DEVELOPMENT OF A COMPREHENSIVE SYSTEMATIC QUANTIFICATION OF THE COSTS AND BENEFITS (CB) OF PROPERTY LEVEL FLOOD RISK ADAPTATION MEASURES IN ENGLAND

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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, I confirm that the intellectual content of the work is the result of my own efforts and no other person.

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ABSTRACT

Studies in the UK and elsewhere have identified