood Resilience*, PFR has been defined as measures that reduce the flood risks to people and property empowering households to minimise flood impacts, speed up recovery and reoccupation (Kelly, et al., 2019). Since it is impossible and uneconomical to reduce all flood risk or defend against all possible floods (Environment Agency, 2009). Moreover, there is no 100% guarantee that homes benefiting from these schemes are totally protected, because both the passive and active defences may fail. These active defence are the hard and soft structural measures in place while the passive defence entails the non-structural measures. As a result, there will always be a residual risk. Therefore, in order to tackle the underlying factor that not all homes are able to benefit from the level of protection provided through the structural and non-structural measures, the PFR measures is utilised as an effective means of managing flood risk for existing buildings. The PFR measures are designed to deal with the residual flood risk.

In terms of protection of properties, a hierarchy of options has been recognised which is associated with decreasing residual flood risk, although this depends on the flood type and building being considered (Department for Communities and Local Government, 2007). These are summarised as follows:

i. Avoidance: comprises a range of measures including location of buildings in areas of least risk (land use planning), raising properties above the flood level, use of bunds or other hard defences to keep floodwater away.

ii. Resistance: comprises of measures that are taken to prevent floodwater from entering into the building and damaging its fabric and contents.

iii. Resilience (also known as the recoverability measures): entails sustainable measures that can be integrated into the building fabric, fixtures and fittings in order to lessen the potential of damage caused by floodwater. These measures would allow for quicker drying and easier cleaning, and also ensure that the structural integrity of the building is not compromised thereby reducing the recovery time for the building to be re-occupied.

iv. Reparability: forms a subset of resilience, covering design of elements that facilitate replacement and repair, such as sacrificial finishes

The concept of PFR recognizes that in some cases a hybrid approach might be favoured in which the amount of water entering a property is limited, together with the likely damage that is caused (Proverbs & Lamond, 2017). PFR is primarily divided into two forms; resistant and recoverability measures. Research has demonstrated clearly that adopting resistance and recoverability measures is beneficial in financial as well as psychological terms. The term “resilience” has recently been introduced to disaster management dialogue. It may, therefore, be argued that to be able to measure effectively the level of protection provided by the resilience measures, it would be useful to undertake a review of the concept of resilience and its applicability to the field of flood risk management and its definition within the context of flood risk management at household levels. The concept of resilience and a more detailed discussion of PFR is discussed in more detail in the next chapter.

2.7 SUMMARY

This chapter has presented a review of literature focusing on the component of flood risk, the impact of flooding within the built environment and the flood mitigation approaches. Critically, the review also focuses on the impacts of flooding on household, with particular attention to the intangible impacts. The next chapter examines the concept of resilience in greater depth and the property level flood resilience measures.

CHAPTER THREE: THE CONCEPT OF RESILIENCE

3.1 INTRODUCTION

The entrance of the term resilience into the flood risk discourse could be seen as the birth of a new culture of disaster response. The concept has gradually found more space in both theoretical and practical terms in a wide range of flood risk reduction discourse areas and in some interventions. However, its application to real world problems is complex and not always easy. The central aim of this research is to develop a method of measuring the resilience of individual home to the risk of flooding. In order to achieve this aim, a consideration of the concept of resilience is, therefore, relevant to the research.

The purpose of the chapter is, therefore, to review and critique the variety of definitions, concepts, and theories of resilience. Synthesizing what is known in this area will help elucidate the nature of this complex phenomenon and serve to offer a clear understanding into the concept of resilience and also to provide a basis for the conceptualisation of the property flood resilience.

To this end, the narrative is divided into three main sections. The first considers the different ways resilience is defined, and discusses how it has been conceptualised in different fields of study. This definitional debate is important because concepts provide researchers with theoretical boundaries that help determine the nature, direction and reliability of research inquiry (Fletcher & Sarkar, 2013). The second examines the dimensions of resilience and discusses the need for lucidity in defining two pivotal concepts: resilience as an outcome and as a process heading towards a desired outcome. The final section reviews the concept in the context of flood risk management.

3.2 THE COMPLEX NATURE OF RESILIENCE

The term resilience is derived from the Latin word resilire which means to bounce back or to recoil, a word that has enjoyed prominence in terms of research for the past four decades (Fleming & Ledogar, 2008). It should be noted here that the concept of resilience is a many-sided field of study that has been addressed by psychologists, sociologists, ecologists, engineers and many others over the past few decades addressing the strengths that people and systems demonstrate to enable them to rise above adversity (VanBreda, 2001). Research on resilience has increased substantially over the past two decades (Fleming & Ledogar, 2008) and is now also receiving increasing interest from those involved with policy and practice in relation to its potential impact on health, well-being and quality of life (Windle, 2010). About fifty years of research in resiliency has seen a lot brought forward in both perspectives and opinions (Thomsen, 2002; and Unger, 2005).

Despite the vast body of research on the subject of resilience, there is no agreement on a single definition among researchers and, inevitably, different definitions have been offered (Djordjević, et al., 2011; Oladokun and Montz, 2019). This lack of consensus has resulted into conceptual divergence or pluralism when the notion is applied to any phenomenon (Desjardins, et al., 2015). According to Fisher (2015), over 70 definitions of resilience are available in the scientific literature varying between two extremes, recovery and adaptive resilience. Recovery resilience is the property that defines the ability of a system to bounce back after stress. While at the other end, adaptive resilience is seen as the capacity of socio-ecological system to readjust or transform in response to unfamiliar, unexpected and extreme shock. Owing to these developments, the next section aims to review the concepts of resilience theory applied in different fields and subsequently presents the dimensions of resilience.

3.3 RESILIENCE IN VARIOUS FIELDS

While the field of resilience is broad and diverse (VanBreda, 2001), the concept is still evolving and has been developing in various fields (Hosseini et al., 2016). In some aspects the term is well developed and explored while in others it is still nascent (VanBreda, 2001). The emerging theory of resilience or resilience thinking, as applied in these disciplines, is based on several key concepts and ideas, including thresholds or tipping points, alternate stable states or regimes, regime shifts, complex adaptive systems, adaptive cycles, panarchy and transformability (Holling 2001; Folke 2006; Walker and Salt 2006). The way the term is conceptualized by each discipline is evident in the fundamental beliefs principles that govern them. The different views to resilience as offered by several disciplines are reviewed in subsequent sections with reference to definitions and the concepts.

3.3.1 Psychological Resilience

In the early 1970s, the term ‘resilience’ began to be used as a substitute for stress resistance in psychological studies of children (Hollnagel, et al., 2011). However, it soon became a regularly used term in psychology, with the word stress often referred to as adversity or trauma. These words continue to appear in many definitions of resilience, at times in different forms. According to the American Psychological Association (2014), resilience is seen as the process of adapting well in the face of adversity, trauma, tragedy, threats or even significant sources of stress. Also, as cited by Gauvin-Lepage et al. (2014), resilience is seen from a similar standpoint as the capacity to withstand traumatic situations and the ability to use such situations to start something new. The definition entails the combination of the coping and adaptive abilities of the subject in question.

Meanwhile, the focus of psychological resilience is mostly human. Human beings typically encounter a variety of difficulties and challenges during the course of their lives, ranging from daily hassles to major life events. Indeed, Bonanno and Mancini (2008) noted that most individuals experience at least one potentially traumatic event (PTE) in their lifetime. The term ‘‘potentially’’ is important because it draws attention to the differences in how people react to life events and whether trauma occurs as a result. To illustrate, some individuals become overwhelmed by everyday hassles (DeLongis et al., 1982) whereas others react positively to the most testing of experiences (Bonanno, 2004). Therefore, Masten (1994) directly referred resilience to people from high risk groups with better outcomes than expected, good adaptation in spite of adversity and quick recovery from trauma. This was echoed by Hardy et al. (2004) as they also associated the term resilience to people, acknowledging resilient people as those individuals who can show the ability to remain in good shape, recover, or even thrive in the face of adversity. Meanwhile, it is the study of psychological resilience that seeks to understand why these individuals are able to thrive amidst the pressure they experience in their lives. Therefore, the search for factors that make an individual resilient to the stressors they encounter has been the thrust of early research. Over the past two decades psychologists' understanding of human functioning in demanding situations has developed rapidly, with resilience being examined across a range of contexts, including business organizations (Riolli & Savicki, 2003), education (Gu and Day, 2007), military (Palmer, 2008), sport performance (Galli and Vealey, 2008), and communities (Brennan, 2008).

3.3.2 Engineering Resilience

Resilience in engineering implies the ability of an engineered system to autonomously sense and respond to adverse changes in health conditions, to withstand failure events, and to recover from the effects of these unpredicted events (Yodo & Wang, 2016). According to Yodo and Wang (2016), engineering resilience is the concept that fuses resilience ability into engineering practices.

Meanwhile, Holling (1973), in an attempt to define engineering resilience, draws a distinction between resilience and stability, he defined resilience as the ability of a system to return to its stable state after a momentary disturbance. Hollnagel (2013) gave a similar definition in support of Holling's view when he defines resilience as bringing ecological systems to exist close to a stable steady-state. The approach however seems to revolve around a system's ability to return to the steady-state after being disturbed without assuming an entirely new position. Hence, this places resilience and stability as two important properties as regards defining engineering resilience. These properties are measured by the system's speed of return to stability and the amount of disturbance required to take it off stability (Tilman and Downing, 1994; de Bruijn, 2004; Folke, 2006; Davoudi, 2012). However, in a bid to measure these properties, some core engineering attributes for fail-safe design, such as predictability, constancy and efficiency, have become the focal point. According to De Bruijn et al. (2017), sustaining a function and the conservation of an existing situation are fundamentals to engineering resilience.

This engineering approach to measuring resilience has been referred to as the traditional, old dominant perspectives which indirectly assumed that the system remains constant over time, that is, there will be a stable and an infinitely resilient environment where the flow of resource could be controlled and that naturally things will go into equilibrium as soon as the human stressors are removed (Folke, 2006). Although this may hold true for situations of moderate shocks and predictable events, the impact of disruptive and unexpected extreme events may be huge on the system's functioning which will in turn trigger a profound system change (transformation). However, to keep a system close to being stable and infinitely resilient will require apt consideration of uncertainty. For an engineered system to adapt to changes, this ability has to be designed into the system.

Meanwhile, subject to operation in unpredictable and uncertain conditions, complex engineered systems may require extraordinarily high safety precautions in design to account for unforeseen failure modes, such as those induced by adverse natural disasters (Yodo & Wang, 2016). However, in the early design stage, it is very challenging, if not impossible, for system designers to determine all the possible failure modes.

The approach has provided one of the foundations for economic theory (Schulze, 1996). It has also found its way into the safety management purview. In the early 2000s, safety specialists started using resilience engineering to describe an alternative approach of dealing with safety issues, accidents as well as risks and also focusing on helping people cope with complexity under pressure to achieve success (Woods, 2000; Hollnagel, 2013). In the safety management domain, it has been defined as the inherent ability of a system to adjust its functioning before, during, or after exposure to disturbances, so that it can sustain required operations under both expected and unexpected conditions (Hollnagel et al., 2011). Its acceptability into other fields of study highlights its relevance.

Engineering resilience is increasingly being applied in planning, architecture and building technology with focus on flood hazard mitigation and the deployment of flood resilient design and technologies to adapt or construct buildings to reduce the probability of failure, reduce the consequences during failure and/or to reduce recovery time after failure by flood water (Garvin, 2012). Laboy and Fannon (2016) gave a comprehensive example of the dimensions of engineering resilience relevant to architecture, but also useful in flood risk management.

To date, the implementation of the engineering resilience concept has been widely adopted in various engineering disciplines. Many of the engineering resilience implementations are associated with large-interconnected-complex systems, such as transportation systems (Omer, et al., 2013), power systems (Francis & Bekera, 2014), production systems (Yodo & Wang, 2016), multitier-supply chains (Spiegler, et al., 2012), general infrastructure systems (Ouyang, et al., 2012), health care systems (Patterson & Wears, 2015) and many more.

3.3.3 Ecological Resilience

Much work on resilience has concentrated on the capacity to absorb shocks and still maintain function, which defines the qualities of the engineering resilience (Folke, 2006). However, there is another aspect of resilience that concerns the capacity for regeneration, re-organization, adaptation, transformation and development, which has been less in focus but is essential for the sustainability discourse (Gunderson and Holling, 2002; Berkes et al., 2003). This type of resilience emphasizes conditions far from any steady state condition, where instabilities can flip a system into another regime of behaviour, i.e. to another stability domain (Holling, 1973). The concept of ecological resilience presumes the existence of multiple stability domains and the tolerance of the system to perturbations that facilitate transitions among stable states. Hence, ecological resilience refers to the width or limit of a stability domain and is defined by the magnitude of disturbance that a system can absorb before it changes stable states (Holling, 1973; Ludwig et al., 1996). According to Holling (1973), this kind of resilience measures the ability of an ecosystem to absorb changes and still exist. In this case, in terms of measurement, resilience is viewed as the magnitude of disturbance that can be absorbed before the system redefines its structure by changing the variables and processes that control behaviour (Gunderson, 2000).

Hence, in this approach, the useful measure of resilience is the size of stability domains, or, more meaningfully, the limit of disturbance a system can accommodate before its controls shift to another set of variables and relationships that dominate another stability region (Folke, 2006). The relevant focus is not on constancy but on variability (Folke 2006). Therefore, the attributes that define this kind of approach are unpredictability, persistence, change (Holling, 1973) attributes embraced by biologists with an evolutionary perspective and by those who search for safe-fail designs (Schulze, 1996).

Though it is argued that managing for resilience enhances the likelihood of sustaining desirable pathways for development in changing environments where the future is unpredictable and surprise is likely (Walker et al., 2004; Adger et al., 2005). However, resilience in ecological systems is not easily observed, and there seems at present to be no agreed relationship, for example, between the diversity of ecosystems and their resilience (Pimm, 1984; Naemm et al., 1994; Tilman, 1997).

In terms of application, those who emphasize the stability domain definition of resilience (ecological resilience), on the other hand, come from traditions of applied mathematics and applied resource ecology at the scale of ecosystems. Examples include the dynamics and management of freshwater systems (Fiering, 1982), of forests (Holling, et al., 1977), of fisheries (Walters, 1986), of semiarid-grasslands (Walker, et al., 1969) and of interacting populations in nature (Dublin et al., 1990; Sinclair et al., 1990).

3.3.4 Socio-Ecological Resilience

The understanding that engineering and ecological systems are exposed to both gradual changing drivers and shocks that threaten the stability domain itself and causes it to change has called for the consideration of the temporal dimension of resilience (Zevenbergen, et al., 2008). Therefore, in addition to a structural and/or systemic approach to resilience, a perspective that encompasses human agency is required with emphasis on everyday forms of resilience (Davidson, 2010; Brown and Westaway; 2011; Brown, 2016).

The acknowledgement of this temporal dimension has resulted in the emergence of the framework of socio-ecological resilience. Berkes and Folke (1998) started to use socio-ecological systems as an integrated perspective of humans in-nature, and related it to the, at that time, emerging concept of resilience (Holling, 1973; Folke 2006 and 2016). They pointed out that in the socio-ecological systems perspective, the delineation between social and natural systems is artificial and arbitrary. Therefore, in socio-ecological systems, there is interplay between systems of human societies and ecosystems. The concept of a socio-ecological system emphasizes that humans are part of nature and that these systems function in interdependent ways. It recognizes nonlinear dynamics thresholds, identifies how periods of gradual change interplay with periods of rapid change and also shows how to address uncertainty in projections of slow changing drivers such as climate change, population growth and resource depletion (Folke, 2006; Gersonius et al., 2010).

Therefore, the concept of socio-ecological resilience has been defined as the capacity of linked social–ecological systems to absorb persistent disturbances such as floods so as to retain essential structures, processes and feedbacks (Folke, 2006). In this concept the social refers to the human dimension in its diverse facets, including the economic, political, technological and cultural, while the ecological represents the layer of Earth where life exist, the biosphere (Folke, et al., 2016). Consequently, human beings play a leading role in the adaptability, transformability and resilience of a Social ecological system, whether in building the desirable structures (Armitage and Johnson, 2006; Folke et al., 2016), the shaping of systems policy (Olsson et al., 2004; Anderies et al., 2006; Booher and Innes, 2012) or the legitimation of the trade-off between socioeconomic and biophysical phenomena and processes (Robards, et al., 2011). It should be clear that human development cannot be dissociated from the environment, particularly when it relates to human well-being, as much as people think that human ingenuity and technology may allow this (Folke, et al., 2016). Human well-being in all its dimensions, like, quality of life in terms of freedom and choice, good social relations, personal security, and material needs, ultimately rests on biosphere capacity and the interplay with the Earth system (Folke, et al., 2016).

Further, Levin et al. (2013) see the socio-ecological systems as complex adaptive systems and emphasise the relevance of socio-ecological resilience approach as a lens to address and understand these complex dynamics (Folke et al. 2010; Biggs et al. 2012; Folke 2016). The resilience thinking does this by explicitly focusing on understanding how periods of gradual change interplay with periods of rapid change in intertwined socio-ecological systems that are threatened with true uncertainty. It also identifies the impact that this has on people and the environment (Folke, et al., 2016). In addition, socio-ecological resilience also reflects the degree to which complex adaptive systems are capable of self-organization and to which these systems can build capacity for learning and adaptation (Folke, 2006; Cutter et al., 2010).

In the face of an environmental disaster like flooding, socio–ecological resilience is defined as the degree to which a particular relationship between social processes and ecological dynamics can be disturbed without serious loss of complexity of both, rather than the speed at which the status quo can be restored after disturbance (Goldstein, 2008).

3.3.5 Socio-Technical Resilience

While the psychological resilience focuses on human and the engineering resilience focus on engineering systems, the socio-technical resilience pays attention to the interaction between the social (humans) and how they promote or undermine resilience for one or both. The socio-technical system is an important system to consider while studying PFR. In the 1950s, the Tavistock Institute, a British non-profit organisation, conducted study on the consequences of the introduction of powered machinery on coal miners' employment, management-labour interactions, and the lives, families, and societies of coal miners (Hoffman and Militello, 2008). Since then, socio-technical systems theory has been developed and applied internationally by both researchers and practitioners for nearly 60 years. They have a long history and are intended to ensure that the technical and organisational aspects of a system are considered together (Baxter and Sommerville, 2011). The overarching philosophy, which embraces the combined design and optimization of organisational systems (incorporating both social and technical factors), has maintained its practical relevance and has grown in popularity among audiences outside the social sciences (Eason, 2008). Socio-technical systems are increasingly being studied in a wider range of domains.

Socio-technical systems design methods are an approach to design that consider human, social and organisational factors, as well as technical factors in the design of organisational systems (Baxter & Sommerville, 2011). The outcome of applying these methods is a better understanding of how human, social and organisational factors affect the ways that work is done and technical systems are used (Baxter and Sommerville, 2011). This understanding can contribute to the design of organisational structures, business processes and technical systems (Baxter and Sommerville, 2011).

However, speaking of socio-technical resilience, the aim is to bridge the gap that exists within the realm of socio-technical systems in order to advance socio-technical resilience. Scholars of social-ecological systems recognise technology as an important influence on resilience (e.g. Langridge et al, 2006; Young et al, 2006; Anderies et al, 2004). With a number of contrasting relevant definitions of 'resilience' (Berkes et al, 2003; Stirling, 2008), this influence may alternatively be positive or negative, depending on the context (Smith and Stirling, 2008). Leach et al., (2010) perceive society, technology, and environment as co-constituted and co-emergent entities, what they referred to as a nexus. Social-ecological systems and socio-technical systems are each understood to display complex, multi-scale and adaptive properties; and the associated recommendations for the sustainable governance of these systems emphasises approaches based on learning, experimentation and iteration. In recent years, scholars who are active in the sociotechnical research domain have engaged with the literature on social-ecological systems (Foxon, et al., 2009; Smith and Stirling, 2010). In parallel, scholars in the social-ecological systems field are calling for more attention to technology and the built environment (Anderies, 2014; Redman and Miller, 2015; McPhearson et al., 2016). As these scholars highlight, bridging across the two fields requires careful conceptual work and both theoretical and more practical collaboration (Ahlborg, et al., 2009). Unfortunately, the calls have not yet resulted in much joint research and theoretical advances regarding this nexus (Ahlborg, et al., 2009).

With a focus on socio-technical resilience, techno-centric, resilience-based strategies can be effective at preventing major disruptions in well-constrained and understood circumstances.

McPhail et al. (2018), on the other hand, believe that there are limits to the applicability of solely technological practises, and that infrastructure systems appear to be increasingly running up against these limits. Markolf et al. (2019) point out that the effectiveness of these strategies can be diminished by many challenges such as climate variability and unpredictability, changes in demographics and preferences, complexity and interconnectedness within infrastructure systems, and unpredictable human behaviour. Therefore, the main concern with these infrastructures appears to be our ability to recognize and respond to these limits in a timely manner, because when robust and techno-centric adaptations do fail, it is often to catastrophic effect. Key challenges for the management of the combined socio-technical system emerge at this point, because social systems responding to and shaping technologies and infrastructures operate with incomplete information, and institutions in charge of one technology or infrastructure may lack the necessary knowledge or administrative reach to manage cascading events.

Also, the type of benchmark performance that could be used to assess whether and how socio-technical system resists or recovers from an external shock, on the other hand, has limited applicability for social systems because social systems are rife with transitions. A shock can be used to fundamentally restructure a system so that it performs better than before, rather than simply returning to its previous performance levels. Therefore, in terms of resilience, the real focus of the socio-technical system is adaptation and transformation.

As previously said, both social and technological systems are complicated, and their interactions necessitate paying close attention not only to the workings of each separately, but also to how they are interrelated and shape one another over time. Developing resilient socio-technical systems is an iterative process in which individuals and organisations learn as well as technology and solutions evolve – all while dealing with fundamental uncertainties and surprises.

3.3.6 Comparison of the Four Frameworks

In previous sections, five resilience frameworks were presented: psychological resilience, engineering resilience, ecological resilience, social-ecological resilience and socio-technical resilience. The scope is narrowed in this way because the literature has tended to consider these conceptualizations most relevant particularly in the context of disaster risk management. Psychological resilience has been defined as a dynamic process through which individuals exposed to sustained adversity or potentially traumatic events experience positive psychological adaptation over time. The focus is on mental resilience strengthening. It seeks to understand why some individuals are able to withstand – or even thrive on – the pressure they experience in their lives. Engineering resilience is used to express ability of a system to return to an equilibrium or steady state after a disturbance. The attention is on the property of a system to “bounce back” to the previous state. Its focus being static with single equilibrium. Ecological resilience acknowledged that systems have different stable states and when faced with disturbances may be transformed by tipping from one stability domain to another, while still retaining their main characteristics. Its focus being static and multiple equilibrium. In socio-ecological or adaptive resilience, it is acknowledged that systems undergo constant changes and have no stable state. Here, resilience is the ability of the system not only to bounce back but also to adapt and transform. This aims to overcome the limitations of both the engineering and ecological resilience approaches as it provides a dynamic and non-equilibrium environment, so as overcome the static nature of these two approaches and address the adaptive capacity of systems needed to adjust to gradually changing conditions (transformation). Finally, the socio-technical systems are understood to display complex, multi-scale and adaptive properties; and the associated recommendations for the resilience of these systems emphasises approaches based on learning, experimentation and iteration.

Of these five, the psychological resilience tends to exist in a different purview, unlike the other four that express the progression from a single equilibrium state (engineering) to multiple equilibrium state (ecological) which is further expanded and elaborated to include the system's abilities to self-organize and adapt to changes (socio-ecological and socio-technical). However, the psychological resilience is vital to the investigation of the PFR as it aims to address one of the major impacts of flood on household, the psychological impacts. It is essential to understand how individuals respond to these flood impacts and identify factors that provides mental resilience strengthening.

Meanwhile, Rodina (2018) emphasises the importance of the other three resilience as he identified in his review of 149 articles focused on resilience in water management between 1982 and 2017. The review showed that 45.6% utilized an engineering resilience definition, 18.8% used a social-ecological resilience definition and 11.4% used an ecological resilience definition making a total of 75.8 % (about three-fourth) (Rodina, 2018). Centering the focus to the most applicable definitions will help to move the debate forward by excluding more peripheral definitions of the term.

The relationship between these concepts can be illustrated by means of the familiar ball and cup model of system stability (Gunderson 2000). Figure 3.1 depicts an example of the ball and cup model used in resilience to illustrate the engineering, ecological, socio-ecological and socio-technical resilience approaches while Table 3.1 presents a summary of the main features of resilience in the five fields of study.

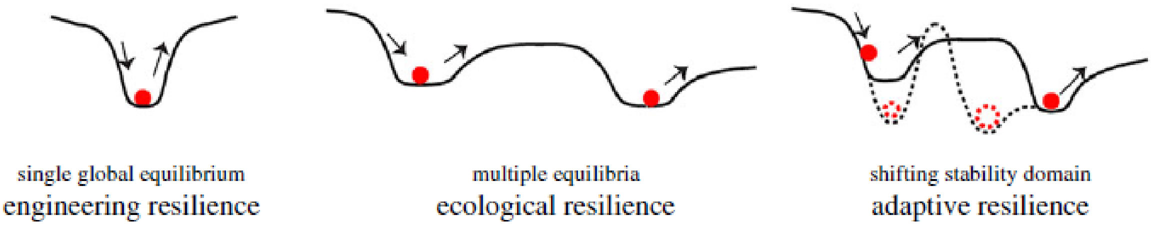


Figure 3.1. Ball and cup model of system stability in the three resilience frameworks (Laboy and Fannon, 2016).

In the ball and cup model of system stability and resilience: the ball represents the current state of the system; the arrows represent disturbances; the cup-shaped landscape represents its current domain of attraction, that is, all possible states within some normal range of variation for that system. The depth of cup represents stability (persistence close to an equilibrium or steady state), whereas the width of the cup represents resilience (the amount of disturbance the system can absorb while remaining within the same domain of attraction).

Table 3.1: Resilience Concept in different field of study

RESILIENCE CONCEPT	CHARACTERISTICS	FOCUS ON	CONTEXT	RECIPIENT
Psychological Resilience	coping, thriving amidst adversity	recovery, adaptive capacity		Human
Engineering Resilience	Return time, efficiency	Recovery, constancy	Proximity of a stable equilibrium	Engineering System
Ecological Resilience	Buffer capacity, withstand shock, maintain function	Persistence, robustness	Multiple equilibrium, stability landscapes	Ecosystem
Socio-ecological Resilience	interplay disturbance and reorganisation, sustaining and developing	adaptive capacity, transformability, learning innovation	integrated system feedback, cross scale dynamic interactions	Human, ecosystem
Socio-technical Resilience	considers human, social, organisational factors and technical factors in designing organisational systems	Adaptive Transformability Learning adjustment		Human, Society Technology

Adapted from (Carpenter, et al., 2001)

In FRM it follows that the concept of resilience emerged to challenge scientists, policy makers and practitioners in FRM field to progress from the traditional paradigm (of flood prediction and control), towards one of system and whole life thinking referred to as a flood resilient approach (Brown and Damery, 2002; Ashley, et al., 2013). The traditional approach, predominantly, leads to the implementation of structural engineering solutions, while the flood resilient approach fosters an integrative and adaptive, long-term approach (Sayers, et al., 2014). The broader concept of socio-ecological resilience which represents an integrated system feedback has provided guidance for building more resilient FRM systems as they are established on the following features (Sayers, et al., 2002; Dawson, et al., 2011; Huntjens, et al., 2011; Zevenbergen, et al., 2013):

i. it accepts that knowledge will never be perfect and that changes are uncertain and hence 'optimal' or 'best' solution does not exist;
ii. it takes a long-term view, while cultivating the capacity to monitor and learn from intermediate outcomes and to adapt (short-term incremental changes) and keep options open to transform (long-term system changes);
iii. it considers all of the potential interventions that may alter flood risks (ranging from flood preparedness to prevention); and
iv. it facilitates participation and collective action and learning.

These resilient approaches aim to establish a balance between flood protection, prevention and preparedness, both now and in the future (Zevenbergen, et al., 2008; Gersonius, et al., 2010; Aerts, et al., 2014).

Since the protection, prevention, coping, adaptation and transforming properties are needed in the FRM approach at one stage or another. The built environment will need protection and coping capacity against flood risk while the human element who interact with the built environment will require the adaptive capacity. Therefore, it is never a matter of choosing a concept and discarding the rest but rather a combination of these concepts in an optimal manner.

3.4 DIMENSIONS OF RESILIENCE AS AN OUTCOME OR A PROCESS

The previous section presents resilience as it is seen in different fields (Psychology, Engineering, Ecology, Socio-ecology and Socio-technical), while subsequent sections present the approaches that have been adopted in conceptualising resilience. The concept has been applied majorly in two ways across these disciplines. Kaplan (1999) simply put it as a concept generally defined in two broad ways: as a desired outcome or as a process leading to a desired outcome. Though, Manyena (2006) admitted that classifying the numerous definitions of resilience as outcome- or process-oriented is not an easy task, however, understanding the distinction between these dimensions is key to conceptualising resilience in any domain, particularly flooding. Therefore, it is essential to review these two approaches, and examine the ways they are applied in the different fields of study, in order to adequately and effectively apply the concept to property flood mitigation.

3.4.1 Outcome-Based

Outcome focused resilience typically emphasizes the maintenance of functionality; that is, patterns of competent behaviour or effective functioning (Olsson, et al., 2003). It seeks to observe explicit end points of the structure put in place to ensure that a system continues to function. In this dimension, resilience depends on properties such as a system’s capacity to withstand a disturbance without functional failure, the degree to which system components are substitutable, and the speed of recovery after being displaced by disturbance (Bruneau et al., 2003; Liao, 2012). The engineering resilience is defined by these properties. This outcome-based perspective highlights the importance of understanding competing resilience outcome priorities such as determining when the system has begun to stabilize after an event and restore damaged resources (McDaniels, et al., 2008). According to Manyena (2006), this makes the approach a command-and-control panache that risk preserving the status quo. The concept has been adopted in the domain of disaster reduction emphasizing recovery from shocks and retaining the status quo (Mayunga, 2007).

The outcome-based approach is predominantly applied in Engineering where it adopts the recovery capacity. It is conceived as the ability of systems to resist shocks and remain in the same state (Kallaos, et al., 2014). It emphasises on resisting, coping with and recovering from flood impact. Also, it is applied in the psychological resilience as 'an outcome pattern following a potentially traumatic events (PTE) characterized by a stable trajectory of healthy psychological and physical functioning'' (Bonanno et al., 2011, p. 513). They found that people's responses vary a great deal, but they are by and large on track for resilient outcomes.

3.4.2 Process-Based

In the process dimension, resilience is measured in actions rather than system properties (Hollnagel, et al., 2011). This measurement involves what the system does, such as the way it senses, anticipates, adapts, learns or functions at all times and specifically in response to disturbance.

Process-based resilience is seen as an emergent behaviour of a complex adaptive system (Park, et al., 2013) which reflects the degree to which these systems are capable of self-organization and building the capacity for learning and adaptation (Folke, 2006). Essentially, the focus of the process-based resilience is to understand the mechanisms that makes a system adjust and successfully adapt to the impact of a risk setting (Olsson, et al., 2003). This concept of resilience has been adopted in the domain of climate change adaptation as a way to deal with both gradual, disturbing changes and shocks (Linkov, et al., 2014).

In ecology, socio-ecology and socio-technical, the process-based approach is adopted to conceptualise resilience, mainly as an adaptive capacity. Socio-ecological resilience is observed as a process, where the post-disruption state can be different from the pre-disruption state, but the whole recovery process is resilient (Folke, 2006; Wardekker et al., 2010; Linkov et al., 2014). In addition to its application as outcome-based, psychological resilience has been conceived as a process that changes over time. For example, Luthar et al. (2000) referred to it as a "dynamic process encompassing positive adaptation within the context of significant adversity" (p543). A summary of these dimensions of resilience and their interpretation across different disciplines is shown in Table 1.

However, in applying the concept of resilience to property flooding, it is paramount to develop a resilient system where the outcome can be varied by constantly regulating the processes that generate the outcome. For instance, the drivers that make a system resilient to risk should be flexible in such a way that it will adjust to accommodate change to risk exposure. Therefore, since the focus of this research is on household resilience which is a combination of the physical and human components, it becomes pertinent to adopt the outcome-based approach to the physical components such as the building components and materials type defined the engineering resilience. However, the process-based approach is applied to the human components, this is focus of psychological and socio-ecological resilience. These are further expatiated in the next chapter.

Table 3.2: Dimensions of Resilience in different disciplines

DIMENSIONS OF RESILIENCE		
Disciplines	Outcome-based	Process-based
Psychology	effective functioning of young people exposed to risk	positive adaptation in the face of adversity
Engineering	ability to recover from disturbance	
Ecology		capacity to absorb disturbance and adapt
Socio-ecology		ability to transform and adjust to disturbance
Socio-technical		ability to transform and adjust to disturbance

3.5 APPLICATION OF RESILIENCE IN FLOOD RISK MANAGEMENT (FRM)

As important as it is to review concept of resilience described in other disciplines and to examine the approach in which the term has been conceptual, however, in order to operationalize resilience, to eliminate any form of ambiguity and ensure that it is measurable, it is necessary to specify resilience 'of what, for what and to what' (Carpenter et al., 2001). According to Brand and Jax (2007), the use of resilience as a frame for viewing flood risk management in particular is critically dependent on a well specified meaning of resilience.

Also, the right set of measures to use depends on the context. The context of this research has been clearly expressed in the introduction chapter. It is the resilience of residential property (both physical and human components) to flood risk exposure (flood impacts). Although, FRM and flood resilience have the potential to act as strong complements to one another (Disse, et al., 2020), the emergence of resilience in multiple disciplines presents a challenge and opportunity in its operation within the domain of flood risk management (Zevenbergen, et al., 2020). One of the challenges of resilience, though widely used in flood risk management policies, is that it is still largely in the conceptual phase (Zevenbergen, 2016). The number of empirical and quantitative case studies to demonstrate its practical relevance in FRM is still limited (Winderl, 2014). Which means that in reality, resilience tends to be only marginally applied as a supplement to flood risk management (Disse, et al., 2020).

Therefore, from a flood risk management perspective, in a bid to provide the required meaning and address some of these challenges, many questions arise, such as Hartmann and Jüpner (2020):

i. How does resilience add to and change the existing flood risk management system?
ii. How can resilience contribute to a more effective and efficient flood risk management approach?
iii. What are the specific advantages of integrating resilience in flood risk management?
iv. How can resilience be measured and quantified?
v. Which parameters are most relevant?

The last two questions are reviewed in the next chapter where the conceptual framework for the study is presented. The concept of resilience represents a new way of thinking about FRM expanding its scope from just the ability to ‘resist’ when exposed to high water levels which have been foreseen in the design, towards;

(i.) the ability to *recove*r (engineering) from a flood event (and/or to reduce the impacts that arise when flows occur that exceed the design standard) and

(ii.) the ability to *adapt* or to *transform* (psychological, ecological, socio-ecological and socio-technical) the existing approach based on the recognition that the conditions have been or will change in the future.

This context encompasses, implicitly, the inclusion of the terms reactive and proactive resilience (Jackson & Ferris, 2015). The latter refers to activities that occur before the disturbance and therefore is close to the ability to adapt and transform (process-based), whereas reactive resilience is more aligned with the ability to resist and recover (outcome-based).

According to Folke et al. (2010) a flood resilient system possesses the following: the capacity to resist floods (e.g., by flood defenses), the capacity to absorb and recover from floods (e.g., by spatial planning, disaster management, insurance), (engineering resilience) and the capacity to adapt and transform (in order to moderate potential damages, to take advantage of opportunities, and to cope with the consequences of floods and respond in a flexible way) (ecological resilience) (Folke, et al., 2010).

The UNISDR (2009) accepts that flood resilience sits just in between engineering and community resilience (socio-ecological), which concentrates on the ability of communities to thrive through and past hardship and to keep the built environment secured. Flood resilience captures the ability to thrive through flood events and recover from the disruptions occurred to the engineering assets. Meanwhile, for property flood resilience, it relates to the measures that reduce the risks to people and property enabling households and businesses to reduce flood damage, speed up recovery and reoccupation (Kelly, et al., 2019).

It is increasingly argued that optimizing the capacity to resist floods, absorb and recover from floods, and to adapt and transform, though requires a diversified portfolio of FRM, calls for a multidisciplinary approach. Meanwhile, in terms of benefits, Gersonius et al. (2016) opined that the adoption of a more resilient flood risk strategy will often enhance system robustness. The robustness property is an extension of the traditional FRM approach which focuses on structural/engineering measures and take into account all possible measures to deal with flood risk, including spatial planning, communication, evacuation, and emergency response.

One of the primary objectives of resilience (in almost every definition of the term) is to improve the recovery following an event (Disse, et al., 2020). Though, FRM may provide an excellent tool for accountability and reduction of damages, but flood resilience will aid in the reduction of losses (quantitative and qualitative) in the aftermath of an event. Therefore, the key aim of the adoption of this type of strategy is to address the consequence component of risk, and a key mechanism associated with the strategy is the reduction of flood impacts (Gersonius, et al., 2016).

3.6 SUMMARY

Resilience is a vague concept that is understood and interpreted differently across disciplines (psychology, engineering, ecology, socio-ecology and socio-technical). This review has shown how these disciplines have conceptualised resilience either as an outcome or a process. Also, it has examined how it's applied in the context of FRM.

As noted, the term resilience is based around the idea of the ability of a system to plan ahead or adjust to 'cope, accommodate, resist or adapt and recover' from a risk impact. When it is taken as an outcome, it is defined as the ability to cope with a hazard event. However, process-related resilience is defined more as an ability derived from continual learning and taking responsibility for making better decisions to improve the capacity to handle hazards. Whether resilience is taken to be an outcome or a process, its application to flood risk management nevertheless marks an important conceptual step forward. It is considered as a promising concept for preventing and mitigating the impacts of flood risk

Meanwhile, in the recent past, major flood disasters have indeed acted as catalysts for changing the FRM approaches. Currently, there is a growing recognition that FRM systems are complex systems. They bring together human, ecological and technical components. Contemporary thinking about the behaviour of these systems has led to a paradigm shift in managing those systems. The broader concept of socio-ecological resilience has provided guidance for building more resilient FRM systems.

The next chapter reviews extant resilience framework in FRM and more specifically property flood resilience. Also, it reviews the variables that represents resilience in the context of property flooding and presents a conceptual framework that synthesise the concepts of resilience theory applied in these different fields.

CHAPTER FOUR: CONCEPTUAL FRAMEWORK DEVELOPMENT

4.1 INTRODUCTION

This chapter presents the conceptual framework developed in the light of extant literature on the flood risk management in the context of household flood risk (Chapter Two) and the concept of resilience (Chapter Three). The framework has been developed to address the identified gaps in previous studies, taking into account the complex nature of the concept of resilience and a synthesis of concepts from the resilience literature to propose a property flood resilience (PFR) model.

This chapter has been structured around three thematic areas: reviewing existing resilience frameworks to identify any limitations in the application to measure PFR; outlining the make-up of property level resilience, with relevant variables required to measure flood resilience in each subsystem; and finally, a hybrid model that combines physical and human elements of the PFR is presented and described. This chapter seeks to address the third objective which is to develop a conceptual framework, specific to domestic property in the UK, for estimating the property flood resilience based on a synthesis of the extant literature.

4.2 A REVIEW OF THE EXISTING RESILIENCE FRAMEWORK

The development of resilience frameworks has been seen as a positive step towards understanding resilience and operationalizing the concept. Meanwhile, many conceptualizations of resilience have been constructed, often referred to as working definitions, for practical applications (Disse, et al., 2020). This form of conceptualisation, the working definitions, contains more expanded ideas and makes use of more concrete terms than the more abstract concepts contained in psychological, engineering, ecological, socio-ecological or socio-technical resilience described in the previous chapter (Disse, et al., 2020). However, these abstract concepts form the basis on which the working definitions are developed.

Since these working definitions are created specific to their application, they are numerous and vary widely (Disse, et al., 2020). Although, several of these definitions utilize similar terminology, it is essential to re-emphasize that there is no one-size-fits-all resilience framework, nor should there be (Levine, 2014; Schipper and Langston, 2015). Therefore, in the development of a conceptual framework which measures PFR, it is essential to bear in mind the inadequacies of the existing resilience models design to operate at household level.

The last few years have seen the development of a number of disaster resilience measurement frameworks (Oddsdottir et al., 2013; Winderl, 2014; Schipper and Langston, 2015; Ostadtaghizadeh et al, 2015). Meanwhile, reviews and analyses of the existing literature on disaster resilience measurement catalogue a plethora of models ranging from the household to the national scale; from single hazards to multiple hazards; and from general resilience to those designed for different purposes (Mitchell, 2013; Constas and Barrett, 2013; Levine, 2014). Also, several national and international aid agencies have proposed versions of resilience indicators (Alinovi et al., 2009; USAID, 2013) and a number of regional disaster resilience indicators have also been developed (Cutter et al., 2010; Resilience Capacity Index, 2017). Bahadur et al (2015) already make the examination easier with their review of resilience frameworks, from the household to the national level, most of which have been developed since 2013. Therefore, the aim here is to draw on these and highlight some of the challenges associated with implementing these frameworks to measure PFR.

Appendix D sets out the resilience frameworks found in various disaster resilience literature. The table shows the limitation of applying these frameworks to measure the PFR. Also, according to Winderl (2014), none of the frameworks at household level seems sufficient to measure the PFR, because majority of the framework are developed to address specific contexts, either addressing the building or the human resilience to flood impacts.

4.3 ADDRESSING THE LIMITATIONS

The absence of a unified approach to resilience in FRM has led to the development of frameworks or working definitions, that are created specific to their application (Disse, et al., 2020). The working definition is adopted in in this research to develop a framework specific for measuring PFR. Therefore, in order to address the current situation Dabson (2015) summarizes that the challenge is to develop a measurement system that is comprehensive across physical, economic, and social dimensions of the components that make up the individual home as a system. A conceptual framework for resilience measurement has to capture all possible pathways to well-being in the face of shocks (Food and Agriculture Organization, 2016). In this study, the physical aspect relates to the dimension that captures the building characteristics; the social aspect captures the awareness and interaction between residents and other organisations that could offer help prior to, during and after flood event; while the economic dimension relates to the financial capability of both the building and residents to survive flood impacts.

Another vital question to answer is the possibility of developing a framework that can quantify resilience. (Unger, 2005). This is likely due to the difficulty of standardizing approaches to resilience which are often highly localized and strongly varying. However, without sound resilience measurement practices, it is difficult, if not impossible, to adequately determine how prepared a system is to face a flooding event. It is similarly difficult to determine which interventions should be made and to what extent those interventions will improve resilience. This directly hinders the ability of stakeholders to make informed decisions and to produce an accountability of investments in resilience measures. Some of the tools and models that have been applied to measuring resilience are: ecological models (Cumming et al., 2005; Van Nes and Scheffer, 2007), metrics (Allen, et al., 2005), indicators (Chillo et al., 2011; Dai et al., 2012), composite index (Kotzee and Reyers, 2016) and resilience surrogates (Bennett, et al., 2005). Therefore, the measurement of resilience, in its localized form, is among the most applicable and important aspects of resilience. Meanwhile, in the purview of FRM, measuring flood resilience is not an easy task. Partly because there is no shared definition yet and, hence, the selection of resilient indicators is a highly subjective matter. Partly also because in the flood domain, resilience is always about the interaction between people (e.g., past experience, income level, health status) and the physical environment (e.g., the flood protection level, material selection of flood barriers, buildings) and being able to define and quantify these actors of the human and physical environment. Quantifying the resilience of a building to flood requires the use of indicators which give summary of a very complex behaviour of a system, the building system, or of the effects of a strategy or plan (de Bruijn, 2004). Some variables that can represent these indicators are potentially available, such as the flood characteristics. Meanwhile, the variables relating to the building characteristics such as the construction and material type, and socio-economic factors of the residents can be obtained through survey.

Therefore, in light of this discussion, in a way to evaluate and compare resilience of properties, that is state to what degree a property is more resilient to flood than another, it is imperative to understand how the variables and drivers of change within the system relate. The next section describes the components and the variables that make up the PFR, setting the ground for the development of framework for quantifying PFR.

4.4 THE MAKE-UP OF THE PFR SYSTEM

According to Kelly et al. (2019), PFR includes measures that reduce the flood risks to people and property. Therefore, based on this definition, it becomes pertinent to state that each of these components requires a different approach of safeguarding and dealing with the pressure that comes from flooding and its impacts. This is due to the differences that exist in both components. So to think of PFR is to think of minimising the flood risk exposure to both components, the building and its residents. The building is static in nature, and does not have a mind of its own except the design and structure that the design consultants, engineers and developers put in place (Adedeji et al. 2018). Therefore, its limit is defined by the design specifications. In contrast the human component is dynamic and the flexibility of the human mind and body allows adaptive responses to mitigate the impact of flooding.

The next sections examine these components and identifies where each component sits in the multifaceted resilience discourse. The aim is to create an appropriate approach that is specific in its operation to quantify resilience in each sub-system. The conceptual framework for property level flood resilience illustrates how these components intend to be resilient against the impacts of flooding.

4.4.1 The Resilience of the Building Component

For safeguarding the building component, the engineering approach to resilience has been applied. According to Garvin (2012), the approach is regularly applied in the purview of architecture and building technology, and when applied to the context of property flooding, it comprises of the resistance of a building to and its ability to recover from the impact of flooding (Hollnagel, et al., 2008). According to Kallaos et al. (2014), this conception often corresponds to inanimate, physical objects, like buildings, which can either withstand stress or recover by returning to the equilibrium state of functioning. This, however, involves the adoption of flood resilient strategies and technologies to adapt or construct buildings that remain intact or unaffected by flood water (Garvin 2012). That is, equipping the building with the ability to deal with the flood risk prior to the flood event, the capacity to cope during flooding and also to quickly recover during the aftermath.

In this component, the coping ability and capacity for quick recovery of buildings is often achieved through application of the norms of engineering designs, materials, construction techniques and retrofit strategies developed to protect the physical integrity of the building, enhance its ability to withstand flooding (Kallaos et al. 2014) and reduce its many impacts described in Chapter 2. The adoption of property-level flood resilience measures is another means of enhancing the building recovery capacity. It is a process in which physical improvements are made to the building after it has been flooded either through resistance measures (preventing flood water from entering) or resilience measures (minimising the damage when flood water enters) (Joseph et al., 2011).

These measures, designs and engineering standards define the limits of the building as regards its resilience to flood characteristics. Therefore, the level of resilience is determined by the speed of recovery of a building to fully inhabitable state. Meanwhile, when the flood risk exposure is higher than the building is designed for, recovery becomes difficult. Apparently, the focus of the measurement is entirely on recovery (Hollnagel, et al., 2008). This makes it difficult to apply the process-based approach where adaptability is required; and the building cannot learn from the flood action and adjust itself, with little or no human intervention, to a new regime and yet maintain desired functioning. To this end, the outcome-based approach is appropriate as it represents the essence of these design in terms of recovery.

The outcome-based resilience, applied in the engineering field, is conceived as the ability of the building to resist shocks and remain in the same state (Kallaos, et al., 2014). It emphasises on resisting, coping with and recovering from flood impact. The outcome-based approach is centred on the resilience outcome obtained through the performance of these strategies. According to Eriksen and Kelly (2007), this approach addresses the question: What can be done to protect the building and its content from the impact of flooding?

While these designs and engineering standards are intended to protect the building, they are not sufficient to convene resilience of the entire system of the flooding, made of both the building and its residents (Kallaos et al. 2014). Consequently, this conception does not apply well for complex, dynamic systems and networks such as the human component and societies where recovery does not necessarily imply returning to the initial state (Kallaos et al. 2014). Therefore, to make buildings more resilient, the resilience of the residents must be considered and this requires a different approach because individuals respond to disturbance in different ways.

4.4.2 The Resilience of the Human Component

For the residents, experiencing a flood event is a primary cause of stress, therefore, it is important to realise that the stress and strain which comes as a result of cleaning up of homes and recovery may also be a problem (Lock et al. 2012). This could have profound effects on well-being and mental health of residents that may persist over extended periods of time (Stanke et al., 2012). Notwithstanding, some people have shown to be resilient and cope well with being flooded despite being distressed by it. This form of resilience emanates from an individual’s ability to recover from stress together with the capacity to anticipate the changing shape of risk before the occurrence of failures and harm. A person’s ability to mentally and emotionally get back on track from flood impact does not, however, mean that he/she will simply return to his/her original state (Almedom, 2013). The performance of these individuals must continually adjust to changes in the nature and magnitude of the risk component (Hollnagel, 2006). Folke (2006) sees this as the ability to build capacity for learning and adaptation. The plasticity of the human being – mind and body – permits adaptive responses to the impact of flooding. Therefore, for humans, the general focus of resilience has been to understand how individuals deal with internal or external forces of change without compromising their well-being (Chuang, et al., 2018). The understanding of this kind of protection is well captured and furnished by the psychological resilience. Across the literature it has been emphasized that the psychological wellbeing of an individual under stresses speaks a lot about their ability to change continually and adapt (Berkes & Ross, 2012).

According to the Extreme Events and Health Protection (2014), an apt approach for managing people who have been affected by flooding is based on a set of principles and actions, rather than interventions that anyone can perform. It involves providing support for individuals who are suffering from the impact of flooding. Further, psychological resilience helps to study and understand the response of humans to the flood perturbation. Therefore, at an individual level, the psychological wellbeing of residents confers considerable protection (Friedli, 2009; Rose et al., 2016).

Consequently, the outcome-based approach applied for the building resilience is not appropriate for human resilience because of the dynamic nature of the human mind. Meanwhile, unlike buildings, every individual can decide on how he or she responds to the impact of flooding. The decision defines their resilience. This approach is process-based where resilience is viewed as a deliberate process leading to desired outcomes (Manyena, 2006).

4.5 VARIABLES SELECTION

Another critical stage in the definition and conceptualisation of the framework is the identification and selection of variables that represent each of these components. Flood resilience is an applied, complex area with multiple actors and variables (Twigger-Ross, et al., 2014). According to Thurston et al. (2010) the generic term, property level flood risk variables cover sources of information relating to flood history, flood risk and flood mitigation for the residential properties and its residents. This section describes the drivers that acts on the flood properties domain which contains the building and human components affected by the characteristics of the flood risk exposure.

4.5.1 Flood Characteristics

The geographical and hydrological data are foundational for the establishment of a flood risk assessment system (Chaochao, et al., 2016). These data are mostly the flood characteristics and are presented in the conceptual framework. The focus is to protect the building and its residents against these actors (the flood characteristics). Experts in FRM field have developed models that enables the evaluation of some of these properties like the flood depth, velocity and duration (Kvočka, 2017). Also, as regards to the relative intensity and frequency of potential flood events, some organisations and experts have made certain data available (Thurston, et al., 2010). Meanwhile, a range of products is available in assessing these data at individual property level, these including the Flood Map, historical flood event outlines, National Property Dataset (NPD 2008), National Flood Risk Assessment (NaFRA) products and flood risk assessment (FRA) products (Thurston, et al., 2010). These flood characteristics and associated data are key to assessing the level resilience with the PFR viewed as the ability of both the building and residents to cope with the impact of the flood properties.

4.5.2 Building Characteristics

The data/information that provides insight on the resilience of the physical building to flooding include: building material and construction type, the likely points of water entry, availability of resistance and resilience measures referred to as PFR (ODPM, 2003; Dhonau, et al., 2016). These are essential features because the water retention capacity of material differs. For instance, dense materials retain little water but dry slowly, whereas porous materials can retain large amounts of water but can often be dried quickly. Also, some types of construction and the addition of extensions can result in voids being created within the fabric of a building. According to Lamond et al., (2009), the PFR is an essential element of modern FRM strategy, therefore, this information is relevant for the assessment of resilience of the building, structurally and in terms of safeguarding its contents.

The features of a building located in high flood risk areas are different from those located in low risk areas, where often the former is designed to accommodate flooding. Many of these features are put in place actively or in standby mode as back-ups to be activated in the event of flooding or its aftermath. These features are listed in Table 4.2 with their contributions to flood damage reduction. Some of these prevent water from getting into the building such as the resistance measures which could be permanently or temporarily deployed, while others entail the use of materials that will not get damaged in contact with water and designs that promote quick recovery. These are referred to as the resilience measures. The permanent and temporary resistance measures are designed to stop water from entering into the building either by shutting existing openings such as doors, windows, airbricks, vents and pipes, or by preventing entrance through the walls. For the permanent measures, no action is needed to deploy the device that will stop the water, while the temporary measures will need to be installed before flood water arrives. The measures are designed to reduce the damage flood water can cause by limiting the point of water entry and providing homeowners extra time to move ground floor contents to a safe zone. However, the measures may only be effective for a limited time and water depth (Dhonau et al. 2016).

In the case of differential head of 0.6 m (USACE, 1988) it is recommended to let water into the building to avoid build-up of water pressure outside the building walls that can lead to serious structural damage or collapse. Therefore, in case where water is allowed into the building, features that minimise damage and allow for quick and easy cleaning and drying are considered. The interior of the building, fixtures, fittings, furniture, floor covering and wall hangings are made from materials that are not damaged by water. This is essential because it allows the quick recovery of buildings back to a habitable state (Dhonau et al. 2016). Therefore, the key is to measure the effectiveness of these features to prevent or minimise flood impact to the physical component of the building.

4.5.3 Human Variables

For the resilience of humans to a flood event, it is clear that the human coping ability differs and certain factors have been identified as responsible for influencing the way humans deal with the impact of flooding. For the residents, certain factors are considered to influence response to flood risk and flood events. Some of these factors are gender, age, education level, employment status, nationality, health status, flood awareness (Huang, et al., 2010; O'Sullivan, et al., 2012). Research has been carried out to examine the health impacts of flooding on individuals with some of these characteristics (Buckle, et al., 2000). In fact, research done on gender has shown that the impact of floods on men and women is different and distinct (Tapsell & Tunstall, 2000). Other studies suggest that women or girls may be at greater risk than men or boys of mental health problems following exposure to flood disaster (Tunstall, et al., 2006).

For the social dimensions and health status, the following residents: elderly (Age 70+), lone parents, children (Age 12−) and people whose activities are limited by ill-health or disability are more vulnerable to the impact of flooding than others (DEFRA 2006). Financial capacity is another factor that could influence decision making as regards the choice of insurance policy and property level flood protection to acquire. This could affect the coping and recovery capacity of both components and greatly impact resilience. Table 4.2 shows the human factors that support resilience to flooding and their contributions.

According to Adedeji et al. (2018), the human resilience can be improved by better preparation and building capacity to resist floods or to minimise the impacts. These could be achieved by understanding how these factors influence reaction to flood impact. Better preparation could come in the form of flood risk awareness, which implies understanding all actions necessary to minimize the impact of flooding (Jha et al., 2012). Meanwhile, building adaptive capacity could mean the lessons learnt from past flood experience or taking cue from people with past flood experience.

Table 4.1: Resilience measures and their implications on damage reduction

MEASURES	COMPONENTS		APPROACH	AREA ADDRESSED	IMPLICATION
	BUILDING	HUMAN			
Flood door	✓		Resistance	Point of water entry	Prevent the entrance of water through door openings
Flood window	✓		Resistance	Point of water entry	Prevent the entrance of water through window openings
Non-return valve on drains and pipes	✓		Resistance	Point of water entry	Prevent the entrance of water through drains and pipes
Water resistant paint	✓		Resistance	Point of water entry	Prevent the entrance of water through walls
Automatic anti-flood airbricks	✓		Resistance	Point of water entry	Prevent the entrance of water through air gaps
Demountable door barriers	✓		Resistance	Point of water entry	Prevent the entrance of water through door openings
Demountable window barriers	✓		Resistance	Point of water entry	Prevent the entrance of water through window openings

Toilet plugs	✓		Resistance	Point of water entry	Prevent the entrance of water through toilet openings
Pipe bungs	✓		Resistance	Point of water entry	Prevent the entrance of water through pipes
Raised service meters	✓		Resistance	Property level flood protection	Access to power and communication during flood event
Sump and pump systems	✓		Resistance	Property level flood protection	Controls the level of water within the building
Raised door threshold	✓		Resistance	Construction type	Prevent the entrance of water into the building
Two or more storeys	✓		Resilience	Construction type	Increases safe indoor flood level and allows the movement of ground floor content to safer floor
Water resistant materials in kitchen and bathroom	✓		Resilience	Material type	Makes cleaning easier and drying faster

Tiled surface	✓		Resilience	Material type	Makes cleaning easier and drying faster
Valuable items kept upstairs	✓	✓	Resilience	Safe storage	Avoid loss of memorabilia
Insurance status	✓	✓	Adaptive	Economic status	Enhance quick recovery
Raised electrics and sockets	✓	✓	Resilience	Property level flood protection	Avoid damage and electrocution
Flood experience		✓	Adaptive	Adaptive capacity	Possess flood memory to learn from
Flood awareness		✓	Flood risk intervention	Raising awareness of flood risk	Increased level of preparedness
Income level		✓	Resilience	Economic status	Improves financial capability
Level of education		✓	Adaptive	Educational status	Ability to develop a flood plan
First aid kit		✓	Resilience	Health status	For emergency treatment of injuries
Employment status		✓	Resilience	Social status	Enhance quick recovery

4.6 THE PROPERTY LEVEL FLOOD RESILIENCE FRAMEWORK

Consequently, resilience is seen as a quality, characteristic or result that is generated (as in the case of the building resilience) or developed by the processes that fosters or promotes it (as in the case of the human resilience). Based on the foregoing discussion, a new hybrid framework is developed to conceptualise property level flood resilience (see Fig. 4.1). This hybrid framework contains the two components that make up the individual property, the building and the human components. Each component is embedded within the appropriate discipline and approach

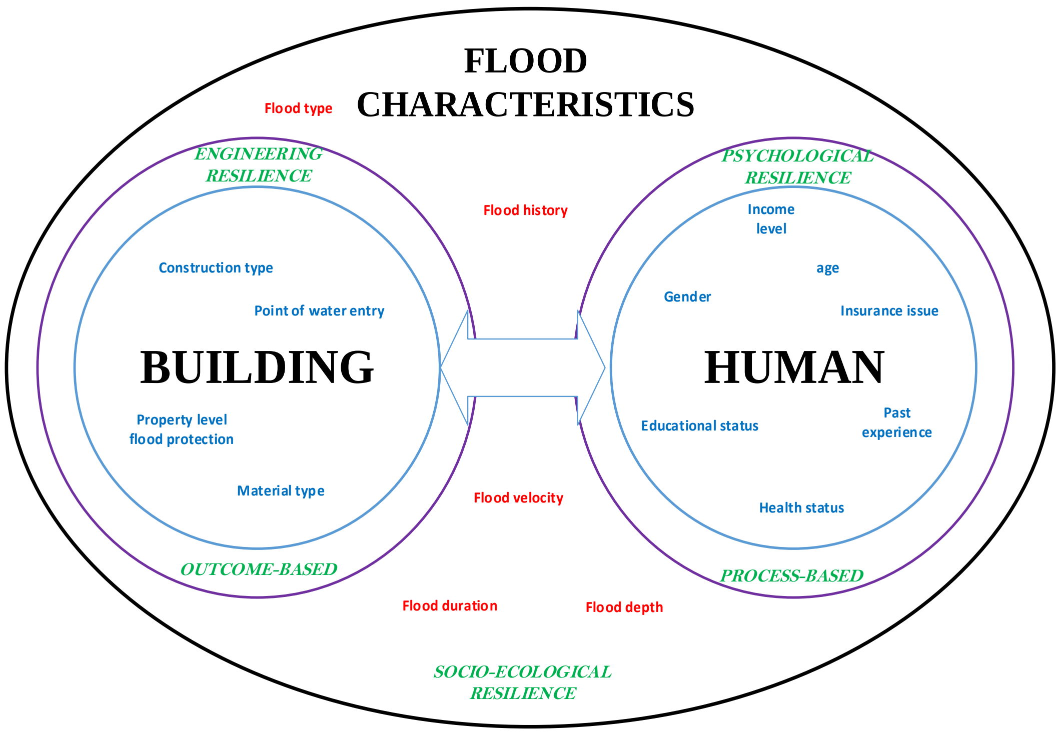


Figure 4.1: The property level flood resilience framework

For the building component, the engineering resilience is applied with an outcome-based approach which focused on what can be done to protect the building and its contents (Eriksen and Kelly, 2007). While for the human component, the psychological resilience was applied using the process-based approach which emphasises what should be done to strengthen the residents' capacity to respond and adapt to flood risk exposure. The double-pointed arrow in the centre between the components indicates their interaction. This implies that whatever decision or action (process-based) taken to enhance the human resilience may also affect the rate of recovery of the building (outcome-based) (Adedeji et al. 2018). For instance, an individual who purchases flood insurance has taken a step that will enhance their resilience (Manyena, 2006) and also a decision that will impact the overall outcome of the building resilience. Similarly, a building with a poor recovery capacity will impact the level of changes required and the action taken by humans to adapt to such situations. According to Lock et al. (2012), it is important to know that the stress and strain associated with dealing with cleaning up of homes and recovery may also be a problem. Therefore, an individual who finds oneself in this kind of situation may develop the adaptive capacity to alleviate the mental stress resulting from the disruption and upheaval.

At this point, the socio-ecological resilience is adopted to focus on the interaction between the physical component of the building, social interaction of human with the environmental properties of flood.

4.7 SUMMARY

This chapter has presented the development necessary for the measurement of flood resilience within the context of property level flood risk. The property level flood resilience framework was developed to determine the level of protection that is present in the key components, building and human. The conceptual framework reveals variables and the relationships between the variables of the PFR and the associated benefits of reducing impacts of flooding on households.

This chapter marks the end of the theoretical development of the framework to be used for the empirical research. Chapters 2 and 3 presented the extensive literature review while Chapter 4 has distilled this analysis into a conceptual framework for empirical analysis. This conceptual framework will be tested at the empirical stage of this research by collecting and analysing data. Therefore, chapter 5 presents details of the research methodology adopted for undertaken this research work.

CHAPTER FIVE: RESEARCH METHODOLOGY

5.1 INTRODUCTION

In preceding chapters; the aim and objectives of the research were presented (in chapter one), while the critique from the extant literature review were presented (in chapters two and three) which led to the development of the conceptual framework (in chapter four). This chapter describes and justifies the research methodology that was adopted to test and validate the PFR model. There are three principal research approaches that can be employed in researches, namely qualitative, quantitative and mixed methods (Creswell, 2003). To understand the basis upon which the research methodology was adopted, the research approach is first discussed. Arguments are presented to justify the choice of the approach and the specific research methods applied in the data collection. Thus, this chapter provides the platform on which objective 4, will be achieved, the collection of data required to test the PFR model.

5.2 RESEARCH PHILOSOPHY

To think that research methods are only specific techniques for collecting and analysing data in such a way that reliable conclusions can be made, is not enough. It is believed that without adequate knowledge of what research is, and requisite understanding of the context in which these research methods are used, it will be difficult to identify the appropriate research method to use and why it is used. According to Arbnor and Bjerke (1997), it is difficult to empirically or logically determine the best approach to use for research. However, the methodology with which research is done and the research objectives are achieved is greatly influenced by the philosophical position of the researcher (Flick, 2009; Saunders et al., 2016). This is sustained by Khaldi (2017) who believes that the type of research methodology chosen by a researcher is determined by the research philosophy which the researcher adheres to. This research philosophy will support the research objectives and also determine the research instruments that will be designed and used to translate the approach into practice. Therefore, a clear understanding of the philosophical foundations of research will undoubtedly provide the guide needed to opt for and justify the choice of a particular paradigm (Khaldi, 2017). Consequently, this study agrees with the submission of other researchers about the need for a philosophical standpoint for research. Therefore, before presenting the philosophical stance of this research, a discussion of research philosophies is hereby presented.

5.2.1 Philosophical Assumptions

The discussion on the choice of research methodologies is guided by research philosophies and assumptions underlying each of the research approaches, techniques and methods. These include assumptions about human knowledge (epistemological assumptions) and about the realities one encounters in the research embarked on (ontological assumptions). Different research paradigms inherently contain opposing ontological and epistemological views, this implies that they possess divergent assumptions of reality and knowledge which underpin their particular research approach. These assumptions inevitably shape how one understands the research aim, the methods used and how the findings are interpreted (Crotty 1998). These assumptions are discussed in the next subsections.

5.2.1.1 Ontological Assumption

The first assumption is the ontology. It describes the researcher's perception of the nature of reality (Guba and Lincoln, 1994). This is supported by Richards, (2003) view, as he sees ontology as the assumptions we make about the kind and nature of reality and what exists. Ormston et al (2014 p4) emphasise that the focus of ontology is to address the question, *"whether or not there is a social reality that exists independently from human conceptions and interpretations and, closely related to this, whether there is a shared social reality or only multiple, context-specific ones"*. Hence, ontology can be considered as a belief system that mirrors the way an individual make sense of what represent a fact. Therefore, identification of the ontology at the beginning of research process is critically important. Many ontological positions exist (Johnson and Gray 2010; Tashakkori and Teddlie 2010); however, the dichotomy between realism and relativism can be used to demonstrate clearly the importance of ontology to research in any field. The realist ontology holds that a single reality exists that can be studied, understood, and experienced as a *truth*; this implies that a real world exists independent of human experience (Moses and Knutsen, 2012). The relativist ontology, on the other hand, opines that reality emanates from within the human mind, this implies that multiple realities exist, it is relative according to each individual who experiences it at a given time and place.

5.2.1.2 Epistemological Assumption

The second assumption, epistemology, relates to the study of the nature of knowledge, with emphasis on the possibility of gaining knowledge of the world (Hughes and Sharrock, 1997). According to Tennis (2008), epistemology is the claim on what knowledge is valid in research, and therefore what constitutes acceptable sources of evidence (for presenting that knowledge) and acceptable end results of knowledge (findings). Epistemology is therefore, concerned with all aspects of the validity, scope, and methods of acquiring knowledge, and how the extent of its applicability can be determined (Moon & Blackman, 2014).

To explain epistemological positions, the continuum provided by Crotty (1998) is considered. This continuum focuses on the relationship between the subject and the object, two main positions of epistemology. Subjectivism and objectivism have been described as a continuum’s polar opposites with varying philosophical positions aligned between them.

In objectivism, researchers remain detached from their subjects (Pratt 1998). Objectivists believe they can discover an objective truth that is empirically verifiable, valid, generalizable, and independent of social thought and social conditions (Crotty 1998). Proponents of this position, objectivism, are realists. Subjectivism on the other hand refers to the meaning that comes from anything but the object to which it is ascribed (Crotty, 1998). This implies that the object itself makes no contribution to the meaning that is imposed on the object by the subject (Crotty, 1998). Subjectivist epistemology believes that what makes up knowledge is based on how people perceive and understand reality. Thus, reality is pluralistic (i.e., reality can be expressed in a range of symbol and language systems) and plastic (i.e., reality is stretched and shaped to fit the purposes of individuals) (Pratt 1998; Powell 2001). Proponents of this position, subjectivism, are relativists.

5.2.2 Research Paradigm (Worldview)

Every paradigm is based upon its own ontological and epistemological assumptions. It is impossible to engage in any form of research without committing, often implicitly, to ontological and epistemological positions. The difference in ontological and epistemological positions often lead to different research approaches towards the same phenomenon (Grix, 2004). This will become evident as the positivist and interpretive paradigms are explored. These two paradigms, positivism and interpretivism, are commonly adopted in the FRM field.

5.2.2.1 Positivism and Post-Positivism Paradigm

The purpose of the positivism research approach is scientific explanation (Antwi & Hamza, 2015). A basic assumption of this paradigm as Ulin et al., (2004) remarked is based on the goal of science which is to develop the most objective methods possible to get the closest approximation of reality. Easterby-Smith et al., (2012) report that one of the key design of positivism is that the world exists externally, and that its characteristics can be measured using objective means rather than being inferred subjectively by sensation, reflection or intuition.

As della-Porta and Keating (2008:21) points out, for the positivists:

> *The world exists as an objective entity, outside of the mind of the observer, and in principle it is knowable in its entirety. The task of the researcher is to describe and analyse this reality. Positivist approaches share the assumption that, in natural as in social sciences, the researcher can be separated from the object of his/her research and therefore observe it in a neutral way and without affecting the observed object.*

These assumptions mirrored the strong version of positivism which was fully interested with natural sciences excluding thereby all social sciences from their concern. Not all researchers, however agree with this strong form of positivism. Many supported another version referred to as the weak version or the post-positivism view which Phillips (1990:33) sums up as follows:

> *... although the object of our inquiry exists outside and independent of the human mind, it cannot be perceived with total accuracy by our observations; in other words, complete objectivity is nearly impossible to achieve, but still pursues it as an ideal to regulate our search for knowledge.*

The post positivists paved the way for the inclusion of social sciences in the realm of science and see research in a similar manner to natural science research; The assumption is that social reality is composed of measurable objective facts which can be accurately measured with the use of statistics to test causal relationships (Khaldi, 2017). Therefore, postpositivists hold a deterministic philosophy in which causes determine outcomes.

The key assumptions of this position are summed up by Phillips and Burbules (2000:121):

i. Knowledge is conjectural: absolute truth can never be found. Thus, evidence established in research is always imperfect and fallible. It is for this reason that researchers state that they do not prove a hypothesis; instead, they indicate a failure to reject the hypothesis.
ii. Research is the process of making claims and then refining or abandoning some of them for other claims more strongly warranted.
iii. Data, evidence, and rational considerations shape knowledge.
iv. Research seeks to develop relevant, true statements, ones that can serve to explain the situation of concern or that describe the causal relationships of interest.
v. Being objective is an essential aspect of competent inquiry; researchers must examine methods and conclusions for bias.

The ontological position of positivism/postpositivism is one of realism and the epistemological position is objectivism. The positivism and postpositivism paradigm seek predictions and generalizations; thus, methods often generate quantitative data. Examples include: standardized tests, closed ended questionnaires and descriptions of phenomena using standardized observation tools (Pring, 2000). Analysis involves descriptive and inferential statistics. Inferential statistics allow sample results to be generalized to populations.

5.2.2.2 The Interpretivism Paradigm

Interpretivism is contradictory to positivism. It assumes that logic and reality are produced based on the changes of experience (Partington, 2002) which requires social scientists to grasp the subjective meaning of social action (Bryman & Bell, 2015). Interpretivism focuses on the ways people make sense of the world by sharing experiences with others through the medium of language (Easterby-Smith et al., 2012). The interpretive paradigm does not question ideologies, it accepts them. Therefore, based on the interpretivism, the social world can only be understood from the standpoint of individuals who are participating in it (Cohen et al., 2007). Interpretive methods yield insight and understandings of behaviour, it is concerned with the uniqueness of a particular situation, contributing to the underlying pursuit of contextual depth (Myers, 1997). However, while interpretive research is recognised for its value in providing contextual depth, results are often criticised in terms of validity, reliability and generalisability (Perry, 1998; Farzanfar, 2005) The purpose of inquiry is to understand a particular phenomenon, not to generalize to a population.

The ontological position of interpretivism is relativism and the epistemological position is subjectivism. Interpretivism, by its nature promotes the value of qualitative data in pursuit of knowledge (Kaplan & Maxwell, 1994). Examples include: case studies (in-depth study of events or processes over a prolonged period), phenomenology (the study of direct experience without allowing the interference of existing preconceptions), hermeneutics (deriving hidden meaning from language), and ethnography (the study of cultural groups over a prolonged period). Inquiry strategy include: open-ended interviews, focus groups, open-ended questionnaires, open-ended observations, think aloud protocol and role-playing.

5.3 THE PHILOSOPHICAL POSITION OF THIS RESEARCH

The driving forces for the choice of a research methodology in any study are not the advantages or disadvantages associated with a particular method but the research problem or objectives of the study (Mertens, 2003; Creswell, 2003). The study has been driven from the onset by the need to derive quantitative measures of the PFR present in individual homes located in flood risk areas. This commitment, dictates the choice of a quantitative approach and research method as the foremost paradigm for this study.

From the research aim posed in Chapter 1, it is evident that the study is laden with measurement and therefore to obtain objective measurements, it is logical to adopt positivism as the research world view for the phenomenon being investigated. The aim of the research to quantify the PFR of individual property and the desire to have a tool and decision support model that is robust and objective in its recommendations and interpretation of the finding dictates the choice of a quantitative research method. The quantitative research is hugely adopted by the positivist, and is known for quantifying relationships between variables (Egbu, 2007). Therefore, the positivism research paradigm is adopted with a *realistic ontology* as it mirrors the causal reality. In this study, it is identified that certain factors classified as building features; flood characteristics; insurance and socio-economics factors are responsible for raising or depleting the resilience of individual household to flood risk. The study seeks to estimate the effect of these explanatory factors on the resilience of individual home. However, it is expected that any improvement in the resilience will be attributed to these factors.

The desire to have a tool and decision support model that is robust and objective in its recommendations and interpretation of the finding dictates the choice of the *objectivism epistemological* stance. According to Crotty (1998), objectivists believe they can discover an objective truth that is empirically verifiable, valid, generalizable, and independent of social thought and social conditions (Crotty 1998). Therefore, to avoid being biased, it important for the researcher to detach from the phenomenon under study.

5.4. DIFFICULTY OF USING THE QUALITATIVE RESEARCH APPROACH

Due to the subjective nature of the human mind, a qualitative approach is required to understand how individuals respond to flood risk and gain insight into the factors that are responsible for resilience to the psychological effects of flood. This, without a doubt, will add some flavour to the research findings. A mixed method would have been the best method to use. The qualitative approach, with interviews as a means of collecting data, would have been the most appropriate for further exploring the human elements and sociological factors, as well as gaining understanding of how individuals and communities respond to flood impact.

The hope of conducting any type of interview or meeting with individuals willing to share their perspectives was hampered by the pandemic situation caused by the COVID-19 virus. As a result of the pandemic situation, the government-imposed restrictions on leaving homes and gathering in order to combat the virus and reduce the risk of contracting and spreading the virus. Telephone interviews could have been an alternative approach, but many of the potential interviewees were coping with the difficult circumstances caused by the pandemic, such as the inability to meet with family members, the fear of contracting the virus, and the pain caused by the loss of loved ones, among other issues. It was a difficult time for the world to deal with, and because of the sensitive nature of the study, the option of conducting interviews was dropped. Apparently, this was the least of people's concerns at the time. As a result, the research for the human side of the PFR draws on previous studies to understand the factors that contribute to human resilience. An exploratory analysis was carried out in order to gain insight into the human response to flood impact (see sections 4.4.2, 4.5.3).

5.5 DATA COLLECTION

In conducting quantitative research, three main approaches are typically employed. These approaches are identified by Fellows and Liu (1997) and Creswell (2003) as desk, experiments and survey. The survey approach was adopted for this study because of the various advantages it has over others and because of its strength in enabling attributes of a larger population to be identified from a small group of individuals (Babbie, 1990).

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; obtaining first-hand information on their perception of the effectiveness of PFR measures to minimise flood impacts on the households cannot be elicited through other means apart from eliciting it directly from the homeowners.

The survey approach employs the use of questionnaire as a tool for collecting the required data. There is no single comprehensive rule for when to use a questionnaire in research. The choice and use of questionnaires in quantitative research designs is usually based on a variety of factors such as the type of information to be gathered and the available resources for the study. In this particular study, questionnaires were deemed particularly suitable for this phase of the research for the following reasons:

- the need to gather lots of data about many different households in diverse geographical regions which could then be used to generalise as far as possible to the wilder population.
- the need to conceal the identity of the participants to enhance participants' chance of providing honest response, due to the relative sensitivity of the topic
- 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. Within the household context, it is difficult for a researcher to be a part of the context, the questionnaire therefore gathers information from individual household.

5.6 SAMPLE FRAME

The study focuses on households in the UK located within the flood risk zones. Meanwhile, it was reported that about 5.2 million properties in England only are exposed to flood risk (Environment Agency, 2014). This figure represents about one in six properties (around 17%). It was considered necessary to select sample frame for the analysis, because it is impractical to include all the properties in the sample size due to time and resources constraints (Cresswell, 2003). Also, the main advantage of sampling is its 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). However, to ensure that the sample frame is a representative of the entire properties located within the flood risk zones, the selection was based on the need to represent the widest possible variation both geographical and flood typology. The flood sites used in the empirical stage of the research were selected from locations flooded within the last 10 years. The rationale is simply because PFR is a new FRM approach which came into existence in the last few decades and its uptake is still being encouraged (Rose, et al., 2016), though, it is rapidly becoming the focus of protection against flood risk at property level.

5.7 SAMPLE SIZE

The determination of sample size is an important issue in quantitative research that seeks to make statistically based generalisations from study results to the larger world (Fox, et al., 2007). To generalise in this way, the sample size must be appropriate so that the results are representative, and the statistics must be able to discern associations or differences within the results of a study (Fox, et al., 2007). Lakens (2021) identifies six approaches that can be used to justify sample size in a quantitative study (see Table 5.1). These include the most frequently used and applicable approaches for single studies. The first justification is that data from nearly the entire population has been gathered. The second justification focuses on resource constraints, which are almost always present but rarely evaluated explicitly. The third and fourth reasons are based on a desired statistical power or accuracy. The fifth justification is based on heuristics, and finally, researchers can choose a sample size without considering any other factors. Each of these justifications can be stronger or weaker depending on the conclusions that researchers want to draw from the data they intend to collect.

Table 5.1: Overview of possible justifications for the sample size in a study

	Type of justification	When is this justification applicable?
1	Measure entire population	A researcher can specify the entire population, it is finite, and it is possible to measure (almost) every entity in the population.
2	Resource constraints	Limited resources are the primary reason for the choice of the sample size a researcher can collect.
3	Accuracy	The research question focuses on the size of a parameter, and a researcher collects sufficient data to have an estimate with a desired level of accuracy.
4	A-priori power analysis	The researcher question has the aim to test whether certain effect sizes can be statistically rejected with a desired statistical power.
5	Heuristics	A researcher decides upon the sample size based on a heuristic, general rule or norm that is described in the literature, or communicated orally.
6	No justification	A researcher has no reason to choose a specific sample size, or does not have a clearly specified inferential goal and wants to communicate this honestly.

Source: (Lakens, 2021).

In some cases, data could be collected from (almost) the entire population under investigation. However, in this case, more than 5.2 million properties are located in flood zones. Furthermore, this does not imply that all of these properties have been flooded. As a result, estimating the population that have been flooded with precision becomes difficult.

Based on resource constraints; all researchers face two resource constraints: time and money (Lakens, 2021). In practise, sample size is always constrained by the available resources. The PhD programme has a timeframe for completion and thesis submission, and it is typically expected to complete both the research and the thesis within the PhD timeframe. In addition to time constraints, financial resource constraints frequently have a direct impact on how much data can be collected. For example, the financial burden of collecting approximately 5.2 million responses is enormous and nearly impossible. However, to determine sample size in the presence of these challenges, statistical power analysis is usually preferable (Jeon, 2015). In addition, to the threat posed by covid-19 to the response rate, the approach of a-priori power analysis was considered with a focus on testing the effect size that can be statistically rejected with a desired statistical power.

For the regression analysis; a commonly used interpretation is to refer to effect sizes as small (f^2 = 0.02), medium (f^2 = 0.15), and large (f^2 = 0.35) based on benchmarks suggested by Cohen (1988). This study will consider the medium effect size of 0.15, as the concept of resilience is still in the development stage in PFR. A generally accepted minimum level of power is 0.80 (Cohen, 1988). The alpha level (Type I error rate) is set at 5% in concordance with common practice (Lakens et al, 2018). This resulted into a minimum sample of 87 (see Appendix B-19 for the result of the G*Power analysis). However, in the case where the sample size obtained for the study is less than the estimated sample size above, a post hoc power analysis test will be carried out. This investigates the likelihood of detecting an effect when one truly exists (avoiding a Type II error) and thus increasing the reliability of the result.

5.8 TARGETTED RESPONDENTS

With the help of flood risk maps, it is much easier to identify residential properties in flood risk areas. Postcodes in flood-prone areas can be generated, and then addresses that fall in these areas can be obtained. in this case, we will assume that all postcodes in these areas have had one or more flood events, which is not always the case. The most difficult challenge is identifying homeowners who have had flood experience, which includes internal property flooding. Therefore, to significantly reduce the likelihood of sending a survey to the wrong audience. The steps taken were as follows:

i. The flood risk maps are used to obtain flood risk areas. The flood risk maps are 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 signpost 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 the Lake District, which I visited before the COVID-19 pandemic.
iv. These postcodes were entered into address finder (doogal.com) to obtain the addresses that corresponded to these postcodes. Though it was not guaranteed that all addresses within these postcodes would have experienced these flood events. However, this 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 most 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 recipient to return the questionnaire if they had not experienced flooding or to transfer the survey to someone they knew had.

5.9 QUESTIONNAIRE DESIGN

Proper questionnaire design is vital to successful data collection and ultimately to the realisation of the research aim (Babbie, 1990; Fellow and Lui, 1997; Creswell, 2003). A good questionnaire is imperative for good survey results. There are no established rules for designing questionnaire, therefore the steps adopted to design questionnaire for this study were taken from experiences accumulated through various studies. Hence, recommended best practice encouraged in the literature by Oppenheim (1992); Devaus (2002); Barker (2003) and Blaikie (2010) were considered. This practice includes making sure the questionnaire is easy to read and understand, as short as possible, capable of being completed within minutes and organised to follow smoothly without any hidden bias. It is necessary that respondents understand the questions in a way that the researcher wants as this will eliminate the probability of potentially incorrect responses. Owing to these, the questionnaire was subject to review, also, the layout and format were given much consideration. The questionnaire is divided into sections addressing the variables presented in the conceptual framework (chapter 4).

The questionnaire was designed to be fairly short. According to Joseph (2014) a fairly short questionnaire is estimated to be completed within 30mins. The questionnaire was estimated to be completed in about 20 minutes. It was accompanied by a letter of introduction explaining the purpose of the questionnaire (see Appendices A-2 and A-4). Also, in a bid to make the questionnaire 'respondent-friendly', it consisted of multiple choice questions requiring ticked-box responses.

5.9.1 Questionnaire Review

The effective translation of the desired question content into appropriate words does the trick in gathering responses. Meanwhile, lack of appropriate words can result in the respondent misunderstanding the question and supplying inappropriate answers or refusal to answer.

It was recognised that a good survey instrument does not just happen, it is a result of design and re-design in order to improve both appearance and content (Samwinga, 2009). In order to evaluate the clarity and comprehensiveness of the questionnaire, as well as the feasibility of the survey as a whole, a review of the questionnaire was carried out. The aim of the questionnaire review process is to test the wording, identify any ambiguity in the questions, and test respondents' understanding of the questions.

Although, the questions have been carefully designed and informed by a comprehensive review of previous related research, yet it was further tested drawing on informal discussions with few homeowners affected by flooding, and 5 fellow doctoral students were handed a copy of the questionnaire and a review form (see appendix A-6 for copy of the review form) to help look out for errors in spelling, and provide feedbacks on questions in terms of clarity.

The 5 reviewers reported that the questionnaire was easily understandable and required 20 to 25 minutes for completion. Additionally, the reviewers validated the content of the questionnaires, although minor changes to the final design of the questionnaire were undertaken based upon the received feedback, and a final questionnaire was developed.

5.9.2 Structure of the Questionnaire

Questionnaire sequencing is very important to obtain required information from the participant. A proper sequence of questions reduces significantly the likelihoods of individual question being misunderstood (Roopa & Rani, 2012). The first few questions are particularly important because they are likely to influence the attitude of respondents and in seeking their desired attention (Roopa & Rani, 2012). Therefore, the first set of questions in the questionnaire demands information on the physical feature of the properties, the construction and type of material used both for the building and its contents. It is expected that homeowners will possess a reasonable level of understanding about their properties and be able to provide answers to certain questions as regards to the physical features and technical specification of their properties. These questions relate to the factors that influence the building resilience. The next section seeks information on flood experience and risk awareness. This entails questions on flood history, flood type, flood risk level, flood risk awareness and flood depth. It is considered important for these set of questions to come next since the focus of the questionnaire is on flood resilience. So as to keep the respondent abreast of the purpose of the questionnaire.

The third section seeks to obtain information on the effectiveness of the PFR (resistance and resilience) measures installed. This is the most important information needed to develop the building resilience scale. The respondents are required to rate certain flood resistance and resilience measures. The rating was designed to use a likert-type 5-point scale with boxes to be ticked; and 1 being “very effective” for measure in question, while 5 being ”not effective at all“. These sets of questions are designed to produce the building resilience scale. The fourth section seeks respondents to rate the overall severity of the flood in terms of its impact on their building and its contents. The respondents were asked to rate the relative severity on a likert-type 5-point scale; with 1 being “very serious”, while 5 being ”not at all serious”.

The next section of the questionnaire demands information on the socio-economic data of respondents, such as: sex, age, income level, educational statues. Furthermore, data on length of time in which respondents have lived in the property was also collected. This is considered necessary so that the respondents can be grouped into socio-economic classes. Also, this can be used to assess the effect of socioeconomic factor (human factors) on flood resilience. It consists of multiple choice questions requiring ticked-box responses. Also, questions on flood insurance were placed just after the section on socioeconomic factors also designed as multiple choice questions.

The most sensitive questions, are those on the psychological impact of flood on the households which some respondents may not want to respond to if placed at the beginning. Therefore, this is strategically placed towards the end of the questionnaire so that this question will not put respondents off in answering other questions. However, it is worth noting that this question is very important as it has been designed to produce the human resilience scale. Respondents were asked to rate the relative severity on a likert-type 5-point scale; with 1 being "strongly agree" to the psychological impact in question, while 5 being "strongly disagree". This is designed to collate information on the household response to flood impacts. Impacts such as, health effect of flooding, stress of flood event, disruption to daily life, anxiety and worry about future flooding were included.

Some of the answer options are quite limited; this is an area where the qualitative research method would have been more beneficial. However, in order to reduce ambiguity further clarification were made. For instance, in question *member of my family suffers from job loss*, "the job" entails any form of income generation either from being employed, self-employed or any other form. Respondents are expected to rate the level of impact based on the impact on income and the period of inactivity caused by the disruption.

Furthermore, questions such as *away from work for a long time* appear to assess the impact of time spent away from work. The respondent may find this difficult to interpret. To put this in context, the answer choices for this question were based on National Flood Forum (NFF) estimates that it takes 6 to 18 months for people and businesses to recover from flood events. Anything above this threshold is considered a long-term effect. This is also applicable to the section on *Questions on Residents' Recovery Time*. Therefore, these questions attempt to categorise the psychological impact into short and long term effects. Although, in other circumstances, people may have a significantly longer recovery period, and detailed information about their experience would have been useful to the study. Again, this highlights the limitations of this approach and emphasises the relevance of qualitative data, which allows for in-depth exploration of such questions.

Finally, the questionnaire aims to collect data from respondents based on their flood experiences, which is why the target audience was carefully selected. Furthermore, if a respondent has had several flood events, the questionnaire should be completed based on the most recent experience. If the recipient, on the other hand, has no past flood experience but knows someone who has and is willing to complete the form, he or she may do so.

5.9.3 Questionnaire Administration

There are five strategies that the quantitative researcher can adopt to administer questionnaires (Nesbury, 2000). These five strategies, referred to as mail, fax, phone, web-based or internal surveys and personal face-face interview, are further classified into three categories (see table 5.2). Table 5.2 shows the advantages and disadvantages of three class of strategies that can considered in administering questionnaire.

Table 5.2: The Pros and Cons of Questionnaire Administration

	Pros	Cons
Postal	Can reach a large geographical area	No clarification available during completion
	People are used to completing paper-and-pencil surveys	Need a motivated population to return the survey
	Can take the survey with you and complete it anywhere and anytime	Respondents must be able to read, see, and write
	Great for sensitive issues	
Telephone/administered	Information is obtained immediately	Possible bias from the administrator
	Can explore answers with respondents	Higher level of resources
Email/internet	Negligible distribution costs	Respondent must be "online"
	Only "acceptable" answers can be allowed (validation)	Respondents must be able to use a computer, a mouse, and/or keyboard
	Required the question to be answered	Respondents must be able to use a web browser
	Can give respondent links that give additional explanation	Reliant on technology that can fail

(Source: MacDonald and Headlam, 2015)

The self-administered postal survey is therefore adopted as the method of distribution. This method was selected because cost is minimised, unlike the face to face and telephone methods that are quite expensive to carry out (Dillman, 2000). Also, it is appropriate for the sensitive nature of data required, given the devastating and tragic effect of floods on households, and can reach large geographical areas (MacDonald & Headlam, 2015). Several other doctoral researches in the same field have adopted this approach of data collection (like Lamond, 2008; Joseph, 2014).

A booklet format of the questionnaire administration was preferred to an electronic format as recommended by Dillman (2000). This is due to the difficulty in obtaining the email addresses or other electronic contacts of prospective respondents which is needed for the distribution of the questionnaires in the electronic format. It was also identified from past researches that not all the respondents will find it easy to access the electronic format most especially any elderly citizens (Lamond, 2008; Joseph, 2014).

A key challenge of the postal questionnaire survey is the low response rate associated with the approach (Creswell, 2009). This was addressed by increasing the number of questionnaires administered and also informing respondents in advance about the study and its purpose; guaranteeing confidentiality of responses and promising anonymity to respondents; and making provision for a pre-paid return envelope for completed questionnaires (Oppenheim, 1992). According to past researchers such as Lamond (2008), Ikpe (2009) and Joseph (2014), administering questionnaires with self-address and prepaid envelops, has been found to increase response rates; therefore, it was decided to adopt similar mailing strategy in this research.

The choice of the recipient is respected as the survey is made voluntary by seeking their consent to participate in the survey. This is made possible by giving recipient the opportunity to go through the covering letter (appendix A-4) before accessing the questionnaire. This helps them to make decision on whether they want to go on completing the questionnaire or discard it. Also, the covering letter acknowledges that they might not want to revisit their flood experience and assures them that receiving the letter does not mean they are at risk from flooding but points them to where they can get advice if they are worried about anything. Recipients are granted the option of disposing the questionnaire unopened if they would like to. Therefore, the questionnaire is sealed in a separate envelop and together with the covering letter and consent form, is placed in the main mailing envelop.

The data collection stage of the research was scheduled to start in March 2020, however, due to the nation-wide lockdown caused by the COVID-19 pandemic it was rescheduled till the lockdown was eased on the 14th of August 2020. The data collection stage was brought to an end by the end of December 2020. Following the completion of data collection phase of the research, the next research activity is to analyse the collected data.

5.10 DATA ANALYSIS

The collated data is analysed using IBM SPSS Statistics 25 software. The reason for selecting the SPSS statistical package is because it is sufficient to perform all the statistical analysis required; both descriptive and inferential. It facilitates the calculation of all the essential statistics, such as descriptive statistics, reliability test, ANOVA, correlation and multiple regression analysis, required for data analysis and findings presentation.

Furthermore, SPSS is easily available and user friendly so it can be learnt within a short period of time. There are number of books available that can provide the knowledge required to familiarise oneself with the SPSS application and also to equip ones with the skill needed to use the tool to present and interpret data.

5.10.1 Descriptive Analysis

Descriptive analysis was conducted on the data collected. Based on this analysis, the most typical values (frequency, mean, median, mode and percentage) were adopted. According to Reaves (1992), descriptive analysis is a way of describing a particular situation or event. It is an aspect of statistics that allows researchers to summarise and illustrate large quantities of data with measures that can be easily understood by an observer (Burns, 2000). Descriptive statistics summarised raw scores, e.g., average, percentage, variance (Hammond et al. 2000). Generally, the results will be presented using frequency tables and as a percentage of the total respondents or respondents that answer a particular question.

5.10.2 Statistical Techniques for Validity Test

Straub et al (2004) recommended that a new survey instrument needs to be validated by using statistical techniques such as a reliability test and factor analysis. The reliability test is useful to confirm the internal consistency of measures while the factor analysis is needed to confirm the construct validity with respect to both convergent and discriminant validity. Based on the recommended guidelines, a survey instrument retains a high internal consistency (reliable) if the estimated Cronbach's alpha is above 0.70. Following the above guidelines, the aforementioned statistical techniques are employed to validate the survey instrument of this research (Chapter 6).

5.10.3 Overall Scale Construction and Parametric Test for Difference

Given that all items for a construct are internally consistent (with high reliability) then they can be utilised to construct a scale (aggregate measure) in any of these two ways (Moore and Benbasat, 1991). The first is to construct a scale that involves summing or averaging the mean of the items that load highly on a factor (Gorsuch, 1988; Moore and Benbasat, 1991). The second is to construct a scale (aggregate measure) that requires considering the score of factors (Moore and Benbasat, 1991). Moore and Benbasat (1991) argued that since the relative weight of an item in a scale is based on its loading on the factor, its scores may be considered more exact than averaging means. However, employing the latter option, factor scores, for constructing scales (aggregate measures) is the less preferred method. This is because factor scores are often less interpretable and generalisable than using the first option that entails summing or averaging the mean of items.

Meanwhile, a number of studies have adopted the approach of averaging the mean of items as a means of constructing aggregate measures, and these applications were reported to be entirely adequate (Brown et al, 2002; Koufaris, 2002; Oh et al, 2003; Olson and Boyer, 2003). Therefore, averaging responses to the individual items will be utilised to develop aggregate measures for the building and the human resilience scales in this research. Once the scale is created, it will be in a ratio instead of being ordinal and then it will be easy to carry out the normality test to check the appropriateness of conducting a parametric analysis and applying analysis of variance (ANOVA) to examine differences.

When more than two conditions or groups of an independent variable are compared, ANOVA is more appropriate to test the difference between and within these variables (Brace et al, 2003; Hinton et al, 2004). It is relevant to apply ANOVA to determine whether means that are obtained from more than two independent respondent groups are significantly different from each other (Brace et al, 2003; Hinton et al, 2004). In this research, ANOVA will be applied to test the scale mean differences (building and human resilience scales) when test variables possess more than two independent groups.

5.10.4 Correlation analysis

Fleming and Nellis (1994) described correlation analysis as a statistical technique, which estimates the relationship among variables. Field (2009) affirmed that correlation shows both the strength and the direction of the relationship between a pair of variables. The strength of the correlation is commonly expressed by a number referred to as the coefficient of correlation, usually denoted by the letter "*r*", (also known as the Pearson coefficient of correlation) (Motulsky, 1995). The direction is represented by the positive or negative sign the *r* value takes. Values of the correlation coefficient are always between -1 and +1 (Bryman and Cramer, 1999; Blaike, 2003).

For instance, a correlation coefficient of +1 indicates that two variables are perfectly correlated, simply, they are positively linearly related. However, a correlation coefficient of -1 indicates that two variables are also perfectly correlated but negatively linearly related. A correlation coefficient of 0 indicates that no linear relationship exists between the two variables.

In the SPSS software, the correlation coefficient is usually produced with a significance level. The position of significance level in correlation equation is to help identify which of the coefficients are significant. According to Field (2009) a significance level that is less than 5% indicates that a genuine relationship exists, which does not just occur by chance. Therefore, correlation analysis will be performed on the questionnaire data to establish the relationship between the building and human resilience, the two key components of the PFR model.

5.10.5 Statistical Techniques for Testing Relationship

In order to explain the relationship between the independent and dependent variables to test the PFR conceptual model, multiple linear regression analysis will be utilised. The correlation is only capable of estimating the relationship between a pair of variables. In a case where more than two variables are involved, the multiple regression analysis is required. Multiple linear regression is a statistical technique commonly used to explain the relationship between independent and dependent variables with ordinal or scale data (Brace et al, 2003; Oh et al, 2003). It is usually used when a researcher is seeking to ascertain the causal effect of one variable on another.

For this research, the purpose of performing multiple linear regression analysis is to examine whether significant relationships exist between the independent variables (building characteristics; flood characteristics; flood insurance, socioeconomic factors) and dependent variable (building resilience and human resilience scales).

According to Field (2009), the regression analysis procedure tests the null hypothesis that the slope parameter of the independent variable is zero against the alternative hypothesis that the slope parameter is different, that is, more than zero. Therefore, *p*-value less than 5%

(level of significance), indicates that the null hypothesis will be rejected and it can be concluded that the dependent variable and the independent variables are statistically related. In that case, the model may be used to predict the dependent variable.

5.11 DEALING WITH MISSING DATA

Missing data is not uncommon and was anticipated in the research. Some respondents may not answer all the questions that are contained in the questionnaires. According to Kang (2013), missing data present the following problems: First, missing data will reduce statistical power, which represents the probability that the null hypothesis will be rejected by the test when it is false. Second, the missing data can cause bias in the estimation of parameters. Third, it can diminish the representativeness of the samples. Fourth, it may complicate the analysis of the study. Each of these misrepresentations may threaten the validity of the findings and can lead to invalid conclusions. In dealing with missing data, different imputation methods exist; these include case substitution, mean substitution, cold deck imputation, regression imputation and multiple imputations (Hair et al. 1998). Mean substitution is one of the more widely used methods as the mean is considered the best single replacement value (Hair et al. 1998). This approach was adopted in this research for replacing missing data before carrying out the analysing of the affected variables. The theoretical background of the mean substitution and the rationale for adopting it in this research is because the mean is a reasonable estimate for a randomly selected observation from a normal distribution (Kang, 2013). The SPSS missing value analysis option was used to analyse the patterns of missing data.

5.12 ETHICAL CONSIDERATIONS

Ethical consideration poses a concern to any researcher and any institution that carries out research. As much as practicably possible, any research involving human participants should be based on the participants' freely given consent (SRA, 2003). Research into flood resilience of households with flood risk exposure in the UK, requires information on the experience of flood victims. This is a very sensitive area given the devastating nature and tragic effect of floods on households. In addition, to remind flood victims of the flood event again may bring back the bad memory of the event. Therefore, the data collection method adopted for this research has to undergone rigorous ethical approvals. Consequently, the important ethical concerns that this research presents are to ensure integrity and confidentiality and to ascertain that no harm (especially emotional distress) was caused to the respondents and their households. This research will primarily involve voluntary participants with no obligation to participate in the research, including the option of refusing to participate at any stage of the study. Thus, consent of respondents will be requested through the consent form (see appendix A-3) which will be distributed to participants at the beginning of the data collection process. Also, information was provided about the purpose of the survey and potential benefits of the study. The consent and the introduction letters can be found in appendices A-3 and A-4 respectively.

Confidentiality was addressed by ensuring the identity of participants, locations and their properties have remained anonymous. This is highlighted by BSA (2017) that the importance of respecting participants' anonymity and privacy is essential. However, in a case where participant supply any sensitive information, this shall also remain confidential.

Another important ethical concern was the storage and the disposal of data (Fellows and Lui, 2008). Since it was expected that this research will continue to produce publications and perhaps discussions beyond the actual completion and examination of the research work, therefore, the original data collected will have to be stored for such purposes. In doing that, the data will be stored in a manner that ensures integrity, anonymity and confidentiality, for such purposes. According to BSA (2017) it is vital to ensure that data is securely stored. As pointed out by Fellows and Lui (2008), data may lose its relevance from a user's perspective, and so when the stored data from this research becomes less useful it will be disposed permanently.

In conforming to the established trend, the Birmingham City University (BCU) put in place a rigorous ethical validation procedure to assist researchers conform to a reasonably accepted standard. Therefore, full ethic approval was granted by the University Ethic committee prior to embarking on the survey. The approval letter is found in appendix A-1.

5.13 SUMMARY

The Chapter has presented a detailed outline of the research philosophy, assumptions and paradigm and stated the research paradigm adopted for undertaking this research. The positivism research paradigm was adopted as the research paradigm for guiding this particular research. To validate and understand the conceptual framework, it was found that a quantitative research would be more appropriate. This was chosen based on the evidence from the literature and on the need to obtain quantitative measures to provide comprehensive and reliable quantification of the PFR.

Data collection strategy employ in the empirical stage of the research involves the use of questionnaire survey; sources of the data have been described in the chapter. The data collection tool used in this research was the self-administered postal survey. The reasons for the aforementioned selection were also provided in a detailed manner. The targeted population for questionnaire administration is homeowners who had experienced flood events.

Issues relating to data analysis were then discussed. Details of different statistical data analysis techniques to be used are also presented in the chapter. It was concluded that a number of statistical techniques such as, Cronbach test, normality test, ANOVA test, multiple linear regression analyses are appropriate to be utilised for data analysis purposes. Issues relating to missing data and research ethics were discussed.

CHAPTER SIX: DESCRIPTIVE DATA PRESENTATION AND ANALYSES

6.1 INTRODUCTION

In this chapter, the descriptive analysis and findings of the primary data collected through the questionnaire survey are presented. This includes information regarding the description of the sample, the response rate, and the relevant demographic characteristics of respondents. The descriptive statistics include: frequency distribution; and measures of central tendency such as means, medians, modes and measures of dispersion. The aim of this analysis is to provide a detailed examination of the dataset in order to establish the validity of the findings to be drawn from the respondents‘ information. Further, this initial analysis examined the respondents‘ characteristics, prior to subjecting the dataset to further analysis presented in chapter 7 and 8 towards the development of a model for the measurement of PFR.

The chapter is structured as follows: Section 6.2 presents the response rate to the survey. Section 6.3 then describes the demographic profile of the survey respondents and the description of the material and construction type of the surveyed properties. This section also includes a description of the findings relating to the flood characteristics and flood insurance status of the respondents. The findings relating to the building, human and the overall (combined) resilience measures are then presented in section 6.4. The validity and reliability of each dependent variable (building, human and overall resilience ratings) is presented in section 6.5. Finally, the summary and conclusions of the chapter are provided in Section 6.6.

6.2 RESPONSE RATE

A total number of 760 questionnaires were distributed to addresses believed to have had some experience of flooding. Achieving the target response across the different categories of flood characteristics proved to be more difficult than expected, especially in terms of flood types. Particularly, it was challenging identifying postcodes and addresses of properties who have suffered from ground water flooding. A sizeable sample of 83 survey 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 given that the only incentive provided to respondents was a summary of the findings of the research. In addition, the situation at the time when the survey was administered, the nationwide lock-down, caused by the covid-19 pandemic made it extremely difficult to have high responses.

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. It was a difficult time for the world to cope with and so the survey did not receive more attention from the target audience as it was the least of their concern at that moment.

Concerning the response rate, Takim et al., (2004) reported that the response rate norm for postal questionnaire surveys is 20-30%. Other sources that support this view include Black et al. (2000), which reported a response rate of 26.7% for a questionnaire survey conducted stating that response rates in this region are not unusual. Although, the response rate obtained in this survey appears to be lower compared to the standard response rate for postal questionnaires, lower response rates in the region of 14.7% (Soetanto et al., 2001) have been described as the norm for comprehensive questionnaires. Others such as Samwinga (2009) reported a response rate of 11% in his flood related research; Sutrisna (2004) reported a response rate of 8.8% and Ankrah (2007) reported a response rate of combined pilot and main survey of 15.42%. Thus, owing to the sensitive nature of the research and the extraordinary impacts of the pandemic, a response rate of 10.9% can be considered adequate and valid for the purposes of analysis. Also, most of the respondents requested a summary of the findings (more than 50% of the respondents) which indicates interest in the research work.

6.3 ROLE OF INCENTIVE ON THE SURVEY

While incentives have been shown to improve response rates, it is worth noting that a high response rate does not guarantee that a survey is free of bias. It is possible to have a group of respondents who do not represent the target audience in any way. Consequently, much effort has gone into identifying the target audience. Therefore, in order to boost the credibility of the response, the questionnaire was sent to those who had been affected by floods in some way.

The incentive is especially important for encouraging homeowners to take part in the survey and thereby increasing response rates. There is substantial evidence that financial incentives improve response rates to mail questionnaires (Armstrong 1975; Church 1993; Moses and Clark, 2004; Yu et al., 2017). In terms of monetary incentives, there were two options: direct payment for each completed response or inclusion in a prize draw upon receipt of a completed questionnaire. The latter was chosen because it is less likely to attract people for whom the questionnaire was not designed. Previous research has shown that, while both types of incentives improve response rates, direct payment attracts more people (Moses and Clark, 2004; Yu et al., 2017). In addition, this was chosen based on the recommendation of a top researcher who has had success using this type of incentive in a similar research area. Regardless of these reasons, the collected data was subjected to a series of statistical tests, such as Agreement and Reliability tests, to assess the respondents' agreement and reliability. In addition, the data was subjected to the Cronbach's test to determine internal consistency.

6.4 DESCRIPTIVE ANALYSIS OF SOCIO-DEMOGRAPHIC AND PROPERTY CHARACTERISTICS

This section provides a narrative summary of the property and flood risk characteristics and demographics of the participants in the study. Socio-demographic assessments were carried out to establish the level of representation in terms of age, educational and income levels offered by the respondents. Also, a summary of the property characteristics was intended to provide a background within which the findings of the survey and subsequent analyses can be taken as valid, to ensure that any inferences that are extended to the population from the sample are valid. Also, to determine the level of bias in responses provided by different respondents.

6.4.1 Socio-Demographic Characteristics

Descriptive data analysis was carried out on the survey data to explore the socio-demographic characteristics of the respondents. This comprises of age and gender distribution of the respondents and also, educational qualification and distribution of the annual household income.

6.4.1.1 Age Profile

Table 6.1 shows the age distribution of respondents. Among the 83 responses, about 16% of the respondents are within the age bracket 25-40 years. More than half (53%) of respondents were within the age bracket 41-64 years; this is followed by age bracket 65-74 years (19.3%), while people over 75 years only accounted for approximately 12% of the respondents. It can be inferred from Table 6.1 that the result is heavily weighted towards middle-aged class.

Table 6.1: Age distribution

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	25-40years	13	15.7	15.7	15.7
	41-64years	44	53.0	53.0	68.7
	65-74years	16	19.3	19.3	88.0
	75years +	10	12.0	12.0	100.0
	Total	83	100.0	100.0	

6.4.1.2 Gender Division

In terms of gender, the number of male respondents is slightly higher than female, with 6% more responses obtained from the males (53%) in comparison to the female (47%) respondents (Table 6.2).

Table 6.2: Gender of Respondents

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	female	39	47.0	47.0	47.0
	male	44	53.0	53.0	100.0
	Total	83	100.0	100.0	

6.4.1.3 Educational Qualifications

The profile of respondents' educational qualifications is presented in Table 6.3. This shows that more than 50% of respondents has at least a degree or equivalent with 22.9% having a post graduate qualification. About 25% of the respondents had either A-level (14.5%) or vocational qualification (10.8%). Meanwhile, 15.7% of the respondents possess only GCSE/O-level qualification while around 9% had no formal education. This is essential for the research to identify the impact of respondents with no education on flood resilience, to identify how much impact 'no formal education' has on PFR. According to the Higher Education Student Statistics: UK, 2016/17, the total number of qualifications achieved in 2016/17, first degree qualifications accounted for 55% of all HE qualifications obtained in the UK and masters taught qualifications accounted for 22% (Office for National Statistics, 2017). The figure in the survey is close to that of national statistics for the post graduate qualification.

Table 6.3: Highest educational qualification

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	no formal qualification	7	8.4	8.4	8.4
	GCSE/O-Level	13	15.7	15.7	24.1
	A-Level/Higher/BTEC	12	14.5	14.5	38.6
	vocational/NVQ	9	10.8	10.8	49.4
	degree or equivalent	23	27.7	27.7	77.1
	post graduate qualification	19	22.9	22.9	100.0
	Total	83	100.0	100.0	

6.4.1.4 Household Income

It was recognised that the household income question can be a sensitive question for respondents to answer. Therefore, in the design of the questionnaire the household income question was strategically located towards the end of the questionnaire. Of those who provided household income data information (Table 6.4), 31.3% earned annual income less than £20,000, while about 43.4% earned between £20,000-£40,000. Further, 18.1% of the respondents earned between £40,000-£60,000. Only 7.2% of the respondents earned over £60,000. It cannot be said that this is typical of national picture of income levels of people living in floodplain areas because at present there is no national data to compare this data with. However, this is similar to the report on flood related survey by Joseph (2014) where almost 70% earned less than £40,000 and about 7% earned above £60,000.

Table 6.4: Annual household income

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	less than £20,000	26	31.3	31.3	31.3
	£20,000-£39,999	36	43.4	43.4	74.7
	£40,000-£59,999	15	18.1	18.1	92.8
	£60,000 and above	6	7.2	7.2	100.0
	Total	83	100.0	100.0	

6.4.2 Property and Flood Characteristics

Further descriptive data analysis was carried out on the survey data to explore the property characteristics and flood experience of the respondents. Property characteristics comprise the distribution of property types, number of storeys, presence of cellar or basement and wall type, how long respondents have lived in their individual properties. Flood characteristics of respondents explored include, flood experience, flood source, flood depth and duration in the properties.

6.4.2.1 Property Type

The survey included three main property types, with the exclusion of flats, where it was possible to identify them as such from the address details; the main reason for excluding flats is that the database shows that most of the flats are owned by either Local Authorities or Housing Associations in which case most of them are tenanted. Table 6.5 shows the distribution of respondents by property type. Terraces (with the inclusion of end of terrace) were the most common property types represented in the survey responses representing 42.2% of the sample. This is closely followed by detached property types at approximately 34%, while semi-detached is approximately 24%.

Table 6.6 shows the comparison of survey respondents with national figures taken from the English house condition survey 2020. The sample contained a higher percentage of terraced housing than the national picture (almost one and a half times as more) (42.2% to 28.6%). However, this figure is close to that reported by (Joseph, 2014), in a similar survey administered to flood risk areas, with a difference of 4%. However, the percentage of other property types in the sample, detached and semi-detached, are close to that in the national picture with only a 2.9% difference for the semi-detached. The spread of property types represented in the sample can be said to represent UK housing stock, therefore, conclusions drawn on the sample can be representative of UK housing stock exposed to different levels of flood risk.

Table 6.5: Property type

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	detached	28	33.7	33.7	33.7
	semi-detached	20	24.1	24.1	57.8
	terrace	35	42.2	42.2	100.0
	Total	83	100.0	100.0	

Table 6.6: Dwelling type, by tenure, 2019

		private sector	social sector
Houses	small terraced	10.2	12.1
	medium/large terraced	18.4	15.3
	semi-detached	27.0	17.1
	detached	20.7	0.7
	bungalow	7.7	10.5

(National Statistics, 2020)

6.4.2.2 Number of storeys

Table 6.7 shows the comparison of survey respondents with national figures taken from the English house condition survey 2020. The sample contained a higher percentage of properties with a single storey (78.3%). The samples contain equal number of properties with 2+ stories and bungalow (10.8% in each case).

Table 6.7: Number of storeys

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	0	9	10.8	10.8	10.8
	1	65	78.3	78.3	89.2
	2	9	10.8	10.8	100.0
	Total	83	100.0	100.0	

6.4.2.3 Cellar or basement

A majority of the respondents had no cellar or basement in the property which is typical of the case for properties located in flood risk areas. Meanwhile, 73.5% of the properties do not have cellar or basement while 26.5% have either cellar or basement (Table 6.8).

Table 6.8: Cellar or Basement

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	no	61	73.5	73.5	73.5
	yes	22	26.5	26.5	100.0
	Total	83	100.0	100.0	

6.4.2.4 Length of Residency in the Neighbourhood

Respondents were asked to indicate how long they have lived in their various neighbourhood. Table 6.9 shows that 59% of the respondents have lived in their properties for over 16 years; while 13.3% respondents have been in their neighbourhood between 11-15 years and 14.5% have been in their neighbourhood between 6-10 years. Although, majority of these people moved to the neighbourhood after the 2007 flood event but they all were present during the 2015-16 flood caused by Storm Desmond another flood event with huge impacts. Finally, 13.3% have only lived in the neighbourhood for at most 5 years (0-5 years).

Table 6.9: Time lived in the neighbourhood

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	0-5 years	11	13.3	13.3	13.3
	6-10 years	12	14.5	14.5	27.7
	11-15 years	11	13.3	13.3	41.0
	16-20 years	25	30.1	30.1	71.1
	21-25	14	16.9	16.9	88.0
	26+	10	12.0	12.0	100.0
	Total	83	100.0	100.0	

6.4.2.5 Flood experience

Among those residents with experience of flooding a further set of questions explored the frequency of their flooding experience. It can be seen from table 6.10 that 32.5% of the respondents have not previously experienced flooding. Meanwhile, about half (49.4%) of flooded residents have experienced flooding once. The frequent flooders, i.e. those who had flooded two times or more represented 18.1% of the total flooded residents.

Table 6.10: Frequency of flood experience

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	0	27	32.5	32.5	32.5
	1	41	49.4	49.4	81.9
	2	15	18.1	18.1	100.0
	Total	83	100.0	100.0	

6.4.2.6 Flood Type

Flood type is a key factor, however table 6.11 indicates that only three types of flooding were captured with the respondents most concerned about riverine flooding (49.4%). More than thirty percent of the respondents were concerned with surface water flooding (32.5%) while 18.1% were concerned with ground water flooding. Concerning flood awareness, table 6.12 shows that about half of the respondents were aware of the flood risk area before they moved into their property (50.6%) and approximately half of the respondents not aware of the flood risk level (49.4%).

Table 6.11: Source of flooding are you most concerned about

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	river flooding	41	49.4	49.4	49.4
	surface water flooding	27	32.5	32.5	81.9
	groundwater flooding	15	18.1	18.1	100.0
	Total	83	100.0	100.0	

Table 6.12: Flood risk awareness before moving into the property

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	yes	42	50.6	50.6	50.6
	no	41	49.4	49.4	100.0
	Total	83	100.0	100.0	

6.4.2.7 Flood Depth

Table 6.13 shows the distribution of flood depths amongst the flooded residents. The majority of flooded residents experienced inundation to their properties up to 90 cm above ground level (83.1%). The number of residents who experienced very deep flooding was

22.9% of the entire sample. The standard height required to keep water at bay (out) is at least 90cm (ODPM, 2003).

Table 6.13: Flood depth of the flood event recently experienced

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	up to 4in (up to 10cm)	14	16.9	16.9	16.9
	4.25-12in (11-30cm)	17	20.5	20.5	37.3
	12.25-24in (31-60cm)	23	27.7	27.7	65.1
	24.25-36in (61-90cm)	15	18.1	18.1	83.1
	+36.25in (91cm and above)	14	16.9	16.9	100.0
	Total	83	100.0	100.0	

6.4.3 Flood Insurance Profile

Respondents were asked what kind of flood insurance they have. The results presented in Table 6.14 shows that a majority of the respondents (90.4%) had insurance covering both building and contents, which is what one would expect in flood risk areas, while 3.6% had insurance covering building only and 3.6% had insurance covering contents only, with 2.5% having no insurance.

Table 6.14: Flood insurance type

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	none	2	2.4	2.4	2.4
	building only	3	3.6	3.6	6.0
	content only	3	3.6	3.6	9.6
	building and content	75	90.4	90.4	100.0
	Total	83	100.0	100.0	

6.4.3.1 Length of insurance

Table 6.15 shows that most of the respondents have been insured for more than 9 years (69.9%), this indicates that majority had been insured at least before the 2015/16 flood. About 19% were insured in the first 3 years while 10.8% have been insured between 4-8 years.

Table 6.15: Length of year insured

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	0-3 years	16	19.3	19.3	19.3
	4-8 years	9	10.8	10.8	30.1
	9+ years	58	69.9	69.9	100.0
	Total	83	100.0	100.0	

6.4.3.2 Flood insurance claim

Respondents were asked if they have made any insurance claim following being flooded (Table 6.16). About 70% of respondents had made a claim, while just over 30% stated that they had not made any claim.

Table 6.16: Flood Insurance Claim

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	yes	56	66.3	70.0	70.0
	no	24	28.9	30.0	100.0
	Total	80	95.2	100.0	
Missing	System	3	4.8		
Total		83	100.0		

Table 6.17 shows that, of the 70% of respondents who have made flood insurance claim, around 96% have made at most 2 claims. More than one-third (67.9%) have made a single claim and just 1.8% each have made 3 and 4 insurance claims.

Table 6.17: Number of insurance claims made

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1	38	45.8	67.9	67.9
	2	16	19.3	28.6	96.4
	3	1	1.2	1.8	98.2
	4	1	1.2	1.8	100.0
	Total	56	67.5	100.0	
Missing	System	27	32.5		
Total		83	100.0		

Also, a majority of the respondent who made claims had their premium moderately increased (42.9%), while 23.2% had their premium unchanged and 33.9% had significant change in their premium after they made a claim (table 6.18).

Table 6.18: Status of premium or excess after making a flood claim

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	significantly	19	22.9	33.9	33.9
	moderately	24	28.9	42.9	76.8
	none	13	15.7	23.2	100.0
	Total	56	67.5	100.0	
Missing	System	27	32.5		
Total		83	100.0		

6.4.4 Respondents' Interest in Research Findings

Approximately 65% of the respondents were interested in receiving a summary of the research findings (Table 6.19). This suggests a good deal of interest in the subject under investigation and its relevance to flood risk management as a whole.

Table 6.19: Respondents who want summary findings

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	yes	54	65.1	65.1	65.1
	no	29	34.9	34.9	100.0
	Total	83	100.0	100.0	

6.5 HOMEOWNER'S RATING OF THE EFFECTIVENESS OF PFR MEASURES

This section presents the narrative summary of the homeowners' rating of the effectiveness of the PFR measures for the building resilience (resistance and resilience measures) and the rating of the psychological impacts of flood on their households for the human resilience. In addition, the time of recovery is considered for the overall resilience. Further, an inter-rater agreement and reliability were carried out on the responses received. This is described in the subsequent sections.

6.5.1 Analysis of Respondent's Measure of the Effectiveness of the PFR Measures

Data on the effectiveness of PFR measures, comprising of the resistance and resilience measures, was collected using a five-point Likert scale ranging from 'very effective' to 'not effective at all'. A weighting was assigned to each level of agreement; where 'very effective' = 5, 'quite effective' = 4, 'don't know' = 3, 'not very effective' = 2, 'not effective at all' = 1. An agreement and reliability tests were carried out on the responses received presented in section 6.5.

The result of the analysis of homeowners' rating of the effectiveness of PFR measures is presented in Tables 6.20 and 6.21 for resistance and resilience measures, respectively. As can be seen, the standard deviations are relatively small compared to the mean ratings and this indicates that there is little variability in the data (Blaikie, 2010). This can also be seen from the mode and median values, which are approximately the same and the fact that the mean ratings are also approximately the same as the median values. According to Field (2009), these generally reveal that the mean ratings are a good fit of the data. In order for all the mean ratings to be interpreted with confidence, it is important to establish an evidence of agreement amongst the respondents which is further conducted in the next section.

Table 6.20: Descriptive summary of the resistance measures rating

Resistance Measures	Mean	Median	Mode	Std. Deviation	Minimum	Maximum
Demountable door guard	2.77	3.00	1	1.468	1	5
Demountable window guard	3.06	3.00	2	1.338	1	5
Airbrick cover	2.92	3.00	2	1.450	1	5
Sewage bung	3.05	3.00	5	1.481	1	5
Toilet pan seal	3.04	3.00	4	1.493	1	5
Sump pump	3.12	3.00	4	1.356	1	5
Floodgate	2.72	3.00	1	1.459	1	5
Non-return valves utility waste pipe	2.98	3.00	5	1.490	1	5
Non-return valves overflow pipe	2.51	2.00	1	1.347	1	5
Use of sandbags to prevent water entering	2.70	2.00	1	1.552	1	5

Table 6.21: Descriptive summary of the resilience measures rating

Resilience Measures	Mean	Median	Mode	Std. Deviation	Minimum	Maximum
Raised floor above predicted flood level	3.18	3.00	5	1.433	1	5
Boiler mount on wall	3.65	4.00	5	1.542	1	5
Washing machine on first floor or above	2.98	3.00	3	1.405	1	5
Oven with raised under type	2.96	3.00	2	1.469	1	5
Electric metre above predicted flood level	3.47	4.00	5	1.451	1	5
Raising electrical sockets above likely flood level	3.27	4.00	5	1.570	1	5
Gas metre above predicted flood level	3.28	3.00	5	1.484	1	5
Having a flood plan	3.14	3.00	5	1.499	1	5
Moving vulnerable items to first floor	3.35	4.00	5	1.534	1	5
Lightweight moveable furniture	3.14	3.00	4	1.380	1	5

6.5.2 Analysis of Rating of the Psychological Effects of Flood on Homeowners

Respondents were asked to state the extent to which flood events have psychologically affected members of their household. Data on the psychological effects was collected using a five-point Likert scale ranging from ‘strongly agree’ to ‘strongly disagree‘. A weighting was assigned to each level of agreement; where ‘strongly disagree‘ = 5, ‘disagree‘ = 4, ‘neutral‘ = 3, ‘agree‘ = 2, ‘strongly agree‘ = 1. A reliability test was carried out on the responses received presented in section 6.5. Table 6.22 shows the summary of the result of rating of the psychological effects. For each of the statements the ratings by the respondents ranged from 1 (strongly disagree) to 5 (i.e. strongly agree). As can be seen, the standard deviations are relatively small compared to the mean ratings and this indicates little variability in the data. Also, the mode and median values are approximately the same and the fact that the mean ratings are also approximately the same as the median values generally reveal that the mean ratings are a good fit of the data.

6.5.3 Analysis of Rating of the Time of Recovery from the Flood Impacts

Respondents were asked to indicate the approximate time for the member of the household and the property to get back to normal. Data on the recovery time was collected using a seven-point scale ranging from ‘not applicable’ to ‘recovery time of over 12 months‘. A weighting was assigned to each level of agreement; where ‘not applicable‘ = 7, ‘less than 1 month‘ = 6, ‘1-3 month(s)‘ = 5, ‘4-6 months‘ = 4, ‘7-9 months‘ = 3, ‘10-12 months‘ = 2, ‘over 12 months‘ = 1. A reliability test was carried out on the responses received presented in section 6.5. Table 6.23 shows the summary of the result of rating of the recovery rate. As can be seen, the standard deviations are relatively small compared to the mean ratings and this indicates little variability in the data. Also, the mode and median values are approximately the same and the fact that the mean ratings are also approximately the same as the median values generally reveal that the mean ratings are a good fit of the data.

Table 6.22: Descriptive summary of the psychological effect rating

PSYCHOLOGICAL IMPACTS	Mean	Median	Mode	Std. Deviation	Minimum	Maximum
I was upset about the damage caused by the flood	4.04	4.00	5	1.214	1	5
My family was disrupted	3.51	4.00	5	1.573	1	5
My children missed school	2.56	2.50	1	1.421	1	5
I lost items of sentimental value	3.47	4.00	5	1.594	1	5
I was away from work for a long time	2.63	2.00	1	1.456	1	5
Members of my family suffered from job loss	2.18	2.00	1	1.359	1	5
I still suffer from psychological disorder because of recurrent flooding	2.55	2.00	1	1.270	1	5
It took me some time and effort to return to normal after each flood event	3.53	4.00	4	1.501	1	5
Since last flood event, members of my family have deteriorating health problem	2.32	2.00	1	1.408	1	5
I feel anxious at the sight of rain or when river level rises	3.42	4.00	4	1.277	1	5
I have experienced increased in stress level	3.29	4.00	4	1.438	1	5

I have had problems dealing with insurers/loss adjusters	2.57	2.00	1	1.465	1	5
It has been difficult dealing with builders	3.10	3.00	4	1.436	1	5
It is difficult coping with loss of or distress to pets	2.13	2.00	1	1.245	1	5

Table 6.23: Descriptive summary of the recovery time rating

RECOVERY TIME	Mean	Median	Mode	Std. Deviation	Minimum	Maximum
How long did you have to vacate your property?	4.08	4.00	6	2.055	1	7
How long did you take off work?	4.07	4.00	5	1.986	1	7
How long did your kids take off school?	4.02	4.00	5	1.925	1	7
How long did it take to get the house to normal?	4.28	4.00	7	1.990	1	7
How long did it take for member of the household to recover from health issues caused by the flood event?	3.63	4.00	1	2.029	1	7

6.6 AGGREGATION ISSUES AND RELIABILITY TESTING

This section presents findings based on the correlation analysis using the aggregated data. Table 6.23 provides the descriptive statistics for study dependent variables, including the means, standard deviations, intra-class correlations (ICC), inter-item reliabilities. When judgments about a subject are made on a numerical scale, inter-rater agreement means that the respondents assigned exactly the same values when rating the same subject (Manu, 2012). Inter-rater agreement test is often used in organisational multi-level research (Bliese, 2000) and has been applied in other related studies in construction, such as Tuuli (2009), Anvuur and Kumaraswamy (2010), Manu (2012) and also in flood risk management by Joseph (2014).

6.6.1 Agreement and Reliability Test

The choice to average across the responses provided, in order to compute the final score for each rated components, is based on the raters agreement and reliability. To aggregate matched pairs data, the inter-rater agreement and inter-rater reliability were considered. The inter-rater agreement denotes the degree to which ratings from respondents are interchangeable; viz., it reflects the extent to which raters provide essentially the same rating, i.e. the consensus (Tinsley and Weiss, 1975; Kozlowski and Hattrup, 1992; LeBreton and Senter, 2008). The presence of significant agreement means that the aggregated (i.e. mean) ratings can be considered as being credible representations of the respondents‘ individual agreement with each of the statement on homeowners‘ measures of effectiveness for the PFR measures. The inter-rater reliability refers to the degree to which ratings of different respondents are proportional when expressed as deviations from their means, that is, the consistency (Kozlowski and Hattrup, 1992; Bliese, 2000; LeBreton et al., 2003).

Therefore, the inter-rater agreement was assessed using the single-item inter-rater agreement index (R_{wg}) (James et al., 1984, 1993) for each variable (see Table 6.23). The rule of thumb value for R_{wg} is 0.60 (James, 1982) and the more commonly acceptable value of 0.70 which indicates that the respondents are in strong agreement.

Both inter-rater agreement and inter-rater reliability were assessed using the intra-class correlations. ICC(a)s and ICC(b)s were calculated using McGraw and Wong's (1996) formula with a one-way random-effects analysis of variance (see Table 6.23). High values may only be obtained when there is both absolute consensus and relative consistency in respondents' ratings (LeBreton and Senter, 2008). Gittell et al. (2010) state "the ICC(a) provides an estimate of the reliability of a single respondent's assessment of the unit mean" and "ICC(b) provides an overall estimate of the reliability of unit means" (p. 498). In this study, the ICC(a) values are 0.56 for the building resilience scale, 0.309 for the human resilience scale, and 0.599 for the overall resilience scale which were higher than the median value of 0.12 reported by James (1982). This indicates that the respondents had high agreement and also the answers from any one of the respondents was reliable. The ICC(b) values are 0.932 for the building resilience scale, 0.862 for the human resilience scale, and 0.882 for the overall resilience scale which were 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.

6.6.2 Further Reliability Test

Table 6.23 illustrates the Cronbach's coefficient alpha values that were estimated to examine the internal consistency for the building, human and overall resilience scales. Cronbach's coefficient varied between 0.951 for the building resilience measurements, (which is a combination of the resistance and resilience measures), 0.899 for the human resilience scale (represented by the psychological impact), and 0.882 for the overall resilience measurements, (represented by the time of recovery).

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 human resilience and the overall resilience measures possess high reliability, while the building resilience is excellently reliable (Table 6.24).

The high Cronbach's alpha values for these variables imply that they are 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 6.24: 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 resilience measures	0.56	0.932	0.638	0.951	Excellent
Human resilience	Average score for 14 psychological flood impact	0.309	0.862	0.679	0.899	High
Overall resilience	Average score for 5 recovery time questions	0.599	0.882		0.882	High

6.6.3 The Common Method Bias

The Harman one-factor test was conducted to examine the common method bias for the rest of the data. Significant common method bias would result if one general factor accounts for the majority of covariance in the variables (Podsakoff and Organ, 1986). The Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy was first computed to determine the suitability of employing factor analysis, and the results are presented in Table 6.25. The KMO is estimated using correlations and partial correlations in order to test whether the variables in a given sample are adequate to correlate. A general 'rule of thumb' is that as a measure of factorability, a KMO value of 0.5 is poor, 0.6 is acceptable and a value closer to I is better (Brace et al, 2003; Hinton et al, 2004).

The results illustrated in Table 6.25 suggest that the KMO is above the recommended acceptable level of 0.6 as the obtained value is 0.625. The aforementioned results confirm that the KMO test supports the sampling adequacy and it is worth conducting a factor analysis. This means that the KMO value indicates the possibility of factor existence in the data and as it was assumed in the conceptual model.

Further, Bartlett's test of sphericity is conducted for the purpose of confirming the relationship between the variables. If there is no relationship, then it is irrelevant to undertake factor analysis. As a general rule, a p value <0.05 indicates that it is appropriate to continue with the factor analysis (Brace el al, 2003; Hinton et al, 2004). However, the result illustrated in Table 6.25 suggests that the calculated p value is < 0.001, which means that there are relationships between the variables in question. Therefore, it was considered appropriate to continue with the factor analysis.

Consequently, a principal axis factoring analysis with oblique rotation method was performed for the rest of the items. The results showed eleven factors with eigenvalues greater than one which accounted for 72.738% of the total variance, with the first factor accounting for 11.882% of the variance. Since a single factor did not emerge and one general factor did not account for most of the variance, common method bias is unlikely to be a serious problem in the rest of the data (Podsakoff and Organ, 1986).

Table 6.25: KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.625
Bartlett's Test of Sphericity	Approx. Chi-Square	105.617
	Df	55
	Sig.	.000

6.7 SUMMARY

The descriptive analysis of the data derived from the questionnaire survey has been presented in this chapter. Emphasis was laid on the demographic representation of the respondents, and the building and flood characteristics of the completed participants. It is important to establish these distributions of the respondents for which inferences will be drawn from this research and to be able to establish the validity of the research findings. It has been established in this chapter the interest of respondents in the research work, which indicates the relevance of the topic under investigation to the society.

Following the presentation of the descriptive summary of collected data, there was a discussion of the validation and reliability of the building, the human and the overall resilience scales. The section initially presented findings that illustrated the reliability and agreement tests. The reliability test confirmed that the measures are internally consistent, as all the resilience scales possessed a Cronbach's alpha above 0.70. For the agreement test, the ICC(a) which provides an estimate of the reliability of a single respondent's assessment of the unit mean gave values higher than the reported median value of 0.12, which signifies that the respondents had high agreement and also that the answers from any one of the respondents was reliable. The ICC(b), which provides an overall estimate of the reliability of unit means, gave values which were higher than the recommended 0.60 cut-off point by Glick (1985) which signifies that the respondents can be reliably differentiated in terms of all of the variables in this study

Finally, the construct validity was established utilising the Harman one-factor test. This provided evidence of KMO value (0.625) greater than 0.60, a significant probability of Bartlett's test of sphericity (< 0. 001), evidence that a single factor did not emerge and one general factor did not account for most of the variance. In the next chapter, the inferential data analysis is carried out.

CHAPTER SEVEN: PRELIMINARY INFERENTIAL ANALYSIS OF THE PROPERTY FLOOD RESILIENCE (PFR)

7.1 INTRODUCTION

Further to the preliminary data description presented in chapter 6, this chapter presents some inferential data analysis, culminating to the model testing and validation. The data were subjected to bivariate and multivariate analyses, to identify underlying associations between variables, as well as differences between groups of respondents. Statistically significant differences and associations were recorded and reported.

This chapter has been organized into the following sections. The first section presents the Normality test of the dependent variables (the building, the human and the overall resilience scales). This is carried out to determine the kind of test appropriate with respect to the data obtained, with parametric analysis required if data is normally distributed and non-parametric if otherwise. In the next section, an ANOVA test was used to compare the means of two independent groups in order to determine whether there is statistical evidence that the associated population means are significantly different. The aim of such analysis was to identify some of the important variables in the data set which will later aid in the resilience measurement. In the third section, test of association, Pearson Product Moment Correlation Coefficient, were carried out on the identified factors to address questions regarding possible correlations between the variables and also if there is any relationship between the overall resilience scale and the building and human resilience scales.

7.2 TEST FOR NORMALITY

The assessment of variables for normality is a prerequisite of many statistical analyses, particularly where the study aims to generalize findings to the population from which the sample was drawn (Tabachnick and Fidell, 2013). Generally, it is accepted that normality of variables tends to produce better solutions due to the use of the parametric data analyses which is more robust (Farell and Gale, 2003). Bradley (1982) reports that statistical inference becomes less and less robust as distributions depart from normality, rapidly so under many conditions. Therefore, in order to test for normality, Pallant (2005) and Tabachnick and Fidell, (2013) propose the use of either statistical or graphical approach. The statistical measures, which is more accurate and preferred, comprise the computations of the Kolmogorov-Smirnov *p* statistic, Kurtosis and Skewness values. Ideally, the *p*-value should be more than 0.05 representing a non-significant result, whilst the Kurtosis and Skewness measures should be as close to zero as possible. However, in reality data are often skewed and kurtotic. Therefore, a small departure from zero is acceptable.

Meanwhile, the graphical approach involves the visual inspection of the histogram, normal Q-Q and detrended Q-Q plots. Consequently, the histogram should appear reasonably normal (i.e a peak near the middle of the distribution), the normal Q-Q plot should appear as a reasonably straight line, and the detrended Q-Q plot should not contain any real clustering of points, with most collecting around the zero line (refer to Pallant 2005: p53-58; Tabachnick and Fidell, 2001: p73-77).

Therefore, for the normality test using the SPSS 24.0 the following numerical outputs are investigated:

- Skewness and kurtosis z-value (which should be somewhere in the span of ± 1.96)
- The Shapiro-Wilk test p-value (which should be above 0.05)

  The null hypothesis H_0 for this test of normality is that data are normally distributed

  The alternative hypothesis H_1 states otherwise.

  The null hypothesis is rejected if the $p - value$ is below 0.05

The data do not have to be perfectly normally distributed but should be approximately normally distributed. The normality test was carried out using the SPSS 24.0, the skewness and kurtosis z-value together with the Shapiro-Wilk test *p*-value were carried out for each of the variables and the results are presented in table 7.1 for the building, human and the overall resilience scales.

Table 7.1: Result of the normality test of the resilience scales

Dependent Variables	Skewness	Kurtosis	Kolmogorov Smirnov	Shapiro-Wilk
Building resilience scale	0.784	1.317	0.2	0.406
Human resilience scale	0.39	-0.73	0.2	0.679
Overall resilience scale	-0.148	-1.294	0.2	0.123

A Shapiro-Wilk's test ($p > 0.05$) showed that both the building, the human and the overall resilience scales were approximately normally distributed with skewness values of 0.784, 0.390 and -0.148 and kurtosis of 1.317, -0.730 and -1.294 respectively (see table 7.1). These values lie between the span of ± 1.96. For the output of the graphical result see appendix B-4. Based on this result, it is considered appropriate to carry out a parametric analysis with the data set. The following section examines the relationship between the independent variables and the dependent variable for both the building and the human resilience scales.

7.3 DIFFERENCES WITHIN THE GROUPS (ANOVA'S)

Following the advice of Ratner (2010), it is important not to introduce all the available variables in the survey into the regression model at the same time. It is however, essential, to carefully consider the independent variables that may be relevant. Irrelevant independent variables may appear to be significant due to chance or can reduce the possibility of determining relevant variables' significance. Therefore, the ANOVA is first carried out so as to select and apply only significant independent variables into the regression models (for the building and human resilience models).

The choice of the ANOVA test is based on the design of the survey questions which comprise of more than three variables for each section with most of the survey questions possessing three or more categories. Also, the ANOVA test offers a broader approach to measure whether variables varied significantly across the groups and particularly because it is used to compare three or more variables. According to Hodzic and Islamovic (2020), this is essential in quantitative studies, especially when multiple factors are studied simultaneously in order to examine and compare their effects. In addition, the overall goal of ANOVA is to select a model that only contains terms and factors that add valuable insight to the value of the response, or in other words, a model that only includes statistically significant terms (Agresti and Finlay, 2009). Therefore, the ANOVA is sufficient to identify factors that can impacts resilience both at the physical (building) and human levels from the dataset.

There are different kind of ANOVA test based on the number of factors under consideration. However, the factorial ANOVA is performed which is appropriate when the number of independent variables (factors) is more than one.

Factorial analysis of variance (ANOVA) is a statistical procedure that allows researchers to explore the influence of two or more independent variables (factors) on a single dependent variable. According to Hodzic and Islamovic (2020), factorial design is used in experiments which involve several factors where it is necessary to study the joint effect of the factors on response. In contrast to a one-way ANOVA, a factorial ANOVA uses two or more independent variables with two or more categories to predict change in a single dependent variable.

7.3.1 Selecting the Factors for the Building Resilience

A factorial ANOVA was conducted that examined the effect of the different set of independent variables (building characteristics; flood characteristics; flood insurance) on the building resilience scale. Each set consists of several factors with the aim of examining their effects on the building resilience scale (see Figure 7.1). The factorial ANOVA seems appropriate and suitable for dealing with cases that has two or more categorical independent variables (either with or without the interactions) and a single normally distributed interval dependent variable. The normality test has been examined in section 7.2. In this study, the response is the building resilience scale. The following sub-section presents the results of the factorial ANOVA test carried out with each set of variables and also reports variables that are statistically significant to the building resilience scale. In addition, the non-significant statistical results are reported.

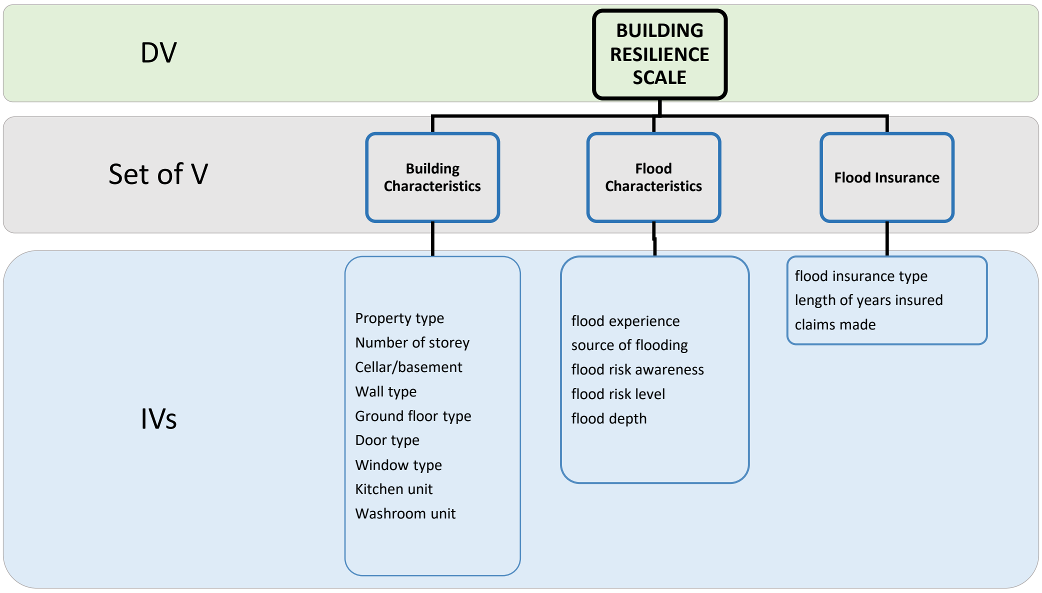


Figure 7.1: Factors captured in the questionnaire to measure the building resilience scale

7.3.1.1 Building Characteristics

The first set of variables examined are those relating to the building characteristics. It is important to first look at the interactions among the IVs because the outcome of this interactions will influence how the results of the resilience model can be interpreted. The interactions between the IVs are not statistically significant (that is IVs have *p* values greater than 0.05 or low correlation when paired – see Appendix B15). This implies that the interpretation of the main effects on the building resilience is complete or not misleading. Although, it does not mean that the IVs have zero interaction amongst themselves, but it only implies that the interactions are not significant enough to project their influence on the dependent variable.

If the statistical test results in $p < .05$ we can say, by the rules of the statistical convention for ANOVA test, that the study passed the threshold criteria to allow us to assert the inference, and so we can state that the study demonstrates that independent variable affects the building resilience scale (Visentin, et al., 2020).

From table 7.2, the property type, presence of cellar or basement, wall type, ground floor type and kitchen unit variables show that difference in mean with the building resilience scale are statistically significant. The p values are 0.027; 0.022; 0.035; 0.001 and 0.007 respectively. This indicates that of the 9 variables on property and materials used for building components, only 5 show to be statistically significant in measuring the building resilience scale. The variables relating to number of storeys, door type, window type and washroom unit are not statistically significant to explain the building resilience.

Table 7.2: Tests of Between-Subjects Effects (Building Characteristics)

Dependent Variable: Building Resilience (0,1)

Source	Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	.314[a]	17	.018	2.780	.002
Intercept	1.279	1	1.279	192.310	.000
Property type	.051	2	.025	3.817	.027
Number of storeys	.021	2	.011	1.592	.211
Cellar or basement	.037	1	.037	5.534	.022
Wall type	.047	2	.023	3.528	.035
Ground floor type	.073	1	.073	10.995	.001
Door	.001	1	.001	.219	.641
Window	.001	1	.001	.202	.655
Kitchen unit	.071	2	.036	5.363	.007
Washroom unit	.048	4	.012	1.789	.142
Error	.432	65	.007		
Total	22.970	83			
Corrected Total	.747	82			

a. R Squared = .421 (Adjusted R Squared = .270)

7.3.1.2 Flood Characteristics

The second set of variables are those relating to flood characteristics. Therefore, a factorial ANOVA was conducted that examined the effect of the independent variables (flood experience and risk awareness) on the building resilience scale. From the table 7.3, the flood experience, source of flooding and flood risk level show statistical significance in the mean with the building resilience scale. The *p* values are 0.01; 0.028 and 0.013 respectively (table 7.3). This shows that of the 5 variables on flood experience and risk awareness, only 3 show to be statistically significant in measuring the building resilience scale. Meanwhile, across the literature, both insignificant variables in this set are considered to impact the building resilience. It is recommended that water should be allowed into building when flood depth is more than 90cm (Wingfield, et al., 2005).

Table 7.3: Tests of Between-Subjects Effects (Flood Characteristics)

Dependent Variable: Building Resilience (0,1)

Source	Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	.187[a]	12	.016	1.950	.043
Intercept	13.250	1	13.250	1657.061	.000
Flood experience	0.27	2	0.13	16.62	.001
Source of flooding	.060	2	.030	3.759	.028
Flood risk awareness	.008	1	.008	.944	.335
Flood risk level	0.45	3	0.15	18.95	.013
Flood depth	.014	4	.004	.442	.778
Error	.560	70	.008		
Total	22.970	83			
Corrected Total	.747	82			

a. R Squared = .251 (Adjusted R Squared = .122)

7.3.1.3 Flood Insurance and Claims

A third set of variables are those relating to flood insurance. A factorial ANOVA was conducted that examined the effect of the independent variables (flood insurance) on the building resilience scale. From the table 7.4, none of the IVs shows statistical significance in the mean with the building resilience scale. All the variables have p values greater than 0.05 (see table 7.4).

Table 7.4: Tests of Between-Subjects Effects (Flood Insurance and Claim)

Dependent Variable: Building Resilience (0,1)

Source	Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	.047[a]	8	.006	.572	.795
Intercept	14.912	1	14.912	1460.106	.000
Flood insurance type	.025	2	.013	1.229	.302
Length of years insured	.004	2	.002	.219	.804
Claim or no claim	.006	1	.006	.558	.459
Number of claims made	.011	3	.004	.374	.772
Error	.480	47	.010		
Total	15.439	56			
Corrected Total	.527	55			

a. R Squared = .089 (Adjusted R Squared = -.066)

7.3.1.4 Non-Significant Results

While there are issues with the separation of results into the binary categories of 'significant' and 'non-significant' with no shades of grey (Sterne & Davey Smith, 2001), this method of reporting is commonly accepted as the norm. However, an explanation of the non-significant results is provided. According to Mlinaric et al. (2017) there is an ethical obligation to report studies, not just the significant result but the insignificant too, that made use of human subjects who have volunteered themselves usually at some risk to benefit others. Though the *p* values for the variables relating to the insignificant factors are greater than 0.05, yet we cannot rush into concluding that these factors do not influence the building resilience. There are two possibilities for a non-significant result. One is that the null hypothesis is true—that there is no real effect. Alternatively, the study hypothesis could be true, but there is not sufficient evidence in the study to support the hypothesis (Visentin, et al., 2020). Simply, we don't have sufficient evidence to claim that these factors affect the building resilience.

Though most researches agree that the presence of higher floor in a building is a factor that can influence the resilience of the building to flood impacts where vulnerable items on ground floor can be easily moved to higher floor (Oladokun, et al., 2017). This option helps to limit the amount of damaged caused on the ground floor. Also, in addition to the use of flood gates and flood barriers, some properties owners have installed waterproof doors, while others opt for doors made with materials that can be easily cleaned and dried such as the use of PVC doors. However, from the results in table 7.2, the data set seems insufficient to capture this.

Therefore, instead of concluding that these factors with insignificant results do not influence the building resilience, it is rather important to retain them as possibility as we do not have enough evidence to reject the factors. There are several reasons for a false negative (type II error) resulting in non-significance and the power analysis is applied to report non-significant results throughout this chapter. The probability of correctly rejecting the null hypothesis is known as the power of a statistical test (Cohen, 1988). A power analysis requires knowledge of three things. The first is the alpha level, which is 5% across this study in concordance with common practice (Lakens et al, 2018). The second information required is the power we aim to achieve with our test - the probability of detecting an effect when one truly does exist (avoiding making a Type II error). A generally accepted minimum level of power is 0.80 (Cohen, 1988). The final piece of information required for a power analysis is the effect size that is anticipated, or simply, what the test is capable of revealing. Information about the magnitude of the effect found, allowing its practical importance to be considered. This information cannot be adequately gleaned from only a *p*-value (Durlak, 2009). A commonly used interpretation is to refer to effect sizes as small (d = 0.2), medium (d = 0.5), and large (d = 0.8) based on benchmarks suggested by Cohen (1988).

Therefore, with these three pieces of information we can calculate required sample sizes, using statistical software such as G*Power (Erdfelder et al, 1996). The G*Power is recommended as a convenient and powerful open-source application that can calculate effect sizes for a range of tests and designs. Therefore, a post hoc power analysis was further conducted with the program G*Power to find out whether the non-significant results were due to a lack of statistical power with power (1 - β) set at 0.80 and α = .05. The power to detect a small-sized effect (d = 0.2) and medium-sized effect (d = 0.50) were illustrated in table 7.5. Essentially, the test was performed and none of the variables were identified to have even small or medium sized effects. Therefore, we can safely conclude that the power for detecting both small and medium effects was low (under-powered), suggesting that we cannot rule them out but further data is required to support predictions.

Table 7.5: Power analysis results for the non-significant factors (Building resilience)

Variable	Observed power
no of storey	0.055
door type	0.053
window type	0.061
bathroom unit	0.11
Flood risk awareness	0.107
Flood depth	0.087
Flood insurance type	0.139
Length of years insured	0.051
Claim or no claim	0.148
Number of claims made	0.057

7.3.2 Selecting the Factors for the Human Resilience

A factorial ANOVA was conducted that examined the effect of the different set of independent variables on the human resilience scale. The different sets are socioeconomic factors of residents; flood characteristics and flood insurance (see figure 7.2). Each consists of several factors with the aim of examining their effect on the human resilience scale (see Figure 7.2). The factorial ANOVA seems appropriate and suitable for dealing with cases that has two or more categorical independent variables (either with or without the interactions) and a single normally distributed interval dependent variable. The normality test for the human resilience scale has been examined in section 7.2. In this case, the response is the human resilience scale. The following sub-section presents the results of the ANOVA test carried out with each set of variable and also reports variables that are statistically significant to the human resilience scale. Also, the non-significant statistical results are reported.

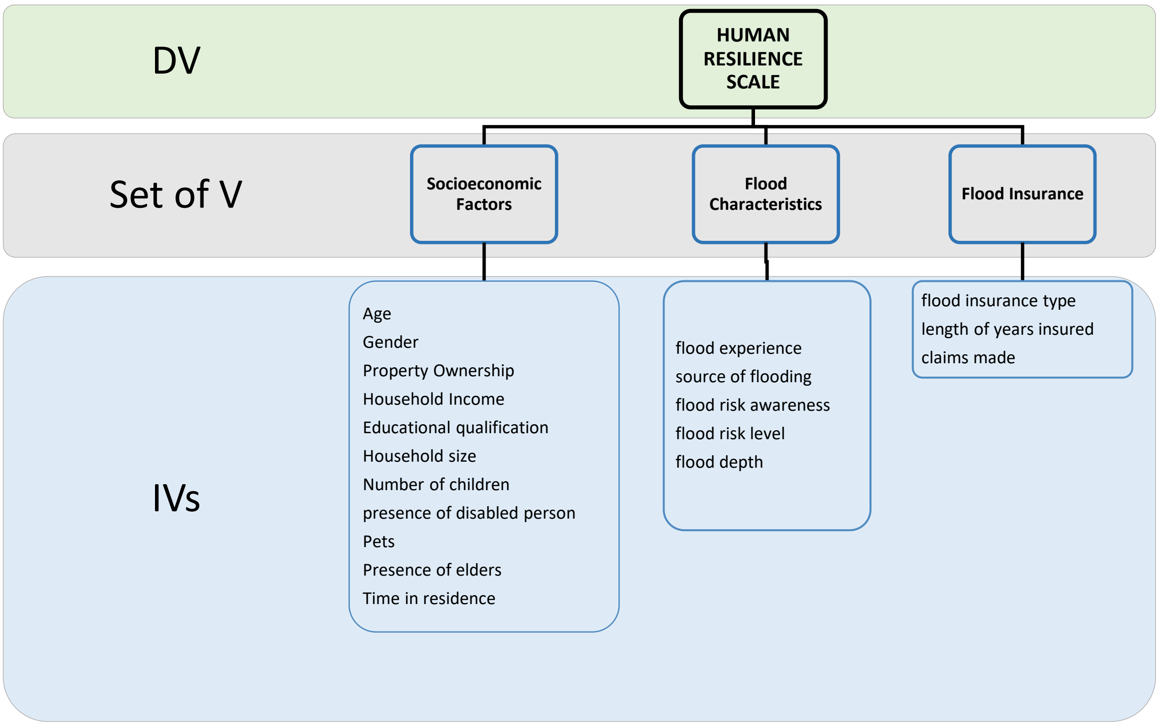


Figure 7.2: Factors captured in the questionnaire to measure the human resilience scale

7.3.2.1 Socio-economic factors

A factorial ANOVA was conducted that examined the effect of the first set independent variables (socio-economic factors) on the human resilience scale. The factorial ANOVA seems appropriate and suitable for dealing with cases that has two or more categorical independent variables (either with or without the interactions) and a single normally distributed interval dependent variable. It is important to first look at the interaction among the IVs as the result of this interaction will influence how the results can be interpreted. The interactions between the IVs are not statistically significantly (that is IVs have *p* values greater than 0.05 or low correlation when paired – see Appendix B17). This implies that the interpretation of the main effects on the human resilience is complete or not misleading.

From the table above, the age range, gender, property ownership, number of children, presence of disabled person and years lived in neighbourhood variables show difference in mean with the human resilience scale to be statistically significant. The p values are 0.005; 0.001; 0.012; 0.005 and 0.000 respectively (table 7.6). This indicates that of the 11 variables on socio-economic factors used only 6 show to be statistically significant in measuring the human resilience scale.

Table 7.6: Tests of Between-Subjects Effects (Socio-economic factors)

Dependent Variable: Human Resilience (0,1)

Source	Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	2.799[a]	29	.097	3.980	.000
Intercept	1.964	1	1.964	80.997	.000
Age	.218	3	.106	4.373	.098
Gender	.203	1	.203	8.389	.005
Property Ownership	.281	1	.281	11.568	.001
Household Income	.187	3	.062	2.575	.064
Educational Qualification	.145	5	.029	1.192	.326
Household Size	.160	3	.053	2.205	.098
Number of Children	.234	2	.117	4.833	.012

Presence of disabled person	.208	1	.208	8.572	.005
Pets	.051	3	.017	.695	.559
Elderly ones	.070	2	.035	1.452	.243
Time in Residence	.754	5	.151	6.215	.000
Error	1.285	53	.024		
Total	23.971	83			
Corrected Total	4.085	82			

a. R Squared = .685 (Adjusted R Squared = .513)

7.3.2.2 Flood Characteristics

A factorial ANOVA was conducted that examined the effect of the independent variables (flood experience and risk awareness) on the human resilience scale. The interactions between the IVs are not statistically significantly (that is all IVs have p values greater than 0.05). This implies that the interpretation of the main effects on the human resilience is complete or not misleading. From the table 7.7, none of the IVs shows statistical significance in the mean with the human resilience scale. All the variables have *p* values greater than 0.05 (see table 7.7).

Table 7.7: Tests of Between-Subjects Effects (Flood Characteristics)

Dependent Variable: Human Resilience (0,1)

Source	Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	.639[a]	12	.053	1.082	.389
Intercept	12.904	1	12.904	262.161	.000
Flood experience	.125	2	.063	1.270	.287
Source of flooding	.077	2	.039	.784	.461
Flood risk awareness	.110	1	.110	2.227	.140
Flood risk level	.188	3	.063	1.271	.291
Flood depth	.109	4	.027	.552	.698
Error	3.446	70	.049		
Total	23.971	83			
Corrected Total	4.085	82			

a. R Squared = .156 (Adjusted R Squared = .012)

7.3.2.3 Flood Insurance and Claim

A factorial ANOVA was conducted that examined the effect of the independent variables (flood insurance) on the human resilience scale. From the table above, both the flood insurance type and claim made show statistical significance in the mean with the human resilience scale. The p values are 0.022 and 0.005 respectively (table 7.8).

Table 7.8: Tests of Between-Subjects Effects (Flood Insurance and Claim)

Dependent Variable: Human Resilience (0,1)

Source	Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	.874[a]	6	.146	3.324	.006
Intercept	3.195	1	3.195	72.906	.000
Flood insurance type	.447	3	.149	3.397	.022
Length of year insured	.020	2	.010	.228	.797
Claim made	.370	1	.370	8.451	.005
Error	3.156	72	.044		
Total	23.172	79			
Corrected Total	4.030	78			

a. R Squared = .217 (Adjusted R Squared = .152)

7.3.2.4 Non-significant test

Post hoc power analysis was further conducted with the program G*Power to find out whether the non-significant results were due to a lack of statistical power with power (1 - β) set at 0.80 and α = .05. The power to detect a small-sized effect (d = 0.2) and medium-sized effect (d = 0.50) were illustrated in table 7.9. Thus, we cannot completely rule out that there was a small or medium-sized effect of negation in the factors. Therefore, we can safely conclude that the power for detecting both small and medium effects was low (under-powered), suggesting that a larger sample would allow us to support predictions.

Table 7.9: Power analysis results for the non-significant factors (Human resilience)

Variable	Observed power
age	0.703
household income	0.054
Educational qualification	0.055
Household size	0.056
Presence of pets	0.051
Presence of elderly ones	0.283
Flood experience	0.173
Source of flooding	0.373
Flood risk awareness	0.213
Flood risk level	0.426
Flood depth	0.089
Length of years insured	0.071

7.4 CORRELATION

Test of correlation was carried out to assess the existence of relationship between the building, the human and the overall resilience. Pearson's correlation coefficient was used to measure the strength of the relationship between these scales. Pearson's correlation coefficient requires only data that are interval or ratio level for it to be an accurate measure of the linear relationship between two variables (Field, 2005). Because the building, human and overall resilience scales are at the ratio level, it implies that this technique can be reliably applied to this research to estimate the strength of the relationship between these variables. Moreover, as argued by Field (2005), this technique is a useful precursor to regression modelling as it provides, prior to developing a full model, a fair idea of how closely a change in one variable is tied to a change in another variable and vice versa and also whether multicollinearity exists among the predictors. Multicollinearity is the situation where predictors are highly correlated with each other (i.e. r > 0.9) and is a source of concern in regression (Blaikie, 2003; Brace et al. 2003 & Field, 2005). Otherwise, it can be therefore concluded that there is no collinearity within the data (Field, 2005). The correlation matrix produced in this analysis is shown in Table 7.10. The significant level is 0.000 (2-tailed).

Table 7.10: Correlations

Correlations

		Building Resilience (0,1)	Human Resilience (0,1)	Overall Resilience (0,1)
Building Resilience (0,1)	Pearson Correlation	1	.407	.132
	Sig. (2-tailed)		.000	.032
	N	83	83	83
Human Resilience (0,1)	Pearson Correlation	.407	1	.041
	Sig. (2-tailed)	.000		.015
	N	83	83	83
Overall Resilience (0,1)	Pearson Correlation	.132	.041	1
	Sig. (2-tailed)	.032	.015	
	N	83	83	83

**. Correlation is significant at the 0.05 level (2-tailed).

The Pearson's correlation (r) (refer Table 7.10) reveals a moderate positive relationship, between the building resilience and the human resilience (r = .407; P < 0.000). This means that as the building resilience increases, there is a corresponding increment in the human resilience. This finding, thus, provides further evidence in support of assertions made in conceptual framework (chapter 4) which illustrates an arrow between the building and human components of the PFR, indicating that there is a relationship between these components. The Pearson's correlation (r) also show that there is a weak positive relationship between the overall resilience scale and the building and human resilience scale with (r = 0.132; p = 0.032) and (r = 0.041; p = 0.015) respectively. Therefore, since the Pearson correlation between the building and the human resilience is less than 0.90, it shows that there is no multicollinearity within the independent variables (building and the human resilience) required to measure the overall resilience. It can be concluded from this result that there is sufficient evidence of a linear relationship between the resilience values of these components to proceed with the regression modelling.

7.5 SUMMARY

This chapter is devoted to identify significant factors from the dataset. The first step was to carry out a normality test on the dependent variables, building, human and the overall resilience sales, to check for the appropriate inferential test to adopt. All three variables were normally distributed indicating that parametric test is appropriate. The Analysis of variance (ANOVA), was employed in the identification of factors required to measure the building and the human resilience models. The result showed that eight factors were significant to measure the building resilience while seven factors were significant to measure the human resilience. The non-significant test carried out conclude that the power for detecting both small and medium effects was low (under-powered), suggesting that a larger sample would allow us to support predictions.

Finally, the Pearson's correlation coefficients were performed to show that there is a relationship between the overall resilience scale and both the building and human resilience scales. It can be concluded from the result that a linear relationship exists between the overall resilience scale and the building and human resilience scales and therefore we can proceed with the regression modelling.

These analyses were aided by the use of quantitative data analysis computer programme, SPSS and the G*Power software. Having identified the relevant factors to measure the building and the human resilience models, the next chapter describes the development of the PFR model, which includes the building, human and the overall resilience models.

CHAPTER EIGHT: PROPERTY FLOOD RESILIENCE (PFR) MODEL DEVELOPMENT

8.1 INTRODUCTION

This chapter is devoted exclusively to the development of the models relating to the building, human and overall resilience. The analyses in this chapter is undertaken using the regression analysis. The regression analysis is applied to examine the relationships among the explanatory factors identified in section 7.3 and predicted variables, the building and the human resilience to flood risk. The overall resilience is also evaluated from the building and human resilience scales.

The chapter has been organised into the following section. Section 8.2 discuses model selection while section 8.3 gives an overview of the Multiple Regression analysis, the model accuracy and assumptions governing the multiple regression. Section 8.4 evaluates the building resilience model; section 8.5 evaluates the human resilience model while; section 8.6 reports the analysis that combine the building and the human resilience scales into a single resilience scale referred to as the overall resilience measure. The chapter closes with a succinct summary of the findings of the study. This chapter addresses the fifth objective of the research which is to analyse the data statistically with a view to explore the relationship between the building, the human and the overall resilience.

8.2 MODEL SELECTION

Artificial Neural Network (ANN), Regression, and Structural Equation Model are some of the statistical methods capable of modelling relationships between variables (Jeon, 2015). However, for a researcher, the most important question is which statistical methods to use. ANNs are powerful statistical modelling tools with a high potential for theoretical and practical improvements in learning sciences, but they are best suited for exploratory modelling (Musso, et al., 2013). Furthermore, the output of ANNs cannot be fully translated into a meaningful set of rules because they store information about input-output relationships in a complex, distributed, and implicit manner (Edelsbrunner and Schneider, 2013). These issues impede systematic theory building as well as communication and justification of model predictions in practical contexts. Regression techniques and SEM have advantages similar to ANNs but without the drawbacks (Edelsbrunner and Schneider, 2013). They can deal with many variables, non-linear effects, multi-way interactions, and incomplete data (Edelsbrunner & Schneider, 2013). As a result, these more theory-driven and sparse modelling techniques are preferred over ANNs. The PFR model can be developed using both the Regression model and the SEM. However, the rules for SEM are more complicated, and the calculations are more difficult, even though the overall message remains unchanged (Alavifar, et al., 2012). This complication may lead to incorrect results interpretation (Jeon, 2015). While this study recognises that SEM is a powerful statistical tool that can be used to further develop the PFR model, the regression model was chosen because its rules and computation are less complicated than SEM. The regression model is described in detail in the following sections.

8.3 MULTIPLE REGRESSION ANALYSIS

Multiple regression is one of the statistical techniques used in testing the conceptual framework developed in this research. Consequently, the selection is based on the ability of the regression analysis to estimate the value of a parameter based on one or several influencing factors. Therefore, the regression analysis is deemed fit for estimating the level of property flood resilience based on identified factors reported in the framework (chapter 4) and also for testing the framework. Hence, it is crucial to dedicate a section to describe what the technique entails, its assumptions and limitations. However, the section only provides an overview of the subject and description of the key terminologies used in multiple regression. Therefore, for more information on the subject, cited literature or any other good statistics textbooks should be consulted (Freund and Wilson, 1998; Field, 2000; Tabachnick and Fidell, 2001).

Regression analysis is often used to estimate the value of a given parameter based on factors that are considered as influencing that parameter. These influencing factors are often referred to as the independent or predictor variables (IV) while the parameter to be predicted is referred to as the dependent variables (DV). Therefore, the main goal of regression analysis is to investigate the relationship between the DV and the several IVs (Tabachnick and Fidell, 2001). Furthermore, the aim of multiple regression is to explore and quantify this relationship between a numerical dependent variable and one or more qualitative predictor variables (Rodríguez del Águila & Benítez-Parejo, 2011).

However, there are different kind of the regression analysis. For instance, in a situation where the investigation considers the influence of one predictor variable on a dependent variable, this is referred to as a simple linear regression. Alternatively, where the influence of more than one independent variable on a dependent variable is examined then this is termed multiple regression analysis. The latter type is applied in this study. Multiple regression models are a generalisation of simple linear regression in cases where there are more than one independent or predictor variable (Rodríguez del Águila & Benítez-Parejo, 2011). Multiple regression analysis (MRA) is therefore an extension of bivariate of simple linear regression. This result in a general equation which takes the following form, representing the best prediction of a DV from several IVs:

$$y = \alpha + b_1x_1 + b_2x_2 + \cdots + b_nx_n + \varepsilon$$

$Equation$ 8.1

Where:

y is the dependent variable

α is the intercept or constant

b_1, b_2 and b_n are regression coefficients for independent variables x_1, x_2, and x_n respectively (n denotes the total number of variables included)

x_1, x_2, and x_n are the independent variables

ε is a random variable called the error term

The Multiple Regression Analysis need not to be undertaken *manually* as it can be easily carried out using statistical software packages such as SPSS and Excel even by *statistical dummies*.

8.3.1 Model Accuracy in Multiple Regression

In multiple regression analysis a number of parameters are used to ascertain the accuracy and reliability of the regression model. Four of the parameters are investigated in this analysis. First parameter to consider is the overall model accuracy in MRA which is measured by the coefficient of determination often referred to as the R square (symbol: R^2). This parameter measures the amount of variation in the dependent variable that is accounted for by the model and assumes value between 0 and 1: as the value approaches 1 the model becomes more accurate, with the exclusion of chance effects (Field, 2000). It is not possible to provide rules of thumb for acceptable R^2 values because it depends on the complexity of the model and research discipline (Henseler et al., 2009; Hair et al., 2011). Therefore, a model with R^2 value of say 0.60 indicates that the independent variables used in the model accounts for 60% of the factors affecting the value of the dependent variable. It means that the model does a fairly good job (60%) at predicting or estimating the dependent variable.

Another parameter that can be considered as a close relative to the R^2 is the adjusted R^2. Meanwhile, in an ideal state, the adjusted R^2 is expected to be the same or very close to the value of R^2. However, it is well known that the R^2 value systematically overestimates the amount of variance explained in the population, which is arguably the more relevant quantity. Therefore, to estimate the amount of variance explained in the population, the adjusted R^2 is introduced. The adjusted R^2 statistic ‘correct’ R^2 to show how well the model would apply to the general population from which the sample was drawn. It accounts for the loss of predictive power (shrinkage) in the model R^2 (Samwinga, 2009). Stephanie (2018) cautions about how to differentiate between R^2 and adj. R^2. She opined that the R^2 expresses an ideal state and shows how well data points fit a regression line assuming every single predictor explains the variation in the dependent variable which is not true. Whereas, the adjusted R^2 tells how well the data points fit a regression line showing the percentage of variation explained only by the independent variables that actually affect the dependent variable. Pallant (2005) recommends the use of the adjusted R^2 in place of the R^2 value where the sample size is small.

The third parameter to be considered when interpreting the regression model is the Durbin-Watson statistic. The parameter is an indicator that test the validity of the assumption of independence of errors. Also, the Durbin-Watson test of serial correlation of the residuals can be used to check the assumption of normality (Norusis, 2003; Field, 2009). It assumes values from 0 to 4. Based on Field (2000) suggestion, a value closer to 2 is better whereas values lower than 1 or greater than 3 must certainly be cause for alarm. Therefore, if there is no autocorrelation (where subsequent observations are related), the Durbin-Watson statistic should be between 1.5 and 2.5. Figure 8.1 shows the Durbin Watson Statistics for regression which serves as a guide for making decision on the validity of the assumption on the independence of errors.

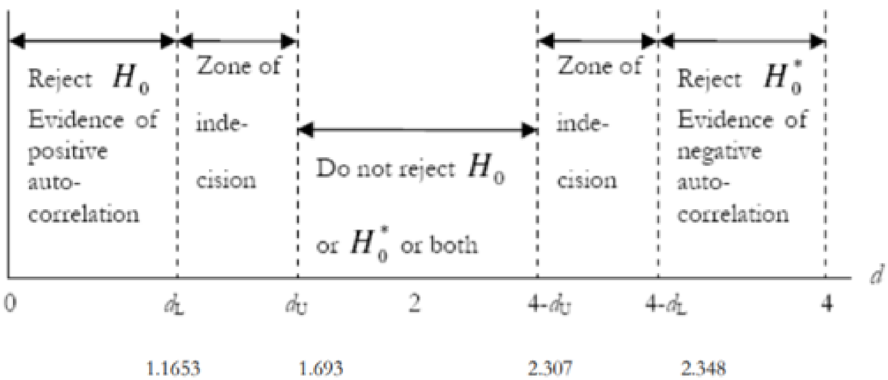


Figure 8.1: The Durbin-Watson Statistics for Regression

Source: Gujarati, 2003. p.469.

The fourth check for model accuracy is the analysis of variance (ANOVA). The test checked if the model is significantly better at predicting the dependent variable compared to using the mean of the DVs (Field, 2000). An F-ratio is obtained which indicates the ratio of improvement in prediction as a result of fitting the model relative to the inaccuracy that might still exist. If any improvement has occurred the ratio must be greater than 1. Meanwhile, in order to assess the statistical significance of the model results, the significance value corresponding to the F-ratio in the ANOVA table must be examined. This tests the null hypothesis that the probability of the population parameter is zero: the greater the value the more likely that the IV is not significant in the model. If the significant value is greater than 0.05 (5%), then it may be concluded that the model is not significant. A cut-off point as high as 0.1 (10%) is sometimes used instead of 0.05.

8.3.2 Multiple Regression Assumptions

Underlying some multivariate procedures and most statistical tests of their outcomes is the compliance to certain assumptions. Likewise, multiple regression has assumptions that need to be satisfied before the technique can be considered suitable for the data. Field (2009) asserted that it is only when all these assumptions are met that the model result can be accurately applied to the population. The main assumptions that are required for the MRA are briefly described in this section. However, a detailed discussion can be found in chapter 5 of Tabachnick and Fidell (2001). Also, a summary of the data's compliance with these assumptions is presented in sections 8.4.4, 8.5.4 and 8.6.4 (for the models), where the sample data were tested using MRA.

8.3.2.1 Cases-to-IVs Ratio (Sample size)

The sample size is often raised as an issue to consider when applying multiple regression. Pallant (2005) points out that the issue of concern here is the generalizability of the findings from the sample employed. Although there is no universal rule on the minimum sample size to which MRA can be applied, yet the cases-to-IVs ratio has to be substantial or the solution will look perfect— and meaningless. With more IVs than cases, one can find a regression solution that completely predicts the DV for each case, but only as an artefact of the cases-to-IV ratio. There are some guidelines that have been offered in various texts. Pallant (2005), for instance adopts a rather stringent $N>50+8m$ rule, where N is the sample size and m, the number of IVs. Meanwhile, a more recent suggestion is that offered by Khamis and Kepler (2010), using reliability as a criterion, they suggest $n \geq 20 + 5m$. This could be considered a minimum sample size and therefore adopted for this study.

8.3.2.2 Normality, Linearity, Homoscedasticity, Independence of Residuals

These four assumptions all relate to various aspects of the distribution of scores and the nature of the underlying relationship between the variables (Pallant, 2005). In an ideal state, all the assumptions should be satisfied by the data set. The first part of these four assumptions, test for normality, was already described in section 7.2.

Assumption on Linearity: For the multiple regression to accurately estimate the relationship between the dependent and independent variables, the relationships has to be linear in nature (Casson & Farmer, 2014). The danger of carrying out multiple regression when the relationship between independent variables (IV) and the dependent variable (DV) is not linear, is that the results of the analysis will under-estimate the true relationship. This underestimation comes with two risks: increased chance of a Type II error for that IV and an increased risk of Type I errors (overestimation) for other IVs that share variance with that IV.

Therefore, in order to investigate the assumption on linearity, Berry and Feldman (1993) and Pedhazur (1997), suggest several ways to detect non-linearity. Of all the ways suggested, the preferred method of detection is examination of residual plots, also referred to as scatterplots of the relationship between each of the IVs and the DV (Pallant, 2005). Carson and Farmer (2014), opined that an examination of the residuals is the most important aspect of regression model checking and should be performed for all regression analysis (Casson & Farmer, 2014). According to them, this is a critical assumption and the creation of a scatter plot of the residuals versus the predicted values is a simple and effective step in the diagnostic process. Therefore, for linearity assumption to be met, the points will randomly occupy the space within the scatterplot (as in Figure 8.2a) a non-random pattern in the scatterplot indicates a problem (Figures 8.2b and c)

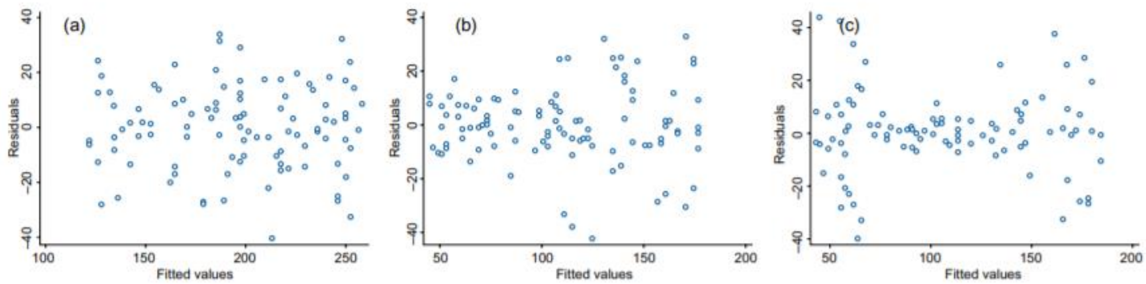


Figure 8.2: Scatter plots of data and residuals. (a–c) Residuals versus fitted (predicted values). (a) 'Well-behaved' residual pattern, demonstrating randomness (Casson & Farmer, 2014)

For homoscedasticity; Homoscedasticity means that the variance of errors is the same across all levels of the IVs. If all data points lie close to the regression line, then the variance is small; if the vertical spread about the regression line is large, then the variance is large. For homoscedasticity, each data point is assumed to contribute equally to the total information, and hence, should have the same variance. Also, because the vertical spread of the data is an estimate of the error, therefore, the assumption is that the error has a constant variance. However, when the variance of errors differs at different values of the IV, then heteroscedasticity is indicated. According to Berry and Feldman (1993) and Tabachnick and Fidell (1996) slight heteroscedasticity has little effect on significance tests; however, when heteroscedasticity is marked, it can lead to serious distortion of findings and seriously weaken the analysis thus increasing the possibility of a Type I error.

Casson and Farmer (2014), attest that the assumption of homoscedasticity (constant variance of errors) can also be assessed by the visual examination of the scatter plot of residuals versus the predicted values, just as in the case of linearity. A random spread suggests that the variance is constant (homoscedastic) as in figure 8.3a. If the spread varies then the assumption of constant variance is violated (heteroscedastic) as in figure 8.3b and c.

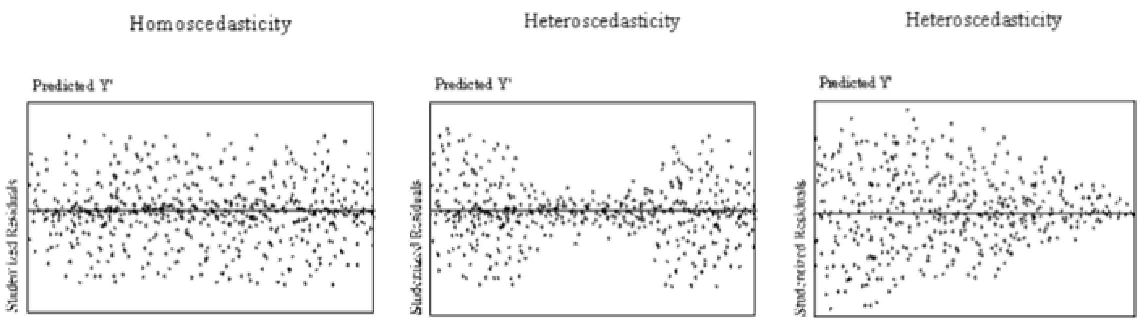


Figure 8.3: Examples of homoscedasticity and heteroscedasticity.

Independence of Residuals:

The assumption on independence of residuals is the effect of homoscedasticity, which implies that, if all data points carry the same information load, then we can also assume that the data points are not correlated, that is, that we have independent observations from the underlying population (Casson & Farmer, 2014). This means that one data point must not be capable of influencing another. This assumption can be checked using the Durbin-Watson statistic which is already explained in section 8.3.1

8.3.2.3 Multicollinearity

Multicollinearity is another assumption to consider in multiple regression. When performing a regression analysis, an important cause of concern is the existence of multicollinearity amongst the independent variables. It is likely to exist when the independent variables included in the analysis are not truly independent and measure redundant information (Myers, 1990). Multicollinearity exists when two or more IVs are too strongly correlated (say, $r \geq 0.90$) between the IVs (Pallant, 2005). Berry (1993) reports that when r is 0.9, the standard errors of the regression coefficients are doubled; when multicollinearity is present, none of the regression coefficients may be significant because of the large size of standard errors. It is ideal that the IVs in multiple regression analysis should be correlated (preferably $r > 0.30$) but not too strongly correlated. The computation of the regression coefficients requires inversion of the matrix of correlations among the IVs, an inversion that is impossible if IVs are singular and unstable and if they are multicollinear.

SPSS provides two options to assess whether multicollinearity exists in generated models and also to estimate the extent that it may be causing a problem in the models. Variance Inflation Factor (VIF) and its reciprocal (Tolerance), a collinearity diagnostic produced in SPSS was used to meet this purpose (Myers, 1990; Brace et al, 2003). The most commonly cited cut off value for VIF is 10 (Myers, 1990; Field, 2000; Pallant, 2005). Also, a tolerance of below 0.10 indicates that multicollinearity is a problem. According to Myers (1990), if the VIF value for any constructs surpasses 10, then there is a possibility of multicollinearity amongst constructs. If detected, in order to overcome this problem, a variable with a VIF value more than 10 needs to be deleted (Myers, 1990).

8.3.3 Evaluating the Influence of Individual Independent Variables

After having established that the overall model is significant and that the assumptions are met, the most important part of the analysis is the interpretation of the effects of the various independent variables used to explain the dependent variable. In regression, coefficients are generated for each independent variable which are central to the interpretations made about the model. First, the significance levels for the regression coefficients are assessed through the t statistics. Coefficient with *p*-value less than 5%, implies that the corresponding independent variable relates significantly to the dependent variable. Several types of coefficients were obtained from the regression analysis output. However, two statistics are fundamental to proper interpretation of the model, these are the unstandardized and standardized coefficients (Grace & Bollen, 2005).

8.3.3.1 The Unstandardized Coefficients (Bs)

Unstandardized coefficients are great for interpreting the relationship between an independent variable and an outcome. The most direct interpretation of the standardised coefficient is the amount of change that occurs in the predicted value of the dependent variable as a result of a change in an independent variable (Thayer, 1991). It indicates the effect of a 1-unit increase in the independent variable (on the scale in which the original independent variable is measured) on the dependent variable. Characteristic of unstandardized parameters is that they are expressed in the original units of the explanatory and dependent variables (Grace & Bollen, 2005). With reference to a simple linear regression, unstandardized coefficients represent the slope of the relationship. The same is true in multiple regression, although the slope is in n-dimensional space.

Meanwhile the unstandardized coefficient has its limitation, for instance, it is not useful for comparing the effect of an independent variable with another one in the model as their influence also depends on the type of scale used. Comparing the unstandardized coefficients would in any case amount to independent variables with different unit of measurement. Therefore, it does not provide answer to the question of which variable have greater impact on the dependent variable. Conversely, the standardization of the coefficients based on the standard deviations of the variables is the approach typically used to make coefficients comparable. This is the next type of coefficient discussed.

8.3.3.2 Standardized β coefficients

The importance of the standardized regression coefficients can be seen by its coverage in popular statistical textbooks (e.g., Hays, 1994; Cohen et al., 2003). The standardized coefficient also referred to as the betas (βs) provides avenue to compare the relative effect of differently measured independent variables. It expresses the effect of a single standardized deviation change of the independent variable on the dependent variable. This is achieved by expressing β as standard deviations with a mean of zero. These are useful measures to rank the predictor variables based on their contribution (regardless of sign) in explaining the dependent variable. The variable with the largest standardised coefficient, that is significant, makes the strongest unique contribution to explaining the DV, when the variance explained by the other IVs is controlled for (Pallant, 2005).

Further, standardized coefficients can be linked to the explained variance in the dependent variable. According to Grace and Bellon (2005), the standardized coefficients are expressed in terms of correlations, which represent the variation associated with the relationships. In the case of simple regression (involving a single predictor variable), the unstandardized coefficient represents the slope of the regression model, while the standardized coefficient represents the square root of the variance explained in the response variable. However, when it comes to multiple correlated predictors, it becomes a bit complex and it cannot be so generalized.

8.4 REGRESSION ANALYSIS – BUILDING RESILIENCE

The multivariate analysis involved the stepwise removal of variables from an initial list of 8 variables covering building characteristics (5) and flood characteristics (3) covering 22 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; Norsusis, 2003; Bryman and Cramer, 1999). In this technique, variables are chosen by SPSS based on mathematical criteria. This is done by searching for the IV which makes the best prediction of the DV, in other words, the IV with the highest simple correlation with the DV (Field, 2000). In order to accurately accommodates the variables, dummy coding was used for variables with two or more categories. Dummy coding in regression is important as it takes care of the limitation of multiple-regression analysis, that is, it accommodates only quantitative response and explanatory variables. The dummy coding allows qualitative explanatory variables, usually called factors, to be incorporated into a linear model. The next stage is to assess the overall goodness-of-fit of the model to the data and also ensure that assumptions are not violated.

8.4.1 The Regression Model (Model Accuracy)

The analysis resulted in eight variables with 12 significant categories (factors) as shown in Table 8.1. The first table of interest is the model summary (Table 8.1). 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 8.1: Model Summary (Building Resilience Scale)

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

The ’R‘ represents the multiple correlation coefficient. It 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 8.1, 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 study in related field (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% (100%-49.2%) 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 section 7.3.

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 8.1) 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). 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 result of the addition of useless variable 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.

8.4.2 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 8.1) which ends up in the non-rejection zone for autocorrelation. Therefore, the data is not auto-correlated.

8.4.3 Statistical Significance of the Model (The ANOVA)

The *F*-ratio in the ANOVA table is another parameter that tests whether the overall regression model is a good fit for the data. The table 8.2 shows that the independent variables statistically significantly predict the dependent variable, $F(11, 71) = 6.261$, $p (0.000) < 0.05$ (i.e., the regression model is a good fit of the data). Therefore, the t and F values obtained in the analysis are valid.

Table 8.2: The F-table ANOVA (Building Resilience)

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.368	11	.033	6.261	.000[b]
	Residual	.379	71	.005		
	Total	.747	82			

a. Dependent Variable: Building Resilience (0,1)

b. Predictors: (Constant), what is the flood risk of the locality you resides?, property ground floor type, property wall type, what source of flooding are you most concerned about?, how many times did you experience flooding to this property?, kitchen unit, property type, cellar_or_basement

8.4.4 Evaluation of Assumptions

Most statistical tests rely upon certain assumptions about the variables used in the analysis. When these assumptions are not met the results may not be trustworthy, resulting in a Type I or Type II error, or over- or under-estimation of significance or effect size(s). The results of the test of assumptions are described here.

8.4.4.1 Ratio of Cases to IVs

With 83 respondents and 8 IVs, using the Khamis and Kepler (2010) suggestion for computing the minimum sample size required, ($n \geq 20 + 5m$), where m is the number of IVs. The number of cases is well above the minimum requirement of 60 for testing individual predictors in the standard multiple regression. Therefore, the assumption of minimum ratio of cases to IVs is met.

8.4.4.2 Multicollinearity and Singularity

None of the tolerances listed in appendix B-10 approaches zero. Collinearity diagnostics indicate no cause for concern as only cases where tolerance fall below 0.1 requires attention.

From the result, the least tolerance value is 0.40 for the high risk category of the flood risk level (FRL), presence of cellar or basement (C/B) with highest value of 0.865 for detached property type (PT).

In addition, to check for the VIF if the assumption is met. Appendix B-10 illustrates that the VIF for this model varied between 1.156 for both detached property type (PT) and resident who had experience flood once (FE) and 2.50 for high risk flood level (FRL), which are much below the recommended cut-off level of 10 commonly suggested (Myers, 1990; Brace et al, 2003). Therefore, both the VIF and tolerance values suggest that the independent variables (i. e. PT, CB, WT, GFT, KU, FE, FS, and FRL) included in this study do not suffer from the problem of multicollinearity.

8.4.4.3 Normality, Linearity, Homoscedasticity, Independence of Residuals

Before running the multiple regression analysis, data were pre-screened to check if they complied with the assumptions for normality, linearity, homoscedasticity, independence of residuals and multicollinearity (Tabachnick & Fidell, 2001). The degree and nature of linearity and homoscedasticity was determined using scatterplots.

A visual inspection of the normal P-P plot of the regression standardised residuals between the dependent variable and its predictors show the residuals aligning themselves just close to the fit line. This, in agreement to the normality test carried out in section 7.2, show that the data is normally distributed. Further, the scatter plot of the standardised residual against the standardised predicted values were visually examined to check whether assumptions of linearity and homoscedasticity were met. If the distribution is non-linear, the scatterplot will appear oval in shape or the majority of residuals fall above the zero line or below the zero line. See appendices B-13 for the scatterplots. The scatterplots show that the assumptions of linearity and homoscedasticity were met. This implies that the data are linear and homoscedastic.

However, for the assumption on Independence of residuals, this is examined using the Durbin-Watson statistic. In this case, the value is 1.840 which ends up in the non-rejection zone so we can conclude that this assumption has been met.

8.4.5 Estimated Model Coefficients

Table 8.3 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 8.3 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 building resilience model is given as:

> *Building Flood Resilience 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.

Table 8.3: Regression coefficients

Independent variables	Parameters	Unstandardised Coefficients		Standardised Coefficient	t - value	sig (p)
		B	Std Error	Beta		
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

The regression slope for a detached property is 0.057 (5.7%) more than a semi-detached property. Property with no cellar or basement contributes 0.067 (6.7%) value to the building resilience scale more than those built with either a cellar or basement. This implies that cellar or basement are more prone to experience damage particularly from ground water flooding. For the wall type, cavity wall contributes 0.047 (4.7%) value to the building resilience more than timber wall type. For the ground floor type, concrete floor contributes more to resilience than walls made of timber with a value of 0.062 (6.2%). The slope of a plastic kitchen unit is 0.057 (5.7%) unit more than wooden kitchen unit. Plastics can be easily cleaned and dry in short period of time unlike wood that may rot or swell when exposed to water for a long period of time. A zero flood experience has a negative slope which indicates a contribution of 0.037 unit less than cases with prior flood experience. Surface water flood type shows the least negative impact on resilience with a 0.086 unit more than river flood type and 0.01 unit more than ground water flood type. Finally, the very low flood risk area has the least negative impact on resilience with a regression slope of 0.097 unit more than high flood risk areas; low flood risk area contributes 0.066 unit more than the high flood risk area while the medium flood risk area has 0.058 unit more than the high flood risk areas. The regression slope represents the contribution of each category to the building resilience scale.

8.4.6 Standardised Coefficients

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 8.4 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 8.4: Standardised coefficients

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

8.5 REGRESSION ANALYSIS – HUMAN RESILIENCE

The multivariate analysis involved the stepwise removal of variables from an initial list of 7 variables covering socio-economic factors (5) and flood insurance (3) covering 20 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 next stage is to assess the overall goodness-of-fit of the model to the data and also ensure that assumptions are not violated.

8.5.1 The Regression Model (Model Accuracy)

The analysis resulted in six variables with 12 significant categories (factors). The first table of interest is the model summary (Table 8.5). This table provides the R, R^2, adjusted R^2, and the standard error of the estimate, which can be used to determine how well the regression model fits the data:

Table 8.5: Model Summary (Human Resilience)

Model	R	R^2	Adjusted R^2	Std error of the estimate	Durbin-Watson	Sig
Human resilience	0.781	0.61	0.539	0.15426	1.747	0.000

The 'R' represents the multiple correlation coefficient. An R-value of 0.781 in this case, indicates a strong positive correlation. The key information from table 7.12 is the R^2 value (also called the coefficient of determination) of 0.610. This shows that the independent variables explain 61% (more than a half) of the variability of dependent variable, the human resilience. This is quite high, in comparison to the results from other study in related field (Joseph, 2014 with R^2 value of 0.17; EA/DEFRA (2005), with R^2 value 0.26) Bryan (2017) with R^2 value of 0.412. In addition, according to Frost (2017) warning about the R^2 that small R^2 values are not always a problem, and high R^2 values are not necessarily good. For instance, for an outcome variable like human behaviour which is very hard to predict, a high value of R^2 is almost impossible: although values above 0.2 are generally regarded as good within the context of social science surveys (EA/DEFRA, 2005). Therefore, owing to this an R^2 value of 0.61 can be considered reliable and satisfactory since the value is more than 0.2. Although, this implies that 39% (100%-61%) 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. For instance, one key factor that did not feature in the regression but might truly influence the human flood resilience is factor related to flood characteristics. None of the variables on flood characteristics appear to be significant from the dataset (see section 7.3.2.2).

Meanwhile, to accurately report the data interpretation, the 'Adjusted R^2' (adj. R^2) is another important factor. A value of 0.539 (reported in table 7.2) indicates that truly 53.9% 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 0.539 shows that more than a half of the variability in the human resilience scale is predicted by the socio-economics factors; (gender, property ownership, number of children, presence of a disabled person, year spent in neighbourhood); flood insurance (insurance type, claims made). High discrepancy between the values of R^2 and the Adj. R^2 is a sign of a poor fit of the model. Therefore, the level of discrepancy in this result is low with a difference of 0.071 (about 12%).

The standard error (in this case is 0.15426) of a model fit is a measure of the precision of the model. As R^2 increases the standard error will decrease. On average, the estimates of human resilience with this model will be wrong by 0.15426. This value is low and does not raise issue for concern.

8.5.2 The Durbin-Watson Statistic

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. Meanwhile, 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 Durbin-Watson (DW) test. (Gujarati, 2003). In cases where 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 1.747 (see table 7.3) which ends up in the non-rejection zone for autocorrelation. Therefore, the data is not auto-correlated.

8.5.3 Statistical Significance of the Model (THE ANOVA)

The *F*-ratio in the ANOVA table is another parameter that tests whether the overall regression model is a good fit for the data. Table 8.6 shows that the independent variables statistically significantly predict the dependent variable, $F(12, 66) = 8.612$, $p (0.000) < 0.05$ (i.e., the regression model is a good fit of the data). Therefore, the *t* and *F* values obtained in the analysis are valid.

Table 8.6: The F-table ANOVA (Human Resilience)

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	2.459	12	.205	8.612	.000[b]
	Residual	1.571	66	.024		
	Total	4.030	78			

a. Dependent Variable: Human Resilience (0,1)

b. Predictors: (Constant), two, building and content, less than 11years, are you, have you made any insurance claim at the event of flooding (if yes please answer question 3a and 3b), less than 26years, less than 16years, is there anyone with disability, building, is the property, less than 6years, content only, less than 21years, one

8.5.4 Evaluation of Assumptions

Most statistical tests rely upon certain assumptions about the variables used in the analysis. When these assumptions are not met the results may not be trustworthy, resulting in a Type I or Type II error, or over- or under-estimation of significance or effect size(s). The results of the test of assumptions are described here.

8.5.4.1 Ratio of Cases to IVs

With 83 respondents and 7 IVs, using the Khamis and Kepler (2010) suggestion for computing the minimum sample size required, ($n \geq 20 + 5m$), where m is the number of IVs. The number of cases is well above the minimum requirement of 55 for testing individual predictors in the standard multiple regression. Therefore, the assumption of minimum ratio of cases to IVs is met.

8.5.4.2 Multicollinearity and Singularity

None of the tolerances listed in appendix B-11 approaches zero. Collinearity diagnostics indicate no cause for concern as only cases where tolerance fall below 0.1 requires attention. From the result, the least tolerance value is 0.409 for the category of homeowner who have lived in the neighbourhood between 16-20 years, with highest value of 0.807 for female category of the gender variable.

In addition, to check for the VIF if the assumption is met. Appendix B-11 illustrates that the VIF for this model varied between 1.163 for the category of two children in the variable number of children in household and 2.446 for the category of homeowner who have lived in the neighbourhood between 16-20 years. Which are much below the recommended cut-off level of 10 commonly suggested (Myers, 1990; Brace et al, 2003).

8.5.4.3 Normality, Linearity, Homoscedasticity, Independence of Residuals

Before running the multiple regression analysis, data were pre-screened to check if they complied with the assumptions for normality, linearity, homoscedasticity, independence of residuals and multicollinearity (Tabachnick and Fidell, 2001). The degree and nature of linearity and homoscedasticity was determined using scatterplots.

A visual inspection of the normal P-P plot of the regression standardised residuals between the dependent variable and its predictors show the residuals aligning themselves just close to the fit line. This, in agreement to the normality test carried out in section 7.2, show that the data is normally distributed. Further, the scatter plot of the standardised residual against the standardised predicted values were visually examined to check whether assumptions of linearity and homoscedasticity were met. If the distribution is non-linear, the scatterplot will appear oval in shape or the majority of residuals fall above the zero line or below the zero line. See appendices B-14 for the scatterplots. The scatterplots show that the assumptions of linearity and homoscedasticity were met. This implies that the data are linear and homoscedastic.

However, for the assumption on Independence of residuals, this is examined using the Durbin-Watson statistic. In this case, the value is 1.747 which ends up in the non-rejection zone so we can conclude that this assumption has been met.

8.5.5 Estimated Model Coefficients

The table 8.7 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*).

This table 8.7 gives interesting information about the regression model. We begin with the coefficients that form the regression equation to predict human resilience level. This is generated from the unstandardized coefficients of the parameters that are statistically significant. Since all the coefficients are significant with *p* values less than 0.05, then the model is given as:

Human Resilience Level = 0.547 – 0.05 (female Gender) – 0.079 (tenant) – 0.055 (one child) + 0.055 (no disabled person) – 0.075 (21-25 time in residence TR) – 0.099 (16-20 time in residence TR) – 0.114 (11-15 time in residence TR) – 0.127 (6-10 time in residence TR) – 0.163 (0-5 time in residence TR) – 0.165 (no flood insurance) – 0.145 (content only flood insurance type) + 0.078 (no insurance claim made).

Table 8.7: Regression coefficients (Human Resilience)

Independent variables	Parameters	Unstandardised Coefficients		Standardised Coefficient	t – value	sig (p)
		B	Std Error	Beta		
Slope	constant	0.547	0.102		10.713	0.000
Gender	male	*Reference*				
	female	-0.05	0.039	-0.22	-2.568	0.013
Property Ownership	owner	*Reference*				
	tenant	-0.079	0.077	-0.2	-2.056	0.044
Number of Children	none	*Reference*				
	one	-0.055	0.056	-0.162	-1.959	0.050
	more than one	*Not Significant*				
Presence of Disabled Person	Yes	*Reference*				
	None	0.055	0.049	0.191	2.229	0.029
Time in Residence	more than 25 years	*Reference*				
	21-25 years	-0.075	0.069	-0.245	-2.168	0.034
	16-20 years	-0.099	0.077	-0.301	-2.544	0.013
	11-15 years	-0.114	0.071	-0.348	-3.212	0.002
	6-10 years	-0.127	0.071	-0.373	-3.555	0.001
	0-5 years	-0.163	0.059	-0.664	-5.529	0.000
Flood Insurance Type	building & content	*Reference*				
	None	-0.165	0.074	-0.466	-4.468	0.000
	content only	-0.145	0.118	-0.245	-2.459	0.017
Insurance Claim made	Yes	*Reference*				
	None	0.078	0.046	0.314	3.369	0.001

The regression intercept (labelled Constant in SPSS) takes the value of 0.547 (54.7%), is the predicted value for the human resilience if all independent variables fall on the reference point, gender = male, property = tenant, number of children = none, presence of disabled person = 0, *time in residence TR* = 26+ years, flood insurance type = both building and content, and claim made = yes. The regression slope for female gender is -0.05. This implies that the male gender is 0.05 unit more resilient than the female gender (5% more). Tenant offers 0.079 unit (6.7%) less than property owners. This could be as a result of the responsibility of property owners to protect their properties against flood impact. Also, where the household contain just one child, the regression slope for the ‘one child’ category is -0.055 which implies that it is 0.055 unit less that household with no child. Meanwhile, household where a disabled person is present offers a 0.055 unit less on the human resilience scale than those without disabled person. For the variable years spent in the neighbourhood, 0-5 years contributes 0.163 (16.3%) value to the human resilience less than those who has spent over 25 years in the neighbourhood; 6-10 years contributes 0.127 unit less than those who has spent over 25 years; 11-15 years contributes 0.114 unit less; 16-20 years contributes 0.099 unit less; and 21-25 years contributes 0.075 unit less. For the flood insurance type, where only contents are insured against flood risk, this contributes 0.145 unit less to the human resilience than when both building and contents are insured. Meanwhile, where neither building nor content is insured, this contributes a value of 0.165 less with respect to both building and cases where both building and contents are insured. Finally, for variable, claim made, the regression slope is 0.078. This implies that the ‘no insurance claim’ category contributes 0.078 unit more than the ‘insurance claim made’ category. The regression slope represents the contribution of each category to the human resilience scale.

8.5.6 Standardised coefficients

Accordingly, the standardized coefficients are called beta weights, given in the “beta” column. These are useful measures to rank the predictor variables based on their contribution (irrespective of sign) in explaining the level of the human resilience scale. The parameters in table 8.8 are arranged in decreasing order of the beta weight with the 0-5 year(s) category of the time in residence (TS) being the highest contributing (-.664) predictor to explain the human flood resilience, and the next is the no flood insurance category of the Flood insurance type (FI) IV (.466), while the least is the one child category of the number of children (NC) IV (-0.162). This suggests that three of the first four categories that have the largest impact on the human resilience scale belong to the variable 'time spent in residence'.

Table 8.8: Standardised coefficients

Parameters	Standardised Coefficient Beta
constant	
0-5 years (TR)	-0.664
no flood insurance (FI)	-0.466
6-10 years (TR)	-0.373
11-15 years (TR)	-0.348
no claim made (IC)	0.314
16-20 years (TR)	-0.301
21-25 years (TR)	-0.245
content only (FI)	-0.245
female (G)	-0.220
tenant (PO)	-0.200
no disabled person (DP)	0.191
one child (NC)	-0.162

8.6 REGRESSION ANALYSIS – OVERALL RESILIENCE

A multiple regression analysis was performed with the overall resilience scale as the dependent variable (ratio scale) while the building and human resilience scales (both ratio scale) are the independent variables. The cut-off for 'significance' was taken as the probability that the observed relationship occurring by chance was less than 0.05 (5%). The next stage is to assess the overall goodness-of-fit of the model to the data and also ensure that assumptions are not violated.

8.6.1 The Regression Model (Model Accuracy)

The first table of interest is the model summary (Table 8.9). This table provides the R, R^2, adjusted R^2, and the standard error of the estimate, which can be used to determine how well the regression model fits the data.

Table 8.9: Model Summary (Overall Resilience)

Model	R	R^2	Adjusted R^2	Std error of the estimate	Durbin-Watson	Sig
Overall resilience	0.428	0.184	0.163	0.11528	1.726	0.000

The "R" represents the multiple correlation coefficient. It is considered as one of the measures of the quality of the prediction of the dependent variable; in this case, the overall resilience. A value of 0.428 in this case, indicates a fairly positive correlation.

Another key information from the table 8.9 is the R^2 value (also called the coefficient of determination) of 0.184. This shows that both the building and the human resilience scales explain 18.4% of the variability of the overall resilience. This is quite similar, in comparison to the results from other study in related field (Joseph, 2014 with R^2 value of 0.17; EA/DEFRA (2005), with R^2 value 0.26). Therefore, owing to this an R^2 value of 0.184 can be considered satisfactory since the value falls within the values obtained in researches of related field. The low value of R^2 is however, caused by factors other than the predictors included in the building and human resilience models, so adding other independent variables could improve the fit of the overall model.

Meanwhile, to accurately report the data interpretation, the 'Adjusted R^2' (adj. R^2) is another important factor. A value of 0.163 (reported in table 8.9) indicates that truly about 16.3% of variation in the overall resilience is explained by the predictors (comprising of both the building and the human resilience) which are to be kept in the model. High discrepancy between the values of R^2 and the Adj. R^2 is a sign of a poor fit of the model. Therefore, the level of discrepancy in this result is low with a difference of 0.021 (about 11.4%).

The standard error (in this case is 0.11528) 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 human resilience to flood. As R^2 increases the standard error will decrease. On average, the estimates of the overall resilience with this model will be wrong by 0.11528. This value is low and does not raise issue for concern.

8.6.2 The Durbin-Watson Statistic

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 Durbin-Watson 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 1.726 (see table 8.9) which ends up in the non-rejection zone for autocorrelation (as in figure 8.1). Therefore, the data is not auto-correlated.

8.6.3 Statistical Significance of the Model (The ANOVA)

The *F*-ratio in the ANOVA table is another parameter that tests whether the overall regression model is a good fit for the data. The table shows that the independent variables statistically significantly predict the dependent variable, $F(2, 80) = 8.992$, $p (0.000) < 0.05$ (i.e., the regression model is a good fit of the data). Therefore, the *t* and *F* values obtained in the analysis are valid.

Table 8.10: The F-table ANOVA (Overall Resilience)

ANOVAa

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.239	2	.119	8.992	.000[b]
	Residual	1.063	80	.013		
	Total	1.302	82			

a. Dependent Variable: Overall Resilience

b. Predictors: (Constant), Building Resilience (0,1), Human Resilience (0,1)

8.6.4 Evaluation of Assumptions

Most statistical tests rely upon certain assumptions about the variables used in the analysis. When these assumptions are not met the results may not be trustworthy, resulting in a Type

I or Type II error, or over- or under-estimation of significance or effect size(s). The results of the test of assumptions are described here.

8.6.4.1 Ratio of Cases to IVs

With 83 respondents and 2 IVs, using the Khamis and Kepler (2010) suggestion for computing the minimum sample size required, ($n \geq 20 + 5m$), where m is the number of IVs. The number of cases is well above the minimum requirement of 30 for testing individual predictors in the standard multiple regression. Therefore, the assumption of minimum ratio of cases to IVs is met.

8.6.4.2 Multicollinearity and Singularity

None of the tolerances listed in appendix B-12 approaches zero. Collinearity diagnostics indicate no cause for concern as only cases where tolerance fall below 0.1 requires attention. From the result, the tolerance values for the building and the human resilience scales are both 0.969 which is way higher than 0.1.

In addition, to check for the VIF if the assumption is met. Appendix B-12 shows that the VIF for the overall resilience model is 1.032 for both the building and the human resilience scales. This is much below the recommended cut-off level of 10 commonly suggested (Myers, 1990; Brace et al, 2003). Therefore, both the VIF and tolerance values suggest that the independent variables included in this study do not suffer from the problem of multicollinearity.

8.6.4.3 Normality, Linearity, Homoscedasticity, Independence of Residuals

Before running the multiple regression analysis, data were pre-screened to check if they complied with the assumptions for normality, linearity, homoscedasticity, independence of residuals and multicollinearity (Tabachnick & Fidell, 2001). The degree and nature of linearity and homoscedasticity was determined using scatterplots.

A visual inspection of the normal P-P plot of the regression standardised residuals between the dependent variable (overall resilience scale) and its predictors (building and the human resilience scales) show the residuals aligning themselves just close to the fit line. This, in agreement to the normality test carried out in section 7.2, show that the data is normally distributed. Further, the scatter plots of the standardised residual against the standardised predicted values were visually examined to check whether assumptions of linearity and homoscedasticity were met. If the distribution is non-linear, the scatterplot will appear oval in shape or the majority of residuals fall above the zero line or below the zero line. The scatterplots in appendix B-15 below show that the assumptions of linearity and homoscedasticity were met. This implies that the data are linear and homoscedastic.

However, for the assumption on Independence of residuals, this is examined using the Durbin-Watson statistic. In this case, the value is 1.726 (see table 8.9) which ends up in the non-rejection zone so we can conclude that this assumption has been met.

8.6.5 Estimated Model Coefficients

The table 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*).

This table 8.11 gives interesting information about the regression model. It begins with the coefficients that form the regression equation. This is generated from the unstandardized coefficients of the parameters that are statistically significant. Since both coefficients (the building and human resilience scales) are significant with *p* values less than 0.05, then the model is given as:

Overall Resilience Level = 0.244 + 0.315 (Building Resilience Level) + 0.276 (Human Resilience Level)

Table 8.11: Regression coefficients (Overall Resilience)

Independent variables	**Parameters**	**Unstandardised Coefficients**		**Standardised Coefficient**	**t - value**	**sig (p)**
		B	**Std Error**	**Beta**		
Slope	Constant	0.244	0.072		6.081	0.000
Building resilience scale		0.315	0.135	0.316	3.081	0.003
Human Resilience scale		0.276	0.058	0.35	3.413	0.001

The regression intercept (labelled Constant in SPSS) takes the value of 0.244 (24.4%), is the predicted value for the overall resilience if the values of the building and human resilience scales are zeros. The unstandardized coefficient of the building and the human resilience scales are 0.315 and 0.276 respectively. This implies that when the value of the building resilience and human resilience for a particular household is known, the overall resilience can be found. For instance, at the reference points, the building resilience is 0.309, and the human resilience is 0.547, therefore, the overall resilience can be computed by applying the overall resilience model. This value is close to the average of both the building and the human resilience (average: 0.428).

$$\textit{Overall Resilience Level} = 0.244 + 0.315\,(0.309) + 0.276\,(0.547) = 0.492$$

8.6.6 Standardised coefficients

Accordingly, standardized coefficients are called beta weights, given in the 'beta' column. The beta weight measures how much the outcome variable increases (in standard deviations) when the predictor variable is increased by one standard deviation assuming other variable in the model is kept constant. These are useful measures to rank the predictor variables based on their contribution (irrespective of sign) in explaining the level of the overall resilience scale. The parameters in table 8.12 are arranged in decreasing order of the beta weight with the human resilience scale contributing more to the overall resilience (0.350) and the building resilience scale contributing the least (0.316) to explaining the overall resilience

Table 8.12: Standardised coefficients

Parameters	Standardised Coefficient
	Beta
Constant	
Building Resilience Scale	0.316
Human Resilience Scale	0.35

8.7 SUMMARY

This chapter is devoted exclusively to the development of the models relating to the building, human and overall resilience. Regression analyses, is employed in the development of the models. Also, the regression assumptions were considered alongside the model's accuracy. The results of the regressions analysis show that the assumptions of regression were met for the three models. The models appear to be accurate based on the R, R^2, adj. R^2 and Durbin-Watson parameters. Similarly, regression analysis was employed to evaluate the unique contribution of the factors (generated from chapter 7) on the building and human resilience. Also, the unique contribution of the building and human resilience scales on the overall resilience was evaluated. These analyses were aided by the use of quantitative data analysis computer programme, SPSS. Having developed the PFR model the next chapters: chapter 9 discusses the results while chapter 10 describes the validation process, which includes both external and internal validation.

CHAPTER NINE:DISCUSSION OF RESEARCH FINDINGS

9.1 INTRODUCTION

The previous chapter presented the findings obtained from the analysis of the questionnaire survey responses. This chapter presents a detailed discussion of the findings reported in that analysis including a comparison with the existing body of knowledge. The usefulness and relevance of the findings are also elaborated in this chapter. Hence this chapter corresponds with objective 6 in seeking to refine the PFR model towards its potential relevance for practical application in FRM at individual home level.

The chapter discusses the results of the factors that measures resilience in the building (physical) and the human (psychological) in relation to extant literature. Also, the implication of each factor, as it relates to the PFR model is discussed with emphasis on how these factors can be improved.

9.2 DISCUSSION OF THE BUILDING RESILIENCE MODEL

It is apparent that various types of factors influence the flood resilience of properties. This section examines these factors in light of the extant literature with the main purpose of establishing that the developed model is appropriate in the light of the purpose of the research investigation.

9.2.1 Property Type

Several studies report that property type (i.e., detached, semi-detached) is a factor that influences flood resilience (Keating, et al., 2015). However, these studies did not specify which of the property type is more resilient to the flood damage. From the result in Chapter 8, the detached property appears to be less resilient than the semi-detached property. One possible reason the detached property is less resilient may be due to cost of reinstating the property from flood damage. The report by Keating et al. (2015) shows that the detached property has the highest mean cost for reinstating when affected by flood event, while the terrace has the least. This implies that on the average it costs more to protect the detached property against flood damage than semi-detached and terrace property type (Keating, et al., 2015). On this basis, the results of the analysis support the report by Keating et al (2015). This indicates that, detached property owners will require more financial capacity to be able to protect their properties and deal with the associated flood risk.

9.2.2 Cellar or Basement

A report by the Environment Agency on the practical advice to help homeowners reduce the flood impacts from groundwater reveals that basements are particularly prone to flooding and remedial measures are often challenging to implement (Environment Agency, 2011).

Therefore, the Environment Agency provide guidance on basement developments in flood zones stating that basements should be avoided in these areas since they are susceptible to rapid inundation by floodwater. This advice was given to help developers minimise potential flood impacts to new buildings in flood risk areas.

Therefore, a property without a cellar or basement will be more resilient than properties with cellar/basement. The finding from this study has confirmed this statement by the Environment Agency with some hard evidence (see the result in Table 8.10). Properties without cellar or basement were about 7% more resilient to flood impacts on building and its contents than properties with cellar or basement.

9.2.3 Property Ground Floor Type

Raising the floor levels above the predicted flood level is often regarded as the preferred option for resilience by many – see for examples (ODPM, 2003; Bowker et al., 2007). However, this option highlights a few issues to be considered. For example, this requires some certainty that floodwaters will not rise much above the existing floor levels, the predicted flood level is well understood, and that there is sufficient ceiling height within the property to accommodate this. This also comes with some additional costs which not all homeowners would be able to afford. However, considering the two floor types (concrete and timber) that featured in the research; the result of this research showed that the concrete floor is more resilient than the timber-framed floor.

According to research by the Association of British Insurers (ABI) (2009), concrete floors are more resilient than timber floors. In fact, it is suggested that timber floor should be replaced with solid concrete particularly when property is exposed to frequent flooding (Bowker, et al., 2007). The concrete floor is preferred, although less sustainable, as it provides an effective seal against rising flood water. However, the degree to which it is more resilient was not specified. The findings of this research have helped to establish a value on the effect. The results from the analysis supports the findings of the ABI and DEFRA, and states further that the concrete floor is 6.2% better 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 is in need of replacement. This is reflected 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 the study therefore shows that this replacement will increase resilience by 6.2%.

Timber floors are prone to swelling and may become distorted when in contact with flood water for a long period of time. Further, timbers that become wet and take time to dry may be at risk of decay in the long term. Meanwhile, masonry and concrete are unlikely to be severely damaged when in direct contact with floodwater.

9.2.4 Wall Type

For the wall type variable, the comparison is between timber frame and cavity. Masonry cavity walls have been the most popular choice for UK housing since their use became widespread in the 1920s. From guidance and reports on PFR, there exists some consensus on wall constructions, with support for the use of masonry cavity as it appears to reduce water penetration, whilst recognising that this type may inhibit drying of the internal building fabric (Tagg et al., 2007). Cavity walls will help to minimise the transfer of moisture from the outer to inner leaf and also provides space to locate insulation, which may be fully or partially filled. Also, the Concrete Centre (2007) considered materials such as masonry to be more flood resilient than other building materials as they do not warp, decay or lose structural integrity as a result of flooding.

According to Tagg et al. (2007), the idea of avoiding cavities is quite interesting, since this is an important feature in preventing rain penetration. However, evidence from the literature seems to indicate that some form of closed cell foam is the preferred cavity insulation, although other forms may be equally suitable if used on the external wall (Tagg et al., 2007). Therefore, the research finding on the *property wall type variable* (masonry cavity wall is more resilient than the timber-framed wall) is consistent with findings from the extant literature and the discussion on the ground floor type variables. Consequently, this study contributes by specifying the degree to which the masonry cavity wall is more resilient than the timber wall. It shows that the masonry cavity wall is 4.7% more resilient to flood impact than the timber wall type.

9.2.5 Kitchen Unit

The results indicate that the plastic kitchen unit is more resilient to the impacts of flooding than the wooden kitchen unit. Kitchen units, which are traditionally constructed from chipboard, offer little, if any, resilience against flood damage (Wassell et al., 2009).

However, Dhonau et al. (2020) reported how a solid wooden kitchen was effortlessly and totally washed down following a flood event. According to Hunter (2015), kitchen units below flood level should be made of waterproof materials such as plastic or stainless steel hardware. Although, in terms of aesthetics, these may not be the preferred option but in regard to resilience, these are preferred to traditional wooden kitchen units. Also, plastic kitchens are potentially expensive and homeowners are often reluctant to install them (Lamond, et al., 2016).

The Poly-Vinyl Chloride (PVC) kitchen unit is a better alternative in terms of aesthetics. The 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 these are seen as easy to decontaminate as 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 research has confirmed that kitchen units made of plastic are more resilient. Relative to the wooden kitchen unit, the plastic kitchen unit can be easily cleaned and dried after it comes in contact with 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.

9.2.6 Flood Experience

The experience of past flood events has been shown to be a key determinant for better risk preparation in studies across a variety of countries (Burningham et al. 2008; Gow et al. 2008; Kung and Chen 2012; Wachinger et al. 2013; Bubeck et al., 2018). Tapsell et al. (2010) state that the flood recurrence in an area can make residents more aware of the risk and thereby cause them to adopt measures to lessen the impacts. Put simply, the experience motivates them to become better prepared against subsequent flood events. However, it is worth noting that they conclude that this comes with an intangible cost on the home owners, such as increased anxiety about future flooding (Werrity et al., 2007).

Experience of flooding was found to be a key factor prompting the implementation of protective and loss reducing actions in response to a flood warning and during a flood event (DEFRA/EA, 2009). Conversely, not knowing what to do results to an increase in the stress suffered during flood event (Fielding et al., 2007; Carroll et al., 2009). Therefore, in theory, those who have experienced a flood event should be better prepared to cope with the effects of a subsequent flood (DEFRA/EA, 2009).

This implies that property owners with flood experience will be more likely to take steps to reinforce their properties against flooding unlike their counterparts with no prior experience. This is consistent with the results obtained in this study where flood experience (FE) was found to be a significant variable (see table 8.10.).

Meanwhile, there are some findings in Scotland that reports otherwise, that prior experience may hinder response and preparedness in some circumstances (Owusu et al. 2015; Harries et al. 2018). These reports show that some people may not expect a worse event than the one they have previously experienced. Also, it accounts that some flood victims might just want to forget about their experiences and move on with life, - for them, preparation increases anxiety and worry about future flooding; others particularly if they suffered significant damage before may conclude that their actions will not reduce damage or make any difference (McCarthy, 2004). However, it is clear that prior experience helps to motivate better preparedness against subsequent flood events (Nye et al., 2011; Kuang and Liao, 2020).

9.2.7 Flood Source

The results show that of the three flood sources considered, riverine flooding was found to be the most significant in terms of its impact on building resilience. This result supports the findings of Sayers et al (2020), who reported that riverine flooding is the dominant risk in recent times and contributes the greatest to economic damage, while groundwater continues to have a limited contribution at a national scale, although will be important locally (Sayers et al., 2020).

Whilst the risk of flooding from rivers and surface water can be minimised by structures such as embankments, walls and dams, it is presently impossible to construct effective defences to prevent the broad-scale emergence of groundwater. This might explain why its impact on building resilience was more than that of surface water flooding.

Further, comparing both surface water and groundwater flooding, many reports accept that of these two flood sources, groundwater is more difficult to prevent. According to the Environment Agency (2011), groundwater flooding is often more difficult to prevent than surface water flooding. For property owners, the precautions and options available that can be taken against groundwater flooding are rather limited (Environment Agency, 2011; Environment Agency, 2014) and thereby making it challenging to develop and improve resilience.

The most effective way to deal with groundwater flooding is to use 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 a low point into which water can drain.

However, one of the key challenges is the need to consider where the water will be pumped to because pumping from one place to another may cause flooding elsewhere. Also, one key advice is to ensure that water is pumped out only when flood levels outside the property begin to be lower than that inside. This is essential as it reduces the risk of structural damage. Concerning these challenges, it is essential to seek advice from a structural engineer. All of these considerations need to be thought of and settled prior to flood events and are not a case of contemplation during flood events (Environment Agency, 2011).

9.2.8 Flood Risk Level

Based on the EA flood risk maps in the UK, flood risk levels are classified as very low, low, medium and high. By risk we mean not just the chance that flooding will occur (the probability), but also the flood impacts. Hence, high flood risk means that each year, there is a 3.3% or greater chance of flooding (Environment Agency, 2011). While very low meaning that each year, there is less than a 0.1% chance of flooding. The findings of this study show that properties located in high flood risk areas are less resilient than those properties in very low risk areas. This result is consistent to the interpretation of the flood risk map. Building houses away from the high flood risk zones is the most effective way to reduce risk. However, where properties already exist, a comprehensive flood risk assessment has to be carried out.

9.3 DISCUSSION OF THE HUMAN RESILIENCE MODEL

Here, the human resilience model is subject to cross examination with the body of literature and in similar fields of study. This section discusses the factors found to be significant in light of the extant literature and in order to show how the finding are consistent with those found in the literature. Therefore, the purpose of the discussion is to establish that the developed model is appropriate in the light of the purpose of the research investigation.

9.3.1 Gender

Gender is one of the key factors, in the study, for measuring the human resilience to flood impacts. The research finding showed that the male gender is more resilient to flood impacts than the female gender. Earlier research studies have indicated that females are more vulnerable to the effects of extreme weather (Balbus and Malina 2009; Graham, et al., 2019). The literature shows that women may also suffer more from the effects of flooding (Tapsell et al., 1999; Tapsell and Tunstall, 2001; Tunstall, et al., 2006). Possible explanations put forward for this difference were related to women's vulnerable social position and childcare responsibilities (Tapsell & Tunstall, 2008). This is similar to the finding of this research. However, Harvatt et al. (2011) found little evidence of gender differences in householder responses to flooding in the report carried out in high-risk locations in England.

Further, earlier studies show that gender is a factor to consider in terms of flood impacts. For example, the report produced by Fordham (1998) shows that after two flooding events in Scotland, females were more affected than males. One of the reasons highlighted by early research was that women's experiences of flooding are often defined by their role as mothers particularly if they are looking after children (Ketteridge and Fordham, 1997). Women may shoulder a disproportionate burden, for instance, the role of many women as carers not only for children but also for other members of the family makes them more vulnerable (Liu et al., 2006; Medd et al., 2015). This burden may result into long term psychological health issues (Tapsell et al., 2003).

Contrary to Harvett et al. (2011), the EA/DEFRA (2005) believes that whichever health measures are considered, women were found to be more affected than men by flooding. This may be that women are more health conscious or admit to ill effects more readily than men or may be that they do experience more health effects (EA/DEFRA, 2005). This reinforces the claim and strengthens the evidence provided in this research that females are more vulnerable and contribute less to human resilience.

9.3.2 Number of Children

At first sight, it might be expected that two (or more) adults sharing a household without children may be best placed to deal with the effects of flooding (EA/DEFRA, 2005). The findings here show that the presence of a child in a household will reduce the household resilience by a unit of 0.162 (16.2%). This represents a significant impact on resilience. While it was difficult to measure the impact that a household with two or more children will have on human resilience, several reports suggest that the effects of flooding may be worse where households contain one or more children (EA/DEFRA, 2005). The presence of children leads to greater health and psychological effects. Pine and Cohen (2002) acknowledged that children can become distressed during disasters and often leads to a number of psychological problems. These impacts include: fear of water, insomnia, impacts on social life as a result of friends being scattered and being subject to taunts by other children (Carroll, et al., 2006). A survey carried out in England in 2013 found that people with children were more likely to consider themselves at risk (Langley and Silman 2014).

A study carried out by Tapsell and Tunstall (2001) on the health effects of the autumn 2000 floods in the North East revealed that parents were more concerned about the effects of the flooding on their children and child care, and therefore requested for special advice on ways to help them cope with the aftermath of the flooding. It was reported that children were affected in a number of ways from minor health problems to anxiety and stress-related health effects (Tapsell et al. 1999). Also, there may be an extra strain on adults because of the need to try to maintain cleanliness, restore a routine and a level of normality in the face of adverse circumstances in the home for the sake of children. All of these can have a huge impact on the recovery path. Therefore, households without children will be free from this form of worry.

9.3.3 Flood Insurance

In the UK, flood insurance is contained within the standard general household insurance policy provided by most private insurance companies (Lamond, 2008). Buildings and contents insurance can be purchased separately or as a package, and flood cover is usually included in both buildings and contents policies (Lamond, 2008). Insurance is not compulsory but buildings cover is normally mandatory where homes are purchased using mortgage finance (Lamond, 2008). This explains why there may be properties in flood risk areas without flood insurance. According to ONS (2015) report, 21.79% of households in the UK (with the exclusion of Scotland) had not bought structural flood insurance in 2014. Also, the number of households not seeking flood insurance protection seems to be on the increase. Watkiss et al. (2016) noted that while most owner occupiers have buildings insurance, there are much lower levels of contents insurance among tenants, with many in the lowest income decile having no insurance at all.

As expected, of the three significant categories in the flood insurance variable, the ‘building and content’ category contributes the most to the human resilience scale, while the ‘no flood insurance’ category contributing the least. This is true as past reports state that not all flood prone households are insured. Insurance take-up is driven by levels of income (ONS, 2015). Therefore, those that fall in the ‘no flood insurance’ category could be households on income support or representing households without paid employment or investment that can generate income. Many retired people on pensions will also fall within this category and they may have to rely on money from the relief fund and discretionary grants from local council in order to deal with flood damages.

Dealing with insurers and loss adjustors has been consistently highlighted as a key factor influencing both short-term and long-term psychological effects of flooding and increasing stress levels, as does dealing with builders whilst living in temporary accommodation (Tapsell et al., 2003; Werrity et al., 2007). Having insurance should reduce the effects of flooding, as insurance can help recovery from the financial effects which are also related to health effects (Oakley, 2018).

9.3.4 Flood Claim

The Association of British Insurers reveals that flood damages from the 2007, 2013/14 and 2015/16 floods accounted for £3.863 billion of flood damage with 55.6% from residential properties. This highlights the importance of this factor. Over the last 10 years, an average of 19,000 UK households per year have made flood-related insurance claims (Oakley 2018), and the 2007 floods led to 43,000 flood-related domestic insurance claims (Flood Re, 2018).

From existing reports, it appears that those making insurance claims may come with consequences. For most people, making a major claim to an insurance company was not a good experience (as reported in Environment Agency, 2005), Some of the documented impacts are many claimants did not know what to do or who to phone, or what they could claim for. Many people were also dissatisfied with their insurers, with the main complaints being: delays with the claims, attitudes of loss adjustors, lack of information on what they could claim. In addition, premium and excesses could increase after a claim is made, which means more financial burden. All of these issues could result in additional stress on flood victims which will be absent in the case where damage is minimal and insurance claims are not needed.

9.3.5 Disability

The finding of this study show that the presence of disabled house members reduces human resilience. This characteristic has been linked to a greater vulnerability to the impacts of flooding. The review by Thrush et al. (2005) indicates that physical and mental disability as well as long-term illness are factors that require special support in flood events. In addition, they also cited that almost twenty percent of the households surveyed contained at least one long-term ill or disabled member, and that many of those households would find it difficult, if not impossible, to act on a flood warning.

There are different types of disability, each of which presents different difficulties in the event of a flood (DEFRA/EA, 2009). For instance, house members with sensory disabilities such as deafness will find it difficult to hear conventional warning signals and alarms like sirens; those with blindness will not be aware of visual alarms and instructions and also lack the ability to move out quickly from a crowded or unfamiliar situation. Also, for house members with physical disability, they may find it difficult to independently and quickly leave a high-risk area. This research did not consider the effect of these different types of disabilities, however, regardless of the type of disability, the presence of a disabled member was found to minimise the level of flood resilience.

9.3.6 Property Ownership

Tenure is another factor that contributes to the human resilience scale. The results of this study show that property owners are more resilient to flood impacts than those who live in rented properties. A report by Environment Agency (2009) reveals that property owners are less affected by the health impacts of flooding compared to those in rented accommodation. This could be due to property owners exhibiting greater awareness than people who rent accommodation as they have much more at stake. This will motivate them to want to be as informed as possible about measures they can take in the event of a flood. Consequently, property owners are likely to be better prepared to deal with the effects of flooding. Further, tenants are less likely to take action during or before a flood (DEFRA/EA, 2009).

9.3.7 Time in Residence

Based on the research findings, human resilience progressively increases as the factor moves from the '0-5 years' category to '26+ years' category. The findings show that the longer the time of residency the better the resilience. This aligns well with the report by the Environment Agency (2005) which concluded that as far as length of residence is concerned, the key point of interest is that people new to an area will display markedly lower 'awareness' of flood risk than people who had been in residence longer. This shows that it can take time to fully understand the flood characteristics of the resident environment and also to become acquainted with how to obtain the required support against flooding events. According to the Environment Agency (2005), this is perhaps not surprising as one is bound to learn progressively more about an area, the longer one lives there. That said, a lot of information about a new environment will be picked up fairly quickly, with decreasing amounts of new information amassed year by year. These considerations help to explain the increased resilience with households who had been resident in their areas for many years.

9.4 THE PFR MODEL

This subsection reflects on the evidence from the survey findings and the conceptual framework (see Figure 4.1 in Section 4.6), to propose the PFR model. This PFR model was developed after incorporating the related concepts and subjecting the model to testing with the data collected from homeowners in flood risk areas. This model illustrates the outcomes of the statistical analysis including some minor changes and nuances as reported. Hence, the model identifies the key factors which influence the PFR. Including their weighting and influence. The PFR model is described based on the identification of significant factors for both the building and the human components and then finally the combined weight of each of these components with respect to measuring flood resilience in individual households.

Figure 9.1 depicts the PFR model. The size of each of the factors represents the degree of impact each has on resilience. For the building resilience, the significant factors are 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). Compared to the conceptual framework, 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.

For the human component, the significant factors are Gender (G), property ownership (PO), number of children (NC), presence of disabled persons (DP), time in residence (TR), flood insurance type (FT) and insurance claim made (IC). Within the conceptual framework, these factors were included in the socioeconomic (G, PO, NC, DP and TR) and insurance categories (FT and IC). The time spent in residence has the most impact on the human resilience while the presence of children has the least impact.

The arrow connecting the two components indicated the correlation between the building and human resilience (see section 7.4). This represents the model developed to evaluate the overall resilience (see the model in section 8.8) of individual households.

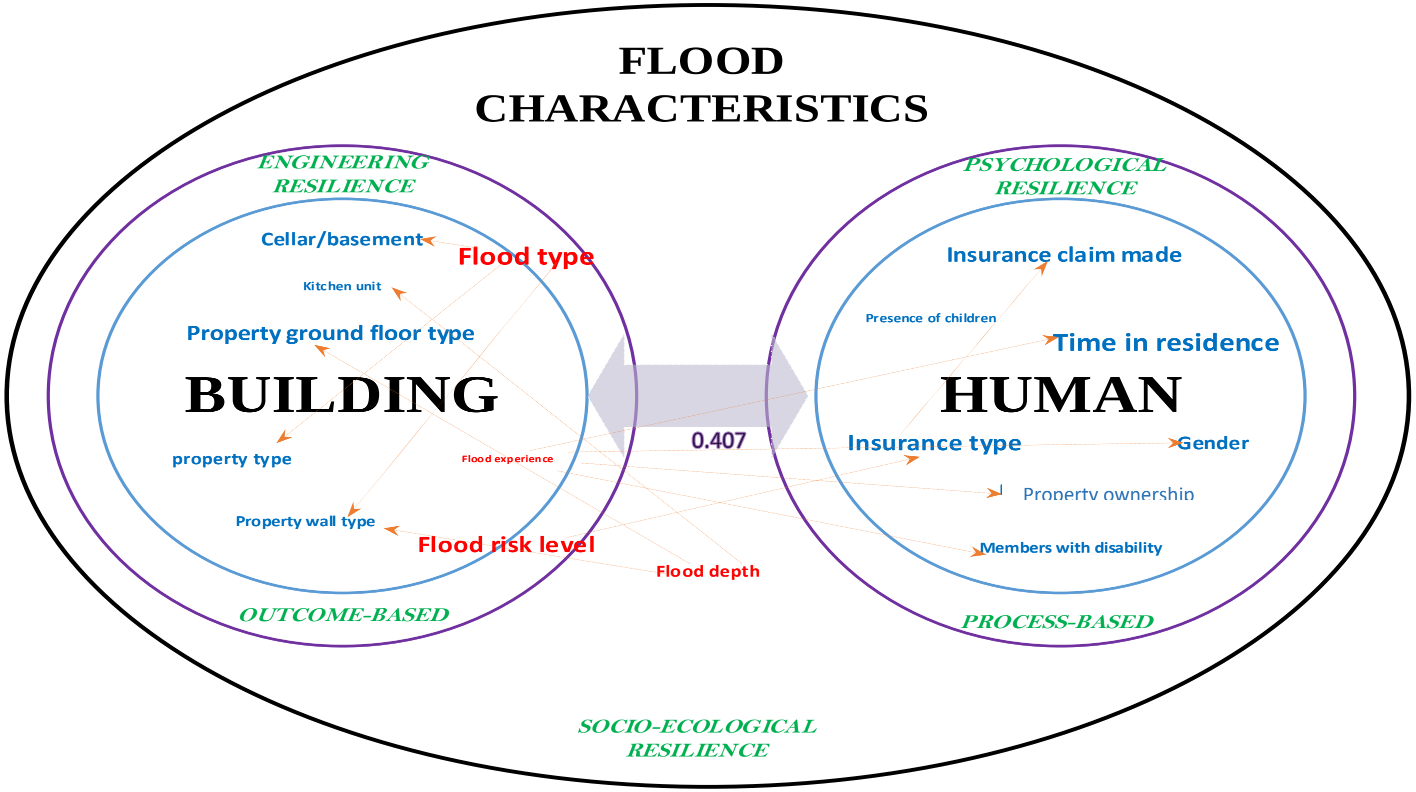


Figure 9.1: The Modified PFR mode

9.5 KEYS TO IMPROVING THE PROPERTY FLOOD RESILIENCE (PFR)

This subsection summarises the above discussion and reflects on the performance of the PFR model. Here, the main focus of discussion is the steps taken to improve the PFR model first at the building (physical) level and then at the human level.

9.5.1 Improving the Building Resilience Model

It is evident that in order to improve building resilience, financial investment is required which some property owners may not be able to afford. There are studies on the cost of reinstating property and guidelines on how to improve resilience. However, a gradual improvement will be less burdensome on the home owner. In considering the building resilience model (table 8.11), it appears that the variables relating to the flood characteristics have the most negative impacts on the building resilience. This indicates that the first step to improving resilience is to relocate to another region with less flood risk. This option may not be possible, and comes with its own financial challenges as well as a fear that their home might be unsaleable or indeed very difficult to sell.

The most impactful factor was found to be replacing timber floors with a concrete floor and was found to increase resilience by 6.2%. Also, there are ways of further increasing the resilience of floors, through the use of water resistant floor coverings like clay or concrete tiles, vinyl sheets with chemical- set adhesive. Carpets, vinyl and wood floorings all slow the floor drying process and so not are advised to be used as floor covering on concrete floors. Meanwhile, ceramic and quarry tiles will absorb less water and do not significantly hinder the drying process.

The next impactful factor was the presence of a cellar or basement. In order to improve the resilience of a building with a cellar or basement, tanking can be used and is a popular way of flood proofing basements but can be quite expensive.

Prior flood experience was also found to be a significant factor towards improving resilience. Homeowners should be encouraged to sensitise themselves about flood risk in order to improve awareness. They can also learn from the experience of others and in most cases this can be acquired by interacting with those with flood experience. They can also join flood groups and attend community forums on flood risk and resilience, such as those arranged by the National Flood Forum (NFF). Also, they can learn by reading people's experience from journals and news archives to help them prepare against potential flood events. It may be difficult to predict exactly the kind and intensity of a potential flood event. However, it is better to be aware of the impending danger and thereby prepare for it rather than to remain ignorant. The implication is that the flood event might come as a huge shock to the unprepared homeowners accompanied with devastating effects that they may find it difficult to recover from. Having a good understanding of the disruption floods can cause will also provide insights on how to improve resilience. Furthermore, being aware of the flood risk and pre-flood measures such as finding out if a property is at risk, understanding flood warning codes and having information on what to do on receipt of a warning will improve the flood resilience of a household tremendously.

The kitchen is the most expensive part of the home and so will require a lot of financial commitment to improve its resilience. When a flood happens, the kitchen is often the costliest item to replace (Dhonau, 2020). Therefore, it is essential to keep flood damage to minimum so that the kitchen can become fully functional not long after the flood water has gone. Therefore, to move from a wooden kitchen unit to a plastic kitchen unit is good investment to properties exposed to flood risk. 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. In these instances, the use of materials that are flood resilient is a better option. For example, steel and ceramic units are materials that can be easily cleaned and dried when they come in contact with water. Plastic kitchens are moisture resistant and can be easily cleaned and dried. Table 9.1 summarises the key findings and the key improvements for the building resilience model.

Table 9.1: 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.

9.5.2 Improving the Human Resilience Model

To improve the human resilience, requires not only financial commitment but also intellectual (mental) capacity building. The financial aspect covers purchasing flood insurance and also ensuring that the measures are put in place to alleviate flood impacts on building. The interest in flood insurance arises first of all from the pursuit to find an efficient way of compensating flood victims who suffer flood losses, and to provide a means of managing the financial risk associated with flood events. In its most basic form, flood insurance creates a platform where flood risks or part of the risk are transferred from insured homeowners to the insurer in return for a payment of the premium. The objective is to minimise financial impacts, which in a way has an indirect effect on the psychological impacts.

Meanwhile, the female gender suffers more from the impacts of flooding due to their role as mothers particularly if they are looking after children. Children are also mostly exposed to the health impacts. According to a report by the Environment Agency, awareness of flood risk decreases health effects (across all measures). Therefore, both women and children would benefit from increased awareness of the flood risk and local community knowledge. It is essential that they familiarise themselves with flood advice and support can be obtained such as from flood forums and flood groups. The National Flood Forum helps local flood action groups to become established and offers coordination at the local level. Such groups can help residents understand their own responsibilities, what they should do in a flood situation and to identify members of the community who need particular help. Also, it is important to develop strong social networks with people who are going through similar ordeal. This can provide a platform where they can discuss their experiences and share ideas on how to overcome their challenges. Social cohesion and social capital have been seen more broadly as important in helping communities to adapt to living with hazards. In addition, having a source of income, for instance by engaging in paid jobs, can enable women to be more resourceful and provide the financial shock absorber to bounce back from potential flood events. Low income has been reported as one of the barriers to installing PFR measures (Park, et al., 2020).

For disabled house members, based on the form of disability, it is vital to have proper understanding of the level of risk, safety precautions and safety measures put in place. A lack of awareness and understanding about resilient measures and their deployment represents a major barrier to their adoption them. Ignorance is not without a cost which in this case may be devastating. Measures should be designed to suit the form of disability and members should be included when making decisions relating to flood protection.

The key findings and the strategy for improving the resilience of each factor for the human resilience is summarised in table 9.2.

Table 9.2: Key Findings and Improvement of the Human Resilience Model

FACTORS	FINDINGS FROM RESEARCH	IMPROVEMENT KEY
Gender	Female are more vulnerable than male	Awareness and sensitisation is the key to improve resilience
Property Ownership	owners are more resilient than tenants	The tenants need to familiarise themselves with the flood characteristics of the locality and the flood status of the properties in which they live in.
Number of Children	Household without children are more resilient	Children needs to be educated on flood impact and the property flood resilience

Disabled Person	More resilient without a disabled house member.	Easy egress to safety location should be designed And disabled person should be familiarised with this and other safety precaution and how to navigate. They should be encouraged to put this to test this prior to the flood event
Time in Residence	Length of time stayed in the locality is an advantage to resilience	The time frame can be shortened through massive awareness
Flood Insurance	Insuring both building and contents against flood risk will keep home owners mind at rest	
Flood Claim Made	Zero flood claim is preferred	

9.6 THE ROLE OF EDUCATION ON FLOOD RESILIENCE

As learning to live with floods has become increasingly important for all communities living in flood-prone areas, including children (Williams and McEwen, 2021). As a result, community awareness and education are seen as a legitimate and growingly important flood mitigation measure. It is regarded as an important response modification mechanism in these situations for preparing people for flooding and recovery (Dufty, 2008). Furthermore, some researchers and flood risk managers believe that improving flood risk education in communities is the single most important action that could be taken to improve flood warning and response (Elliott, et al., 2003). Education is effective at all stages of the crisis, but it has the greatest impact during preparation. As a result, additional educational planning should be considered at this stage (Wisner, 2006; Muttarak and Pothisiri, 2013; Rundmo and Nordfjaern, 2017).

Meanwhile, after several flood experiences, a homeowner may become indifferent to flood resilience, remaining passive about flood awareness or education programmes for valid reasons such as "after all, I'm still affected by flood." Part of the education and awareness includes informing people that it has become increasingly clear that flood mitigation measures alone cannot protect communities from all flood events, but they can reduce the impacts (Dufty, 2008). This does not, however, diminish the importance of being aware and receiving appropriate education. It is critical to know what to do even during and after a flood event; knowing how and where to find help can save a lot of time and money during recovery. According to the Hyogo Framework for Action (HFA) (2005–2015), disasters are reduced when people are well informed and the motivation is to create a culture of flood risk prevention and resilience.

According to previous findings, education is a functional, operational, and cost-effective risk management tool. Some evidence support that it is critical for flood-prone people to learn about flood risk. There are various educational methods that can be used, but none is superior to others. When people are trained, they can better protect themselves and others. The most important thing is to find the method that works best for the community. As a result, stakeholders must plan and design comprehensive educational programmes for those at risk of flooding. People who have received training can better protect themselves and others. As a result, training can reduce both human and financial flood impacts, which is regarded as a more pressing issue for those at risk of flooding.

A large number of studies have confirmed the importance of education to various classes of society at all levels (Sawada, 2006; Shreve, et al., 2014; Johnson, 2014). Elderly people and those with disabilities require special training because of their physical conditions, limitations, or cognitive impairment (Muttarak and Pothisiri, 2013; Rundmo and Nordfjaern, 2017). People with disabilities who are informed about their risk-aversion practises can save themselves in such situations without the assistance of others. According to some studies, training such people is directly related to their survival after disasters (Thomas, et al., 2015). In this regard, various training methods can be used. Furthermore, various types of exercises and manoeuvres can be used for proper planning, which improves individuals' knowledge and skills and is used as a method for evaluating individuals' performance in simulated conditions. Furthermore, the manoeuvres and exercises used for disabled and elderly people differ, and special attention should be paid to these people.

Children's education programmes should be an innovative approach to flood risk reduction. This education programme should be geared toward increasing their perception of flood risk, and it should be explicitly addressed as a way to improve child resiliency and information transmission in order to reduce flood risk in their homes (Sawada, 2006; Faber, et al., 2014; Shreve, et al., 2014; Johnson, 2014). This programme will encourage them to consider the significance of PFR measures and how preparedness can bridge the gap between knowledge and action (Faber, et al., 2014; Bosschaart, et al., 2016). Some benefits of early childhood education are: Earlier onset flood risk prevention education makes it easy for children to think about flood risk, resilience, and risk reduction officials from an early age; individuals who are familiar with the concepts of hazards, risks and resilience in their childhood can respond better and faster when flood events occur; people do not simply forget what they learn at an early age

Increasing evidence suggests that children have important roles to play in Environmental Education and as agents in sustainable flood risk management (Walker et al. 2012; Lawson et al. 2018; Mort et al. 2018; Cuidar Project, 2020). Many agencies tasked with Community Disaster Risk Management (CDRM) and building socio-ecological resilience (Adger, 2000) can incorporate children's participation in strategies to build local capital for household level preparedness (Williams & McEwen, 2021).

Teaching and trainings can take place in a variety of settings, including schools, churches, mosques, and offices, among others. Following training, some members of flood-prone communities should become active members of the group and serve as agents to educate others in the community (Muzenda-Mudavanhu, et al., 2016).

9.7 SUMMARY

This chapter discussed and reflected upon the findings from the survey analysis. First, this chapter discussed the factors that made up the PFR model and compared the outcomes of the analysis with existing literature. By making reference to literature, the findings are found to be broadly consistent with the body of knowledge. Taken together, there is adequate alliance between the research findings and previous studies. Also, the revised model has been presented and discussed with emphasis on the ways to improvement the PFR both at the building and human level. The next chapter (Chapter 10) will describe the validation process, which includes both external and internal validation.

CHAPTER TEN: VALIDATION OF THE DEVELOPED PFR MODEL

10.1 INTRODUCTION

This chapter presents the results of the validation of the PFR model developed to measure flood resilience in individual homes within the UK. The degree to which the research findings can be trusted however rests on the process of validation carried out. Furthermore, the validation provides a foundation for drawing meaningful conclusions. Thus, validation is essential since it reveals the potential objectivity of the PFR model. This chapter, therefore, presents the validation process that was undertaken in respect of this research.

A discussion of the need to validate the PFR model is first presented. Thereafter, an approach for undertaking the validation exercise, both external and internal validation procedures are introduced. Subsequently, the details involved in both validation procedures, with respect to this study, are discussed. This chapter therefore addresses the sixth research objective: to validate the PFR model towards its predictive accuracy and potential relevance for practical application in flood risk management at individual home level.

10.2 NEED FOR VALIDATION

The PFR model developed in previous chapter (Chapter 8) satisfy the MRA assumptions. However, even when the assumptions have been satisfied, a model developed from a sample drawn out of population, will not always be identical to one obtained if the entire population was to be considered (Kukull & Ganguli, 2012). As with many statistical techniques, prediction using MRA does not provide the assurance that every case in the population would conform to the derived model (Frost, 2017). However, if an unbiased model has been derived using MRA, it can be generalised to the population in terms of the average predictions being likely to be similar. Consequently, it is essential to check for the validity of the PFR model to ensure that the sample can be generalised to the relevant population, that is, homes in the UK located in flood risk areas.

Validity implies that the results are consistent over time. There are a number of techniques that are used by statisticians to assess the validity of the model. A suitable technique that has been engaged successfully in recent times to achieve the validation process is the two dimensional methodology identified as; external and internal validation (see for instance, Xiao, 2002; Ahadzie, 2007; Ankra, 2007; Ikpe, 2009). External validation is particularly used with regards to the substantive domain of the research process, while internal validation has been applied to the conceptual and methodological domains.

10.3 EXTERNAL VALIDATION (CROSS-VALIDATION)

The process of external validation considers the ability to generalise the applicability and transferability of the model unto other conditions with similar characteristics (Egbu, 2007).

Various external validation techniques exist. Four commonly used techniques for undertaking external validation have been identified (Snee, 1977; Good and Hardin, 2003; Field, 2005; Ikpe, 2009). These are:

i. Using independent verification obtained by waiting until the future arrives or through the use of surrogate variables;
ii. Splitting the samples into two parts with one part used for estimating the model and the other part for validation;
iii. Re-sampling, taking repeated samples from the original sample and refilling the model each time;
iv. Collection of new data to validate the model.

As a result of resource constraints, in particular time limits, using independent verification when the future arrives was an option that could not be pursued in the course of this study (Ikpe, 2009). Also, the collection of new data, though a good method of model validation, however, in many instances (mostly financial and time limits) this is not practical, particularly, when considering the challenges posed by the COVID-19 pandemic on the data collection process. In this situation a procedure which simulates the collection of new data is needed. A reasonable way to proceed is to split the data in hand into two sets where the first set of data can be used to estimate the model coefficients and remaining data used to measure the prediction accuracy of the model. The re-sampling procedure was also not considered because, as noted by Field (2005), most researchers, particularly in related research, rarely have sufficient data to execute this kind of analysis. Therefore, based on time and resource constraints, splitting the samples for the purpose of estimating and validating the model appears to be the most practical and feasible external validation technique to adopt for the purpose of this study. This data splitting technique is also referred to as cross-validation (Snee, 1977).

According to Arlot and Celisse (2010), cross-validation approach is the most practical and flexible approach one can use for model selection. Cross-validation is one of the most widely used data splitting methods for assessing the correctness and generalisability of a predictive model and to prevent overfitting (Good, 2006; Zhang, 2011). A model that is generalised should be able to accurately predict the same outcome variable from the same set of predictors in a different group of people (Field, 2013). However, if the model is applied to a different sample and this results to a severe drop in its predictive power, then the model clearly does not generalize (Field, 2013).

The rationale for choosing the cross-validation is because (i.) it is conceptually simple, (ii.) it is intuitive, and (iii.) it can be applied to any statistical model family regardless of its technical details (to both parametric and non-parametric models) (Emmert-Streib & Dehmer, 2019).

10.3.1 Data Splitting

Data splitting involves randomly splitting the sample data, computing a regression equation on both halves of the data and then comparing the results generated by both models to test the model's predictive power (Field, 2013). For the validation of the PFR model, the data set is divided into two random samples; a recommended split of 80% for the statistical regression analysis and the remaining 20% as the cross-validation sample, referred to as the hold out sample (Field, 2013; Tabachnick and Fidell, 2013). Selection of cases to be kept in the holdout samples was done randomly using the SPSS's function for "selecting cases" by random selection. The statistical regression on the entire sample has already been done for the building, the human and the overall resilience models (in Chapter 8), also, predicted scores are created for the cross-validation (hold out) sample for both the building, human and overall resilience models. Finally, the R^2 value for the hold out sample is obtained. The main focus in cross validation is not the variance between the resilience predicted by the model for individual cases but rather the variance between the average resilience for the sample used in deriving the model and the average resilience scores predicted for the entire hold out sample (Ikpe, 2009). Hence, to check the accuracy of the models and find out how well the original model generalizes, both the values of the R^2 in the two samples are compared (Tabachnick & Fidell, 2013). A large discrepancy between R^2 for the hold out and entire samples indicates overfitting and lack of generalizability of the results of the analysis (Field, 2013; Tabachnick and Fidell, 2013).

10.3.2 Validation of the PFR Model

Therefore, the aim of this section was to apply the models derived in sections 8.3, 8.4 and 8.5 to a different sample, a hold out sample of twenty percent (20%) of the original sample collected in the survey. The model prediction data shown in Table 10.1 shows the model summary of the building, human and the overall resilience when applied to the hold out sample. The variance is the difference between the actual resilience scores for the individual cases as provided by the respondent and the model prediction score.

Table 10.1: Model Summary of the Hold-out sample for the Building and Human Resilience

MODELS	R	R squared	Adjusted R squared	Std Error of the Estimate	Durbin-Watson
Building Resilience	0.685	0.469	0.412	0.07321	2.114
Human Resilience	0.800	0.640	0.535	0.17654	2.077
Overall Resilience	0.418	0.175	0.078	0.12746	2.248

10.3.2.1 The Cross-Validation of the Building Resilience Model

The correlation between predicted and actual scores of the building resilience model from the cross-validated sample is squared (R^2 = 0.469) (see table 10.1). This value is, however, compared with the R^2 = 0.492 (see table 8.1) for the entire sample (the building resilience model). This represents an average prediction error of 4.7%. This is a good result which implies that the model is validated as 95.3% accurate in predicting the building resilience of a different sample, in this case the hold out sample, drawn from the same population. Since the discrepancy between R^2 for the hold out sample and building resilience model is very small (below 5%), this indicates that the model can be generalised and it can be concluded that the results of the analysis is not overfitting. In this case, the building resilience model produced by the entire sample gives a better prediction than the one generated by the hold out sample.

10.3.2.2 The Cross-Validation of the Human Resilience Model

The correlation between predicted and actual scores of the human resilience model from the cross-validated sample is squared (R^2 = 0.640) (see table 10.1). This value is, however, compared with the R^2 = 0.610 (see table 8.5) for the entire sample (the human resilience model). This represents an average prediction error of 4.9%. This is a good result which implies that the model is validated as 95.1% accurate in predicting the human resilience of a different sample, in this case the hold out sample, drawn from the same population. Since the discrepancy between R^2 for the hold out sample and the human resilience model is very small (below 5%), this indicates that the model can be generalised and it can be concluded that the results of the analysis is not overfitting. In this case, the cross- validation sample is better predicted by the regression equation than the sample that generated the equation. According to Tabachnick and Fidell (2013), this is an unusual result, but one that would make a researcher breathe a sigh of relief after using statistical regression.

10.3.2.3 The Cross-Validation of the Overall Resilience Model

The correlation between predicted and actual scores of the overall resilience model from the cross-validated sample is squared (R^2 = 0.175) (see table 9.1). This value is, however, compared with the R^2 = 0.184 (see table 8.9) for the entire sample (the overall resilience model). This represents an average prediction error of 4.9%. This is a good result which implies that the model is validated as 95.1% accurate in predicting the human resilience of a different sample, in this case the hold out sample, drawn from the same population. Since the discrepancy between R^2 for the hold out sample and the overall resilience model is very small (below 5%), this indicates that the model can be generalised and it can be concluded that the results of the analysis is not overfitting.

10.4 INTERNAL VALIDATION

Internal validity seeks to address how cause-effect relationships are free from sources of bias arising from research design (Ikpe, 2009). Regardless of how good the research design is, it is important to check if internal validity has been achieved (Ankrah, 2007). Some researchers have used a variety of ways to demonstrate internal validity. Proverbs (1998) and Xiao (2002) are two examples of these initiatives, both of which try to demonstrate internal validity by checking for convergence between research findings, published research, and academic validation. The notion is that if convergence is shown among these three, the research's arguments concerning cause-effect relationships are valid.

This approach has been employed in FRM doctorate studies (see Joseph, 2014) to compare the conclusions of this study to those of other published research and to subject the study to peer review. Therefore, applying the same approach, this section aims to demonstrate convergence of the research findings with published work and how the findings has gone through academic and expert review.

10.4.1 Convergence of Questionnaire Development and Analysis

Validation of the questionnaire development is reflected in the convergence with the literature search (Chapter 2) and the theoretical framework adopted (see Chapter 3). Therefore, the inclusion of the predictors in the questionnaire had a reasonable theoretical basis. Different sets of analyses were performed on the data collected, these are; the normality test, ANOVA, correlation analysis, and regression analysis. The findings show that all these analyses replicate the literature (see chapters 7 and 8).

In the test model to evaluate the PFR in individual homes, the model summary for the building (R = 0.702 (70%), R^2 = 0.492 (49%) and R^2 adjusted = 0.414 (41%)); the human resilience (R = 0.781 (78%), R^2 = 0.610 (61%) and R^2 adjusted = 0.539 (54%)); and the overall resilience (R = 0.428 (43%), R^2 = 0.184 (18%) and R^2 adjusted = 0.163 (16%)) demonstrate credible models for evaluating the level of flood resilience in individual homes. They also provide evidence of the appropriateness of the data used in the analysis (see Chapter 6 for detail). Furthermore, the model is significant in all key aspects, *F* values, and Durbin Watson statistics. Consequently, the significantly low *p*-value of less than 5% for the *t*-test for the individual partial regression coefficient reported in Tables 8.3, 8.7 and 8.11 as well as the *F*-test reported in Tables 8.2, 8.6 and 8.10 statistically prove that the result of the regression analysis is significant and could not have been obtained by chance. In addition, the external validation shows that the results are reliable enough to form the basis for generalising the conclusions to the relevant population.

10.4.2 Convergence of Research Findings with Published Research

The convergence of literature is often referred to as theoretical validity which is the presence of agreement or disagreement within the community of inquirers about the terms used (Maxwell, 1992). Convergence of findings from the literature and the output of the model has been shown in several sections by constant reference to the extant literature. Therefore, to avoid repetition, references are only made to the relevant chapter.

Based on the quantitative findings, convergence with past research is evident from the constant reference to the extant literature in the discussion chapter (see Chapter 9). With reference to literature in the discussion of the results, the findings are found to be consistent with the extant literature. This implies that there is adequate convergence between the research findings and previous studies and that the influencing factors identified in the models are replicated in the literature. The model was able to combine building and human resilience, and it also serves as the first PFR quantification.

10.4.3 Academic Validation of Research Findings

The process of disseminating the findings of this research to practitioners, policy makers and the wider academic community through the publication of conference papers, journal papers, presentations at regional flood and coastal committee meeting and Environment Agency and reports involved a review and assessment of the validity of the research and its findings via the peer review process. According to Xiao (2002), peer review provides an opportunity for the methodologies, meanings and interpretation of research to be questioned by independent judges. Further, it is a process of subjecting a scholarly work, research or ideas to the scrutiny of others who are experts in the same field (Kelly, et al., 2014). There are four possible outcomes of peer review. These are: (i) acceptance without change; (ii) acceptance subject to minor changes; (iii) acceptance with major amendments; or (iv) rejection (Runeson and Loosemore, 1999). In all cases the peer review feedback outlines the basis of a decision, which can be incorporated in the research to improve its validity. In addition to the academic scrutiny provided by the peer review of papers, academic forums such as conferences allow members of the academic community of a discipline or research area to also scrutinise the methodologies, meanings and interpretation of a piece of research. Also, work was delivered at meetings with policy makers and experts such as the Environment Agency (EA) and the Regional Flood and Coastal Committee (RFCC). This form of peer review also provides useful feedback, which can be incorporated in the research to improve its validity.

To date, six papers related to this research have been published with 25 citations (see table 10.2) and several presentations made. These are:

Adedeji, T. J., Proverbs, D. G., Oladokun, V. O. and Xiao, H., 2019. Making Homes More Resilient to Flooding: A New Hybrid Approach. In: F. E. Noroozinejad, et al. eds. Resilient Structures and Infrastructure. Singapore: Springer, pp. 159-176.

Adedeji, T. J., Proverbs, D. G., Xiao, H. and Oladokun, V. O., 2018. Towards a Conceptual Framework for Property Level Flood Resilience. International Journal of Safety and Security Engineering, 8(4), pp. 493 - 504.

Adedeji, T. J., Proverbs, D. G., Xiao, H. and Oladokun, V. O., 2019. The application of the flood resilience circle to the city of Birmingham. ARCOM Doctoral Workshop-

Industry 4.0 and Disaster Resilience in the Built Environment, 25th April 2019 at Northumbria University: Newcastle Upon Tyne, UK.

Adedeji, T.J., Proverbs, D. G., Xiao, H., Cobbing, P. and Oladokun, V. O., 2019. Making Birmingham a Flood Resilient City: Challenges and Opportunities. Water, 11(8), p. 1699.

Proverbs, D. G., Oladokun, V. O., Xiao, H. and Adedeji, T. J., 2018. A Conceptual Model for Measuring Flood Resilience at the Individual Property Level. London, Royal Institution of Chartered Surveyors (RICS).

Adedeji, T. J., Proverbs, D. G., Xiao, H. and Oladokun, V. O., (in view). Property Level Flood Resilience. In: J. Lamond, et al. eds. Research Handbook on Flood Risk Management. Edward Elgar Publishing.

Presentations made at reputable meetings:

Presentation of Conceptual framework at the TRENT Regional Flood and Coastal Committee Meeting.

Presentation of Conceptual Framework at the Environmental Agency Lichfield

Table 10.2: Citations in journal, conference, report and doctoral workshop papers

No	**Authorship**	***Year***	***No of citations***
1	Adedeji et al	2019	1
2	Adedeji et al	2018	14
3	Adedeji et al	2019	-
4	Adedeji et al	2019	10
5	Proverbs et al	2018	-
	Total		**25**

10.6 SUMMARY

This chapter reports on the validation of the PFR model. The Chapter describes the validation process, which includes both external and internal validation. In the external validation, cross validation, with data splitting, was employed to confirm the accuracy of the PFR model and its generalisation ability. Twenty percent (20%) of the sample were randomly selected as the hold out sample to test the validity of the model developed. The result of cross validation showed that the building, human and the overall resilience models are 95% accurate which confirmed that the findings are reliable enough to form the basis for generalising to the relevant population.

The internal validation sought convergence of the research findings, published research and academic validation. In this study, a significant number of references have been cited to support the arguments advanced in these papers. Validation of the questionnaire development was reflected through the result of the regression analysis that is statistically significant and show that this could not have been obtained by chance. Five publications: (2) conference papers, two (2) journal papers and two (1) book chapter have been developed and published. Among these three aspects, convergence has been achieved indicating agreement between the research findings and the established knowledge. It is, thus, concluded that this research is convergent with the established knowledge in the FRM domain at household levels and in the applicability of the property flood resilience (PFR). It has successfully combined the building and the human elements of the PFR.

On the basis of the validated research findings, it is appropriate to finally draw conclusions on the entire research, highlights its implications and make relevant recommendations. This is addressed by the next chapters. Overall, this chapter has addressed the sixth research objective.

CHAPTER ELEVEN: CONCLUSIONS AND RECOMMENDATIONS

11.1 INTRODUCTION

The comprehensive analysis of the property flood resilience (PFR) measures has been explored in this research, with a particular emphasis on the residential properties. The PFR has become the focus of flood risk mitigation at household level and has received more attention from stakeholders and policy makers in recent times. This has led to a number of research findings which have been consolidated by the development of the PFR model. Thus, this chapter summarises the entire research and then presents the main conclusions and contribution to knowledge. The research is brought to a close with recommendations for further research and a summary of the practical implication of the research findings. This chapter seeks to address the last objective (Objective 7).

11.2 EVALUATION AGAINST ORIGINAL AIM AND OBJECTIVES

In chapter one of this thesis, the background to the research was presented. The main issue that came to light was that previous research in this domain had failed to develop a means of measuring the PFR measures. As a result, method for measuring the effectiveness of the PFR measures remain elusive in the extant literature while existing models of flood resilience appear to lack the ability to measure the level of resilience present in individual homes. A driving principle behind the research was the increasing interest for research in property flood resilience (PFR) by policy makers and the desire to know the level of flood resilience present in individual homes. Apart from the obvious concern of the property owner to protect their properties, several other property stakeholders and policy makers, Regional Flood and Coastal Committee (RFCC) and Environment Agency, were identified as having an interest in the findings of such research.

Therefore, the aim of this research was to develop a model to measure PFR in individual homes in the UK. Subsequently, a number of research objectives were developed in order to collectively satisfy this aim. Here, the seven research objectives are revisited to highlight the extent to which they were accomplished through the various phases of the research.

11.2.1 Review of Research Objectives

The review of the research objectives below outlines how these objectives were achieved in the course of this research.

Objective 1: To conduct a comprehensive literature review on the nature of flood risk, to contextualise their causes and impacts, with particular reference to impacts on households, and to establish from theoretical perspective measures to reduce or eliminate the identified flood impacts.

This objective is addressed in Chapter 2 with a comprehensive review of extant literature on nature of flood risk, its impacts and the mitigation approaches adopted in property level flood risk (PLFR). The review showed that the rationale behind flood risk management in the UK is based on the principle of source-pathway-receptor with greater emphasis placed on addressing the actual hazard posed by a severe flood rather than the impacts or consequences experienced by the receptors (people, buildings and infrastructure). In other words, the approach is risk-based.

Also, flood impacts were identified in the extant literature, these were categorised as direct and indirect impacts, with further classification into tangible and intangible impacts. It was found that both the human and building are impacted when flood happens with the building suffering from physical losses which are mostly tangible while the humans suffer from psychological impacts mostly intangible.

The literature review revealed there are PFR measures that can be implemented at household levels, which have the potential to reduce these flood impacts on both building and human; these PFR measures are categorised into resistance and resilience measures. Research has demonstrated clearly that adopting resistance and resilience adaptation measures is beneficial in financial as well as psychological terms. While these PFR measures were described as important measures for minimising the flood impacts, which will lead to improve resilience against flood risks, it was established that there is dearth of research towards developing a full understanding of means of measuring the effectiveness of the PFR measures.

Objective 2: To critically review the concept of resilience and its applicability to the study of PFR measures, with the aim of incorporating it in the PFR model.

This objective is addressed in Chapter 3. An in-depth review of concept of resilience was undertaken towards developing a suitable approach for its application in the domain of property flood resilience (PFR) measures. The review revealed that the term resilience is complicated and interpreted differently across many disciplines (psychology, engineering, ecology and socio-ecology) with no agreement on a single definition even in the FRM domain. It accepts that in the context of PFR, flood resilience sits just in between engineering and community resilience (socio-ecological), which concentrates on the ability of communities to thrive through and past hardship and to keep the built environment secured. It showed that the engineering resilience focuses on engineering structures and it relates to the quick recovery of these structures back to functional state while the psychological focuses on human which relates to the adaptive response of individual to stress. Both addresses the two components of the PFR – building and its occupants (human).

The literature revealed that the term has been conceptualised in two different dimensions as outcome-based or process-based with the outcome based focusing on recovery capacity while the process based focus on adaptive capacity. The review revealed that the outcome-based resilience is more appropriate to improve the building resilience to flood while the process-based resilience is more appropriate for the human resilience to flood.

This review concluded that whether resilience is taken to be an outcome or a process, its application to flood risk management marks an important conceptual step forward. It is considered as a promising concept for preventing and mitigating the impacts of flood risk which strengthens the view to adopt the concept for developing a means to measure the PFR. The identification of suitable dimensions of resilience for the building and the human components for the purpose of incorporating it in the model for measuring PFR represented an achievement of the second research objective.

Objective 3: To develop a conceptual framework, specific to domestic property in the UK, for estimating the property level resilience based on a synthesis of the extant literature.

This objective is addressed in Chapter 4. The resilience model is often used to explain the link between different factors that influence the PFR measures. A review of existing resilience framework was undertaken with the intent of obtaining insight into how the components of resilience are incorporated in the PFR framework.

It was revealed from the literature that none of the frameworks at household level was sufficient to measure the PFR. Most of the existing framework are developed to address specific contexts and are difficult to adapt to measure the resilience of individual homes. Also, majority of the frameworks are either addressing the building or the human resilience to flood impacts but not both. By identifying this major gap in the existing resilience model, a conceptual framework of measuring the effectiveness of PFR measures was thus developed considering both the building and the human components. The framework also identified the factors that influence the building and the human resilience of the PFR to flood impacts as an appropriate methodology for addressing this research aim.

Objective 4: to collect data from homeowners in the UK with flood experience on the PFR measures installed in their properties and their effectiveness during flood events.

Chapter 5 provided an overview of the research philosophies and an appropriate research paradigm for guiding this research was selected and justified. Subsequently (and in particular), in order to help establish the necessary convergence with similar studies on PFR, positivism research paradigm was adopted as the underlying research paradigm that influenced the design of the research instrument. The choice was based on the aim of the research to quantify the resilience of individual property and the desire to have a tool and decision support model that is robust and objective in its recommendations and interpretation of the finding. Therefore, this led to the need to empirically verify the developed conceptual model and also to implement the measurement framework dictated the adoption of the quantitative inquiry and a justification for the selection of the survey as a research approach was provided. Drawing on the findings from the extant literature, recent PFR reports and guidance within the UK, a questionnaire was designed to elicit the views of homeowners on flood risks, flood impacts, and the effectiveness of the PFR measures to reduce the impacts of flooding.

Through the questionnaire, homeowners provided information on six main issues: (1) the property and materials used for the building components; (2) the flood experience and risk assessment based on the most recent flood event; (3) the perceived benefits of the flood resistance and resilience measures installed; (4) the flood impact on the households and the extent of damage caused to building and contents; (5) socioeconomic factors of the household; and (6) information on the flood insurance.

The data collection tool used in this research was the self-administered postal method. It was decided that postal method is suitable due to the sensitive nature of information required. Also, it would require respondents to cast their mind back to the past flood event before they can provide answer to some of the questions. Issues relating to data analysis were then discussed in detail and it was concluded that a number of statistical techniques such as ANOVA, correlation and multiple regression analysis were appropriate to be utilised for the data analysis purposes. Altogether, the survey yielded 83 responses representing a 10.9% response rate.

Objective 5: to employ appropriate statistical analysis to the level of PFR with a view to exploring the relationship between the building and the human resilience;

The statistical analysis conducted on the data included descriptive statistics, inter-rater agreement tests, and Cronbach alpha test. The descriptive statistics provided a thorough understanding of the respondents' experience and how flood event has affected their households, thus, the findings drawn from their responses will be a credible reflection of the level of resilience on households. The descriptive statistics, in particular arithmetic mean, was used to aggregate the individual responses of the respondents in order to have a single representative measure in relation to the questions on level of respondents' agreement with the measure of effectiveness of the PFR measures. To ensure that the mean measures are interpreted with confidence, an interrater agreement test was undertaken to confirm that there is significant agreement among the respondents in terms of their judgements on the issues being assessed. Further, statistical analysis was carried out to test the reliability and to examine the internal consistency of both the building and human resilience scale using the Cronbach's alpha test.

In fulfilling this objective, the PFR model was developed using statistical techniques including correlation and multiple linear regression analysis as designated in chapter 8. This produced significantly reasonable R, R^2 and adj. R^2 values. The regression technique included only statistically significant variables that had been proven through the analysis of variance (ANOVA). Also, the regression assumptions test was carried out to ensure that the regression model is reliable, this comprises of the Durbin-Watson test and residual analysis.

Objective 6: Test, refine and validate the PFR model towards its predictive accuracy and potential relevance for practical application in flood risk management at individual home level.

This is addressed in Chapter 9. The validation of the research findings was carried out based on the following validation processes; the research findings, model validation, published research, and academic validation, and convergence between these sources was sought. Among these three aspects, convergence was demonstrated indicating agreement between the research findings and the established knowledge.

The validation through the research finding comprises of the values of R, R^2 and R^2 adjusted which demonstrated a credible model for assessing the level PFR in individual homes. Model validation revealed that the predictive accuracy of the model was robust and, thus, could be generalised. Academic validation was established through publication of the research findings at major international conferences, in journal publications and book chapters. The convergence of the three sources of information provides evidence of the validity of the findings.

Objective 7: To draw conclusions from the findings of the study to provide a basis for proposing implications for flood risk management at household levels and make recommendation for further studies.

The achievement of this objective is addressed by this chapter as given in the following sections.

11.3 MAIN CONCLUSIONS

The following main conclusions are drawn from this research: and are based on underlying research aim propose:

1. A PFR model has been developed, tested and validated to measure the level of flood resilience in individual home. The PFR model comprises of two components: the building (physical) and the human (psychological) components.
2. For the physical component, 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) all significantly explained the building resilience scale, one of the two components that make up the PFR.
3. For the human component, gender (G), property ownership (PO), number of children (NC), disabled person (DP), time in residence (TR), flood insurance type (FI), and insurance claim made (IC) significantly explained the human resilience scale, a second component of the PFR.
4. The building and the human resilience are positively associated. This implies that increase in the resilience of building (physical) component will result to increase in the human resilience and ultimately increase in the overall resilience of individual home, and vice versa. Likewise, increasing the human resilience will result to increase in the building resilience and ultimately increase in the overall resilience and vice versa.
5. It was concluded that awareness and sensitisation are the keys to improving the human resilience. Any household exposed to flood risk will improve their resilience

through social cohesion, that is, being part of social networks like community forum on flood issues and flood groups, where they can receive help, advice and support before, during and after flood events.

11.4 CONTRIBUTION TO KNOWLEDGE

This research has provided new insight into the study of the property flood resilience (PFR) measures from the homeowners' perspective. The contribution of this research to knowledge are discussed under three sub headings: PFR measures, derived from the developed conceptual model, which could be utilised in future studies in the UK and with modification it could be used elsewhere; providing insight into the level of the PFR, which could be used in related studies in the UK; and dissemination of the research findings.

11.4.1 Contribution of the PFR Model

The current state of knowledge in the purview of disaster risk reduction in relation to flood risk research consists of varying dimensions. However, in the context of property level flood resilience, most researches focus on the development and adaptation of buildings to the risk of flooding. Also, it was discovered that several resilience frameworks have been developed to measure systems' resilience to flood, however from extensive literature research on the flood resilience on households, it appears that no previous research has focused on the development of a framework to measure property level flood resilience with respect to both the resilience of the building and the humans. This research makes contributions within this clear gap in understanding. The first contribution of this research is towards theory, as it integrates the appropriate literature on the concept of resilience in order to enhance the knowledge of the property level flood protection from the homeowners’ perspectives. That is, initially, this research evaluates the flexibility of various resilience models when studying the PFR issues. Secondly, it assimilates previous research findings in order to develop a coherent and comprehensive picture of the PFR research conducted within the FRM and resilience fields. Thirdly, this research introduces the first ever quantification of the PFR measures at the household level that integrates factors from different flood resilience models, so as to study and understand how they influence both the building and the human components of the PFR from the homeowner's perspective.

A distinct feature of the developed models is the combination of the building and the human components in the PFR model, which have been treated individually in most previous studies. The model draws on the various approaches adopted in protecting the residential property and its occupants from flood impacts. This empowers the homeowners to make decision on how best to reduce the impacts of flooding by providing clearer path on how to administer interventions. The model has a wide range of potential beneficiaries such as homeowners, loss adjusters, insurers, flood group and government departments and agencies responsible for property level flood protection.

11.4.2 The Level of Resilience in the PFR Model

The second contribution is to empirically confirm the appropriateness of the various factors influencing the property flood resilience and validate the conceptual model. By employing the quantitative approach, this study is an effort that confirms the role of various factors (such as the building characteristics; flood properties; flood insurance and socio-economic) that are responsible for understanding the PFR. The contribution of each factor influencing the PFR has been measured through a questionnaire survey that elicit homeowners' perspectives of the effectiveness of the PFR measures. A 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]. For the human resilience, the most influencing factor is the time in residence [TR] while the least is presence of children [NC]. This is seen as a contribution of the research as most researches on PFR only focus on identifying these factors but the order of influence is lacking. Therefore, this quantitative study clearly illustrated the asymmetry between the factors influencing the PFR (both the building and the human resilience).

11.4.3 Dissemination

Findings from this research have been presented at international conferences, published in conference proceedings, peer reviewed journals, and in book chapters. Further, the findings have been discussed at meetings with PFR stakeholders and policy maker involving the Regional Flood and Coastal Committee (RFCC) and the Environment Agency (EA). A key aim of the dissemination strategy has been to reflect the multidisciplinary nature of the thesis by publishing in the widest range of sources.

In summary, the benefits from this research are wide-ranging because the findings have the potential to be used by many flood risk management stakeholders. The main contribution to the wider public is that the research has the potential to take out the barrier of information in the decision making process on investing in PFR measures. Therefore, it supplements Government policy in encouraging the take-up of PFR measures in the UK.

11.5 IMPLICATIONS OF THE THESIS

The findings of this research have several important implications for PFR stakeholders, insurance companies, government department responsible for flood risk management such as the Environment Agency (EA) and Department of Environment, Food and Rural Affairs (DEFRA) and homeowners. The practical implications of the findings are discussed below:

i. Homeowners: The framework will provide valuable information on the flood resilience levels currently present in the home for the benefit of homeowners. This is important as homeowners are partly responsible for protecting their properties against the impact of flooding (Joseph et al., 2015). The framework does this through quantifying current resilience levels by identifying any measures that have been put in place to reduce the impact of flooding. The framework also considers the characteristics of the property, the nature of flood risk exposure for the particular location and the effectiveness of measures put in place.

ii. Property Experts and Surveyors: The framework will be of help to property experts such as surveyors in valuing property and in offering advice to their clients. One of the key factors that influence the value of real estate including homes is flooding or flood risk (Lamond et al., 2010; Kropp, 2012). The framework provides information that promulgates a clear understanding of the variables and processes involved in flood risk assessment and property level flood resilience. This will provide property experts with a tool to estimate the resilience levels within a property enabling them to provide impartial and professional advice on risk exposure and which measures might best be adopted to help further protect their properties.

Information on the level of resilience will also help in conducting property valuations at the point of sale and /or for mortgage purposes, enabling any existent measures that are in place 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 essential for surveyors to offer good advice on design interventions to improve resilience and make recommendations on the optimal combination of measures for a particular home.

iii. Insurers: Insurers will also benefit from the opportunity to apply and use the framework. Often, it can be difficult for insurers to know how to quantify the benefits of any existent resilience measures, particularly those that needs to be proactively deployed (May et al., 2015). However, the framework is designed to provide a means of quantifying the property flood resilience measures by demonstrating the effectiveness of any resilient measures in place. This will in turn enable insurers to consider how this might affect insurance premiums and excesses which will in turn improve the role of flood insurance as a market-based incentive.

The framework provides an evidence based tool to inform insurers on the levels of resilience present within a given property and how this would reduce the cost of damage. These costs are often shared between the premiums and excesses (Edmonds, 2017) and therefore, this improves understanding of flood risk, taking into account any resistance or resilience measures, allows the insurers to value this risk more accurately. In this situation, improving resilience might translate into reductions of premiums and excesses. The improved understanding of flood risk places the insurers in a position to offer premiums that promote property level flood risk adaptation through resilient reinstatement.

iv. Government/Government Policy: The Government policy as set out in the National Planning Policy Framework discourages the building of homes in areas with a significant risk of flooding. However, in the case of homes already located in these areas, or where development is necessary, the policy encourages such homes to be designed appropriately with ability to cope with floodwaters and ensure quick recovery after a flooding event. This entails the adoption of the property level flood resistance and resilience measures.

Therefore, through the implementation of the framework, the stakeholders involved with properties can encourage the adoption of property flood resilience thereby promoting this policy. The framework also provides a means by which government could monitor the uptake of property level flood resistance and resilience measures by homeowners and see how the policy is achieving its aim of reducing flood risk exposure.

11.6 LIMITATIONS

As with all survey based research there are bound to be limitations, which need to be acknowledged.

- This study aims at developing a means to measure the level of flood resilience of residential property in the UK. Domestic residential property only was considered because commercial properties are subject to a slightly different mitigation approach, particularly for the human components, and insurance regimes. While the review of literature has considered a wide range international studies encompassing different flooding types and designation regimes, this has been limited to residential properties and the empirical analysis has been strictly limited.
- The data coverage is limited to five locations in the UK. While these locations contain some of the most frequently flooded properties, it is possible that there are other locations where flood event is more problematic. 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.
- One of the limitations of this study was related to availability of the sample frame. The Environment Agency is considered to be a most comprehensive sample frame for the target population. However, it could not be employed to obtain the respondent

addresses due to data protection, contractual and liability issues. Therefore, use of the Environment Agency website, and other sources like news archive and online journals to obtain flood designation information (postcodes with flood experiences) is a limitation of the study.

Where more detailed lists were available from the Environment Agency it became clear that a more precise audience can be targeted with better responses possible, this would have lent better precision to the analysis. The results of the study suggest that concentrating on frequently flooded and significantly at risk properties would be appropriate in any further study of this issue.

11.7 RECOMMENDATIONS FOR FURTHER RESEARCH

This research, having focused on developing the model for measuring the PFR measures, cannot claim to have addressed in full all issues related to the building and human resilience measures. Therefore, further research is recommended in the following areas:

- 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 carrying out research on these non-residential properties and public buildings, there is a need to devise a means to tackle the challenges on data accessibility, which is a peculiar issue with these kinds of properties.
- There exists the prospect of a user interface through the development of a mobile application for the implementation of framework 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 framework 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 framework has the potential to be extended to flood resilience measurement at larger scale applications (at the community level, regional level and even national level).

- Also, with further study, the framework provides the opportunity for application in other countries and developing countries through modification of framework to represent the resilient features prevalent in the country of application. This would require a cross-cultural approach when understanding issues related to the PFR. This could encourage transfer of knowledge between countries.

11.8 SUMMARY

This chapter provided an overview and conclusion to the results and discussions of the research presented in this thesis. First, the contents of each chapter were discussed, thereafter, the main conclusions of this research were presented. This was followed by a discussion of the research contributions and practical implications that this research has made. Following that, the research limitations were listed. Finally, the future research directions in the area of property level flood protection were provided.

In summary, the research has developed the PFR model, representing a robust mechanism for decision making on improving the level of flood resilience in individual homes. The model could be used by flood risk management professionals to advise homeowners on how to improve the PLR of their homes. It is, therefore, contended that the developed PFR model have the potential to inform homeowners of the level of flood resilience present in their properties. This research, thus, provides the much-needed comprehensive method of measuring the PFR in the domain of flood risk management at household levels.

REFERENCES

ABI, 2009. *Responding to Major Floods: What to Expect From Your Home Insurer*, London: Association of British Insurers.

Adedeji, T; Proverbs, D; Xiao, H; Cobbing, P; and Oladokun, V., 2019. Making Birmingham a Flood Resilient City: Challenges and Opportunities. *Water,* 11(8), p. 1699.

Adedeji, T. J., Proverbs, D. G., Xiao, H. and Oladokun, V. O., 2018. Towards a Conceptual Framework for Property Level Flood Resilience. *International Journal of Safety and Security Engineering,* 8(4), pp. 493 - 504.

Adger, W. N., 2000. Social and Ecological Resilience: Are They Related?. *Progress in Human Geography,* 24(3), pp. 347-364.

Adger, W N; Hughes, T P; Folke, C; Carpenter, S R; and Rockstrom, J., 2005. Social-ecological resilience to coastal disasters. *Science,* Volume 309, p. 1036–1039.

Aerts, J C; Botzen, W J; Emanuel, K; Lin, N; Moel, H D; and Michel-Kerjan, E O., 2014. Evaluating flood resilience strategies for coastal megacities. *Science,* Volume 344, p. 473–475.

Agresti, A. and Finlay, B., 2009. *Statistical methods for the social sciences.* 4th ed. Upper Saddle River, NJ: Pearson Prentice Hall.

Ahadzie, D. K., 2007. *A Model for Predicting the Performance of Project Managers in Mass House Building Projects in Ghana: Uublished PhD Thesis,* Wolverhampton: University of Wolverhampton.

Ahlborg, H., Ruiz-Mercado, I., Molander, S. and Masera, O., 2009. Bringing Technology into Social-Ecological Systems Research—Motivations for a Socio-Technical-Ecological Systems Approach. *Sustainability,* Volume 11, pp. 1-23.

Alavifar, A., Karimimalayer, M. and Anuar, M. K., 2012. Structural equation modeling VS multiple regression. IRACST – Engineering Science and Technology: An International Journal (ESTIJ), 2(2), pp. 2250-3498.

Alexander, D., 2013. Resilience and disaster risk reduction: an etymological journey. *Natural Hazards and Earth Systems Sciences,* Volume 13, pp. 2707-2716.

Alinovi, L., Mane, E. and Romano, D., 2009. *Measuring Household Resilience to Food Insecurity: Application to Palestinian Households,* Working Paper: EC-FAO Food Security Programme.

Allen, R., Gunderson, L. and Johnson, R., 2005. The use of discontinuities and functional groups to assess relative resilience in complex systems. *Ecosystems,* Volume 8, p. 958– 966.

Almedom, A. M., 2013. Resilience: Outcome, Process, Emergence, Narrative (OPEN) theory. *On the Horizon,* 21(1), pp. 15-23.

American Psychological Association, 2014. *The road to resilience.* Washington, DC: American Psychological Association.

Anderies, J. M., Janssen, M. A. and Ostrom, E., 2004. A framework to analyze the robustness of social-ecological systems from an institutional perspective. *Ecology and Society,* 9(1), p. 18.

Anderies, J M; Folke, C; Hatfield-Dodds, S; Hughes, T P; Lebel, L; Campbell, B; and Wilson, J., 2006. Governance and the Capacity to Manage Resilience in Regional Social-Ecological Systems. *Ecology and Society,* Volume 11, p. 19.

Anderies, J. M., 2014. Embedding built environments in social–ecological systems: Resilience-based design principles. *Building Research and Information,* Volume 42, p. 130–142.

Ankrah, N. A., 2007. *An Investigation into the Impact of Culture on Construction Project Performance: Unpublished PhD Thesis,* Wolverhampton: University of Wolverhampton.

Antwi, S. K. and Hamza, K., 2015. Qualitative and Quantitative Research Paradigms in Business Research: A Philosophical Reflection. *European Journal of Business and Management*, 7(3), pp. 217-225.

Anvuur, A. M. and Kumaraswamy, M., 2010. *Promises, pitfalls and shortfalls of the guaranteed maximum price approach: a comparative case study. Proceeding of 26th Annual*

ARCOM Conference, 6-8 September. Leeds, UK, Leeds, UK: Association of Researchers in Construction Management.

Arbnor, I. and Bjerke, B., 1997. *Methodology for creating business knowledge,* London: SAGE publications Ltd.

Arlot, S. and Celisse, A., 2010. A survey of cross-validation procedures for model selection. *Stat. Surv.,* Volume 4, p. 40–79.

Armitage, D. and Johnson, D., 2006. Can Resilience be Reconciled with Globalization and the Increasingly Complex Conditions of Resource Degradation in Asian Coastal Regions?. *Ecology and Society,* 11(1), p. 2.

Armstrong, J. S., 1975. Monetary Incentives in Mail Surveys. *Public Opinion Quarterly,* Volume 39, pp. 111-116.

Ashley, R; Lundy, L; Ward, S; Shaffer, P; Walker, L; Morgan, C; Saul, A; Wong, T; and Moore, S., 2013. Water-sensitive urban design: opportunities for the UK. *Proceedings of the Institution of Civil Engineers,* Volume 166, p. 65–76.

Ashley, R. M. and Brown, R. R., 2009. *Entrapped in common sense: why water management by current regimes is not sustainable and what we can do about it,* London: Proceedings of the 9th Nordic Environmental Social Science (NESS): Knowledge, learning and action for sustainability 10-12 June 2009.

Babbie, E. R., 1990. *Survey Research Methods,* Belmont, California: Wadsworth Publication Company, USA.

Bahadur, A; Peters, K; Wilkinson, E; Pichon, F; Gray, K; and Tanner, T., 2015. *The 3AS: Tracking Resilience across BRACED,* London: ODI.

Bahadur, A. V., Ibrahim, M. and Tanner, T., 2013. Characterising resilience: unpacking the concept for tackling climate change and development. *Climate and Development,* 5(1), pp. 55-65.

Balbus, J. M. and Malina, C., 2009. Identifying vulnerable subpopulations for climate change health effects in the United States. *Journal of Occupational and Environmental Medicine*, 5(1), pp. 33-37.

Barker, K., 2003. *Elite Housing Associations, Get Key Development Role*: Property Week. 19th December, p.67.

Barsley, E., 2020. *Retrofitting for Flood Resilience: A Guide to Building and Community Design.* London: RIBA Publishing.

Baxter, G. and Sommerville, I., 2011. Socio-technical systems: From design methods to systems engineering. *Interacting with Computers,* 23(1), pp. 4-17.

BEIS, 2017. *UK Measurement Strategy: the value of measurement - supporting information,* London: Department for Business, Energy and Industrial Strategy.

Bennett, E., Cumming, G. and Peterson, G., 2005. A systems model approach to determining resilience surrogates for case studies. *Ecosystems,* Volume 8, p. 945– 957.

Berkes, F., Colding, J. and Folke, C., 2003. *Navigating Social–Ecological Systems: Building Resilience for Complexity and Change.* Cambridge, UK: Cambridge University Press.

Berkes, F. and Folke, C., 1998. *Linking social and ecological systems: management practices and social mechanisms for building resilience.* Cambridge, UK: Cambridge University Press.

Berkes, F. and Ross, H., 2012. Community resilience: toward an integrated approach. *Society and Natural Resources*, Volume 26, pp. 1-16.

Berry, W. D., 1993. *Understanding regression assumptions.* London: Sage Publications, Inc..

Berry, W. and Feldman, S., 1993. Multiple Regression in Practice. In: M. S. Lewis-Beck, ed. *Regression analysis.* London: Sage, pp. 159-244.

Biggs, R; Schlüter, M; Biggs, D; Bohensky, E L; BurnSilver, S; Cundil, G; Dakos, V; Daw, T M; Evans, L S; Kotschy, K; Leitch, A M; Meek, C; Quinlan, A; Raudsepp-Hearne, C; Robarbs, M D; Schoon, M L; Schultz, L. and West, P C., 2012. Toward principles for enhancing the resilience of ecosystem services. *Annual Review of Environment and Resources,* Volume 37, pp. 421-448.

Black, C., Akintoye, A. and Fitzgerald, E., 2000. An analysis of Success Factors and Benefits of Partnering in Construction. *International Journal of Project Management,* 18(6), pp. 423-434.

Blaike, N. W., 2003. *Analyzing Quantitative Data: From Description to Explanation,* London. UK: Sage Publications Ltd.

Blaikie, N., 2010. *Designing Social Research: The Logic of Anticipation.* Cambridge: Polity Press.

Bliese, P. D., 2000. Within Group Agreement, Non-independence and Reliability. In: K. J. Klein and S. W. Kozlowski, eds. *Multilevel Theory, Research, and Methods in Organizations: Foundations, Extensions, and New Directions.* San Francisco: Jossey-Bass, p. 1.

Bonanno, G. A., 2004. Loss, trauma and human resilience: Have we underestimated the human capacity to thrive after extremely aversive events?. *American Psychologist,* Volume 59, pp. 20-28.

Bonanno, G. A., Pat-Horenczyk, R. and Noll, J., 2011. Coping Flexibility and Trauma: The Perceived Ability to Cope With Trauma (PACT) Scale. *Psychological Trauma-Theory Research Practice and Policy,* 3(2), p. 117–129.

Bonnano, G. A. and Mancini, A. D., 2008. The human capacity to thrive in the face of potential trauma. *Pediatrics,* Volume 121, pp. 369-375.

Booher, D. E. and Innes, J. E., 2012. Governance for resilience: CALFED as a complex adaptive network for resource management. *Ecology and Society,* Volume 15, p. 35.

Bosschaart, A., van der Schee, J., Kuiper, W. and Schoonenboom, J., 2016. Evaluating a flood-risk education program in the Netherlands. *Studies in Educational Evaluation,* Volume 50, p. 53–61.

Bouwer, L M; Crompton, R P; Faust, E; Hoppe, P. and Pielke Jr, R A., 2001. Disaster management: Confronting disaster losses. *Science,* 318(5851), p. 753.

Bowker, P., Escarameia, M. and Tagg, A., 2007. *Improving the Flood Performance of New Buildings: Flood Resilient Construction,* London: RIBA Publishing.

Brace, N., Kemp, R. and Snelgar, R., 2003. *SPSS for psychologists: a guide to data analysis using SPSS for windows,* New York: Palgave Macmillan.

Bradley, J. V., 1982. Robustness? The insidious L-shaped distribution. *Bulletin of the Psychonomic Society,* 20(2), pp. 85-88.

Brand, F. S. and Jax, K., 2007. Focusing the meaning(s) of resilience: resilience as a descriptive concept and a boundary object. *Ecology and Society,* 12(1), p. 23.

BRE SCOTTISH LABORATORY, 1996. *Design guidance on flood damage to dwellings,* UK: HMSO for Scottish Office Development Department.

Brennan, M. A., 2008. Conceptualizing resiliency: An interactional perspective for community and youth development. *Child Care in Practice,* Volume 14, pp. 55-64.

Brown, J. D. and Damery, S. L., 2002. Managing flood risk in the UK: towards an integration of social and technical perspectives. *Transactions of the Institute of British Geographers,* Volume 27, p. 412–426.

Brown, K., 2016. *Resilience, Development and Global Change.* London, UK: Routledge.

Brown, K. and Westaway, E., 2011. Agency, Capacity, and Resilience to Environmental Change: Lessons from Human Development, Well-Being, and Disasters. *Annual Review of Environment and Resources,* Volume 36, p. 321–342.

Brown, S. A., Massey, A. P., Montoya-Weiss, M. M. and Burkman, J. R., 2002. Do I really have to? User acceptance of mandated technology. *European Jounial ofInfornzation Systems,* 11(4), pp. 267-282.

Bruneau, M; Chang, S E; Eguchi, R T; Lee, G C; O'Rourke, T D; Reinhorn, A M; Shinozuka, M; Tierney, K; Wallace, W A; and von Winterfeldt, V., 2003. A framework to quantitatively assess and enhance the seismic resilience of communities. *Earthquake Spectra,* 19(4), p. 733–752.

Bryan, K. A., 2017. *Coping with drought and flooding: a framework for engendering household and community resilience to water management extremes,* Exeter: PhD thesis the University of Exeter.

Bryman, A. and Bell, E., 2015. *Business Research Methods.* Oxford: Oxford University Press.

Bryman, A. and Cramer, D., 1999. *Quantitative Data Analysis: A Guide for Social Scientists,* London: Routledge Publication.

BSA, 2017. *Statement of ethical practices* , Belmont, Durham: British Sociological Association (BSA).

Bubeck, P; Botzen, W J; Laudan, J; Aerts, J C; and Thieken, A H., 2018. Insights into flood-coping appraisals of protection motivation theory: empirical evidence from Germany and France: insights into flood-coping appraisals of protection motivation theory. *Risk Analysis,* 38(6), p. 1239–1257.

Buckle, P., Marsh, G. and Smale, S., 2000. New approaches to assessing vulnerability and resilience. *Australian Journal of Emergency Management,* p. 8–14.

Burningham, K., Fielding, J. and Thrush, D., 2008. ‘It’ll never happen to me’: understanding public awareness of local flood risk. *Disasters,* 32(2), pp. 216-38.

Burns, B. R., 2000. *Introduction to Research Methods.* 4th ed. London: Sage Publications Ltd.

Cabinet Office, 2015. *National Risk Register for Civil Emergencies – 2015 edition,* London: Cabinet Office.

Carpenter, S., Walker, B., Anderies, M. and Abel, N., 2001. From Metaphor to Measurement: Resilience of What to What?. *Ecosystems,* Volume 4, pp. 765-781.

Carroll, B., Morbey, H., Balogh, R. and Araoz, G., 2006. *Living in fear: Health and social impacts of the floods in Carlisle 2005. Research Report,* Carlisle: Centre for Health Research and Practice Development - St. Martins College.

Carroll, B., Morbey, H., Balogh, R. and Araoz, G., 2009. Flooded homes, broken bonds, the meaning of home, psychological processes and their impact on psychological health in a disaster. *Health and Place,* 15(2), pp. 540-547.

Casson, R. J. and Farmer, L. D., 2014. Understanding and checking the assumptions of linear regression: a primer for medical researchers. *Clinical and Experimental Ophthalmology,* Volume 42, p. 590–596.

Chaochao, L; Xiaotao, C; Na, L; Qian, Y. and Guangyuan, K., 2016. A Framework for Flood Risk Analysis and Benefit Assessment of Flood Control Measures in Urban Areas. *International Journal of Environmental Research and Public Health,* 13(8), p. 787.

Chapman, P. J., Kay, P., Mitchell, G. N. and Pitts, C., 2013. Surface water quality. In: J. Holden, ed. *Water resources: an integrated approach.* Leeds: Routledge, pp. 79 - 122.

Chillo, V., Anand, M. and Ojeda, R., 2011. Assessing the use of functional diversity as a measure of ecological resilience in arid rangelands. *Ecosystems,* Volume 14 , p. 1168–1177.

Chuang, W C; Garmestani, A; Eason, T N; Spanbauer, T L; Fried-Petersen, H B; Roberts, C P; Sundstrom, S M; Burnett, J L; Angeler, D G; Chaffin, B C; Gunderson, L; Twidwell, D; and Allen, C R., 2018. Enhancing quantitative approaches for assessing community resilience. *Environmental Management,* Volume 213, pp. 353-362.

Church, A. H., 1993. Estimating the Effect of Incentives on Mail Survey Response Rates: A Meta-Analysis. *Public Opinion Quarterly,* Volume 57, pp. 62-79.

Cohen, J., 1988. *Statistical power analysis for the behavioral sciences.* 2nd ed. Hillsdale, New Jersey: Lawrence Erlbaum.

Cohen, J., Cohen, P., West, S. G. and Aiken, L. S., 2003. *Applied multiple regression/correlation analysis for the behavioral sciences.* 3rd ed. NJ: Lawrence Erlbaum Associates Publishers.

Cohen, L., Manion, L. and Morrison, K., 2007. *Research Methods in Education*, London: Routledge.

Comford, T. and Smithson, S., 1996. *Project research in inforination systeins: a student's guide.* London: Macmillan Press Ltd.

Committee on Climate Change, 2018. *Managing the coast in a changing climate*, London: Committee on Climate Change.

Concrete Centre, 2007. *Concrete Reduction in Flood Damage*, London: The Concrete Centre.

Constas, M. and Barrett, C. B., 2013. *Principles of Resilience Measurement for Food Insecurity: Metrics, Mechanisms, and Implementation Plans, presented at Expert Consultation on Resilience Measurement Related to Food Security*, Rome: Food and Agricultural Organization and World Food Programme.

CRED, 2015. *The Human Cost of Weather Related Disasters - 1995 - 2015*, Brussel: Centre for Research on the Epidemiology of Disaster (CRED).

Creswell, J. W., 2003. *Research design: Qualitative, quantitative, and mixed methods approaches.* 2nd ed. Thousand Oaks, CA: Sage.

Creswell, J. W., 2009. *Research Design: Qualitative, Quantitative, and Mixed Methods Approaches.* 3rd ed. London: Sage.

Crotty, M. J., 1998. *The Foundations of Social Research: Meaning and Perspective in the Research Process*, London: SAGE Publications Inc.

CUIDAR Project, 2020. *Cultures of Disaster Resilience among children and young people.* [Online]: Available at: https://www.lancaster.ac.uk/cuidar/en/ [Accessed 2 May 2022].

Cumming, G; Barnes, G; Perz, S; Schmink, M; Sieving, K; Southworth, J; Binford, M; Holt, R; Stickler, C; and Holt, T., 2005. An Exploratory Framework for the Empirical Measurement of Resilience. *Ecosystems*, Volume 8, pp. 975-987.

Cutter, S. L., Burton, C. G. and Emrich, C. T., 2010. Disaster resilience indicators for benchmarking baseline conditions. *J. Homeland Sec. Emerg. Manag.,* Volume 7, p. 1.

Dabson, B., 2015. *Planning for a More Resilient Future. A Guide to Regional Approaches,* Washington: National Association of Development Organizations (NADO) Research Foundation.

Dai, L., Vorselen, D., Korolev, K. and Gore, J., 2012. Generic indicators for loss of resilience before a tipping point leading to population collapse. *Science,* Volume 336, pp. 1175-1177.

Daniel, V. E., Florax, R. J. and Rietveld, P., 2009. Floods and Residential Property Values: A Hedonic Price Analysis for the Netherlands. *Climate Change, Flood Risk and Spatial Planning,* 35(4), pp. 563-576.

Davidson, D. J., 2010. The Applicability of the Concept of Resilience to Social Systems: Some Sources of Optimism and Nagging Doubts. *Society and Natural Resources,* Volume 23, p. 1135–1149.

Davoudi, S., 2012. Resilience: a bridge concept or a dead end. *Planning theory & practice,* 13(2), pp. 299-307.

Dawson, R J; Ball, T; Werritty, J; Werritty, A; Hall, J W; and Roche, N., 2011. Assessing the effectiveness of non-structural flood management measures in the Thames estuary under conditions of socio-economic and environmental change. *Global Environmental Change,* Volume 21, p. 628–646.

de Bruijn, K; Buurman, J; Mensa, M; Dahm, R; Klijn, F., 2017. Resilience in practice: Five principles to enable societies to cope with extreme weather events. *Environmental Science and Policy,* Volume 70, p. 21–30.

de Bruijn, K; Klijn, F; Ölfert, A; Penning-Rowsell, E; Simm, J; Wallis, M., 2009. *Flood risk assessment and flood risk management; An introduction and guidance based on experiences and findings of FLOODsite,* Delft, the Netherlands: Delft Hydraulics.

de Bruijn, K. M., 2004. Resilience indicators for flood risk management systems of lowland rivers. *International Journal of River Basin Management,* 199-210(10.1080/15715124.2004.9635232), p. 2:3.

de Bruijn, K. m., 2005. *Resilience and Flood Risk Management: A Systems Approach Applied to Lowland Rivers,* Netherlands: Delft University Press.

De Vaus, D. A., 2002. *Surveys in Social Research.* 5th ed. London: Routledge.

DEFRA/EA, 2009. *Improving Institutional and Social Responses to Flooding,* Bristol: Environment Agency.

DEFRA, 2005. *Making space for water: Taking forward a new Government strategy for flood and coastal erosion risk management in England,* London: Defra Publications.

DEFRA, 2006. *Flood Risks to People - Phase 2 project record - F2321/PR,* London: Environment Agency and Department for Environment, Food and Rural Affairs.

DEFRA, 2016. *The Property Flood Resilience Action Plan: An action plan to enable better uptake of resilience measures for properties at high flood risk,* London: Department for Environment Food and Rural Affairs.

DEFRA, 2020. *Repairable and Resilient Kitchen Design for Homes in Flood Risk Areas,* London: Department for Environment, Food and Rural Affairs.

della Porta, D. and Keating, M., 2008. *Approaches and Methodologies in Social Sciences: A Pluralist Perspective.* Cambridge: Cambridge University Press.

DeLongis, A; Coyne, J C; Dakof, G; Folkman, S; Lazarus, R S., 1982. Relationship of daily hassles, uplifts, and major life events to health status. *Health Psychology,* Volume 1, pp. 119-136.

Department for Communities and Local Government, 2007. *Improving the Flood Performance of New Buildings: Flood resilient construction,* London: Department for Communities and Local Government.

Department for Communities and Local Government, 2009. *Planning Policy Statement 25: Development and Flood Risk Practice Guide,* London: Department for Communities and Local Government.

Desjardins, E; Barker, G; Lindo, Z; Dieleman, C; and Dussault, A C., 2015. Promoting Resilience. *The Quartely Review of Biology,* 90(2), pp. 147-165.

Dhonau, M., 2020. *Property Flood Resilience: Stories from homes and businesses who have made adaptations to help them recover more quickly after a flood*: MDA Flood Resilience Consultants.

Dhonau, M; Wilson, G; McHugh, A; Burton, R; and Rose, C., 2016. *Homeowners Guide to Flood resilience a Living Document,* England: MDA.

Dillman, D., 2000. *Mail and Internet Surveys, the Tailored Design Method.* 2nd ed. Chichester: John Wiley and Sons.

Disse, M., Johnson, T. G., Leandro, J. and Hartmann, T., 2020. Exploring the relation between flood risk management and flood resilience. *Water Security,* Volume 9, pp. 1-9.

Djordjević, S; Butler, D; Gourbesville, P; Mark, O; Pasche, E., 2011. New policies to deal with climate change and other drivers impacting on resilience to flooding in urban areas: the CORFU approach. *Environ. Sci. Pol.,* Volume 14, p. 864–873.

Doocy, S., Daniels, A., Murray, S. and Kirsch, T. D., 2013. The Human Impact of Floods: a Historical Review of Events 1980-2009 and Systematic Literature Review. *PLOS Currents Disasters*, 16 April.

Doswell, C. A., 2003. Hydrology, Floods and Droughts: Flooding. In: G. R. North, J. A. Pyle and F. Zhang, eds. *Encyclopedia of Atmospheric Sciences.* s.l.:Elsevier Science Ltd, pp. 201-208.

Dublin, H. T., Sinclair, A. R. and MeGlade, J., 1990. Elephants and fire as causes of multiple stable states in the Serengeti-mara woodlands. *Animal Ecology,* Volume 59, pp. 1147-1164.

Dufty, N., 2008. A new approach to community flood education. *The Australian Journal of Emergency Management,* 23(2), pp. 2-7.

Durlak, J. A., 2009. How to select, calculate, and interpret effect sizes. *Journal of Pediatric Psychology,* 34(9), pp. 917-928.

Du, W., FitzGerald, G. J., Clark, M. and Hou, X., 2010. Haelth Impacts of Floods. *Prehospital and disaster medicine,* 25(3), pp. 265-272.

EA/DEFRA, 2005. *The appraisal of human related intangible impacts of flooding. R&D Technical Report FD2005/TR*, London: Defra Flood Management Division.

Eason, K., 2008. Sociotechnical systems theory in the 21st century: another half-filled glass?. In: D. Graves, ed. *Sense in social science: a collection of essays in honour of Dr. Lisl Klein*, p. 123–134.

Easterby-Smith, M., Thorpe, R. and Jackson, P. R., 2012. *Management Research.* 4 ed. London: Sage Publications Ltd.

Edelsbrunner, P. and Schneider, M., 2013. Modelling for Prediction vs. Modelling for Understanding: Commentary on Musso et al. (2013). *Frontline Learning Research,* Volume 2, pp. 99-101.

Edmonds, T., 2017. *Household Flood Insurance,* United Kingdom: House of Commons Library.

EEA, 2016. *Floodplain management: reducing flood risks and restoring healthy ecosystems,* 1050 Copenhagen, Denmark.

Egbu, A. U., 2007. *Impact of Land Use Planning on Urban Housing Development in Nigeria Unpublished PhD Thesis,* Wolverhampton, UK: University of Wolverhampton.

Eleuterio, J., 2012. *Flood Risk Analysis: Impact of Uncertainty in Hazard Modelling Vulnerability Assessments on Damage Estimations, Unpublished PhD Thesis,* Strasbourg: University of Strasbourg.

Elliott, J., Handmer, J., Keys, C. and Tarrant, M., 2003. *Improving Flood Warning – Which Way Forward?.* Canberra, Paper presented at the Australian Disaster Conference, Canberra, 2003.

Elliott, C. R. and Leggett, D. J., 2002. *Reducing the Impacts of Flooding - Extemporary Measures,* London: Construction Industry Research and Information Association (CIRIA).

Emmert-Streib, F. and Dehmer, M., 2019. Evaluation of Regression Models: Model Assessment, Model Selection and Generalization Error. *Machine Learning and Knowledge Extraction,* Volume 1, p. 521–550.

Environment Agency, 2005. *Flooding in Wales - October/November 2000*: Environment Agency.

Environment Agency, 2009. *Flooding in England: a national assessment of flood risk,* Bristol: Environment Agency.

Environment Agency, 2011. *Understanding the risks, empowering communities, building resilience: The national flood and coastal erosion risk management strategy for England,* London: Environment Agency.

Environment Agency, 2014. *Flood and coastal erosion risk management Long-term investment scenarios (LTIS),* Bristol, England: Environment Agency.

Erdfelder, E., Faul, F. and Buchner, A., 1996. GPOWER: A general power analysis program. *Behavior Research Methods, Instruments, and Computers,* Volume 28, p. 1–11.

Eriksen, S. H. and Kelly, P. M., 2007. Developing Credible Vulnerability Indicators for Climate Adaptation Policy Assessment. *Mitigation and Adaptation Strategies for Global Change,* Volume 12, p. 495–524.

Etuonovbe, A. K., 2011. *The Devastating Effect of Flooding in Nigeria: Bridging the Gap between Cultures.* Marrakech, Morocco.

Everitt, B. and Dunn, G., 1991. *Applied multivariate data analysis.* London: Edward Arnold.

Eves, C., 2002. The long term impact of flooding on residential property values. *Property Management,* 20(4), pp. 214-227.

Eves, C., 2004. The impact of flooding on residential property buyer behaviour: an England and Australian comparison of flood affected property. *Structural Survey,* 22(2), pp. 84-94.

Extreme Events and Health Protection, 2014. *Flooding and mental health: Essential information for front-line responders,* England: Public Health.

Faber, M. H., Giuliani, L., Revez, A., Jayasena, S., Sparf, J. and Mendez, J M., 2014. Interdisciplinary approach to disaster resilience education and research. *Procedia Economics and Finance,* Volume 18, p. 601–609.

Farrell, P. and Gale, A., 2003. Career progression path as a determinant of site manager skills. In: D. J. Greenwood, ed. *19th Annual ARCOM Conference, 3-5 September 2003, University of Brighton.* Brighton: Association of Researchers in Construction Management, pp. 183-192.

Farzanfar, R., 2005. *Using Qualitative Research Methods to Evaluate Automated Health Promotion/Disease Prevention Technologies: A Procedure's Manual,* Boston University: Robert Wood Johnson Foundation.

Fay, M., Block, R., Carrington, T. and Ebinger, J., 2009. *Adapting to Climate Change in Europe and Central Asia.* World Bank.

Fellows, R. and Liu, A., 2008. *Research methods for construction.* West Sussex: Blackwell Publishing.

Fellows, R. and Lui, A., 1997. *Research Methods for Construction,* Maiden, MA, USA: Blackwell Science, Oxford.

Few, R., Ahern, M., Matthies, F. and Kovats, S., 2004. *Floods, health and climate change: a strategic review. Working paper 63,* Tyndall: Tyndall Centre for Climate Change.

Field, A., 2005. *Discovering Statistics: Using SPSS for Windows.* London: Sage Publications Ltd.

Field, A., 2009. *Discovering Statistics Using SPSS.* 3rd ed. London: Sage Publications.

Field, A., 2013. *Discovering Statictics Using IBM SPSS Statistics.* 4th ed. London: SAGE Publications.

Field, A. P., 2000. *Discovering statistics using SPSS for Windows: advanced techniques for the beginner,* London: SAGE.

Fielding, J., Burningham, K., Thrush, D. and Catt, R., 2007. *Public responses to flood warnings*: Environment Agency Science Report SC020116.

Fiering, M. B., 1982. Alternative indices of resilience. *Water Resources Research,* Volume 18, pp. 33-39.

FIRA, 2015. *Kitchen Buying Guide,* Hertfordshire: Furniture Industry Research Association.

Fisher, L., 2015. Disaster responses: More than 70 ways to show resilience. *Nature,* 518(7537), pp. 35-35.

Fleming, C. M. and Nellis, G. J., 1994. *Principles of Applied Statistics,* London: Routledge Publication Ltd.

Fleming, G., 2001. *Learning to live with rivers,* London: The Institution of Civil Engineers.

Fleming, J. and Ledogar, R. J., 2008. Resilience, an Evolving Concept: A Review of Literature Relevant to Aboriginal Research. *Pub Med Central,* 6(2), pp. 7-23.

Fletcher, D. and Sarkar, M., 2013. Psychological resilience: A review and critique of definitions, concepts, and theory. *European Psychologist,* 18(1), p. 12–23.

Flick, U., 2009. *An Introduction to Qualitative Research,* London: Sage Publications.

Flood Re, 2018. *Incentivising household action on flooding and options for using incentives to increase the take up of flood resilience and resistance measures,* London: Flood Re.

Folke, C., 2006. Resilience: The emergence of a perspective for social–ecological systems analyses. *Global Environmental Change,* Volume 16, p. 253–267.

Folke, C., 2016. Resilience. In: H. H. Shugart, ed. *Oxford research encyclopedia of environmental science.* New York, New York, USA: Oxford University Press, p. 1.

Folke, C; Biggs, R; Norström, A V; Reyers, B; and Rockström, J., 2016. Social-ecological resilience and biosphere-based sustainability science. *Ecology and Society*, 21(3), p. 41.

Folke, C; Carpenter, S R; Walker, B; Scheffer, M; Chapin, T; and Rockström, J., 2010. Resilience thinking: Integrating resilience, adaptability and transformability. *Ecology and Society,* Volume 15, p. 4.

Food and Agriculture Organization, 2016. *RIMA II: Resilience Index Measurement and Analysis - II,* Rome: Food and Agriculture Organization of the United Nations.

Fordham, M., 1998. Making Women Visible in Disasters: Problematising the Private Domain. *Disasters*, 22(2), pp. 126-143.

Foresight, 2004. *Foresight Flood and Coastal Defence Project,* London: Office of Science and Technology.

Fowler, F. J., 2002. *Survey research methods.* London: SAGE Publications Inc..

Fox, N., Hunn, A. and Mathers, N., 2007. *Sampling and sample size calculation,* Sheffield: Trent RDSU.

Foxon, T. J., Reed, M. S. and Stringer, L. C., 2009. Governing long-term social–ecological change: What can the adaptive management and transition management approaches learn from each other?. *Environmental Policy and Governance,* Volume 19, p. 3–20.

Francis, R. and Bekera, B., 2014. A Metric and Frameworks for Resilience Analysis of Engineered and Infrastructure Systems. *Reliab. Eng. Syst. Saf,* Volume 121, p. 90–103.

Freund, R. J. and Wilson, W. J., 1998. *Regression analysis: statistical modelling of a response variable,* San Diego, Calif: London: Academic.

Friedli, L., 2009. *Mental health, resilience and inequalities,* Denmark: World Health Organisation.

Frost, J., 2017. *How To Interpret R-squared in Regression Analysis.* [Online] Available at: https://statisticsbyjim.com/regression/interpret-r-squared-regression/ [Accessed 15 Oct 2021].

Fuchs, S., Kuhlicke, C. and Meyer, V., 2011. Editorial for the special issue: vulnerability to natural hazards – the challenge of integration. *Natural Hazards,* 58(2), p. 609–619.

Galli, N. and Vealey, R. S., 2008. Bouncing back 'from adversity: Athletes' experiences of resilience. *The Sport Psychologist,* Volume 22, pp. 316-335.

Garvin, S., 2012. *Flood Resilient Building – Part 2: Building in flood-risk areas and designing flood-resilient buildings.* Watford: BRE Press.

Garvin, S., Reid, J. and Scott, M., 2005. *Standards for the repair of buildings following flooding,* London: CIRIA publication.

Gauvin-Lepage, J., Lefebvre, H. and Malo, D., 2014. Family resilience: defining the concept from a humanist perspective. *Interdisciplinary Journal of Family Studies,* 19(2), pp. 22-36.

Gersonius, B., Ashley, R., Pathirana, A. and Zevenbergen, C., 2010. Managing the flooding system's resiliency to climate change. *Proceedings of the Institution of Civil Engineers: Engineering Sustainability,* Volume 163, p. 15–23.

Gersonius, B., Ashley, R., Pathirana, A. and Zevenbergen, C., 2010. Managing the flooding system's resiliency to climate change. *Proc. ICE-Eng. Sustain,* Volume 163, p. 15–23.

Gersonius, B., Ashley, R., Pathirana, A. and Zevenbergen, C., 2013. Climate change uncertainty: building flexibility into water and flood risk infrastructure. *Climatic change,* 116(2), pp. 411-423.

Gersonius, B., van Buuren, A., Zethof, M. and Kelder, E., 2016. Resilient flood risk strategies: institutional preconditions for implementation. *Ecology and Society,* 21(4), p. 28.

Gittell, J. H., Seidner, R. and Wimbush, J., 2010. A relational model of how high performance work systems work. *Organization science,* 21(2), pp. 490-506.

Glick, W. H., 1985. Conceptualizing and measuring organizational and psychological climate: Pitfalls in multilevel research. *Academy of Management Review,* 10(3), pp. 601-616.

Goldstein, B. E., 2008. Skunkworks in the embers of the cedar fire: enhancing resilience in the aftermath of disaster. *Human Ecology,* Volume 36, p. 15–28.

Good, P. I., 2006. *Resampling Methods.* Boston, MA, USA: Springer.

Good, P. I. and Hardin, J. W., 2003. *Common Error in Statistics and How to Avoid Them,* Interscience: John Wiley and Sons.

Gorsuch, R. L., 1988. Exploratory factor analysis. In: J. R. Nesselroade & B. CattellR, eds. *Handbook of inultivariate experiniental psychology.* New York: Plenum Press, p. 1.

Gow, K., Pritchard, F. and Chant, D., 2008. How close do you have to be to learn the lesson? Fire burns!. *The Australasian Journal of Disaster and Trauma Studies,* Volume 2, p. 1–19.

Grace, J. B. and Bollen, K. A., 2005. Interpreting the Results from Multiple Regression and Structural Equation Models. *Ecological Society of America,* 15(5), pp. 283-295.

Graham, H., White, P., Cotton, J. and McManus, S., 2019. Flood- and weather-damaged homes and mental health: An analysis using England's Mental Health Survey. *International Journal of Environmental Research and Public Health,* Volume 16, p. 3256.

Grant, C. and Osanloo, A., 2014. Understanding, Selecting, and Integrating a Theoretical Framework in Dissertation Research: Creating the Blueprint for 'House. *Administrative Issues Journal: Connecting Education, Practice and Research,* Volume 1, pp. 12-22.

Green, C. H., Emery, P. J., Penning-Rowsell, E. C. and Parker, D. J., 1985. *The health effects of flooding: a survey at Uphill, Avon, Enfield,* Middlesex: Middlesex University, Flood Hazard Research Centre.

Green, C. H., Van Der Veen, A., Wierstra, E. and Penning-Rowsell, E. C., 1994. Vulnerability Refined: Analysing Full Flood Impacts and Management. In: E. C. Penning-Rowsell and M. Fordham, eds. *Floods Across Europe: Flood Forecasting, Assessment, Modelling.* London: Middlesex University Press, p. 1.

Grix, J., 2004. *The foundations of research,* London: Palgrave Macmillan.

Guba, E. G. and Lincoln, Y. S., 1994. Competing paradigms in qualitative research. In: N. K. Denzin and Y. S. Lincoln, eds. *Handbook of qualitative research.* Thousand Oaks, CA: Sage, pp. 105-117.

Gujarati, D. N., 2003. *Basic Econometrics.* Fourth Edition ed: McGraw-Hill Higher Education.

Gunderson, L. H., 2000. Ecological Resilience - In Theory and Application. *Annual Review of Ecology and Systematics,* Volume 31, p. 425–439.

Gunderson, L. H. and Holling, C. S., 2002. *Panarchy: Understanding Transformations in Human and Natural Systems.* Washington DC: Island Press.

Gu, Q. and Day, C., 2007. Teachers' resilience: A necessary condition for effectiveness. *Teaching and Teacher Education,* Volume 23, pp. 1302-1316.

Hair, J., Anderson, R., Tathman, R. and Black, W., 1998. *Multivariate data analysis with readings.* 4th ed. Upper Saddle River, NJ: Prentice-Hall.

Hair, J. F., Ringle, C. M. and Sarstedt, M., 2011. PLS-SEM: Indeed a Silver Bullet. *The Journal of Marketing Theory Practice,* Volume 19, pp. 139-152.

Hammond, S., Breakwell, M. G. and Fife-Schaw, C., 2000. *Research Methods in Psychology.* 2nd ed. London: Sage Publication Ltd.

Hardy, S. E., Concato, J. and Gill, T. M., 2004. Resilience of Community-Dwelling Older Persons. *American Geriatrics Society,* Volume 52, pp. 257-262.

Harries, T., McEwen, L. and Wragg, A., 2018. Why it takes an 'ontological shock' to prompt increases in small firm resilience: sensemaking, emotions and flood risk. *International Small Business Journal*, 36(6), p. 712–733.

Hartmann, T. and Jüpner, R., 2020. Implementing resilience in flood risk management. *Wires Water*, 7(6), pp. 1-4.

Harvatt, J., Petts, J. and Chilvers, J., 2011. Understanding householder responses to natural hazards: flooding and sea-level rise comparisons. *Journal of Risk Research,* 14(1), p. 63–83.

Hays, D. G., 1994. On the Painfulness of Progress. *The Society for Cross-Cultural Research,* 28(4), pp. 322-327.

Henseler, J., Ringle, C. M. and Sinkovics, R. R., 2009. The use of partial least squares path modeling in international marketing. *Advances in international marketing,* Volume 20, pp. 277-319.

Hinton, P. R., Brownlow, C., McMurray, I. and Cozens, B., 2004. *SPSS explained,* East Sussex, England: Routledge Inc.

Hodzic, D. and Islamovic, F., 2020. *Factorial ANOVA Experimental Design In R.* Belgrade, Serbia, 9th International Scientific Conference on Defensive Technologies OTEH 2020.

Hoffman, R. R. and Militello, L. G., 2008. *Sociological and ethnographic perspectives, perspectives on cognitive task analysis: historical origins and modern communities of practice.* London: Taylor and Francis.

Holling, C. S., 1973. Resilience and Stability of Ecological Systems. *Annual Review of Ecology and Systematics,* Volume 4, pp. 1-23.

Holling, C. S., 2001. Understanding the complexity of economic, ecological, and social systems. *Ecosystems,* Volume 4, pp. 390-405.

Holling, C. S., Jones, D. D. and Clark, W. C., 1977. Ecological policy design: A case study of forest and pest management. In: G. A. Norton and C. S. Holling, eds. *Proceedings of a Conference on Pest Management, October 1976.* Laxenburg: IIASA CP-77-6, pp. 13-90.

Hollnagel, E., 2006. Resilience: The challenge of the unstable. In: E. Hollnagel, D. D. Woods and N. Leveson, eds. *Resilience Engineering: Concepts and Precepts.* Aldershot, UK: Ashgate.

Hollnagel, E., 2013. *Resilience engineering and the built environment: Building Research and Information,* Denmark: Taylor and Francis.

Hollnagel, E., Memeth, C. P. and Dekker, S., 2008. *Resilience engineering perspectives. Remaining sensitive to the possibility of failure.* volume 1 ed. Vermont, USA: Ashgate, Burlington.

Hollnagel, E., Paries, J., Woods, D. D. and Wreathall, J., 2011. *Resilience engineering in practice: A guidebook.* Farnham, UK: Ashgate.

Hosseini, S., Barker, K. and Ramirez-Marquez, J. E., 2016. A review of definitions and measures of system resilience. *Reliability Engineering & System Safety,* pp. 47-61.

Houston, D; Werritty, A; Bassett, D; Geddes, A; Hoolachan, A; and McMillan, M., 2011. *Pluvial (rain-related) flooding in urban areas: the invisible hazard*, York: Joseph Rowntree Foundation.

Huang, P; Tan, H; Liu, A; Feng, S; and Chen, C., 2010. Prediction of posttraumatic stress disorder among adults in flood district. *BMC Public Health,* 10(1), p. 207.

Hughes, J. and Sharrock, W., 1997. *The Philosophy of Social Research.* 3rd ed. Essex: edition, Pearson.

Hunter, K., 2015. *Future–proofing New and Existing Buildings Flood Resilient Design and Construction Techniques,* Scotland: BRE.

Huntjens, P; Pahl-Wostl, C; Rihoux, B; Schlüter, M; Flachner, Z; Neto, S; and Nabide, K I., 2011. Adaptive water management and policy learning in a changing climate: a formal comparative analysis of eight water management regimes in Europe, Africa and Asia. *Environmental Policy and Governance,* Volume 21, p. 145–163.

Ikpe, E. O., 2009. *Development of Cost Benefit Analysis Model of Accident Prevention on Construction Projects,* Wolverhampton: University of Wolverhampton.

IPCC, 2007. *Climate change 2007: The physical science basis. Contribution of working group I to the fourth assessment report of the Intergovernmental panel on climate change,* Cambridge: Cambridge University press.

IPCC, 2012. *Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation. A Special Report of Working Groups I and II of the Intergovernmental Panel on Climate Change,* Cambridge: Cambridge University Press.

IRGC, 2016. Resource Guide on Resilience. In: Lausanne: EPFL International Risk Governance Center.

Jackson, S. and Ferris, T. J., 2015. *Proactive and Reactive Resilience: A Comparison of Perspectives*: Insight magazine of the International Council on System Engineering (INCOSE).

James, L. R., 1982. Aggregation bias in estimates of perceptual agreement. *Journal of Applied Psychology,* 67(2), pp. 219-229.

James, L. R., Demaree, G. and Wolf, G. R., 1984. Estimating Within-group Interrater Reliability with and without Response Bias. *Journal of Applied Psychology,* 69(1), pp. 85-98.

James, L. R., Demaree, R. G. and Wolf, G., 1993. rwg: an assessment of within group interrater agreement. *Journal of Applied Psychology,* Volume 78, p. 306–309.

Jeon, J., 2015. The Strengths and Limitations of the Statistical Modeling of Complex Social Phenomenon: Focusing on SEM, Path Analysis, or Multiple Regression Models. *International Journal of Economics and Management Engineering,* 9(5), pp. 1634-1642.

Jha, A. K., Bloch, R. and Lamond, J., 2012. *Cities and flooding: A guide to integrated urban flood risk management for the 21st century.* Washington DC: The World Bank.

Johnson, V. A., 2014. *Evaluating Disaster Education Programs for Children: a Thesis Presented for the Degree of Doctor of Philosophy in Emergency Management at Massey University,* Wellington, New Zealand: Massey University.

Johnson, R. B. and Gray, R., 2010. A History of Philosophical and Theoretical Issues for Mixed Methods Research. In: A. Tashakkori and C. Teddlie, eds. *SAGE Handbook of Mixed Methods in Social and Behavioral Research. 2nd edn.* Thousand Oaks, CA: Sage, pp. 69-94.

Joseph, R., 2014. *Cost benefit analysis of resilient reinstatement over traditional reinstatement of flood damaged properties, PhD thesis,* Wolverhampton: University of Wolverhampton.

Joseph, R., Proverbs, D. and Lamond, J., 2015. Homeowners' perception of the benefits of property level flood risk adaptation (PLFRA) measures: The case of the summer 2007 event in England. *International Journal of Safety and Security Engineering,* 5(3), pp. 251-265.

Joseph, R., Proverbs, D., Lamond, J. and Wassell, P., 2011. An analysis of the costs of resilient reinstatement of flood affected properties: a case study of the 2009 flood event in Cockermouth. *Structural Survey,* 9(4), p. 279–293.

Kallaos, J., Wyckmans, A. and Mainguy, G., 2014. *Synthesis review on resilient architecture and infrastructure indicators*: RAMSES Project.

Kang, H., 2013. The prevention and handling of the missing data. *Korean Journal of Anesthesiology,* 64(5), pp. 402-406.

Kaplan, B. and Maxwell, J. A., 1994. Qualitative Research Methods for Evaluating Computer Information Systems. In: J. G. Anderson, C. E. Aydin and S. J. Jay, eds. *Evaluation Health Care Information Systems: Methods and Application.* California: Sage Publications, p. 1.

Kaplan, H. B., 1999. Toward an understanding of resilience: A critical review of definitions and models. In: M. Glantz and J. Johnson, eds. *Resilience and development: Positive life adaptations.* New York: Plenum Press.

Kazmierczak, A. and Connelly, A., 2011. *Buildings and Flooding: a risk-response case study. EcoCities project,* Manchester, UK: University of Manchester.

Keating, K., May, P., Pettit, A. and Pickering, R., 2015. *Cost estimation for household flood resistance and resilience measures – summary of evidence,* Bristol: Environment Agency.

Kelly, D; Barker, M; Lamond, J; McKeown, S; and Blundell, E., 2019. *Code of Practice for Property Flood Resilience, Edition 1,* London: CIRIA.

Kelly, J., Sadeghieh, T. and Adeli, K., 2014. Peer review in scientific publications: benefits, critiques, and a survival guide. *International Federation of Clinical Chemistry and Laboratory Medicine,* 25(3), pp. 227-243.

Kenney, S., Pottinger, G., Plimmer, F. and Pocock, Y., 2006. *Flood risk and property: Impacts on commercial & residential stakeholders' strategies,* Whiteknights, Reading, RG6 6AW: College of Estate Management.

Ketteridge, A. M. and Fordham, M., 1997. Flood warning and the local community context. In: J. Handmer, ed. *Flood warnings: issues and practice in total system design.* London: Hazard Research Centre, Middlesex University, p. 1.

Khaldi, K., 2017. Quantitative, Qualitative or Mixed Research: Which Research Paradigm to Use?. *Journal of Educational and Social Research,* 7(2), pp. 15-24.

Khamis, H. J. and Kepler, M., 2010. Sample Size in Multiple Regression: 20 + 5k. *Journal of Applied Statistical Science,* 17(4), pp. 505-517.

Kotzee, I. and Reyers, B., 2016. Piloting a social-ecological index for measuring flood resilience: A composite index approach. *Ecological Indicators,* Volume 60, p. 45–53.

Koufaris, M., 2002. Applying the technology acceptance model and flow theory to online consumer behavior. *Inforination Systenis Research,* 13(2), pp. 205-223.

Kozlowski, S. W. and Hattrup, K., 1992. A disagreement about within-group agreement: disentangling issues of consistency versus consensus. *Journal of Applied Psychology,* Volume 77, p. 161–167.

Kron, W., 2005. Flood Risk = Hazard • Values • Vulnerability. *Water International,* 30(1), p. 58–68.

Kropp, S., 2012. *The Influence of Flooding on the Value of Real Estate*: Rom, Italy, May 6-10 2012.

Kuang, D. and Liao, K. H., 2020. Learning from Floods: Linking flood experience and flood resilience. *Journal of Environmental Management,* Volume 271, pp. 1-11.

Kukull, W. A. and Ganguli, M., 2012. Generalizability: The trees, the forest, and the low-hanging fruit. *Neurology,* 78(23), p. 1886–1891.

Kundzewicz, Z., 2000. Coping with hydrological extremes. *Water International,* 25(1), pp. 66-75.

Kung, Y. and Chen, S., 2012. Perception of earthquake risk in Taiwan: effects of gender and past earthquake experience. *Risk Analysis: An Official Publication of the Society for Risk Analysis,* 32(9), p. 1535–1546.

Kvočka, D., 2017. *Modelling elevations, inundation extent and hazard risk for extreme flood events. A thesis submitted to Cardiff University.,* Cardiff: Cardiff University.

Laboy, M. and Fannon, D., 2016. Resilience theory and praxis: a critical framework for architecture. *Enquiry,* Volume 13, p. 39–52.

Lakens, D., 2021. *Sample Size Justification*: Collabra: Psychology.

Lakens, D., Scheel, A. M. and Isager, P. M., 2018. Equivalence Testing for Psychological Research: A Tutorial. *Advances in Methods and Practices in Psychological Science,* 1(2), p. 259–269.

Lamond, J., 2008. *Impact of flooding on house prices and insurance, PhD thesis,* Wolverhampton: University of Wolverhampton.

Lamond, J., 2009. *Impact of Flooding on Property Values,* London: RICS.

Lamond, J. E., Proverbs, D. G., Booth, C. A. and Hammond, F. N., 2012. Flooding in the Built Environment: Changing Risk and an Overview of Impacts. In: J. E. Lamond, C. A. Booth, F. N. Hammond and D. G. Proverbs, eds. *Flood Hazards: Impacts and Responses for the Built Environment.* New York: CRC Press Taylor and Francis, pp. 1-6.

Lamond, J. E., Proverbs, D. G. and Hammond, F. N., 2009. Accessibility of flood risk insurance in the UK: confusion, competition and complacency. *Journal of Risk Research,* Volume 12, p. 825–841.

Lamond, J; Harries, T; Twigger-Ross,, C; Rose, C; and Dhonau, M., 2019. *Supporting the uptake of resilient repair in the recovery process,* London: Department for Environment, Food and Rural Affairs.

Lamond, J., Proverbs, D. and Hammond, F., 2010. The impact of flooding on the price of residential property: A transactional analysis for the UK. *Housing Studies,* 25(3), pp. 335-356.

Lamond, J., Rose, C., Bhattacharya-Mis, N. and Joseph, R., 2017. *Evidence Review for Property Flood Resilience Phase 2 Report*, Flood Re.

Lamond, J., Rose, C. and Joseph, R., 2016. *Supporting the uptake of low cost resilience: summary of technical findings (FD2682),* London: Department for Environment, Food and Rural Affairs (DEFRA).

Lancaster, J., Preene, M. and Marshal, C., 2004. *Development and flood risk - Guidance for the construction industry,* London: Construction Industry Research and Information Association.

Langley, E. and Silman, T., 2014. *Public flood survey: 2013 to 2014,* Wales: Department for Environment, Food & Rural Affairs; Environment Agency; Ipsos MORI; Natural Resources Wales; Welsh Government.

Langridge, R., Christian-Smith, J. and Lohse, K. A., 2006. Access and resilience: analyzing the construction of social resilience to the threat of water scarcity. *Ecology and Society,* 11(2), p. 18.

Lawson, D. F., Stevenson, K. T., Peterson, M. N., Carrier, S. J., Strnad, R. and Seekamp, E., 2018. Intergenerational Learning: Are Children Key in Spurring Climate Action?. *Global Environmental Change,* Volume 53, p. 204–208.

Leach, M., Scoones, I. and Stirling, A., 2010. *Dynamic Sustainabilities: Technology, Environment, Social Justice.* London, UK: Earthscan.

LeBreton, J M; Burgess, J R; Kaiser, R B; Atchley, E K; and James, L R., 2003. The restriction of variance hypothesis and interrater reliability and agreement: are ratings from multiple sources really dissimilar?. *Organizational Research Methods,* Volume 6, p. 78–126.

LeBreton, J. M. and Senter, J. L., 2008. Answers to 20 questions about interrater reliability and interrater agreement. *Organizational Research Methods,* Volume 11, p. 815–852.

Levine, S., 2014. *Assessing resilience: why quantification misses the point (Working Paper),* Overseas Development Institute: London.

Levin, S A; Xepapadeas, T; Crepin, A S; Norberg, J; de Zeeuw, A; Folke, C; Hughes, T; Arrow, K; Barrett, S; Daily, G; Ehrlich, P; Kautsky, N; Mäler, K G; Polasky, S; Troell , M; Vincent, J R; and Walker, B., 2013. Social-ecological systems as complex adaptive systems: modeling and policy implications?. *Environment and Development Economics,* Volume 18, pp. 111-132.

Liao, K. H., 2012. A theory on urban resilience to floods—a basis for alternative planning practices. *Ecology and Society,* Volume 17, p. 4.

Li, C; Cheng, X; Li, N; Du, X; Yu, Q; and Kan, G., 2016. A Framework for Flood Risk Analysis and Benefit Assessment of Flood Control Measures in Urban Areas. *International Journal of Environmental Research and Public Health,* 13(8), p. 787.

Linkov, I., Kröger, W., Levermann, A. and Renn, O., 2014. Changing the Resilience Paradigm. *Nature Climate Change,* Volume 4, p. 407–409.

Liu, A; Tan, H; Zhou, J; Li, S; Yang, T; Wang, J; Liu, J; Tang, X; Sun, Z; and Wen, S W., 2006. An epidemiologic study of posttraumatic stress disorder in flood victims in Hunan China. *Canadian Journal of Psychiatry,* 51(6), pp. 350-354.

Lock, S; Rubin, G J; Murray, V; Rogers, M B; Amlôt, R; and Williams, R., 2012. *Secondary stressors and extreme events and disasters.* s.l.:PLOS Disasters.

Ludwig, D., Walker, B. and Holling, C. S., 1996. Sustainability, stability and resilience. *Conserv. Ecol.,* Volume 1, pp. 1-27.

Luthar, S., Cicchetti, D. and Becker, B., 2000. The construct of resilience: a critical evaluation and guidelines for future work. *Child Development,* Volume 7, p. 543–562.

MacDonald, S. and Headlam, N., 2015. *Research Methods Handbook: Introductory guide to research methods for social research.* Manchester: Centre for Local Economic Strategies.

Mandych, A. F., 2009. Classification of Floods. *Natural Disasters,* Volume 2, pp. 63-88.

Manu, P. A., 2012. *An Investigation into the Accident Causal Influence of Construction Project Features. PhD. Thesis,* Wolverhampton: University of Wolverhampton.

Manyena, S. B., 2006. The concept of resilience revisited. *Disasters,* 30(4), p. 433−450.

Markolf, S. A., Hoehne, C., Fraser, A., Chester, M. and Underwood, S., 2019. Transportation resilience to climate change and extreme weather events—Beyond risk and robustness. *Transport Policy,* Volume 74, pp. 174-186.

Masten, A., 1994. Resilience in individual development: Successful adaptation despite risk and adversity. In: M. C. Wang and E. W. Gordon, eds. *Educational resilience ininner-city American: Challenges and prospects.* Hillsdale, NJ: LawrenceErlbaum, pp. 3-26.

Maxwell, J. A., 1992. Understanding and validity in qualitative research. *Harvard Educational Review,* 62(3), pp. 279-301.

May, P; Emonson, P; O'Hare, P; Cobbing, P; Connelly, A; Lawson, N; and Burchard, H., 2015. *Surveying for Flood Resilience in Individual Properties: Guidance for Homeowners,* London: Defra.

Mayunga, J. S., 2007. Understanding and applying the concept of community disaster resilience: a capital-based approach. *Summer Academy for Social Vulnerability and Resilience Building,* pp. 1-16.

McCarthy, S., 2004. *Definition and experience of flooding: residents' and officials' perspectives,* Surrey: PhD Thesis, University of Surrey Library.

McDaniels, T; Chang, S; Cole, D; Mikawoz, J; and Longstaff, H., 2008. Fostering resilience to extreme events within infrastructure systems: Characterizing decision contexts for mitigation and adaptation. *Global Environmental Change,* pp. 310-318.

McGraw, K. O. and Wong, S. P., 1996. Forming inferences about some intraclass correlation coefficients. *Psychological methods,* 1(1), pp. 30-46.

McKenna, J., 2010. *Living in Fear of the Rain: The impact of recent flooding in Greater Belfast,* London: British Red Cross.

McNulty, A. and Rennick, K., 2015. *The experience of flooding in the UK- A research study.* UK: British Red Cross.

McPhail, C., Maier, H. R., Kwakkel, J. H., Giuliani, M., Castelletti, A. and Westra, S., 2018. Robustness metrics: How are they calculated, when should they be used and why do they give different results?. *Earth's Future,* Volume 1, p. 169–191.

McPhearson, T., Pickett, S. T., Grimm, N. B., Niemelä, J., Alberti, M., Elmqvist, T., Weber, C., Haase, D., Breuste, J. and Qureshi, S., 2016. Advancing Urban Ecology toward a Science of Cities. *BioScience,* Volume 66, p. 198–212.

Medd, W A; Deeming, H B; Walker, G A; Whittle, R A; Mort, M D; Twigger-Ross, C E; Walker, M A; Watson, N A; and Kashefi, E C., 2015. The flood recovery gap: A real-time study of local recovery following the floods of June 2007 in Hull, North East England. *Flood Risk Management,* Volume 8, p. 315–328.

Mertens, D. M., 2003. Mixed Methods and the Politic of Human Research: The Transformative Emancipatory Perspective. In: A. Tashakori & C. Teblie, eds. *Handbook of mixed methods in the Social and Behavioural Sciences.* Thousand Oaks CA: Sage Publication Ltd, UK, pp. 100-120.

Merz, B., Hall, J., Disse, M. and Schumann, A., 2010. Fluvial flood risk management in a changing world. *Natural Hazards and Earth System Sciences,* Volume 1.

Mitchell, A., 2013. *Risk and Resilience: From Good Idea to Good Practice – A Scoping Study for the Experts Group on Risk and Resilience,* Paris: Organization for Economic Co-operation and Development.

Mlinaric, A., Horvat, M. and Supak-Smolcic, V., 2017. Dealing with the positive publication bias: Why you should really publish your negative results. *Biochemica Medicine (Zagreb),* Volume 3, p. 27.

Moon, K. and Blackman, D., 2014. A Guide to Understanding Social Science Research for Natural Scientists. *Conservation Biology,* Volume 00, p. 1–11.

Moore, G. C. and Benbasat, I., 1991. Development of an instrument to measure the perceptions of adopting an information technology innovation. *Inforination Systems Research,* 2(3), pp. 192-222.

Mort, M., Walker, M., Williams, A. L. and Bingley, A., 2018. From Victims to Actors: The Role of Children and Young People in Flood Recovery and Resilience. *Environment and Planning C: Politics and Space*, 36(3), p. 423–442.

Moses, S. H. and Clark, T. J., 2004. Effect of prize draw incentive on the response rate to a postal survey of obstetricians and gynaecologists: A randomised controlled trial. *BMC Health Services Research,* 4(14), pp. 1-3.

Moses, J. W. and Knutsen, T. L., 2012. *Ways of knowing : competing methodologies in social and political research.* 2nd ed. New York: Palgrave Macmillan.

Motulsky, H. M., 1995. *Intuitive Biostatistics*, New York, USA: Oxford University Press Ltd.

Musso, M. F., Kyndt, E., Cascallar, E. C. and Dochy, F., 2013. Predicting general academic performance and identifying the differential contribution of participating variables using artificial neural networks. *Frontline Learning Research,* Volume 1, pp. 42-71.

Muttarak, R. and Pothisiri, W., 2013. The role of education on disaster preparedness: Case study of 2012 Indian Ocean earthquakes on Thailand's Andaman Coast. *Ecology and Society,* Volume 18, p. 51.

Muzenda-Mudavanhu, C., Manyena, B. and Collins, A. E., 2016. Disaster risk reduction knowledge among children in Muzarabani district, Zimbabwe. *Nat Hazards.,* Volume 84, p. 911–931.

Myers, M. D., 1997. Qualitative Research in Information Systems. *MIS Quarterly,* Volume 21, pp. 241-242.

Myers, R. H., 1990. *Classical and modern regression with applications.* Boston: PWS-Kent Publishing.

Naeem, S; Thompson, L J; Lawler, S P; Lawton, J H; and Woodfin, R M., 1994. Declining biodiversity can alter the performance of ecosystems. *Nature,* Volume 368, p. 734–737.

National Statistics, 2020. *English Housing Survey Headline Report 2019-20,* London: Ministry of Housing, Communities and Local Government.

Nesbury, D. K., 2000. *Survey Research and the World Wide Web,* Boston: Allyn and Bacon.

Netherton, C., 2006. *EPSRC flood repair network workshop on identification and facilitation of flood damage research,* Sheffield: EPSRC.

Norusis, M. J., 2003. *SPSS 12.0 Statistical Procedures Companion.* N.J: Prentice Hall.

Nye, M., Tapsell, S. and Twigger-Ross, C., 2011. New social directions in UK flood risk management: moving towards flood risk citizenship?. *Journal of flood risk management,* Volume 4, p. 288–297.

O'Sullivan, J J; Bradford, R A; De Dominicis, S; Rotko, P; Aaltonen, J; Waylen, K; and Langan, S J., 2012. Enhancing flood resilience through improved risk communications. *Natural Hazards and Earth System Sciences,* Volume 12, p. 2271–2282.

Oakley, M., 2018. *Incentivising household action on flooding: Options for using incentives to increase the take up of flood resilience and resistance measures,* London: The Social Market Foundation.

Oddsdottir, F., Lucas, B. and Combaz, É., 2013. *Measuring Disaster Resilience,* Birmingham: University of Birmingham.

ODPM, 2003. *Preparing for Flood: Interim guidance for improving the flood resistance of domestic and small business properties,* London, UK: Office of the Deputy Prime Minister.

Office for National Statistics, 2017. Graduates in the UK labour market: 2017. *Office for National Statistics,* 24 November, pp. 2-5.

Oh, S., Alm, J. and Kim, B., 2003. Adoption of broadband Internet in Korea: the role of experience in building attitude. *Jounial ofInfonnation Technology,* 18(4), pp. 267-280.

Oladokun, V., Proverbs, D. and Lamond, J., 2017. Measuring flood resilience: A fuzzy logic approach. *International Journal of Building Pathology and Adaptation,* 35(5), pp. 470-487.

Oladokun, V. O. and Montz, B. E., 2019. Towards measuring resilience of flood-prone communities: a conceptual framework. *Natural Hazards and Earth System Sciences,* Volume 19, pp. 1151-1165.

Olson, J. R. and Boyer, K. K., 2003. Factors influencing the utilization of Internet purchasing in small organizations. *Jounial of Operations Managenient,* Volume 21, pp. 225-245.

Olsson, C A; Bond, L; Burns, J M; Vella-Brodrick, D A; and Sawyer, S M., 2003. Adolescent resilience: a concept analysis. *Journal of Adolescence,* Volume 26, p. 1–11.

Olsson, P., Folke, C. and Berkes, F., 2004. Adaptive co-management for building resilience in social–ecological systems. *Environmental Management,* Volume 34, p. 75–90.

Omer, M., Mostashari, A. and Nilchiani, R., 2013. Assessing Resilience in a Regional Road-Based Transportation Network. *Int. J. Ind. Syst. Eng,* 13(4), p. 389–408.

ONS, 2015. *Nowcasting household income in the UK: Financial year ending 2015*. Office for National Statistics.

Oppenheim, A. N., 1992. *Questionnaire Design, Interviewing and Attitude Measurement.* New ed. London: Pinter Publishers Ltd.

Ormston, R., Spencer, L., Barnard, M. and Snape, D., 2014. The foundations of qualitative research. SAGE. In: J. Ritchie, J. Lewis, C. M. Nicholls and R. Ormston, eds. *Qualitative research practice: a guide for social science students and researchers.* Los Angeles: SAGE, p. 1–23.

Ostadtaghizadeh, A; Ardalan, A; Paton, D; Jabbari, H; and Khankeh, H R., 2015. Community Disaster Resilience: a Systematic Review on Assessment Models and Tools. *PLOS Curr. Disaster,* Volume 1, p. 7.

Ouyang, M., Dueñas-Osorio, L. and Min, X., 2012. A Three-Stage Resilience Analysis Framework for Urban Infrastructure Systems. *Struct. Saf,* Volume 36, p. 23–31.

Owusu, S., Wright, G. and Arthur, S., 2015. Public attitudes towards flooding and property-level flood protection measures. *Natural Hazards,* 77(3), p. 1963–78.

Pallant, J., 2005. *SPSS survival manual: A step by step guide to data analysis using SPSS (version 12).* 2nd ed. Buckingham: Open University Press.

Palmer, C., 2008. A theory of risk and resilience factors in military families. *Military Psychology,* Volume 20, pp. 205-217.

Palmer, M. D., Harris, G. R. and Gregory, J. M., 2018. Extending CMIP5 projections of global mean temperature and sea level rise due to thermal expansion using a physically-based emulator. *Environmental Research Letters,* Volume 13, p. 84003.

Park, J; Seager, T P; Rao, P S; Convertino, M; and Linkov, I., 2013. Integrating Risk and Resilience Approaches to Catastrophe Management in Engineering Systems. *Risk Analysis,* 33(3), p. 356–67.

Park, T., Oakley, M. and Luptakova, V., 2020. *Applying Behavioural Insights to Property Flood Resilience,* Bristol: Environment Agency.

Partington, D., 2002. *Essential Skills for Management Research.* New York: SAGE Publications Ltd.

Patterson, M. D. and Wears, R. L., 2015. Resilience and Precarious Success. *Reliab. Eng. Syst. Saf,* Volume 141, p. 45–53.

Pedhazur, E. J., 1997. *Multiple Regression in Behavioral Research, Explanation and Prediction.* 3rd ed. Orlando, FL: Harcourt Brace.

Penning-Rowsell, E C; Viavattene, C; Pardoe, J; Chatterton, J B; Parker, D J; and Morris, J., 2010. *The Benefits of Flood and Coastal Risk Management: A Handbook of Assessment Techniques.* London: Middlesex University Flood Hazard Research Centre.

Penning-Rowsell, E. and Green, C., 2000. New insights into the appraisal of flood alleviation benefits: Flood damage and flood loss information. *Journal of the chartered Institution of water and environment management,* 14(5), pp. 354-362.

Penning-Rowsell, E. and Wilson, T., 2006. Gauging the Impact of Natural Hazards: The Pattern and Cost of Emergency Response during Flood Events. *Transactions of the Institute of British Geographers,* 31(2), pp. 99-115.

Perry, C., 1998. A Structured Approach to Presenting Theses. *Australasian Marketing Journal,* Volume 6, pp. 63-85.

Petry, B., 2002. *Coping with Floods: Complementarity of Structural and Non-Structural Measures,* New York, NY, USA: Science Press.

Phillips, D. C., 1990. Post-positivistic science: Myths and realities. In: E. G. Guba, ed. *The paradigm dialog.* Newbury Park, CA: Sage, pp. 31-45.

Phillips, D. C. and Burbules, N. C., 2000. *Postpositivism and educational research,* Lanham, NY: Rowman and Littlefield.

Pimm, S. L., 1984. The complexity and stability of ecosystems. *Nature,* Volume 307, p. 321–326.

Pine, D. S. and Cohen, J. A., 2002. Trauma in children and adolescents: risk and treatment of psychiatric sequelae. *Biological psychiatry,* Volume 51, pp. 519-531.

Pitt, M., 2008. *Learning lessons from the 2007 floods,* London: Cabinet Office.

Podsakoff, P. M. and Organ, D. W., 1986. Self-reports in organizational research: Problems and prospects. *Journal of Management,* Volume 12, p. 69–82.

Poole, J. and Hogan, D. E., 2007. Floods. In: D. E. Hogan & J. L. Burstein, eds. *Disaster Medicine.* Philadelphia: Lippincott Williams & Wilkins, pp. 214-224.

Pottinger, G. and Tanton, A., 2011. *Waterproof – flood risk and due diligence for commercial property investment in the UK,* Reading: The College of Estate Management.

Powell, T. C., 2001. Competitive advantage: logical and philosophical considerations. *Strategic Management Journal,* 22(9), pp. 875-888.

Pratt, M. G., 1998. To be or not to be: Central questions in organizational identification. In: D. A. Whetten & P. C. Godfrey, eds. *Identity in organizations: Building theory through conversations.* Sage Publications, Inc, p. 171–207.

Pring, R., 2000. The 'false dualism' of educational research. *Journal of Philosophy of Education,* 34(2), p. 247–260.

Proverbs, D., 1998. *A best practice model for high-rise in situ concrete construction based on French, German and UK contractor performance measures, PhD Thesis, School of Engineering and the Built Environment,* Wolverhampton, UK: University of Wolverhampton.

Proverbs, D. and Lamond, J., 2017. *Flood Resilient Construction and Adaptation of Buildings,* USA: Oxford University Press.

Proverbs, D. and Lamond, J., 2017. Flood Resilient Construction and Adaptation of Buildings. In: S. Cutter, ed. *Oxford Research Encyclopedia of Natural Hazard Science.* Oxford: Oxford University Press, pp. 1-33.

Pugh, D. and Woodworth, P., 2014. *Sea-Level Science: Understanding Tides, Surges, Tsunamis and Mean Sea-Level Changes,* Cambridge: Cambridge University Press.

Queensland Government, 2002. *Guidance on the Assessment of Tangible Flood Damages,* Queensland: Queensland Government.

Ranger, N; Hallegatte, S; Bhattacharya, S; Bachu, M; Priya, S; Dhore, K; Rafique, F; Mathur, P; Naville, N; Henriet, F; Herweijer, C; Pohit, S; and Corfee-Morlot, J., 2011. A preliminary assessment of the potential impact of climate change on flood risk in Mumbai. *Clim Change,* Volume 104, p. 139–167.

Ranger, N. and Surminski, S., 2013. A Preliminary Assessment of the Impact of Climate Change on Non-Life Insurance Demand in the BRICS Economies.. *International Journal of Disaster Risk Reduction,* Volume 3, p. 14–30.

Ratner, B., 2010. Variable selection methods in regression: Ignorable problem, outing notable solution. *Journal of Targeting, Measurement and Analysis for Marketing,* Volume 18, p. 65–75.

Rea, L. M. and Parker, A. R., 1997. *Designing and Conducting Survey Research: A Comprehensive Guide.* 2nd ed. San Francisco, USA: Jossey – Bass Publishers.

Reaves, C. C., 1992. *Quantitative Research for the Behavioural Sciences,* Washington. USA: John Wiley and Sons Inc.

Redman, C. L. and Miller, T. R., 2015. The Technosphere and Earth Stewardship. In: *Earth Stewardship, Ecology and Ethics.* Cham, Switzerland: Springer International Publishing, p. 2.

Resilience Capacity Index, 2017. *Resilience Capacity Index,* Berkeley: University of California.

Richards, C., 2011. *Survey of households flooding in Par and St Blazey on 17 th November 2010: intermediate results,* St Blazey: Par and St Blazey Community Flood Group.

Richards, K., 2003. *Qualitative Inquiry in TESOL,* Basingstoke: Palgrave Macmillan.

Riolli, L. and Savicki, V., 2003. Information system organizational resilience. Omega. *The International Journal of Management Science,* Volume 31, pp. 227-233.

Robards, M. D., Schoon, M. L., Meek, C. L. and Engle, N. L., 2011. The importance of social drivers in the resilient provision of ecosystem services. *Global Environmental Change,* Volume 21, p. 522–529.

Rodina, L., 2018. Defining “water resilience”: debates, concepts, approaches and gaps. *Wiley Interdisciplinary Reviews: Water 6.2*, Volume 6, p. 2.

Rodríguez del Águila, M. M. and Benítez-Parejo, N., 2011. Simple linear and multivariate regression models. *Allergologia et Immunopathologia*, 39(3), pp. 157-173.

Roopa, S. and Rani, M. S., 2012. Questionnaire Designing for a Survey. *J Ind Orthod Soc,* 46(4), pp. 273-277.

Rose, C., 2019. *Understanding the influence of psychology and vicarious experience on property flood resilience choices, PhD thesis,* Bristol: UWE.

Rose, C; Lamond, J; Dhonau, M; Joseph, R; and Proverbs, D., 2016. Improving the Uptake of Flood Resilience at the Individual Property Level. *International Journal of Safety and Security Engineering,* 6(3), p. 607–615.

Rundmo, T. and Nordfjærn, T., 2017. Does risk perception really exist?. *Safety Science,* Volume 93, p. 230–40.

Runeson, G. and Loosemore, M., 1999. Gate-keepers or judges: peer reviews in construction management. *Construction Management and Economics,* 17(4), pp. 529-536.

Samwinga, V., 2009. *Homeowner Satisfaction and Service Quality in the Repair of UK Flood-Damaged Domestic Property,* Wolverampton, UK: University of Wolverampton.

Saunders, M., Lewis, P. and Thornhill, A., 2016. *Research Methods for Business Students.* 7th ed. Edinburgh: Pearson Education Limited.

Sawada, Y., 2006. *The Impact of Natural and Manmade Disasters on Household Welfare,* Gold Coast, Australia: Invited Paper Prepared for Presentation at the International Association of Agricultural Economists.

Sayers, P. B., Horritt, M., Penning-Rowsell, E. and McKenzie, A., 2015. *Climate Change Risk Assessment 2017: Projections of future flood risk in the UK. Research undertaken by Sayers and Partners on behalf of the Committee on Climate Change,* London: Committee on Climate Change.

Sayers, P B; Horritt, M S; Carr, S; Kay, A; Mauz, J; Lamb, R; and Penning-Rowsell, E., 2020. *Third UK Climate Change Risk Assessment (CCRA3) Future flood risk Main Report,* London: Committee on Climate Change.

Sayers, P; Galloway, G; Penning-Rowsell, E; Yuanyuan, L; Fuxin, S; Yiwei, C; Kang, W; Quesne, T L; Wang, L; and Guan, Y., 2014. Strategic flood management: ten 'golden rules' to guide a sound approach. *International Journal of River Basin Management*, 13(2), p. 137–151.

Sayers, P., Hall, J. and Meadowcroft, I., 2002. Towards risk-based flood hazard management in the UK. *Proceedings of the Institution of Civil Engineers: Municipal Engineer,* Volume 150, p. 36–42.

Sayers, P; Li, Y; Galloway, G; Penning-Rowsell, E; Shen, F; Wen, K; Chen, Y; and LeQuesne, T., 2013. *Flood Risk Management: A Strategic Approach,* Paris: UNESCO.

Schipper, L. F. and Langston, L., 2015. *A comparative overview of resilience measurement framework: analysing indicators and approaches,* London: Overseas Development Institute.

Schulze, P. C., 1996. *Engineering within ecological constraints,* Washington, D.C: National Academies Press.

Shreve, C., Fordham, M., Anson, S., Watson, H., Hagen, K., Wadhwa, K., Begg, C., Muller, A., Kuhlicke, C. and Karanci, N., 2014. *Report on risk Perception and Preparedness*: Deliverable 11 of the TACTIC Project.

Sinclair, A. R., Olsen, P. D. and Redhead, T. D., 1990. Can predators regulate small mammal populations? Evidence from house mouse outbreaks in Australia. *Oikos,* Volume 59, pp. 382-392.

Sirochmanová, L., Kozlovská, M. and Bašková, R., 2016. The importance of the criteria of residential buildings from the perspective of future users. *Journal of Civil Engineering,* 11(1), pp. 97-106.

Smith, K., 1996. *Environmental hazards: assessing risk and reducing disaster,* London: Routledge.

Smith, A. and Stirling, A., 2008. *Social-ecological resilience and socio-technical transitions: critical issues for sustainability governance, STEPS Working Paper 8,* Brighton: STEPS Centre.

Smith, A. and Stirling, A., 2010. The Politics of Social-ecological Resilience and Sustainable Socio-technical Transitions. *Ecology and Society,* Volume 15, p. 15.

Smith, K. and Ward, R., 1998. *Physical Process and Human Impacts.* England: John Wiley and Sons.

Snee, R. D., 1977. Validation of Regression Models: Methods and Examples. *Technometrics,* 19(4), pp. 415-428.

Soetanto, R. and Proverbs, D. G., 2004. Impact of Flood Characteristics on Damage Caused to UK Domestic Properties: the Perceptions of Building Surveyors. *Structural Survey,* 22(2), pp. 95-104.

Soetanto, R., Proverbs, D. G. and Holt, G. D., 2001. Achieving Quality Construction Projects Based on Harmonious Working Relationships: Clients' and Architects' Perceptions of Contractor Performance. *International Journal of Quality and Reliability Management,* 18(4/5), pp. 528-548.

Soetanto, R., Proverbs, D. and Nicholas, J., 2002. *Benchmarking domestic property flood damage assessment. University of Wolverhampton report for LLoyds TSB insurance,* UK: University of Wolverhampton.

Spiegler, V. L., Naim, M. M. and Wikner, J., 2012. A Control Engineering Approach to the Assessment of Supply Chain Resilience. *Int. J. Prod. Res,* 50(21), p. 6162–6187.

SRA, 2003. *Ethical Guidelines,* London: The Social Research Association.

Stanke, C; Murray, V; Amlôt, R; Nurse, J; and Williams, R., 2012. The Effects of Flooding on Mental Health: Outcomes and Recommendations from a Review of the Literature. *PLOS Currents Disasters*, 30 May.

Stephanie, G., 2018. *Adjusted R2 / Adjusted R-Squared: What is it used for?.* [Online] Available at: https://www.statisticshowto.com/probability-and-statistics/statistics-definitions/adjusted-r2/
[Accessed 8 Sept 2021].

Sterne, J. A. and Davey-Smith, G., 2001. Sifting the evidence-what's wrong with significance tests?. *British Medical Journal,* 322(7280), p. 226– 231.

Stevens, A. J., Clarke, D. and Nicholls, R. J., 2016. Trends in reported flooding in the UK: 1884–2013. *Hydrological Sciences Journal,* 61(1), pp. 50-63.

Stirling, A., 2008. Opening up and closing down: power, participation and pluralism in the social appraisal of technology. *Science Technology and Human Values,* 33(2), pp. 262-294.

Straub, D., Boudreau, M. and Gefen, D., 2004. Validation Guidelines for IS Positivist Research. *Communications of the Association for Information Systems,* Volume 13, p. 1.

Sutrisna, M., 2004. *Developing a Knowledge Based System for the Valuation of Variations in Civil Engineering Works. Unpublished PhD Thesis,* Wolverhampton: University of Wolverhampton.

Tabachnick, B. G. and Fidell, L. S., 1996. *Using Multivariate Statistics.* 3rd ed. New York: Harper Collins.

Tabachnick, B. G. and Fidell, L. S., 2001. *Using Multivariate Statistics.* 4th ed. Needham Heights, MA: Allyn and Bacon.

Tabachnick, B. G. and Fidell, L. S., 2013. *Using Multivariate Statistics.* 6th ed. Boston: Pearson.

Tagg, A., 2006. *Research on flood resilient construction. EPSRC flood repair network workshop on identification and facilitation of flood damage research,* Sheffield: EPSRC.

Tagg, A., Escarameia, M. and Ortiz, J. M., 2007. *Improving the Flood Resilience of Buildings through Improved Materials, Methods and Details,* London: CIRIA.

Tagg, A; Laverty, K; Escarameia, M; Garvin, S; Cripps, A; Craig, R; and Clutterbuck, A., 2016. *A new standard for flood resistance and resilience of buildings: new build and retrofit,* FLOODrisk 2016 - 3rd European Conference on Flood Risk Management.

Takim, R., Akintoye, A. and Kelly, J., 2004. Analysis of Performance Measurement in the Malaysian Construction Industry. In: S. O. Ogunlana, C. Chareonngam, P. Herabet and B. H. Hadikusumo, eds. *Proceeding of Globalization and Construction.* Bangkok, Thailand: AIT Conference Centre, p. 1.

Tapsell, S., 1999. *The Health Effects of Floods: The Easter 1998 Floods in England*: Flood Hazard Research Centre Article Series, No. 3/99.

Tapsell, S., 2001. *The hidden impacts of flooding: experiences from two English communities.* Davis, California, Integrated Water Resources Management.

Tapsell, S., McCarthy, S., Faulkner, H. and Alexander, M., 2010. *Social vulnerability to natural hazards,* London: State of the art report from CapHaz-Net's WP4.

Tapsell, S. M. and Tunstall, S. M., 2000. The Health Effects of Floods: The Easter 1998 Floods in England. In: D. J. Parker, ed. *Floods.* England, pp. 172-187.

Tapsell, S. M. and Tunstall, S. M., 2001. *The health and social effects of the June 2000 flooding in the North East Region. Report to the Environment Agency, North East Region,* Enfield, Middlesex: Flood Hazard Research Centre, Middlesex University.

Tapsell, S. M. and Tunstall, S. M., 2008. “I wish I’d never heard of Banbury”: The relationship between ‘place’ and the health impacts from flooding. *Health Place,* Volume 14, p. 133–154.

Tapsell, S. M., Tunstall, S. M., Penning-Rowsell, E. C. and Handmer, J. W., 1999. *The health effects of the 1998 Easter flooding in Banbury and Kidlington. Report to the Environment Agency, Thames Region,* Enfield, Middlesex: Flood Hazard Research Centre, Middlesex University.

Tapsell, S. M., Tunstall, S. M. and Wilson, T., 2003. *Banbury and Kidlington Four Years After the Flood: An Examination of the Long-Term Health Effects of Flooding. Report to the Environment Agency, Thames Region,* Enfield: Flood Hazard Research Centre, Middlesex University.

Tapsell, S., Rowsell, E., Tunstall, S. M. and Wilson, T., 2002. Vulnerability to Flooding:Health and social dimensions. *Philosophical Transactions of the Royal Society, London A,* 360(1796), pp. 1511-1525.

Tashakkori, A. and Teddlie, C., 2010. Current Developments and Emerging Trends in Integrated Research Methodology. In: A. Tashakkori and C. Teddlie, eds. *SAGE Handbook of Mixed Methods in Social and Behavioural Research, 2nd edn.* Thousand Oaks, CA: Sage, pp. 803-26.

Taylor, A. and Wong, T., 2002. *Non-structural stormwater quality best management practices - An overview of their use, value, cost and evaluation,* Canberra: Cooperative Research Centre for Catchment Hydrology.

Tennis, J. T., 2008. Epistemology, Theory, and Methodology in Knowledge Organization: Toward a Classification, Metatheory, and Research Framework. *Knowledge Organization,* 35(2/3), pp. 102-112.

Thampapillai, D. J. and Musgrave, W. F., 1985. Flood damage and mitigation: a review of structural and non-structural measures and alternative decision frameworks. *Water Resources Research,* Volume 21, p. 411–424.

Thayer, J. D., 1991. *Interpretation of Standardized Regression Coefficients in Multiple Regression,* Chicago, Illinois: American Educational ResePrch Association.

Thieken, A H; Ackermann, V; Elmer, F; Kreibich, H; Kuhlmann, B; Kunert, U; Maiwald, H; Merz, B; Müller, M; Piroth, K; Schwarz, J; Schwarze, R; Seifert, I; and Seifert, J., 2008. *Methods for the Evaluation of Direct and Indirect Flood Losses.* Toronto, Ontario, 4th International Symposium on Flood Defence: Managing Flood Risk, Reliability and Vulnerability, May 6-8.

Thomas, T. N., Leander-Griffith, M., Harp, V. and Cioffi, J. P., 2015. Influences of preparedness knowledge and beliefs on household disaster preparedness. *MMWR Morb Mortal Wkly Rep,* Volume 64, p. 965–971.

Thomsen, K., 2002. *Building Resilient Students.* Thousand Oaks, CA: Corwin Press, Inc.

Thrush, D., Burningham, K. and Fielding, J., 2005. *Exploring flood-related vulnerability: A qualitative study,* Bristol: Environment Agency.

Thurston, N; Finlinson, B; Breakspear, R; Kidd, B; Glerum, J; Lamond, J; Proverbs, D; and Dhonau, M., 2010. *Availability and Uses of Property Level Flood Risk Data and Information,* London: Department for Environment, Food and Rural Affairs.

Tilman, D., 1997. Biodiversity and ecosystem functioning. In: G. C. Daily, ed. *Nature's services: societal dependence on natural ecosystems.* Washington, DC: Island Press, p. 93–112.

Tilman, D. and Downing, J. A., 1994. Biodiversity and stability in grasslands. *Nature,* Volume 367, pp. 363-365.

Tinsley, H. E. and Weiss, D. J., 1975. Interrater Reliability and Agreement of Subjective Judgments. *Journal of Counseling Psychology,* 22(4), pp. 358-374.

Tunstall, S; Tapsell, S; Green, C; Floyd, P; and George, C., 2006. The health effects of flooding: social research results from England and Wales. *Journal of Water and Health,* 4(3), pp. 365-380.

Tuuli, M. M., 2009. *Empowerment and control dynamics in project teams: A multi-level examination of antecedents, job performance, and consequences, PhD Thesis, Department of Real Estate and Construction,* Hong Kong: University of Hong Kong.

Twigger-Ross, C; Kashefi, E; Weldon, S; Brooks, K; Deeming, H; Forrest, S; Fielding, J; Gomersall, A; Harries, T; McCarthy, S; Orr, P; Parker, D; and Tapsell, S., 2014. *Flood Resilience Community Pathfinder Evaluation: Rapid Evide nce Assessment*, London: Defra.

Ulin, P. R., Robinson, E. T. and Tolley, E., 2004. *Qualitative Methods in Public Health: A Field Guid for Applied Research,* Sanfransisco: Jossey-Bass.

UNECE, 2000. *Guidelines on Sustainable Flood Prevention*.

Unger, M., 2005. *Handbook for Working with Children and Youth.* Thousand Oaks, CA: Sage Publications.

UNISDR, 2009. *United Nations International Strategy for Disaster Reduction (UNISDR),* Geneva, Switzerland: UNISDR.

UNISDR, 2013. *From Shared Risk to Shared Value –The Business Case for Disaster Risk Reduction.* Geneva: United Nations Office for Disaster Risk Reduction.

USACE, 1988. *Flood Proofing Tests – Tests of Materials and systems for Floodproofing structures,* USA: US Army Corps of Engineers.

USAID, 2009. *Community resilience: conceptual framework and measurement. Feed the Future learning agenda,* Rockville, MD Westat : US Agency for International Development.

USAID, 2013. *The Resilience Agenda: Measuring Resilience in USAID,* Washington, D.C: United States Agency International Development.

Van Nes, E. and Scheffer, M., 2007. Slow Recovery for Pertubations as a Generic Indicator of a Nearby Catastrophic Shift. *Am. Nat,* Volume 169, pp. 738-747.

VanBreda, A. D., 2001. *Resilience Theory: A Literature Review*. Pretoria, South Africa: South African Military Health Service, Military Psychological Institute.

Visentin, D. C., Cleary, M. and Hunt, G. E., 2020. The earnestness of being important: Reporting non-significant statistical results. *Journal of Advanced Nursing,* Volume 76, p. 917–919.

Wachinger, G., Renn, O., Begg, C. and Kuhlicke, C., 2013. The risk perception paradox—implications for governance and communication of natural hazards. *Risk Analysis,* 33(6), p. 1049–1065.

Walker, B; Carpenter, S; Anderies, J; Abel, N; Cumming, G; Janssen, M; Lebel, L; Norberg, J; Peterson, G D; and Pritchard, R., 2002. Resilience Management in Social-ecological Systems: a Working Hypothesis for a Participatory Approach. *Conservation Ecology,* 6(1), p. 14.

Walker, B. H., Ludwig, D., Holling, C. S. and Peterman, R. M., 1969. Stability of semi-arid savanna grazing systems.. *Ecology,* Volume 69, pp. 473-498.

Walker, B., Holling, C. S., Carpenter, S. R. and Kinzig, A., 2004. Resilience, adaptability and transformability in social–ecological systems. *Ecol. Soc.,* 9(2), p. 5–13.

Walker, B. and Salt, D., 2006. *Resilience thinking,* Washington, D.C., USA: Island.

Walker, M., Whittle, R., Medd, W., Burningham, K., Moran-Ellis, J. and Tapsell, S., 2012. “It Came up to Here”: Learning from Children’s Flood Narratives. *Children’s Geographies,* 10(2), p. 135–150.

Walters, C. J., 1986. *Adaptive Management of Renewable Resources.* New York: McGraw Hill.

Wardekker, J. A., de Jong, A., Knoop, J. M. and van der Sluijs, J. P., 2010. Operationalising a resilience approach to adapting an urban delta to uncertain climate changes. *Technological Forecasting and Social Change*, 77(6), pp. 987-998.

Wassell, P., Ayton-Robinson, R., Robinson, D. and Salkeld, I., 2009. *Resilient reinstatement - the cost of flood resilient reinstatement of domestic properties,* London: Association of British Insurers.

Watkiss, P., Cimato, F., Hunt, A. and Morley, B., 2016. *Climate Change Impacts on the Future Cost of Living (SSC/CCC004),* York, UK: Joseph Rowntree Foundation.

Werritty, A; Houston, D; Ball, T; Tavendale, A; and Black, A., 2007. *Exploring the Social Impacts of Flood Risk and Flooding in Scotland.* Edinburgh, UK: Scottish Executive Social Research.

White, G., 1945. *Human adjustment to floods: A geographical approach to the flood problem in the United States,* Chicago: University of Chicago.

Williams, S. and McEwen, L., 2021. 'Learning for resilience' as the climate changes: discussing flooding, adaptation and agency with children. *Environmental Education Research,* 27(11), pp. 1638-1659.

Winderl, T., 2014. *Disaster Resilience Measurements: Stocktaking of Ongoing Efforts in Developing Systems for Measuring Resilience*. http://www.preventionweb.net/files/37916_disasterresiliencemeasurementsundpt.pdf.

Windle, G., 2010. What is resilience? A review and concept analysis. *Reviews in Clinical Gerontology,* Volume 1, pp. 1-18.

Wingfield, J., Bell, M. and Bowker, P., 2005. *Improving the Flood Resilience of Building through Improved Naterials, Methods and Details*.

Wingfield, J., Bell, M. and Bowker, P., 2005. *Improving the Flood Resilience of Buildings through Improved Materials, Methods and Details,* Leeds: Leeds Metropolitan University.

Wisner, B. A., 2006. *Review of the Role of Education and Knowledge in Disaster Risk Reduction*.

Woods, D. D., 2000. Designing for resilience in the face of change and surprise: Creating safety under pressure. *Plenary Talk, Design for Safety Workshop, NASA Ames Research Center*, 10 October.

Xiao, H., 2002. *A Comparative Study of Contractor Performance based on Japanesse, UK and US Construction Practice. PhD Thesis School of Engineering and the Built Environment,* Wolverhampton: University of Wolverhampton.

Yeo, S., 2003. Effects of Disclosure of Flood-Liability on Residential Property Values. *Australian Journal of Emergency Management,* Volume 18, pp. 35-44.

Yodo, N. and Wang, P., 2016. Engineering Resilience Quantification and System Design Implications: A Literature Survey. *Journal of Mechanical Design,* Volume 138, pp. 1-13.x

Young, O., Berkhout, F., Gallopin, G. C., Janssen, M. A; Ostrom, E. and van der Leeuw, S., 2006. The globalization of social-ecological systems: an agenda for scientific research. *Global Environmental Change,* Volume 16, pp. 304-316.

Yu, S., Alper, H. E., Nguyen, A., Brackbill, R. M., Turner, L., Walker, D. J., Maslow, C. B. and Zweig, K. C., 2017. The effectiveness of a monetary incentive offer on survey response rates and response completeness in a longitudinal study. *BMC Medical Research Methodology,* 17(77), pp. 1-9.

Zevenbergen, C., 2016. *Flood Resilience,* Lausanne: International Risk Governance Center, IGRC.

Zevenbergen, C., Gersonius, B. and Radhakrishan, M., 2020. Flood resilience. *Philosophical Transactions of The Royal Society A Mathematical Physical and Engineering Sciences,* p. 378.

Zevenbergen, C; van Herk, S; Rijke, J; Kabat, P; Bloemen, P; Ashley, R; and Veerbeek, W., 2013. Taming global flood disasters: lessons learned from Dutch experience. *Nat. Haz.,* Volume 65, p. 1217–1225.

Zevenbergen, C., Veerbeek, W., Gersonius, B. and van Herk, S., 2008. Challenges in urban flood management: travelling across spatial and temporal scales. *J. Flood Risk Management,* Volume 1, p. 81–88.

Zevenbergen, C., Veerbeek, W., Gersonius, B. and Van Herk, S., 2008. Challenges in urban flood management: travelling across spatial and temporal scales. *Flood Risk Management,* 1(2), p. 81–88.

Zhang, F., 2011. *Cross-Validation and Regression Analysis in High-Dimensional Sparse Linear Models,* Stanford: Stanford University.

Zhou, Z., Liu, S., Zhong, G. and Cai, Y., 2017. Flood Disaster and Flood Control Measurements in Shanghai. *Natural Hazards Review*, 18(1), p. B5016001.

APPENDICES

APPENDIX A-1: RESEARCH ETHIC APPROVAL

BIRMINGHAM CITY
University

Faculty of Computing, Engineering & the Built Environment Research Office
Millennium Point, Curzon Street
Birmingham
B4 7XG

BCU_ethics@bcu.ac.uk

13/Feb/2020

Mr Taiwo Adedeji

Taiwo.Adedeji@mail.bcu.ac.uk

Dear Taiwo ,

Re: Adedeji /3549 /R(A) /2020 /Feb /CEBE FAEC - Towards a Methodology for Measuring the Resilience of Properties at Risk of Flooding

Thank you for your application and documentation regarding the above activity. I am pleased to take Chair's Action and approve this activity.

Provided that you are granted Permission of Access by relevant parties (meeting requirements as laid out by them), you may begin your activity.

I can also confirm that any person participating in the project is covered under the University's insurance arrangements.

Please note that ethics approval only covers your activity as it has been detailed in your ethics application. If you wish to make any changes to the activity, then you must submit an Amendment application for approval of the proposed changes.

Examples of changes include (but are not limited to) adding a new study site, a new method of participant recruitment, adding a new method of data collection and/or change of Project Lead.

Please also note that the Computing, Engineering and the Built Environment should be notified of any serious adverse effects arising as a result of this activity.

If for any reason the Committee feels that the activity is no longer ethically sound, it reserves the right to withdraw its approval. In the unlikely event of issues arising which would lead to this, you will be consulted.

Keep a copy of this letter along with the corresponding application for your records as evidence of approval.

If you have any queries, please contact BCU_ethics@bcu.ac.uk

I wish you every success with your activity.

Yours Sincerely,

Professor Sharon Cox

On behalf of the Computing, Engineering and the Built Environment

APPENDIX A-2: RESEARCH INFORMATION SHEET

RESEARCH PROJECT INFORMATION SHEET FOR PARTICIPANTS

TITLE OF RESEARCH PROJECT: Towards a Methodology for Measuring the Resilience of Properties at Risk of Flooding

RESEARCHER(S): *Taiwo Adedeji, Professor David Proverbs, Dr Hong Xiao and Professor Victor Oladokun.*

THE AIMS OF THE PROJECT: *The aim of this research is to develop a model for reliably measuring the level of resilience present in properties at risk of flooding.*

PROJECT DATES: *March 1, 2020 – June 30, 2020*

PARTICIPANTS ROLE IN THE RESEARCH:
You are requested to provide information about your flood experience and the impact it has on your home. Your participation in the research is invaluable and I estimate completion of the questionnaire will take no more than 20 minutes of your time.

CONFIDENTIALITY
Be guaranteed that the study has received approval from the University and complies with the University's strict ethical procedures and standards. Also, this study is completely anonymous, no one will know if you did or did not participate. Data collected will be used to test and validate the model developed for quantifying property level flood resilience. Data will be kept for 3 years after the completion of the research.

WITHDRAWAL FROM THE RESEARCH
Your participation in this research study is strictly voluntary. You may choose not to participate and free to dispose the questionnaire without fear of penalty or any negative consequences. You will be able to withdraw from the survey at any time and all survey responses will be deleted, including the informed consent agreement.

POSSIBLE RISKS TO PARTICIPANTS
Some of the questions in the questionnaire concern your feelings about the previous experience of flood event and we recognise that you may not want to be reminded of the event. You can withdraw from the research at this stage and ***free to dispose the questionnaire*** *if you wish to.*

BENEFITS TO THE PARTICIPANTS
It is hoped that this will lead to the development of a decision support tool to assist homeowners in determining the level of flood resilience present in their property.

RESEARCHER CONTACT DETAILS

Taiwo Adedeji
Email: Taiwo.Adedeji@mail.bcu.ac.uk
Professor David Proverbs
Email: David.Proverbs@bcu.ac.uk

APPENDIX A-3: CONSENT FORM

RESEARCH PARTICIPANT CONSENT FORM

TITLE OF RESEARCH PROJECT: Towards a Methodology for Measuring the Resilience of Properties at
Risk of Flooding

RESEARCHER(S): *Taiwo Adedeji, Professor David Proverbs, Dr Hong Xiao and Professor Victor Oladokun.*

PARTICIPANT DETAILS:

Name:
Address:

Telephone:
DOB (if under 18 years of age):

PROJECT DATES: *March 1, 2020 – June 30, 2020*

PARTICIPANT DECLARATIONS:

<u>Please delete as applicable</u>

- I have been informed of and understand the purposes of the research YES / NO
- I have been given an opportunity to ask questions YES / NO
- I understand that any information which might potentially identify me YES / NO
- will not be used in any published material
- I understand that I may request access to any data collected by the researcher(s) that relates to me: YES / NO
- I agree to participate in the study as outlined YES / NO
- I understand I may withdraw at any time "without prejudice" YES / NO

Date: **Signature:**

APPENDIX A-4: COVER LETTER FOR THE QUESTIONNAIRE

The questionnaire is enclosed within the envelope marked 'The Main Questionnaire' and should only be opened having read this letter of invitation.

Dear Invitee,

Participation Invitation Letter

My name is Taiwo Adedeji, and I am a PhD student studying at Birmingham City University, Birmingham, working under the supervision of Professor David Proverbs, Dr Hong Xiao and Professor Victor Oladokun. My doctoral research aims to cultivate a deeper understanding of the effectiveness of property level protection measures and to develop a framework for measuring flood resilience at the individual property level. This will assist homeowners in determining the level of flood resilience present in their property.

The study is concentrating on residential properties located in flood risk areas. I would like to invite you to participate by completing the enclosed questionnaire. Your participation in this research study is voluntary but would be invaluable to this research. This research will strictly remain anonymous and the information you provide will not be shared with any third party and will only be used for the purposes of this research.

The questionnaire will take no more than 20 minutes of your time to complete. Some of the questions concern your feelings about your previous experiences of flooding which you may find upsetting. It is your right not to answer any of the questions. Also, if you do not want to remember anything about floods you are free to dispose the questionnaire.

By agreeing to participate in the study, you will be giving your consent for the researcher to include your responses in the data analysis which will be reported anonymously. However, you may choose not to participate without fear of penalty or any negative consequences. Also, you will be able to withdraw from the survey on or before 1st of January, 2021 and all survey responses will be deleted on completion of the study.

Be assured that this letter does not mean that you are at risk from flooding but if you are worried, you can seek advice from any of the below.

If you wish to receive a copy of the summary of the results from the research, please indicate as such and we will ensure a summary is forwarded to you.

Thank you for taking the time to consider this invitation and I would like to extend my personal gratitude; your contribution is greatly appreciated.

Yours sincerely,

Taiwo Adedeji
Doctoral Student
(Email: Taiwo.Adedeji@mail.bcu.ac.uk)

Professor David Proverbs
(Email: David.Proverbs@bcu.ac.uk)

APPENDIX A-5: THE QUESTIONNAIRE

FLOOD RESILIENCE QUESTIONNAIRE

This short questionnaire seeks to find out how homeowners are developing resilience against flood impacts. It focuses on identifying homeowners' views on the resilience of their property and the impact of property level protection measures in minimising flood damage. Also, it tries to find out how these measures affect the recovery process of both the building and its residents. Ultimately, the objective of the research is to help homeowners make informed decisions about protecting their home against future flooding, and your input to this research is invaluable and really appreciated.

The questionnaire is divided into a number of short sections and, for your convenience, most of the questions only require ticks in the relevant boxes. In some cases, there are spaces provided for you to add additional information. If you have experienced more than one flood event, please respond to the questions in the light of your most recent flood experience.

The information you give will be held confidentially by Birmingham City University and will not be passed on to any third parties. Respondents will remain anonymous in the storage and reporting of the data provided, by removing any personal level information. The questionnaire has been designed to be completed as easily as possible and should take about 20 minutes. We hope that you will find the questionnaire interesting – if you would like to receive a short summary of our findings, then please indicate in the appropriate space below.

Also, as a thank you, we're offering you the chance to win one of three prizes:

- £150 cash prize
- £100 cash prize
- £50 cash prize

If you have completed the survey, you will qualify to partake in the prize draw!

All the best,

Section 1a: About your property and the materials used for the building components (in cases where more than one option is required, choose all that apply)

1	**property type**	☐ detached	☐ semi-detached		☐ terrace	☐ end of terrace	
2	**number of storeys**		☐ 0	☐ 1	☐ 2	☐ 3	☐ 4+
3	**is there cellar or basement**			☐ Yes		☐ No	
4	**property wall type**		☐ cavity wall	☐ solid wall	☐ timber frame	☐ don't know	
5	**property ground floor type**	☐ concrete	☐ timber	☐ don't know	☐ others-please specify		
6	**doors**	☐aluminium	☐ PVC	☐ steel	☐ timber	☐ plywood	☐ glass
7	**windows**	☐aluminium	☐ PVC	☐ steel	☐ timber	☐ plywood	☐ glass
8	**kitchen unit**		☐ steel	☐aluminium	☐ wood	☐ ceramic	☐ plastic
9	**bathroom (washroom) unit**		☐ steel	☐aluminium	☐ wood	☐ ceramic	☐ plastic

Section 1b: Internal partitions and floor covering material

For the internal partitions between rooms and the ground covering type, please select the kind of materials used and indicate the estimate proportion of each material.

	internal partitions (please select all that apply)						**ground floor covering type (please select all that apply)**						
%	blockwork	brick	timber	plaster board	chipb oard		clay tiles	ceramic tiles	rubber sheet	vinyl sheet	vinyl tiles	carpets	timber/ laminate flooring
less than 25%													
25-50%													
51-75%													
76-100%													
don't know													

Section 2: About your flood experience and risk awareness

1	How many times did you experience flooding to this property?	☐ 0	☐ 1	☐ 2	☐ 3	☐ 4+
2	What source of flooding are you most concerned about?	☐ coastal flooding	☐ river flooding	surface water ☐ flooding	groundwater ☐ flooding	☐ other
3	Were you aware of the risk before you moved into the property?		☐ yes	☐ no	☐ don't know	
4	What is the flood risk of the locality you resides?	☐ very low	☐ low	☐ medium	☐ high	☐ don't know
5	What was the flood depth of the flood event recently experienced?	☐ up to 4 inches (up to 10cm)	4¼ – 12 inches ☐ (11-30cm)	12¼ – 24 inches ☐ (31-60cm)	24¼ – 36 inches ☐ (61-90cm)	+36 ¼ inches (91cm and ☐ above)

What year did you have your most recent flood experience?	

Section 3a: About the resistance measures installed in your property.

Thinking on your most recent flood experience, please indicate whether you have the following resistance measures in place at the time of the event and if so, indicate their effectiveness by ticking the appropriate column.

SN	RESISTANCE MEASURES	tick if available	very effective	quite effective	don't know	not very effective	not effective at all
			1	2	3	4	5
1	demountable door guard	◯					
2	demountable window guard	◯					
3	airbrick cover	◯					
4	sewage bung	◯					
5	toilet pan seal	◯					
6	sump pump	◯					
7	floodgate	◯					
8	non-return valves utility waste pipe	◯					
9	non-return valves overflow pipe	◯					
10	use of sandbags to prevent water entering	◯					

Others - please add

Section 3b: About the resilience measures installed in your property.

Thinking on your most recent flood experience, please indicate whether you have the following resilience measures in place at the time of the event and if so, indicate their effectiveness by ticking the appropriate column.

SN	RESILIENCE MEASURES	tick if available	very effective	quite effective	neutral	not very effective	not effective at all
			1	2	3	4	5
1	raised floor above predicted flood level	◯					
2	boiler mount on wall	◯					
3	washing machine on first floor or above	◯					
4	oven with raised under type	◯					
5	electric metre above predicted flood level	◯					
6	raising electrical sockets above likely flood level	◯					
7	gas metre above predicted flood level	◯					
8	having a flood plan	◯					
9	moving vulnerable items to first floor	◯					
10	lightweight moveable furniture	◯					

Others - please add

Section 4a: Extent of damage caused to building and contents

Thinking about your most recent flood, indicate the level of support received from the following sources. Please rate the severity of the impacts of the flood event experienced on your building and its contents. Please tick all that apply

SN	EXTENT OF DAMAGE CAUSED	very serious	quite serious	don't know	not very serious	not at all serious
		1	2	3	4	5
1	structure (walls, floors and ceiling)					
2	gas and heating systems					
3	electrical system					
4	drainage and sewage systems					
5	personal belongings					
6	damage to furniture and fittings					
7	loss of power, telecommunication					
8	loss of water supply					
9	damage to kitchen unit					
10	damage to floor covering					
11	damage to internal walls					

Section 4b: Damage to appliances

For all the furniture and appliances selected in section 1c please indicate the level of damage caused by ticking the appropriate column.

SN	EXTENT OF DAMAGE CAUSED	very serious	quite serious	don't know	not very serious	not at all serious
		1	2	3	4	5
1	chair					
2	wardrobe					
3	TV set					
4	fireplace					
5	sofa					
6	media cabinet					
7	book shelf					
8	CD/DVD player					
9	satellite receiver					
10	telephone					
11	table					
12	dining set					
13	pet house					
14	mattress					

Section 4c: Damage to kitchen appliances

SN	EXTENT OF DAMAGE CAUSED	very serious	quite serious	don't know	not very serious	not at all serious
		1	2	3	4	5
1	washing machine					
2	tumble dryer					
3	fridge					
4	freezer					
5	coffee maker					
6	electric water boiler					
7	toaster					
8	microwave					
9	blender					

Section 5: About you and your household

1	Please indicate age bracket	☐ less than 25		☐ 25-40	☐ 40-64	☐ 65-74		☐ 75+
2	Are you	☐ male		☐ female		☐ prefer not to say		
3	Is the property			☐ owned			☐ rented	
4	Your annual household income	☐ Less than £10000	☐ £10000-£19999	☐ £20000-£29999	☐ £30000-£39999	☐ £40000-£49999	☐ £50000-£59999	☐ £60000 and above
5	What is your highest qualification?	☐ No formal qualification	☐ GCSE/O-Level	☐ A-Level/Higher/BTEC	☐ vocational/NVQ	☐ Degree or equivalent	☐ post graduate qualification	
6	What is the household size (persons)?		☐ 0	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5+
7	How many children less than 10?		☐ 0	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5+
8	Is there anyone with disability		☐ yes			☐ no		
9	how many pets do you have		☐ 0	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5+
10	members of the household above 69 years		☐ 0	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5+
11	how long have lived in this neighbourhood?		☐ 0-5	☐ 6-10	☐ 11-15	☐ 16-20	☐ 21-25	☐ 26+

Section 6: Questions on Flood Insurance

In the case of multiple flood experience, please answer the questions based on your most recent flood event.

1	What kind of flood insurance do you have?	☐ none	☐ building only	☐ content only	☐ building and content	
2	How long have you been insured?	☐ 1yr	☐ 2-3yrs	☐ 4-6yrs	7-8yrs	9-10yrs	☐ more than 10yrs
3	Have you made any insurance claim at the event of flooding (if yes please answer questions a and b)	☐ yes		☐ no		
a	How many claims have you made since you've been insured?	☐ 1	☐ 2	☐ 3	☐ 4+	
b	Did your premium or excess increase after making a flood claim	☐ significantly	☐ moderately	☐ none		

Section 7: Psychological Impacts

Please indicate to what extent the following psychological effects have affected members of your household.

SN	QUALITY OF RECOVERY	strongly agree	agree	neutral	disagree	strongly disagree
		1	2	3	4	5
1	I was upset about the damage caused by the flood					
2	My family was disrupted					
3	My children missed school					
4	I lost items of sentimental value					
5	I was away from work for a long time					
6	Members of my family suffered from job loss					
7	I still suffer from psychological disorder because of recurrent flooding					
8	It took me some time and effort to return to normal after each flood event					
9	Since last flood event, members of my family have deteriorating health problem					
10	I feel anxious at the sight of rain or when river level rises					
11	I have experienced Increase in stress level					
12	I have had problems dealing with insurers/loss adjusters					
13	It has been difficult dealing with builders					
14	Difficult coping with loss of or distress to pets					

Section 8: Questions on the Level of Support Received

Thinking about your most recent flood, indicate the level of support received from the following sources.

SN	LEVEL OF SUPPORT RECEIVED	none	low	moderate	high
		1	2	3	4
1	family outside the home				
2	neighbours and friends				
3	local authorities				
4	emergency services (like police, fire brigade, ambulance)				
5	place of worship				
6	voluntary flood group				

(Others – please state)

Section 9: Questions on Residents' Recovery Time

Based on your most recent flood experience, please indicate the approximate time it took for member of the household to get back from the following conditions. Please tick all that apply to you.

SN	RECOVERY TIME	less than 1month	1-3 months	4-6 months	7-9 months	10-12 month	over 12 months	not applicable
1	how long did you have to vacate your property?							
2	how long did you take off work?							
3	how long did your kids take off school?							
4	how long did it take to get the house to normal?							
5	how long did it take for member of the household to recover from health issues caused by the flood event?							

Section 10: Other comments about your experience

What further steps have you taken to reduce the effect of flooding on your property?

What role did mediator (like Insurance, community, flood resilience group) play in ensuring quick recovery?

Please use this space to add any comments upon your experience of flood event and the ways in which you recover from the event.

Can you please provide your email to help us reach you if you win any of the prizes?

APPENDIX A-6: FEEDBACK FORM

FEEDBACK ON QUESTIONS

I will appreciate, if you can complete the feedback section. The purpose of this section is to help improve the questionnaire in terms of clarity and also to avoid ambiguous questions.

	Yes	No	Unsure
unclear			
duplication			

If Yes, please state the "section and the number of the question" and provide any suggestion to improve the question.

section	question no	suggestion on improvement

Further Suggestions

Please give further suggestions on improving the questionnaire

Thank you for completing the questionnaire. Please send it back to us in the prepaid envelope. Your answers will assist us in developing a comprehensive method of quantifying resilience at the individual property level.

If you require additional information or any clarification, please feel free to send me an email: to any of the following emails: Taiwo.Adedeji@mail.bcu.ac.uk; David.Proverbs@bcu.ac.uk; Hong.Xiao@bcu.ac.uk.

Data will be handled in confidence by the Birmingham City University and not passed on to any third party.

APPENDIX A-7: DEFINITION OF RESILIENCE MEASURES

MEASURES	DESCRIPTION OF MEASURE	IMAGE
Demountable door guard	Guard fitted to doors to resist flooding	 Source:
Demountable window guard	Guard fitted to window to resist flooding	
Airbrick cover	Watertight cover for airbricks	 
Sewage bung	Inflatable device to insert in U bend of toilet to prevent sewage backflow	
Toilet pan seal	Seal to prevent sewage backflow	

Sump pump	Pump install in the lowest part of the basement to keep the area dry and to prevent it from flooding (especially in cases of ground water flooding.)	
Floodgate	Gate that can be opened or closed to admit or exclude water, especially the lower gate of a lock.	
Non-return valve utility waste pipe	Valve prevents backflow via waste pipe	
Non-return valve overflow pipe	Valve prevents backflow via overflow pipe	
Sandbag	sandbags are used to block doorways, drains and other openings into properties	

APPENDIX B-1: INTRACLASS CORRELATION

i. Building Resilience scale

Intraclass Correlation Coefficient

	Intraclass Correlation[b]	95% Confidence Interval		F Test with True Value 0			
		Lower Bound	Upper Bound	Value	df1	df2	Sig
Single Measures	.560[a]	.433	.689	20.556	43	430	.000
Average Measures	.933[c]	.894	.961	20.556	43	430	.000

Two-way mixed effects model where people effects are random and measures effects are fixed.

a. The estimator is the same, whether the interaction effect is present or not.

b. Type A intraclass correlation coefficients using an absolute agreement definition.

c. This estimate is computed assuming the interaction effect is absent, because it is not estimable otherwise.

Summary Item Statistics

	Mean	Minimum	Maximum	Range	Maximum / Minimum	Variance	N of Items
Item Means	3.130	2.159	3.864	1.705	1.789	.386	20
Inter-Item Covariances	1.641	.788	2.796	2.008	3.550	.203	20
Inter-Item Correlations	.638	.364	.954	.590	2.620	.021	20

Reliability Statistics

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.951	.951	20

Human Resilience Scale

Intraclass Correlation Coefficient

	Intraclass Correlation[b]	95% Confidence Interval		F Test with True Value 0			
		Lower Bound	Upper Bound	Value	df1	df2	Sig
Single Measures	.309[a]	.202	.454	9.935	35	455	.000
Average Measures	.862[c]	.780	.921	9.935	35	455	.000

Two-way mixed effects model where people effects are random and measures effects are fixed.

a. The estimator is the same, whether the interaction effect is present or not.

b. Type A intraclass correlation coefficients using an absolute agreement definition.

c. This estimate is computed assuming the interaction effect is absent, because it is not estimable otherwise.

Scale Statistics

Mean	Variance	Std. Deviation	N of Items
38.86	147.952	12.164	14

Summary Item Statistics

	Mean	Minimum	Maximum	Range	Maximum / Minimum	Variance	N of Items
Item Means	2.776	1.889	4.167	2.278	2.206	.487	14
Inter-Item Covariances	.679	-.178	1.398	1.576	-7.866	.116	14
Inter-Item Correlations	.395	-.122	.723	.845	-5.920	.035	14

Reliability Statistics

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.899	.901	14

Overall Resilience

Intraclass Correlation Coefficient

	Intraclass Correlation[b]	95% Confidence Interval		F Test with True Value 0			
		Lower Bound	Upper Bound	Value	df1	df2	Sig
Single Measures	.599[a]	.477	.718	8.481	48	192	.000
Average Measures	.882[c]	.820	.927	8.481	48	192	.000

Two-way mixed effects model where people effects are random and measures effects are fixed.

a. The estimator is the same, whether the interaction effect is present or not.

b. Type C intraclass correlation coefficients using a consistency definition. The between-measure variance is excluded from the denominator variance.

c. This estimate is computed assuming the interaction effect is absent, because it is not estimable otherwise.

Reliability Statistics

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.882	.881	5

APPENDIX B-2: THE COMMON METHOD BIAS

Table 6.25: KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.625
Bartlett's Test of Sphericity	Approx. Chi-Square	105.617
	df	55
	Sig.	.000

Total Variance Explained

Factor	Initial Eigenvalues			Extraction Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	4.042	13.037	13.037	3.684	11.882	11.882
2	3.208	10.349	23.386	2.877	9.280	21.162
3	2.677	8.636	32.022	2.307	7.441	28.603
4	2.122	6.847	38.869	1.791	5.776	34.379
5	2.081	6.714	45.584	1.684	5.431	39.811
6	1.717	5.540	51.124	1.329	4.288	44.099
7	1.619	5.221	56.345	1.240	4.001	48.100
8	1.540	4.966	61.311	1.077	3.474	51.573
9	1.300	4.193	65.505	.963	3.107	54.680
10	1.156	3.730	69.235	.716	2.310	56.990
11	1.086	3.503	72.738	.645	2.082	59.072
12	.974	3.143	75.881			
13	.916	2.955	78.836			
14	.824	2.659	81.495			
15	.753	2.428	83.923			
16	.635	2.050	85.973			
17	.592	1.910	87.883			
18	.565	1.822	89.705			
19	.522	1.684	91.388			
20	.437	1.411	92.799			
21	.368	1.186	93.985			
22	.343	1.105	95.090			
23	.320	1.031	96.121			
24	.247	.796	96.917			
25	.236	.760	97.678			
26	.189	.610	98.288			
27	.167	.539	98.827			
28	.141	.455	99.282			
29	.086	.278	99.560			
30	.081	.261	99.821			
31	.055	.179	100.000			

Extraction Method: Principal Axis Factoring.

APPENDIX B-3: TEST BETWEEN SUBJECTS EFFECTS

Tests of Between-Subjects Effects

Dependent Variable: Building Resilience (0,1)

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	.307[a]	17	.018	2.669	.002
Intercept	1.276	1	1.276	188.511	.000
Property type	.047	2	.023	3.442	.038
Number of storeys	.019	2	.010	1.408	.252
Cellar/basement	.036	1	.036	5.253	.025
Wall type	.040	2	.020	2.921	.061
Ground floor	.070	1	.070	10.302	.002
Door	.001	1	.001	.188	.666
Window	.002	1	.002	.229	.634
Kitchen unit	.071	2	.036	5.247	.008
Washroom unit	.050	4	.012	1.838	.132
Error	.440	65	.007		
Total	22.970	83			
Corrected Total	.747	82			

a. R Squared = .411 (Adjusted R Squared = .257)

APPENDIX B-4: NORMALITY TEST

Descriptives

			Statistic	Std. Error
Building Resilience (0,1)	Mean		.5174	.01048
	95% Confidence Interval for Mean	Lower Bound	.4966	
		Upper Bound	.5383	
	5% Trimmed Mean		.5158	
	Median		.5125	
	Variance		.009	
	Std. Deviation		.09543	
	Minimum		.28	
	Maximum		.80	
	Range		.52	
	Interquartile Range		.14	
	Skewness		.207	.264
	Kurtosis		.689	.523
Human Resilience (0,1)	Mean		.4895	.02450
	95% Confidence Interval for Mean	Lower Bound	.4408	
		Upper Bound	.5382	
	5% Trimmed Mean		.4875	
	Median		.5000	
	Variance		.050	
	Std. Deviation		.22319	
	Minimum		.04	
	Maximum		1.00	
	Range		.97	
	Interquartile Range		.32	
	Skewness		.103	.264
	Kurtosis		-.382	.523

overall resilience (0,1)	Mean		.4233	.01742
	95% Confidence Interval for Mean	Lower Bound	.3886	
		Upper Bound	.4580	
	5% Trimmed Mean		.4240	
	Median		.4333	
	Variance		.025	
	Std. Deviation		.15873	
	Minimum		.10	
	Maximum		.73	
	Range		.63	
	Interquartile Range		.23	
	Skewness		-.039	.264
	Kurtosis		-.677	.523

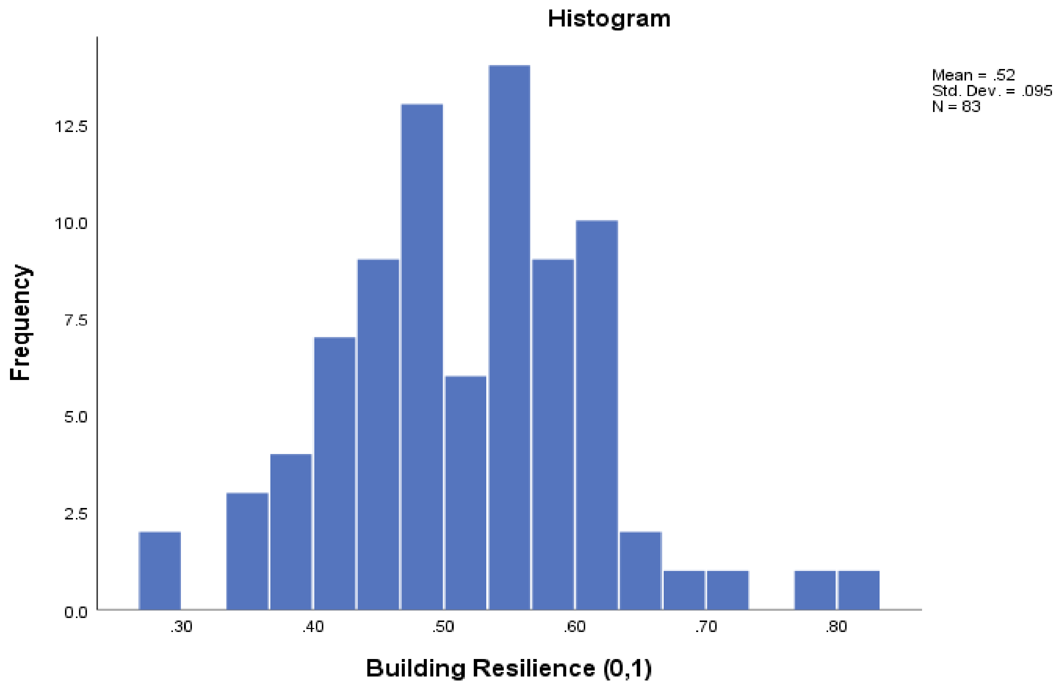
Tests of Normality

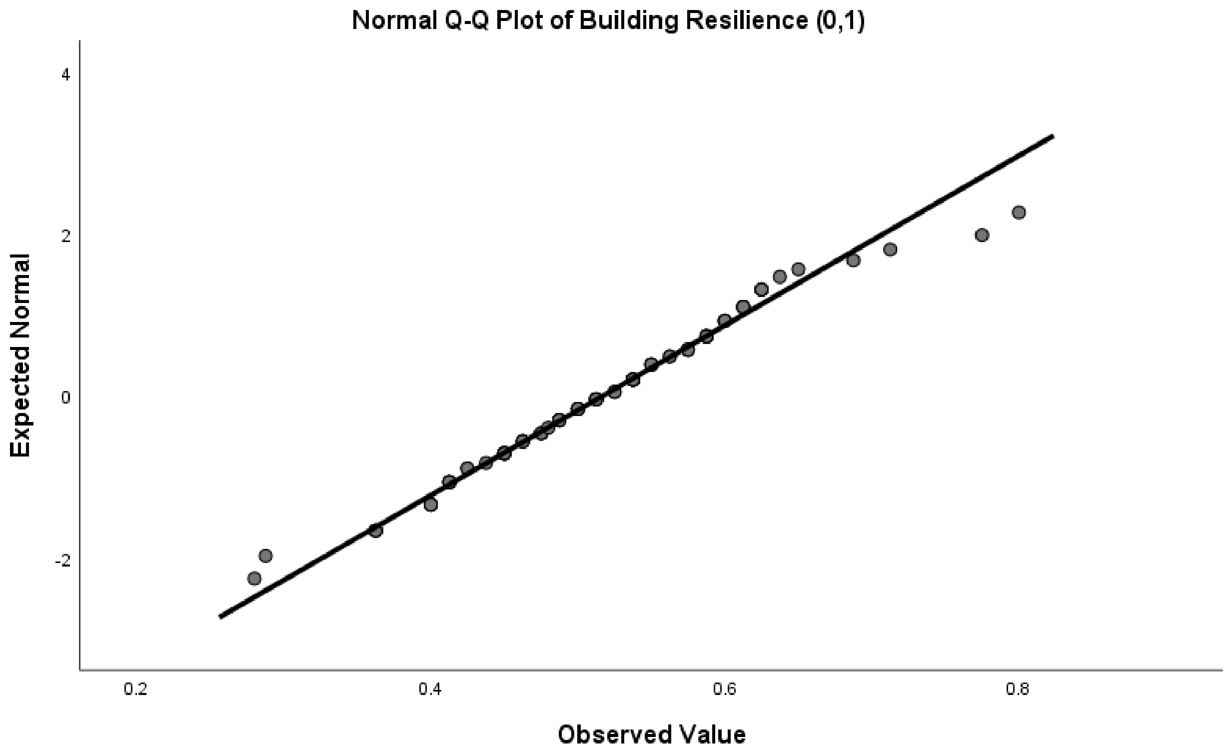
	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Building Resilience (0,1)	.058	83	.200*	.984	83	.406
Human Resilience (0,1)	.064	83	.200*	.989	83	.679
Overall Resilience (0,1)	.080	83	.200*	.976	83	.123

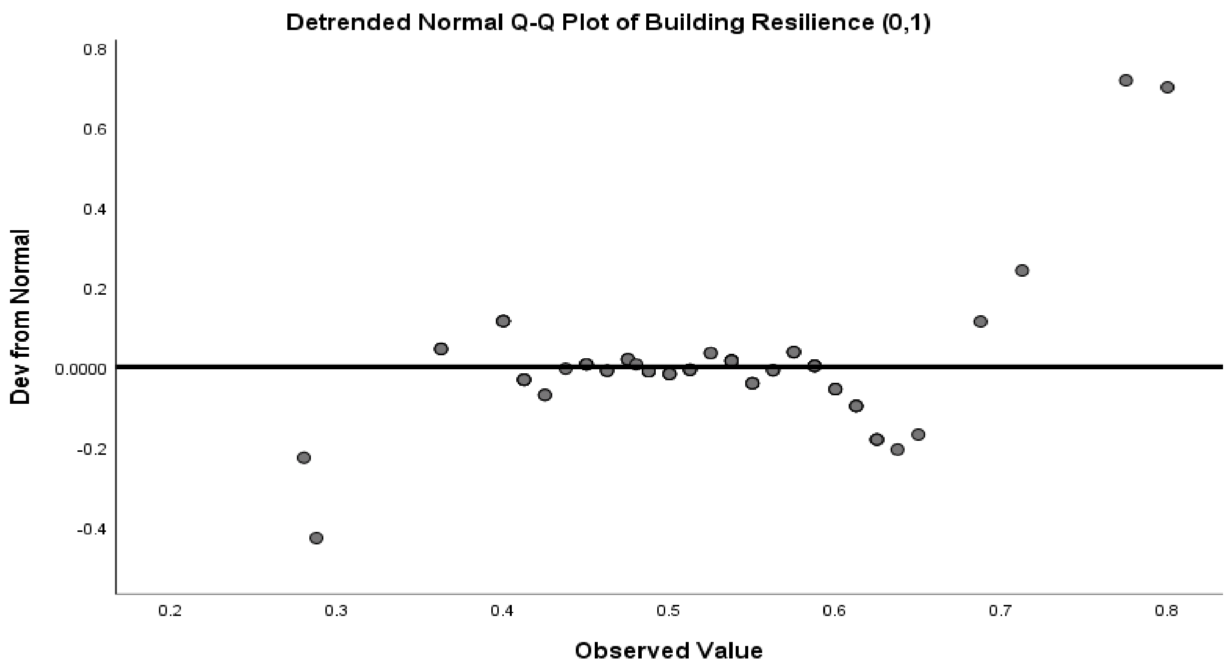
*. This is a lower bound of the true significance.

a. Lilliefors Significance Correction

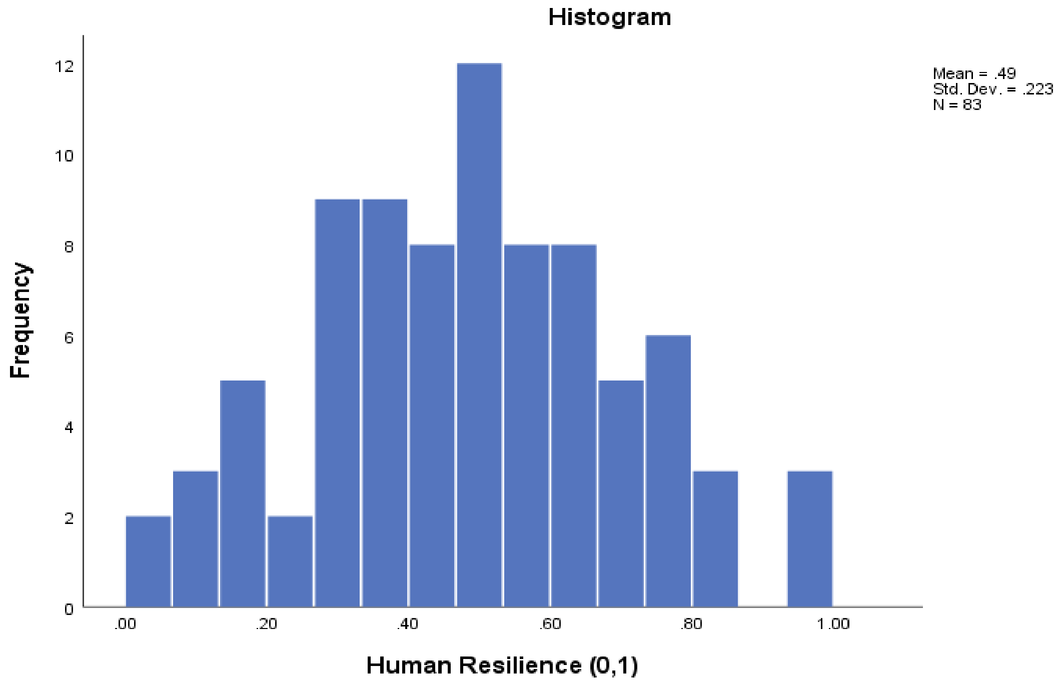
APPENDIX B-5: BUILDING RESILIENCE – HISTOGRAM AND NORMAL PLOTS

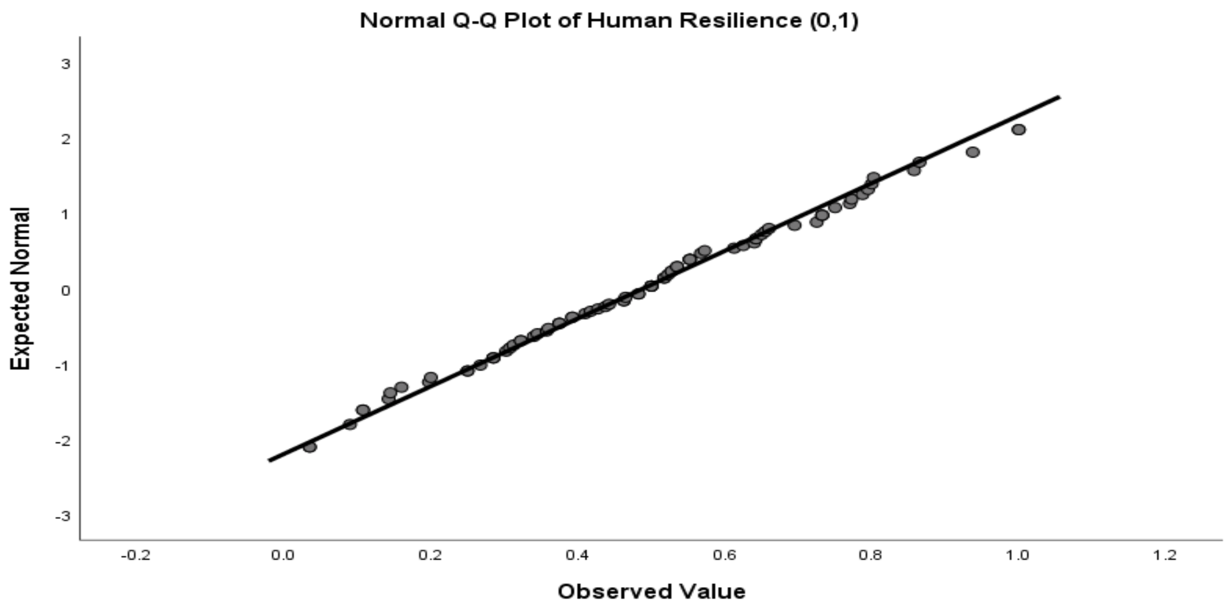


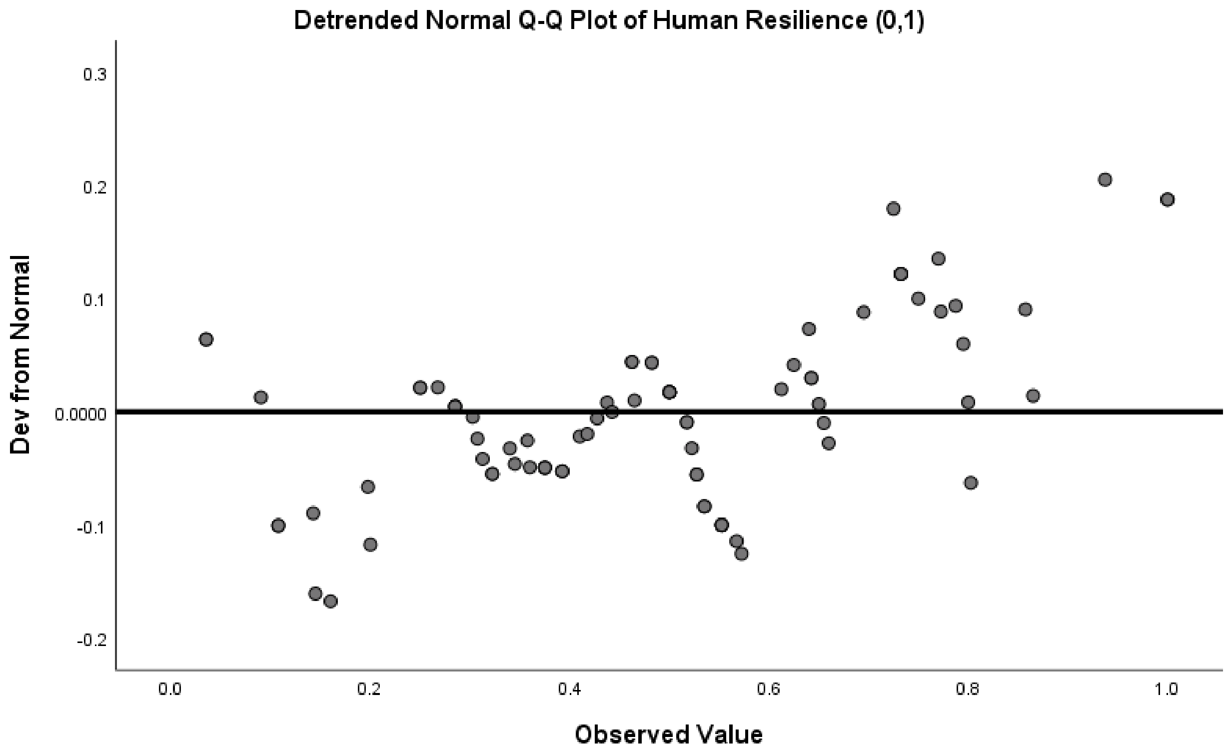




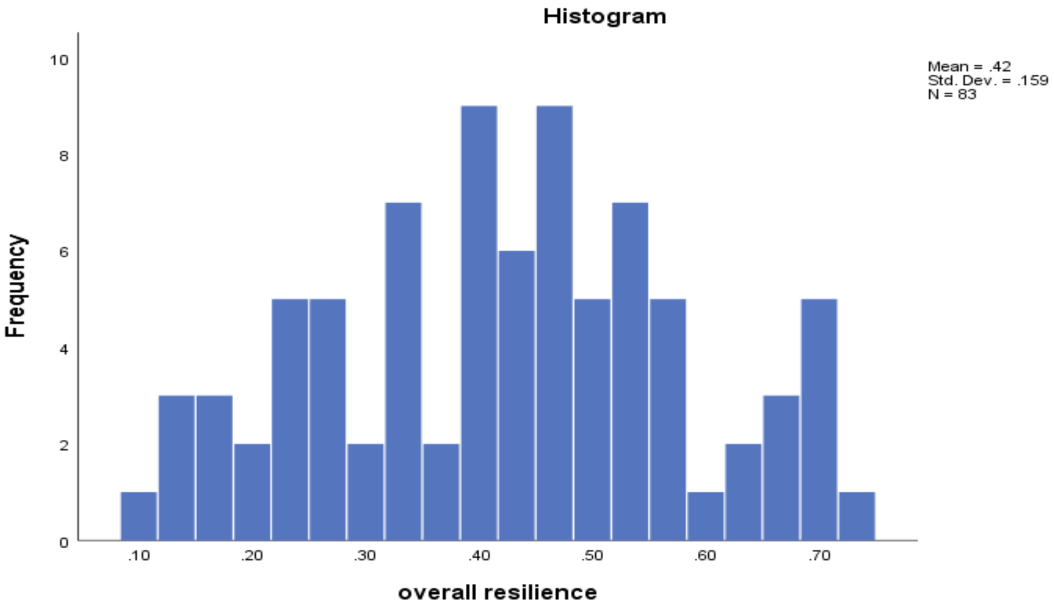
APPENDIX B-6: HUMAN RESILIENCE – HISTOGRAM AND NORMAL PLOTS

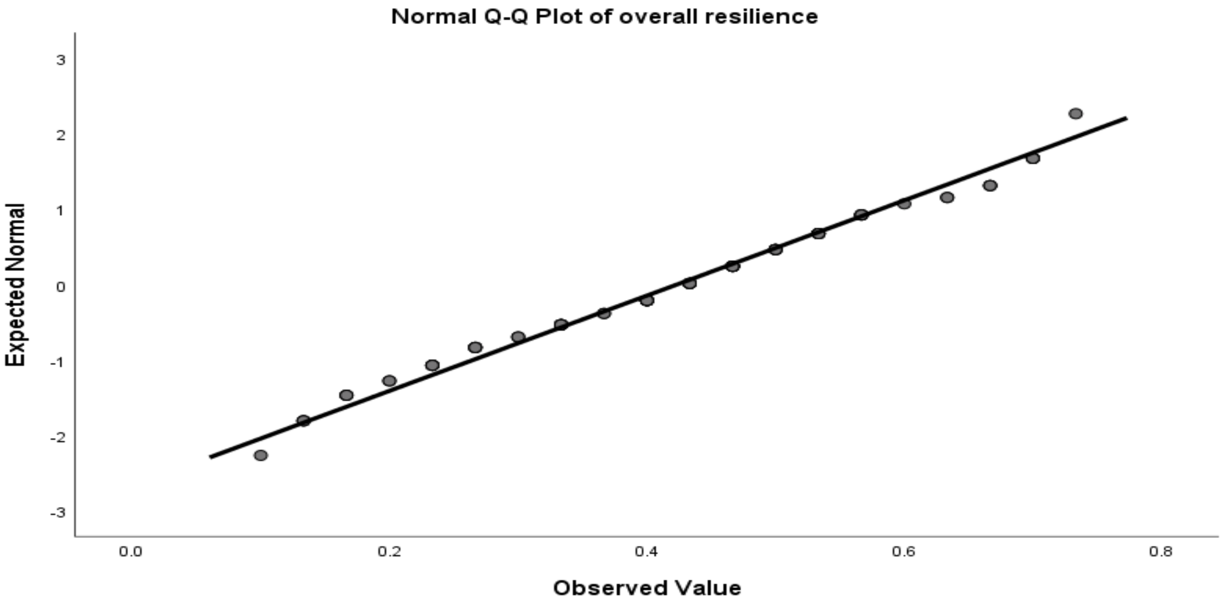

Histogram
Mean = .49
Std. Dev. = .223
N = 83
Frequency
12
10
8
6
4
2
0
.00
.20
.40
.60
.80
1.00
Human Resilience (0,1)

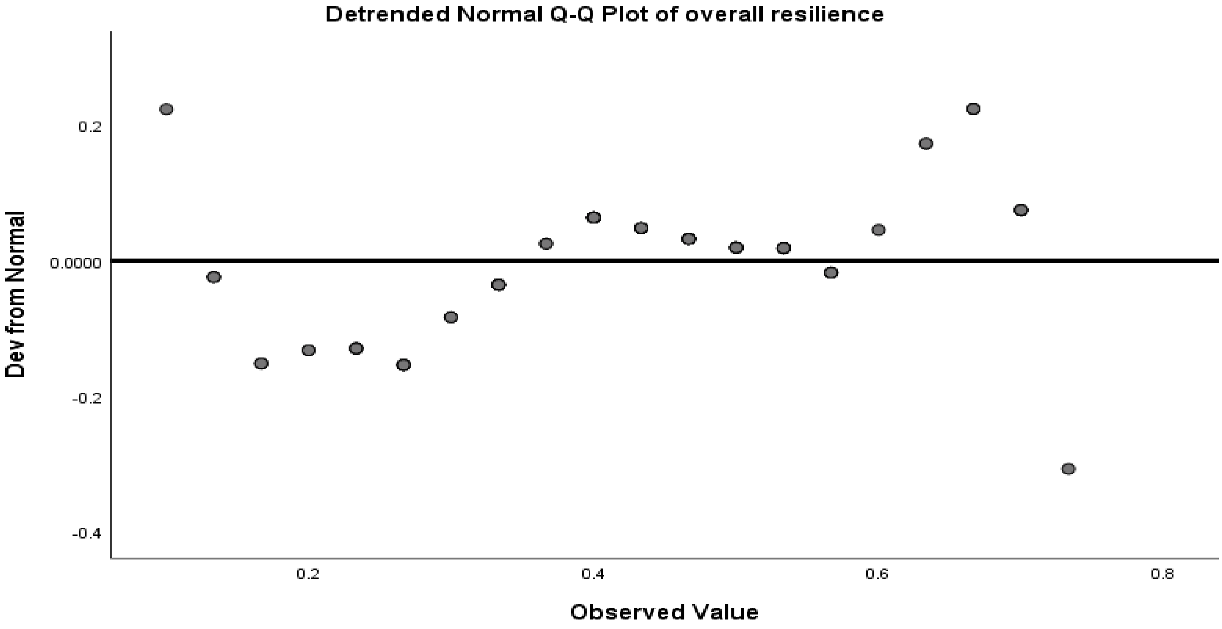

Normal Q-Q Plot of Human Resilience (0,1)
Expected Normal
3
2
1
0
-1
-2
-3
-0.2
0.0
0.2
0.4
0.6
0.8
1.0
1.2
Observed Value


Detrended Normal Q-Q Plot of Human Resilience (0,1)
Dev from Normal
0.3
0.2
0.1
0.0000
-0.1
-0.2
0.0
0.2
0.4
0.6
0.8
1.0
Observed Value

APPENDIX B-7: OVERALL RESILIENCE – HISTOGRAM AND NORMAL PLOTS






Detrended Normal Q-Q Plot of overall resilience
Dev from Normal
0.2
0.0000
-0.2
-0.4
0.2
0.4
0.6
0.8
Observed Value

APPENDIX B-8: NON-SIGNIFICANT TEST (BUILDING RESILIENCE SCALE)

Tests of Between-Subjects Effects

Dependent Variable: Building Resilience (0,1)*

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Noncent. Parameter	C
Corrected Model	.043[a]	10	.004	.381	.948	3.812	
Intercept	.085	1	.085	7.627	.008	7.627	
Number of storey	.000	1	.000	.041	.840	.041	
Doors	.000	1	.000	.025	.875	.025	
Windows	.001	1	.001	.096	.758	.096	
Bathroom (washroom)	.006	1	.006	.528	.471	.528	
Flood risk awareness	.006	1	.006	.502	.482	.502	
Flood depth	.004	1	.004	.327	.570	.327	
Flood insurance type	.009	1	.009	.778	.382	.778	
Length of years insured	.000	1	.000	.009	.925	.009	
Claim or no claim	.010	1	.010	.856	.360	.856	
Number of claims made	.001	1	.001	.066	.799	.066	
Error	.502	45	.011				
Total	16.222	56					
Corrected Total	.545	55					

a. R Squared = .078 (Adjusted R Squared = -.127)

b. Computed using alpha = .05

APPENDIX B-9: NON-SIGNIFICANT TEST (HUMAN RESILIENCE SCALE)

Tests of Between-Subjects Effects

Dependent Variable: Human Resilience (0,1)

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Noncent. Parameter	C
Corrected Model	.921[a]	12	.077	1.699	.086	20.385	
Intercept	.164	1	.164	3.624	.061	3.624	
Age	.289	1	.289	6.384	.014	6.384	
Household income	.002	1	.002	.034	.855	.034	

Educational qualification	.002	1	.002	.046	.831	.046
Household size	.002	1	.002	.049	.825	.049
Presence of pets	.001	1	.001	.011	.915	.011
Presence of elderly ones	.089	1	.089	1.973	.165	1.973
Flood experience	.048	1	.048	1.053	.308	1.053
Source of flooding	.124	1	.124	2.748	.102	2.748
Flood risk awareness	.063	1	.063	1.386	.243	1.386
Flood risk level	.146	1	.146	3.235	.076	3.235
Flood depth	.015	1	.015	.339	.563	.339
Length of years insured	.008	1	.008	.187	.667	.187
Error	3.163	70	.045			
Total	23.971	83				
Corrected Total	4.085	82				

a. R Squared = .226 (Adjusted R Squared = .093)

b. Computed using alpha = .05

APPENDIX B-10: BUILDING RESILIENCE COEFFICIENTS

Coefficients[a]

Building Resilience Model	Unstandardized Coefficients B	Unstandardized Coefficients Std. Error	Standardized Coefficients Beta	t	Sig.
(Constant)	.309	.038		8.140	.000
detached	-.057	.018	-.285	-3.135	.002
No cellar/basement	.067	.020	.312	3.304	.001
Cavity wall	.047	.020	.227	2.360	.021
Concrete ground floor	.062	.018	.327	3.500	.001
Plastic kitchen unit	.057	.025	.224	2.306	.024
No flood experience	-.037	.018	-.191	-2.104	.039
Surface water flood	.086	.024	.428	3.590	.001
Ground water flood	.076	.023	.399	3.343	.001
Very low flood risk	.097	.028	.457	3.418	.001
Low flood risk	.066	.028	.315	2.377	.020
Medium flood risk	.058	.027	.278	2.184	.032

a. Dependent Variable: Building Resilience (0,1)

APPENDIX B-11: HUMAN RESILIENCE COEFFICIENTS

Coefficients[a]

Human Resilience Model	Unstandardized Coefficients B	Unstandardized Coefficients Std. Error	Standardized Coefficients Beta	t	Sig.
(Constant)	.547	.049		10.713	.000
Gender	-.050	.039	-.220	-2.568	.013
Property Ownership	.079	.077	-.200	-2.568	.044

	One child	-.055	.056	-.162	-1.959	.050
	Presence of disabled person	.055	.049	.191	2.229	.029
	less than 6years	-.163	.059	-.664	-5.529	.000
	less than 11years	-.127	.071	-.373	-3.555	.001
	less than 16years	-.114	.071	-.348	-3.212	.002
	less than 21years	-.099	.077	-.301	-2.544	.013
	less than 26years	-.075	.069	-.245	-2.168	.034
	No insurance	-.165	.074	-.466	-4.468	.000
	Content insurance only	-.145	.118	-.245	-2.459	.017
	Insurance claim made	.078	.046	.314	3.369	.001

a. Dependent Variable: Human Resilience (0,1)

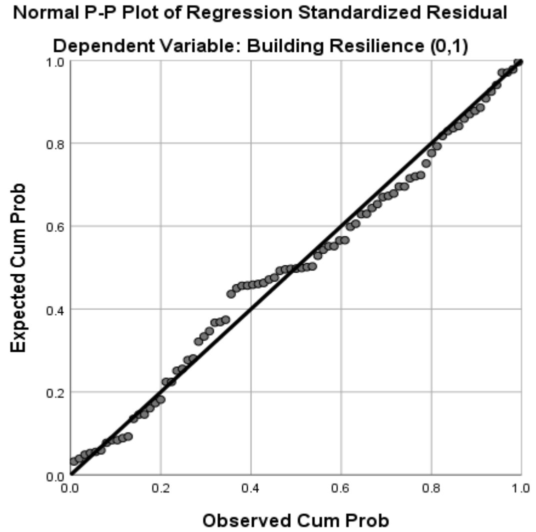
APPENDIX B-12: OVERALL RESILIENCE – VIF AND TOLERANCE

Coefficients[a]

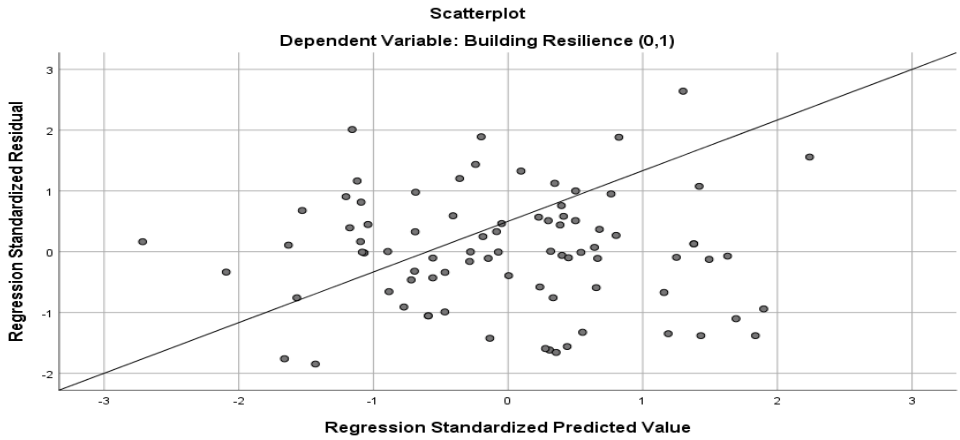
Model		Unstandardized Coefficients		Standardized Coefficients			Corr	
		B	Std. Error	Beta	t	Sig.	Zero-order	P
1	(Constant)	.244	.072		6.081	.000		
	Human Resilience (0,1)	.276	.058	.350	3.413	.001	.294	
	Building Resilience (0,1)	.315	.135	.316	3.081	.003	.254	

a. Dependent Variable: Overall Resilience

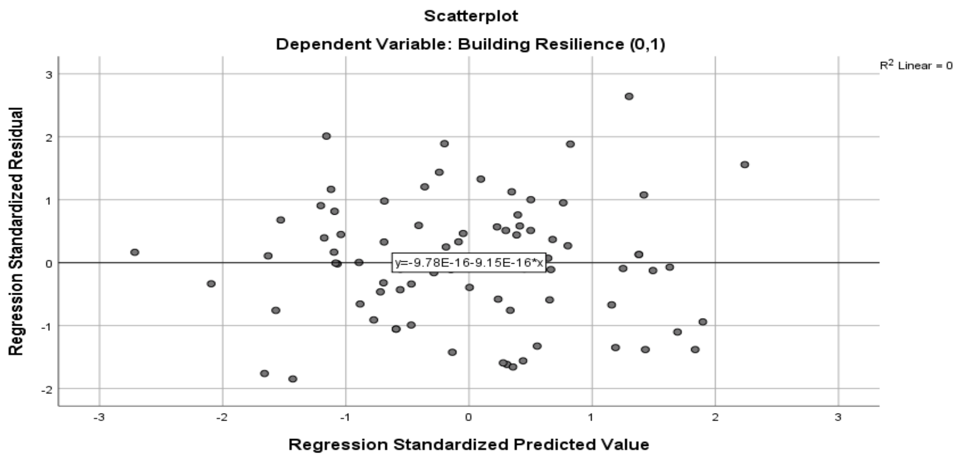
APPENDIX B-13: BUILDING RESILIENCE – SCATTER PLOTS



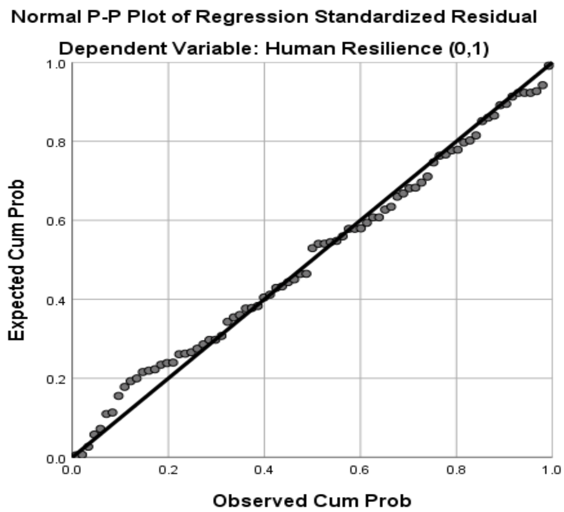
The normal P-P regression standardised residual



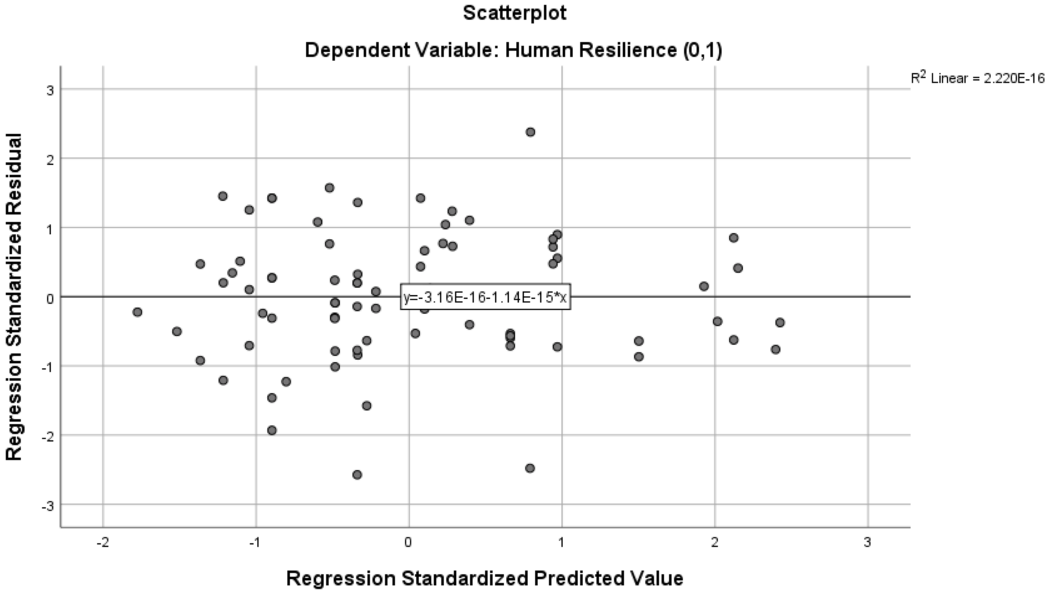
Scatter plot



APPENDIX B-14: HUMAN RESILIENCE – SCATTER PLOTS



The normal P-P regression standardised residual



Scatter plots

APPENDIX B-15: CORRELATION MATRIX – BUILDING CHARACTERISTICS

Correlations

		property type	number of storeys	Cellar/ basement	property wall type	property ground floor type	doors	windows
property type	Pearson Correlation	1	.274*	-.062	-.032	-.206	.206	.066
	Sig. (2-tailed)		.012	.575	.777	.062	.062	.551
	N	83	83	83	83	83	83	83
number of storeys	Pearson Correlation	.274*	1	-.410**	.303**	-.156	.186	.245*
	Sig. (2-tailed)	.012		.000	.005	.159	.093	.026
	N	83	83	83	83	83	83	83
Cellar/basement	Pearson Correlation	-.062	-.410**	1	-.345**	.230*	-.234*	-.171
	Sig. (2-tailed)	.575	.000		.001	.036	.033	.123
	N	83	83	83	83	83	83	83
property wall type	Pearson Correlation	-.032	.303**	-.345**	1	-.158	.345**	.229*
	Sig. (2-tailed)	.777	.005	.001		.154	.001	.037
	N	83	83	83	83	83	83	83
property ground floor type	Pearson Correlation	-.206	-.156	.230*	-.158	1	-.142	-.111
	Sig. (2-tailed)	.062	.159	.036	.154		.202	.316
	N	83	83	83	83	83	83	83
doors	Pearson Correlation	.206	.186	-.234*	.345**	-.142	1	.718**
	Sig. (2-tailed)	.062	.093	.033	.001	.202		.000
	N	83	83	83	83	83	83	83
windows	Pearson Correlation	.066	.245*	-.171	.229*	-.111	.718**	1
	Sig. (2-tailed)	.551	.026	.123	.037	.316	.000	
	N	83	83	83	83	83	83	83
kitchen unit	Pearson Correlation	.143	-.346**	.202	-.251*	-.217*	.040	.009
	Sig. (2-tailed)	.198	.001	.067	.022	.048	.721	.938

	N	83	83	83	83	83	83	83
bathroom (washroom) unit	Pearson Correlation	.058	.174	-.168	.106	-.077	.049	-.078
	Sig. (2-tailed)	.605	.115	.129	.339	.488	.662	.481
	N	83	83	83	83	83	83	83

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

APPENDIX B-16: CORRELATION MATRIX – FLOOD CHARACTERISTICS

Correlations

			Flood experience	Flood source	Flood risk awareness
Spearman's rho	Flood experience	Correlation Coefficient	1.000	-.067	.113
		Sig. (2-tailed)	.	.549	.307
		N	83	83	83
	Flood source	Correlation Coefficient	-.067	1.000	-.079
		Sig. (2-tailed)	.549	.	.476
		N	83	83	83
	Flood risk awareness	Correlation Coefficient	.113	-.079	1.000
		Sig. (2-tailed)	.307	.476	.
		N	83	83	83
	Flood risk level	Correlation Coefficient	-.172	-.210	-.228*
		Sig. (2-tailed)	.120	.057	.038
		N	83	83	83
	Flood depth	Correlation Coefficient	.071	-.046	-.095
		Sig. (2-tailed)	.526	.678	.392
		N	83	83	83

*. Correlation is significant at the 0.05 level (2-tailed).

APPENDIX B-17: CORRELATION MATRIX – SOCIO-ECONOMIC FACTORS

Correlations

			Age	Gender	Property ownership	Annual household income	Highest qualification	Household size (persons)	Number of children	Pr of p
Spearman's rho	Age	Correlation Coefficient	1.000	-.098	-.232*	-.239*	-.391**	-.518**	-.194	
		Sig. (2-tailed)	.	.376	.035	.029	.000	.000	.079	
		N	83	83	83	83	83	83	83	
	Gender	Correlation Coefficient	-.098	1.000	.149	.146	-.127	.208	.087	
		Sig. (2-tailed)	.376	.	.180	.186	.254	.059	.436	
		N	83	83	83	83	83	83	83	
	Property ownership	Correlation Coefficient	-.232*	.149	1.000	.216*	-.006	.262*	.148	
		Sig. (2-tailed)	.035	.180	.	.050	.960	.017	.183	
		N	83	83	83	83	83	83	83	
	Annual household income	Correlation Coefficient	-.239*	.146	.216*	1.000	.162	.294**	.257*	
		Sig. (2-tailed)	.029	.186	.050	.	.144	.007	.019	
		N	83	83	83	83	83	83	83	
	Highest qualification	Correlation Coefficient	-.391**	-.127	-.006	.162	1.000	.189	.056	
		Sig. (2-tailed)	.000	.254	.960	.144	.	.087	.618	
		N	83	83	83	83	83	83	83	
	Household size (persons)	Correlation Coefficient	-.518**	.208	.262*	.294**	.189	1.000	.280*	
		Sig. (2-tailed)	.000	.059	.017	.007	.087	.	.010	
		N	83	83	83	83	83	83	83	
	Number of children less than 10?	Correlation Coefficient	-.194	.087	.148	.257*	.056	.280*	1.000	
		Sig. (2-tailed)	.079	.436	.183	.019	.618	.010	.	
		N	83	83	83	83	83	83	83	

Presence of disabled person	Correlation Coefficient	.135	.128	.030	-.100	-.090	-.125	.072
	Sig. (2-tailed)	.224	.247	.789	.367	.418	.260	.516
	N	83	83	83	83	83	83	83
Number of pets	Correlation Coefficient	-.156	-.059	.004	.091	.069	.092	.086
	Sig. (2-tailed)	.158	.597	.971	.414	.534	.409	.442
	N	83	83	83	83	83	83	83
Household above 69 years	Correlation Coefficient	.639**	.105	-.066	-.224*	-.518**	-.333**	-.153
	Sig. (2-tailed)	.000	.346	.551	.042	.000	.002	.168
	N	83	83	83	83	83	83	83
Time in residence	Correlation Coefficient	.464**	.023	.053	-.109	-.327**	-.314**	-.134
	Sig. (2-tailed)	.000	.835	.636	.327	.003	.004	.228
	N	83	83	83	83	83	83	83

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

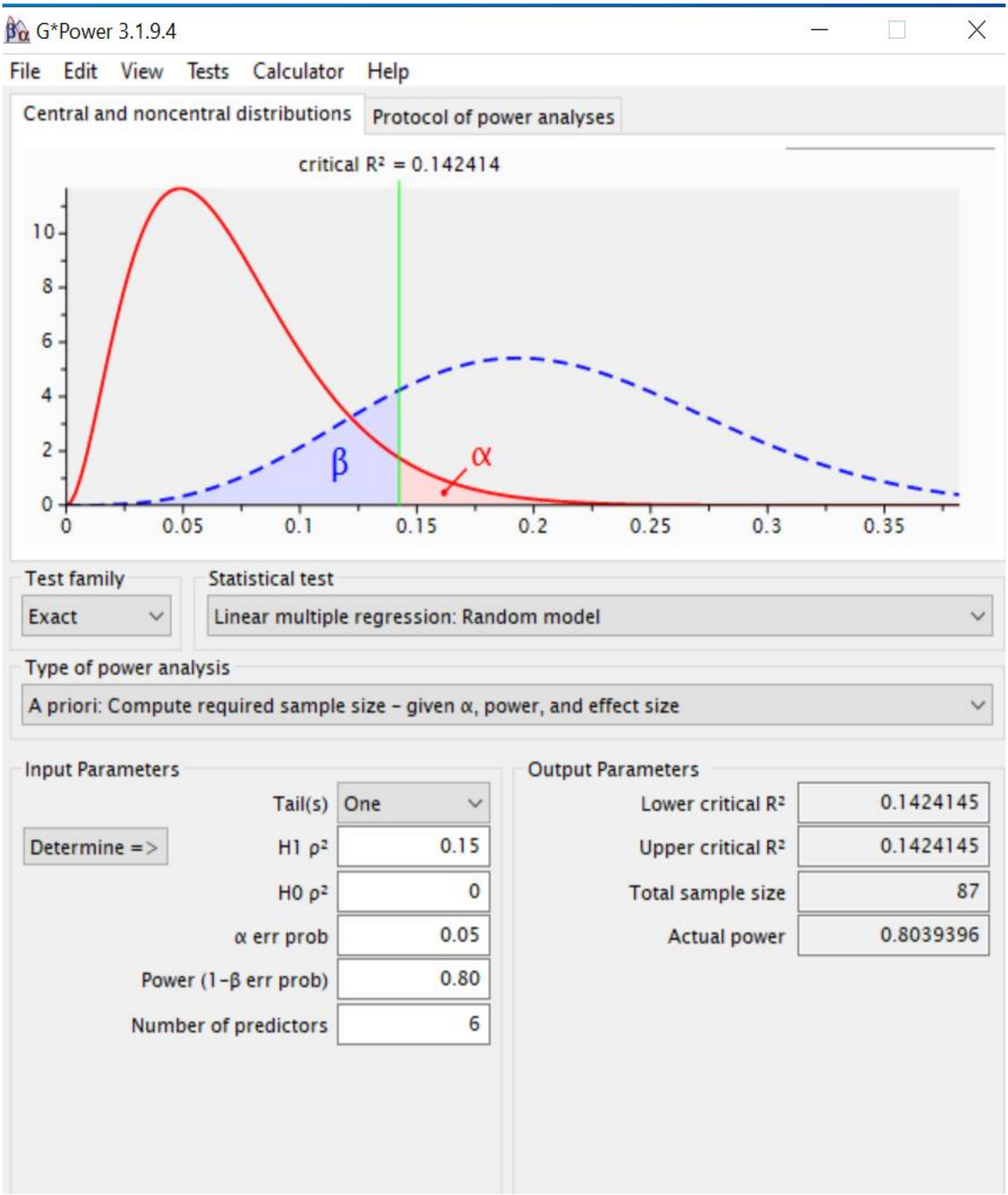
APPENDIX B-18: CORRELATION MATRIX – FLOOD INSURANCE AND CLAIM

Correlations

			Flood insurance type	Length of years insured	C
Spearman's rho	Flood insurance type	Correlation Coefficient	1.000	.145	
		Sig. (2-tailed)	.	.190	
		N	83	83	
	Length of years insured	Correlation Coefficient	.145	1.000	
		Sig. (2-tailed)	.190	.	
		N	83	83	
	Claims made	Correlation Coefficient	-.064	.278*	
		Sig. (2-tailed)	.641	.038	
		N	56	56	

*. Correlation is significant at the 0.05 level (2-tailed).

APPENDIX B-19: G*POWER OUTPUT FOR SAMPLE SIZE ESTIMATION



APPENDIX C-1: LIST OF PUBLICATIONS

Journal Papers and Book Chapter

1. Adedeji, T. J., Proverbs, D. G., Oladokun, V. O. and Xiao, H., 2019. Making Homes More Resilient to Flooding: A New Hybrid Approach. In: F. E. Noroozinejad, et al. eds. Resilient Structures and Infrastructure. Singapore: Springer, pp. 159-176.
2. Adedeji, T. J., Proverbs, D. G., Xiao, H. and Oladokun, V. O., 2018. Towards a Conceptual Framework for Property Level Flood Resilience. International Journal of Safety and Security Engineering, 8(4), pp. 493 - 504.
3. Adedeji, T. J., Proverbs, D. G., Xiao, H. and Oladokun, V. O., 2019. The application of the flood resilience circle to the city of Birmingham. ARCOM Doctoral Workshop- Industry 4.0 and Disaster Resilience in the Built Environment, 25th April 2019 at Northumbria University: Newcastle Upon Tyne, UK.
4. Adedeji, T.J., Proverbs, D. G., Xiao, H., Cobbing, P. and Oladokun, V. O., 2019. Making Birmingham a Flood Resilient City: Challenges and Opportunities. Water, 11(8), p. 1699.
5. Proverbs, D. G., Oladokun, V. O., Xiao, H. and Adedeji, T. J., 2018. A Conceptual Model for Measuring Flood Resilience at the Individual Property Level. London, Royal Institution of Chartered Surveyors (RICS).
6. Adedeji, T. J., Proverbs, D. G., Xiao, H. and Oladokun, V. O., (in view). Property Level Flood Resilience. In: J. Lamond, et al. eds. Research Handbook on Flood Risk Management. Edward Elgar Publishing.

APPENDIX C-2: LIST OF ABSTRACTS OF JOURNAL AND CONFERENCE PAPERS PUBLISHED DURING THE RESEARCH PROGRAMME

A CONCEPTUAL MODEL FOR MEASURING FLOOD RESILIENCE AT THE INDIVIDUAL PROPERTY LEVEL

RICS COBRA 2018 (The Construction, Building and Real Estate Research Conference of the Royal Institution of Chartered Surveyors) 23 – 24 April 2018 RICS HQ, London, UK

The risks of flooding have been ever present for buildings located in flood plains or close to coastal areas. Surface water flooding and flash flooding in urban areas means that buildings located away from flood plains and coastal areas may also be exposed to flooding. While some of these buildings have developed a level of resilience over time, many have very poor, inadequate or lack any level of resilience to floods. This raises the questions as to what level of resilience is appropriate and how best to quantify flood resilience at the level of the individual property. There exists a lack of a general measurement framework for determining the level of flood resilience for an individual property. This research presents a conceptual model for measuring flood resilience at the individual property level adopting a systems dynamic approach. The concepts underpinning the model and the make-up of the approach are discussed, including the identification of components and the development of mathematical models. A systematic review of the available literature is described to identify resilience measures and the capacities that define them. This conceptual model has the potential to provide an evidence based template to inform stakeholders on the level of resilience present within a property and thus enhance the quality of decision making and investment in property level flood risk adaptation measures. Further research is recommended to develop and test the conceptual framework presented herein.

TOWARDS A CONCEPTUAL FRAMEWORK FOR PROPERTY LEVEL FLOOD RESILIENCE

International Journal of Safety and Security Engineering, Vol. 8, No. 4 (2018) 493–504

Resilience is a multifaceted field of study that has been addressed by different disciplines and has been the subject of extensive research. Despite this vast body of research, there is no agreement on a single definition among researchers. Resilience in the context of flooding has become a major focus of flood risk management policy and reflected in current strategy to mitigate the effects of flooding. Furthermore, in recent times, increased attention has been given to property level resilience as part of an integrated approach to flood risk management. Despite this focus on resilience to flooding, there lacks a single definition and consequently, any effective means to quantify and measure resilience at the level of the individual property. This study aims to review and synthesize the concepts of resilience applied in different fields, in order to propose a resilience definition in the context of property level flood resilience. A framework for conceptualising flood resilience in residential property is developed which indicates the associated components and variables. The framework has the potential to be used by a range of key stakeholders in helping to understand current levels of property level resilience and in deciding what interventions might be best considered to improve resilience.

THE APPLICATION OF THE FLOOD RESILIENCE CIRCLE TO THE CITY OF BIRMINGHAM

ARCOM Doctoral Workshop (Industry 4.0 and Disaster Resilience in the Built Environment)

Thursday, 25th April 2019 Northumbria University, Newcastle upon Tyne, UK

Background: Like many cities, Birmingham is exposed to a range of different flood risks from a variety of sources and has experienced a number of significant flooding events in the past two decades. The impacts of these flood events include physical damage to critical infrastructure, buildings and homes; commercial, industrial and residential contents; as well as significant losses caused by business interruption and general disruption to communities. Human losses are also experienced in the form of psychological harm, distress and, in extreme cases, fatalities. There is a growing concern that the current redevelopment and regeneration taking place in the city, coupled with more extreme weather events, will exacerbate these events in the future.

Purpose and Originality: In recognising that flooding cannot be prevented and in line with government policy towards 'living with water', the concept of resilience has become vital for city planners and decision makers to adopt a more managed approach to flood risk. This study aims at identifying the current challenges and opportunities of managing flood risk in the city of Birmingham, drawing on a desk based account of current flood risk management (FRM) practice and diagnostic evidence.

Methodology: This interrogation adopts the use of a 'flood resilience circle model' to help inform the process and consider and address the challenges in a methodological manner aligned to an integrated approach to flood risk management.

Findings: Elements that make up the key FRM stages of prevention, preparation, response and recovery are described. The findings will be of interest to policy makers and decision makers on how to address current weaknesses in FRM practices towards the prospect of a sustainable approach that improves the resilience of the city and delivers multiple benefits.

MAKING BIRMINGHAM A FLOOD RESILIENT CITY: CHALLENGES AND OPPORTUNITIES

Water 2019, 11, 1699 p1-17

The city of Birmingham has experienced a number of significant flooding events in the past two decades. The impacts of these flood events include physical damage to critical infrastructure, as well as significant losses caused by business interruption and general disruption to communities. Human losses and impacts can be life changing. This study identifies the current challenges and opportunities of managing flood risk in the city of Birmingham, drawing on a desk-based account of current flood risk management (FRM) practice and diagnostic evidence. This interrogation adopts the use of a ‘flood resilience circle model’ to consider ways to address the challenges in a methodological manner aligned to an integrated approach to flood risk management. Solutions aligned to the key FRM stages of prevention, preparation, response and recovery are provided. The findings will be of interest to policy makers and decision makers on how to address current weaknesses in FRM practices towards the prospect of a sustainable approach that improves the resilience of the city and delivers multiple benefits. Recommendations made include the adoption of a blue-green systems approach, the development of a new communication strategy aligned to motivating behaviour change, and improved flood forecasting especially for surface water flooding.

APPENDIX

D: OVERVIEW OF EXISTING RESILIENCE FRAMEWORK

SN	ORGANISATION/ AUTHOR	FRAMEWORK	OVERVIEW	LIMITATION
1	Action Research for Community Action in Bangladesh	ARCAB Monitoring and Evaluation Framework Paper	It presents key indicators to track changes in climate change vulnerability and adaptive capacity at the community level. It identifies indicators that track changes in adaptive capacity (e.g. improvements in assets, livelihoods and awareness); to track changes in institutional capacity (e.g. number of local level institutions with the capacity to develop and deliver adaptation services to the climate-vulnerable poor; access to regular and updated sources of weather and climate information). The framework also aims to garner evidence that people are adapting by tracking the use of climate information and behaviour change. As such, it aims to measure the effectiveness of resilience programs.	Model is at community level and does not fully capture the actors of individual property
2	Arup	City Resilience Index	The City Resilience Framework provides a holistic approach to diagnosing the resilience of a city, structured around four dimensions (leadership and strategy, health and wellbeing, economy and society, infrastructure and environment) and 12 goals (e.g. diverse livelihoods, social stability and continuity of critical services) that the framework argues are critical for the resilience of cities. This has informed the structure of the City Resilience Index that includes a set of 52 indicators that stack up against the 12 goals (e.g. indicators 'for diverse livelihoods' include 'the degree of relevant skills and training'). This is a highly operational approach that lends itself to measuring the resilience of cities to diverse shocks and stresses.	Model is at city level, a much wider scale of measurement, and does not comprehensively consider the features of individual property, in terms of building and its components.
3	Barret, C., Constas, M.A	Toward a Theory of Resilience for International Development Applications	This framework advances a theory of resilience as it applies to the challenges of international development. The conceptualization it advances for development resilience focuses on the stochastic dynamics of individual and collective human well-being, especially on the avoidance of and escape from chronic poverty over time in the face of myriad stressors and shocks. It outlines various interventions that can support individuals or households to move above a resilience threshold in spite of their risk exposure. Some of these includes: material support (cash transfers, education, health care), risk reduction (disease resistant seeds, insurance programmes,	The framework cannot be used to determine the resilience of the physical component (building)

			improved police protection), and transformative change (changes in cultural, economic, and socio-political institutions that mediate risks).	
4	Béné, C.	Towards a Quantifiable Measure of Resilience	The argument put forward by this framework is that the 'costs of resilience' (that is, the different ex ante and ex post investments, losses, sacrifices, and costs that people have to undertake at individual and collective levels to 'get through' a shock or an adverse event) provide an appropriate and independent metric to measure resilience across scales and dimensions. The framework shows how the independent nature of this metric offers an explanatory power that can be used to infer, in a testable and rigorous manner potential, causalities between the metric and household and/or community characteristics.	It focuses more on the human side of resilience but did not capture the physical components of the building resilience.
5	Béné, C., Frankenberger, T., and Nelson, S.	Design, Monitoring, and Evaluation of Resilience Interventions: Conceptual and Empirical Considerations	This working paper intends to support the development of robust monitoring and evaluation frameworks for resilience. The paper proposes a logical framework that incorporates unique, resilience specific components of M&E into a conventional logframe. This includes intermediate outcome indicators (which are conceptualized as absorptive, adaptive, and transformative capacities), outcome indicators (which include household coping strategies or the use of early warning systems), and impact indicators (which can be chosen from a variety of wellbeing indicators). The last additional component to monitor is the incidence of shocks and stresses, which should be measured at national levels, at the local level, and at the household level.	The physical components of household resilience (building) not featured in the research
6	Bizikova, L., Tyler, S., Moench, M., Keller, M., Echeverria, D	Climate Resilience and Food Security in Central America: A Practical Framework	This article introduces and tests a method of assessing the resilience of a food system which investigates the food system at various scales. At the household level, the framework considers the resilience of household utilization and access to food. At higher scales, the framework tracks the resilience of broader food system dimensions, such as livelihood resources and supporting services for food production. Finally, the framework includes capacities and institutional factors that enable supporting institutions and policies to operate effectively.	It deals with resilience of a food system and not to flood risk. Therefore, the features of the framework is inadequate to capture the features of the PFR.
7	Cabell, J. and Oelofse, M.	An Indicator Framework for Assessing Agroecosystem Resilience	This framework delineates behavior-based indicators of resilience within agro ecosystems. Based on a review of relevant literature, it presents and discusses an index of 13 such indicators (e.g. socially self-organised, ecologically self-regulated,	The framework is suitable for agro-ecosystems and insufficient to deal

			response diversity, optimally redundant) which, when identified in an agro ecosystem, suggest that it is resilient and endowed with the capacity for adaptation and transformation. Absence of these indicators identifies points of intervention for managers and stakeholders to build resilience where there is vulnerability.	with the features of PFR.
8	Christian Aid	Resilience Framework: Christian Aid's Approach	Christian Aid's framework aims to improve integration of different program areas to create longer-term impact. The framework orients Christian Aid's approach towards strengthening resilience capacities across seven areas: i) shifting power relations; ii) climate resilient agriculture and natural resource management; iii) inclusive markets development; iv) community health; v) disaster risk reduction; vi) humanitarian response; vii) peace-building. The approach advocates for macro-context analysis of power, vulnerabilities, and conflicts. At the community level, the framework advocates for a power analysis focuses on risks, vulnerabilities, and capacities. The framework helps plan interventions and integrate ongoing work.	The framework examines resilience at a larger scale not providing an in-depth analysis into the components of the PFR.
9	Cutter, S., Barnes, L., Berry, M., Burton, C. Evans, E., Tate, E., Webb, J.	A Place-based model for understanding community resilience to natural disasters	This framework proposes a Disaster Resilience of Place (DROP) model to improve comparative assessments of disaster resilience at the local or community level. Drawing from an overview of resilience and vulnerability frameworks and integrating the literatures, the framework proposes various dimensions of community resilience, from ecological, to social, economic, institutional, infrastructure, and 'community competence', which includes psychosocial and cognitive indicators such as risk perception, occurrence of psychopathologies, and satisfaction with quality of life.	The framework does not allow an indepth analysis of the physical components of the building resilience though it captures the human resilience since it largely focuses on social resilience.
10	DFID	Defining Disaster Resilience	This framework is intended to inform DFID's work on resilience and stems from the domain of disaster risk reduction. As such it is aimed at informing resilience initiatives as opposed to only diagnosing the levels of resilience in a system. This framework is comprised of four parts: context (e.g., region/institution), disturbance (e.g., natural hazard, conflict), capacity to deal with disturbance (exposure, sensitivity and adaptive capacity) and reaction to disturbance (survive, cope, recover, learn, transform).	The framework examines resilience at a larger scale not providing an in-depth analysis into the components of the PFR.
11	Food and Agricultural	Resilience Index Measurement	This framework presents the FAO's latest thinking on resilience measurement and adheres to the idea of	It assesses the level of resilience in food

	Organization	and Analysis Model (RIMA)	resilience comprising of absorptive, adaptive and transformative capacity. It argues that resilience is a function of physical dimensions (income and food access; access to basic services; agricultural assets; non-agricultural assets; agricultural practice and technology; social safety nets; climate change; enabling institutional environment;) and capacity dimensions (sensitivity; adaptive capacity). This framework lends itself to evaluating resilience initiatives and diagnosing the level of resilience in a system.	and agricultural system and insufficient to deal with the features of PFR.
12	Food and Agricultural Organization	Self-evaluation and Holistic Assessment of Climate Resilience of Farmers and Pastoralists (SHARP)	The Self-evaluation and Holistic Assessment of climate Resilience of farmers and Pastoralists (SHARP) comprises a base assessment of the current farmer/pastoralist situation through self-assessment with farming communities; a gap analysis of climate change resilience weaknesses based on output of Phase 1 and available data on Climate Change in the relevant region; and proposes specific strategies for each situation. At the core of this approach is a set of 13 indicators for assessing the resilience of agro-ecosystems that cover the degree of social self-organisation, ecological self-regulation, connectedness etc. As such, this is a highly applied approach for diagnosing the resilience of a system.	It assesses the level of resilience in food and agricultural system and insufficient to deal with the features of PFR.
13	Food Security Information Network	Resilience Measurement Principles	This seminal paper on resilience measurement defines resilience and identifies ten principles for designing resilience measurement approaches. Although the principles were elaborated in regards to food security interventions, the principles and technical guidelines are widely applicable to other resilience measurement approaches. The principles cover the following topics: resilience as a capacity that should be indexed to a development outcome; the role of subjective states and qualitative indicators; systems and complex causality; shock and stressor specificity; desirable and undesirable equilibria; detecting volatility; measuring multiple scale and multi-level interactions; the timing of data collection and measurement; connections between resilience and vulnerability; and the ability to explain heterogeneous effects.	Framework focuses on food security intervention and does not feature the capacity to evaluate physical components of the building resilience.
14	Food Security Information Network	A Common Analytical Model for Resilience Measurement	This paper builds on FSIN's Resilience Measurement Principles by proposing a common analytical model for resilience measurement. The key analytical elements components include assumptions about	Framework focuses on food security intervention and does not feature the

			resilience capacities, the causal framework, what resilience specific indicators are needed, the expected rate of change, the types of data collection tools, and the estimation procedures involved in resilience measurement. The paper describes estimation models that could be used to assess the impact of resilience, highlights the importance of quantitative and qualitative methods and indicators, and proposes a construction of resilience capacity measures using categories of indicators.	capacity to evaluate physical components of the building resilience.
15	Frankenberger, T. & Nelson, S.	Background Paper for the Expert Consultation on Resilience Measurement for Food Security	This paper presents a resilience conceptual framework that integrates a livelihoods approach, disaster risk reduction, and climate change adaptation approach to address underlying causes of vulnerability. The framework establishes contextual factors that affect adaptive capacity, defines a unit of analysis (resilience of what or whom), examines adaptive capacity (which is defined as the resources that people have to deal with disturbances, including livelihood assets, institutions, and strategies), and tracks resilience and vulnerability pathways which lead to positive or negative livelihood outcomes. Importantly, the framework includes specific disturbances and mentions the exposure and sensitivity to the population to these shocks or stresses. The assessment is designed to identify leverage points for a theory of change and help develop an appropriate resilience intervention.	Framework focuses on food security intervention and does not feature the capacity to evaluate physical components of the building resilience.
16	Global Environmental Facility	Resilience, Adaptation Pathways, and Transformation Assessment Framework (RAPTA): from theory to application	RAPTA is a tool developed to support effective planning by embedding to the concepts of resilience, adaptation, and transformation at the heart of any intervention. Though it is oriented towards agroecosystem resilience, the framework is flexible and provides step-bystep guidelines to characterize a system, identify important variables, analyze the current and the desired future state of that system. The tool brings together key stakeholders to assess the system and integrates a theory of change for improving resilience to help inform decisions and interventions. The framework also explicitly intends to be used in conjunction with existing frameworks.	The framework is suitable for agro-ecosystems and insufficient to deal with the features of PFR.
17	ICF	Assessing the Impact of ICF Programmes on Household	This framework is aimed at enabling projects to report against Key Performance Indicator 14 (numbers of people with improved resilience as a result of project support) of the International Climate Fund. The methodology is based on the identification of context-	The framework examines resilience at a larger scale not providing an in-depth analysis into the

		and Community Resilience to Climate Variability and Climate Change	specific indicators by individual projects, informed but not prescribed by a consideration of a number of dimensions of resilience where this is appropriate and helpful. These dimensions are (i) assets, (ii) access to services, (iii) adaptive capacity, (iv) income and food access, (v) safety nets, (vi) livelihood viability, (vii) institutional and governance contexts, (viii) natural and built infrastructure, and (ix) personal attributes.	components of the PFR.
18	IFRC	IFRC Framework for Community Resilience	The framework for community resilience provides a systematic approach to measuring resilience at the community level. The framework suggests that at the community level building resilience entails improving the knowledge and health of communities; strengthening the social cohesion of communities; developing well-maintained and accessible infrastructure and services in communities; providing economic opportunities; managing natural assets and strengthening the connectedness of communities.	Model is at community level and does not fully capture the actors of individual property
19	IIED	Tracking Adaptation and Measuring Development (TAMD)	TAMD is an approach to the evaluation of adaptation 'success' that combines assessment of how well climate risks to development are managed by institutions ('upstream' indicators), with assessment of how successful adaptation interventions are in reducing vulnerability and keeping development 'on track' in the face of changing climate risks ('downstream' indicators). Examples of upstream indicators include tracking 'how well national systems conduct climate risk management functions' and the degree to which climate and monitoring and evaluation information is employed in policy and programme design. The aim here is to provide a framework that defines indicators' categories or 'domains' that can be tailored to specific contexts, rather than a 'toolkit' for monitoring and evaluation that prescribes particular indicators.	The framework is designed to monitor and evaluate climate change adaptation and do not designed to measure property flood resilience.
20	International Institute for Sustainable Development	Climate Resilience and Food Security: A Framework for Planning and Monitoring	This framework presents approaches to understanding and monitoring food system resilience to climate change. Based on an overview of existing approaches to understanding food systems as well as climate resilience, the paper describes a new framework designed to support the analysis of community-level food security in the context of climate shocks and stresses, as well as of resilience of food systems at larger scales. By analyzing food access, utilization, and availability at the household level in conjunction	Framework focuses on food security intervention and does not feature the capacity to evaluate physical components of the building resilience.

			with considering important variables related to ecosystem health, infrastructure, services, and institutions at the system level, this framework aims to provide a cross-scalar picture of resilience and food security.	
21	ISET	Planning for Urban Climate Resilience: Framework and Examples from the Asian Cities Climate Change Resilience Network	This is a conceptual framework that emphasizes the role of systems and social agents (both internal and external) for building resilience in cities to shocks and stresses induced by climate change. Strengthening resilience, as described in the framework, includes building the capacity of agents to visualize and act, organize and reorganize, and learn; and the performance of systems with enhanced flexibility and diversity, redundancy and modularity; so that they fail safely rather than catastrophically; the third pillar of the framework is focussed on institutions that include rights/ entitlements, decision-making, information and the application of new knowledge. The framework underlines that to strengthen urban resilience, iterative processes of diagnosing vulnerability, planning, and implementation are required.	It focuses on resilience at a larger scale, that is, cities resilience to shock, therefore, it fails to fully capture the components that make up the PFR.
22	Longstaff, P. Armstrong, N. Perrin, K. May, W. Matthew P and Hidek, A	Building Resilient Communities: A Preliminary Framework for Assessment	This is a preliminary conceptual framework for assessing community resilience. The framework is not specific to particular shocks and identifies core attributes of resilience systems that include resource performance, resource diversity, resource redundancy, institutional memory, innovative learning and connectedness. It identifies adaptive capacity as key element of resilience and is useful for gauging the degree to which a system is resilient. Five key community subsystems (ecological, economic, physical infrastructure, civil society, and governance) that need to be considered during the assessment process are also identified.	Model is at community level and does not fully capture the actors of individual property
23	Lutheran World Relief	Resilience Assessment Benchmarking and Impact Toolkit (RABIT)	This toolkit offers a methodology for understanding community resilience, drawing on resilience attributes of rapidity, scale, redundancy, learning, self-organization, robustness, equality, diversity and flexibility to understand the relative strengths and weaknesses of resilience in a particular community. The tool intends to identify priorities for action, and was trialed in Uganda to evaluate the contribution of ICT to resilience.	Model is at community level and does not fully capture the actors of individual property. Mostly, the components of the building resilience.
24	Mayunga, J.	Understanding and Applying	This framework proposes the use of the capital based approach as a framework to assess community disaster resilience. By building on the foundation laid out by	The framework does not allow an indepth analysis of the

		the Concept of Community Disaster Resilience: A Capital based Approach	others, this framework includes the five major forms of capital – social, economic, physical, human and natural capital. The framework provides indicators of resilience across the five capitals and explains the relationship between the indicators and the capacity of individuals to cope with disasters. The framework also provides an approach to weight indicators and derive a Community Disaster Resilience Index. This framework is not specific to particular shocks and aims to diagnose the levels of resilience at the community level.	physical components of the building resilience though it captures the human resilience it barely touches on the building resilience.
25	Mercy Corps	Our Resilience Approach	The resilience approach adopted by Mercy Corps focuses on tracking three main elements: 1) changes in resilience capacity, including livelihood opportunities, access to and use of essential services 'or other abilities presumed to be linked with more successful coping strategies or adaptations to risk'; 2) development outcomes such as food security, improved health and reduced poverty; 3) the magnitude and levels of exposure to disturbances. The approach argues that improvements in resilience capacities (as a result of specific interventions) with consequential improvements in development outcomes despite increasing shocks and stresses mean a particular resilience intervention has been successful. In some circumstances, the resilience of a system may also increase, despite a dip in development outcomes, if the frequency or intensity of shocks and stresses has also increased with reference to a baseline. In this way, the approach provides a robust conceptual foundation for evaluating the impacts of resilience programmes to diverse shocks and stresses.	The approach is focused on individual to resilience, however, it cannot be applied to the physical components of the building resilience as this was not considered in the approach.
26	Mercy Corps	Strategic Resilience Assessment (STRESS)	STRESS is a methodology for integrating a resilience thinking into program design by developing a measurable Theory of Change that articulates how programs build resilience. The specific objectives of STRESS are to i) identify and analyze drivers and root causes of shocks and stresses across local, regional, and national scales, that undermine development outcomes; ii) define the impacts of shocks and stresses on different sub-groups or geographies and the factors that worsen them; iii) understand the capacity of people, communities, and systems to absorb, adapt, and transform in the face of shocks/stresses, and iv)	The approach is focused on individual to resilience, however, it cannot be applied to the physical components of the building resilience as this was not considered in the approach.

			develop the program team's capacity to understand complexity and build resilience.	
27	National Institute of Standards and Technology	A Framework for Defining and Measuring Resilience at the Community Scale: The PEOPLES Resilience Framework	This framework anchors its understanding of resilience between technological units and social systems. It highlights physical, environmental, political, and socio-economic functions of a system through seven dimensions: i) Population and demographics, ii) environmental and ecosystem, iii) organised governmental services, iv) physical infrastructure; v) lifestyle and community competence, vi) economic development; and vii) social-cultural capital as the key community resilience indices. Importantly, the framework is intended for geo-spacial mapping of resilience functions to better define resilience at the community level.	The framework does not allow an indepth analysis of the physical components of the building resilience though it captures the human resilience it barely touches on the building resilience.
28	OECD	Guidelines for Resilience Systems Analysis	This framework lays out a process of undertaking resilience systems analysis to gauge the levels of resilience in a system. Very broadly, this focuses on identifying assets (using the Sustainable Livelihoods Framework) within a system, identifying the risks that might affect these assets, and then identifying actions to strengthen resilience across the absorptive, adaptive and transformative capacities of the system. The framework identifies system resilience indicators (well-being-type indicators that can map across the five capitals); negative resilience indicators (that track negative coping capacities); process indicators (that track the degree to which the resilience roadmap developed from the resilient systems analysis has been translated into policy and programming); output indicators (that track resilience-building activities); and proxy impact indicators (the proportion of the target population that slips back into poverty).	The framework captures resilience in a broader term and hence did not have the capacity to assess the all the components that make up the PFR (particularly, the building component).
29	Overseas Development Institute	Towards a Characterisation of Adaptive Capacity: A Framework for Analysing Adaptive Capacity at the Local Level	This framework aims to understand and assess adaptive capacity at the local level. It is primarily focussed on shocks and stresses from climate change and serves as an approach to monitor progress, identify needs and allocate development resources to enhance a system's ability to adapt to change. At the heart of this framework are five characteristics of resilience, each with a set of 'features'. This includes 1) Asset base – availability of key assets that allow the system to respond to evolving circumstances; 2) Flexible and forward-thinking decision-making and governance – the system is able to anticipate,	The framework captures resilience in a broader term and hence did not have the capacity to assess the all the components that make up the PFR (particularly, the building component).

			incorporate, and respond to changes in governance structures and future planning; 3) Institutions and entitlements – appropriate institutional environment that allows for fair access to key assets; 4) Innovation – system creates an enabling environment to foster innovation, experimentation, and the ability to take advantage of new opportunities; 5) Knowledge and Information –system has ability to collect, analyse and disseminate knowledge and information in support of adaptation activities.	
30	Overseas Development Institute	The 3As: tracking resilience across BRACED	This approach is an explanatory framework for analyzing resilience outcomes that cut across a diversity of different resilience projects in the BRACED program. The framework applies a set of interrelated resilience capacities – the capacity to adapt to, anticipate, and absorb shocks and stresses – to understand these outcomes. Transformation is treated as separate from resilience capacities, but the approach does stress the importance of analyzing potentially transformative impacts of resilience interventions, including policy shifts, empowerment processes, and technological innovations.	The framework captures resilience in a broader term and hence did not have the capacity to assess the all the components that make up the PFR
31	Oxfam	Oxfam Framework and Guidance for Resilient Development	This framework presents Oxfam's latest thinking on the ways in which the organisation can and should enhance resilience. It highlights six social change processes that can develop absorptive, adaptive, and transformative capacity. The framework highlights Oxfam's role in enhancing these processes across its programmes to create 'pathways to resilience outcomes'. The social change processes included in the framework are, 1) empowerment (promote gender justice, enhance voice, empowerment, and participation, including conflict resolution); 2) securing and enhancing livelihoods (securing and building human, social, natural, physical, and financial capital and household assets, based on sustainable livelihoods framework); 3) informing (developing information and knowledge to support decision-making and action); 4) flexible and forward-looking planning (enabling and enhancing collective, forward-looking, and flexible decision making); 5) accountable governing (securing accountability and enabling institutions); 6) learning (enable people to learn together, support experimentation, and increase potential for social and technological innovation).	The framework does not allow an indepth analysis of the physical components of the building resilience though it captures the human resilience since it largely focuses on social resilience.

32	Practical Action	From Vulnerability to Resilience (V2R)	Setting out key factors that contribute to people's vulnerability (namely hazards and stresses, fragile livelihoods, future uncertainty, and weak governance), this approach provides explanations for the linkages between these factors and sets out ideas for action to strengthen resilience. The framework's defines resilience not only as an ability to manage risks, adapt to change, and ensure food supply, but also brings a strong focus on a household's ability to move out of poverty.	The framework focuses on household's resilience to poverty and therefore only consider the human factors.
33	Speranza, C., Wiesmann, U. and Rist, S.	An Indicator Framework for Assessing Livelihood Resilience in the Context of Social–ecological Dynamics	This framework presents a set of indicators to measure the resilience of social-economic systems in terms of livelihood strategies pursued by communities. The proposed indicators are clustered around three main focus areas: (i) buffer capacity (the extent to which the social-economic system can absorb change and still maintain the same identity and functions); (ii) self-organization (the extent to which individuals' activities cohere within a social system); and (iii) capacity for learning (the extent to which the system itself can take previous experiences into account, e.g., institutions adapting in response to a shock in order to be better prepared for future shocks).	The framework only captures the socio-economic factors. This makes it insufficient for assessing the level of resilience in the physical components of the building.
34	Torrens Resilience Institute	Developing a Model and Tool to Measure Community Disaster Resilience: An Australian Government Initiative	This toolkit provides a method of diagnosing the disaster-readiness of a community. Originating in Australia, the framework assesses community disaster resilience by asking four basic questions: 1) How connected are members of the community? 2) What is the level of risk and vulnerability in the community? 3) What procedures support community disaster planning, response, and recovery? 4) What emergency planning, response, and recovery resources are available in the community? Using these questions, the framework provides guidelines for using a scorecard to help communities measure their disaster readiness and support planning to strengthen disaster readiness.	The framework on community disaster resilience largely captures the socio-economic factors. This makes it insufficient for assessing the level of resilience in the physical components of the building.
35	Tulane University	Haiti Humanitarian Assistance Evaluation: From a Resilience Perspective	This framework was used to evaluate the impact of humanitarian assistance in the wake of the 2010 Haiti earthquake. It is a detailed, operational and evaluative approach for measuring changes in resilience after the earthquake. At the heart of this framework lies the measurement of changes across seven dimensions of resilience – wealth, debt and credit, coping behaviours, human capital, community networks, protection and security; and psychosocial aspects.	This disaster resilience framework was context-specific, to the 2010 Haiti earthquake. Therefore, it's not flexible enough to be adapted to PFR.

36	UNDP	Community-based Resilience Analysis (CoBRA) Conceptual Framework and Methodology	This framework has four broad steps that include identifying priority characteristics of disaster resilience for a target community; assessing the degree to which a community achieves these characteristics (in the normal period, as well as in a period of crisis); examining the characteristics and strategies of disaster-resilient households and identifying the most highly rated interventions or services in building local disaster resilience. 'Community resilience characteristics' that lie at the heart of this framework map across the capital assets- physical, human, financial, natural and social.	The model was designed specifically to reduce drought/disaster risks and improve human livelihoods in disaster-prone communities and seems difficult to apply this to flood risk scenario.
37	UNISDR	Disaster Resilience Scorecard for Cities	This framework provides a checklist for cities to gauge the degree to which they are resilient to the impacts of natural disasters. It is a list of 85 metrics (each with a suggested 5-point scoring system) relating to UNISDR's 'ten essentials' (e.g. organisation and coordination, financial planning and budget, data on hazards). Overall, the framework aims to track resilience across the following aspects – research (including evidence-based compilation and communication of threats and needed responses); organization (including policy, planning, coordination and financing); infrastructure (including critical and social infrastructure and systems and appropriate development); response capability (including information provision and enhancing capacity); environment (including maintaining and enhancing ecosystem services); recovery (including triage, support services and scenario planning).	The model assesses resilience at a larger scale, city resilience. Though, the framework tracks resilience of infrastructure, the focus is mainly on critical infrastructure.
38	USAID	Community Resilience: Conceptual Framework and Measurement. Feed the Future Learning Agenda.	This framework stems from the domain of food security but can be applied to multiple sectors. The framework includes the context (social, ecosystems, political and religious); the disturbance (natural hazard, conflict etc.); community capacities for collective action (assets, social dimensions and areas of collective action); the reaction to disturbance (survive, cope, recover, learn, transform) and livelihood outcomes (economic security, adequate nutrition etc.). Overall, the framework argues that community capacities for collective action mediate the impact of various disturbances on a community allowing it to either proceed on a resilience pathway or tip over into vulnerability.	Framework focuses on food security intervention at the community level and does not feature the capacity to evaluate physical components of the building resilience.

39	Zurich Flood Resilience Alliance	Operationalizing Resilience Against Natural Disaster Risk: Opportunities, Barriers and a Way Forward	The Zurich Flood Resilience Alliance approach to measuring flood resilience is based on a 'systems approach' to understanding the factors that enable communities to withstand flood-related shocks and stresses. The framework explicitly highlights the importance of human capital (e.g. skills and health); social capital (e.g. strong relationships and cooperation); natural capital (e.g. land productivity and water); physical capital (e.g. infrastructure and equipment); and financial capital (e.g. level and diversity of income) for enhancing the resilience of communities to floods. The framework combines an assessment of capital assets (the 5 Cs) in combination with resilience properties of those assets (the 4 Rs), which include robustness, redundancy, resourcefulness and rapidity	The framework focuses on community and captures resilience in a broader term and hence did not fully assess all the components that make up the PFR (particularly, the building component).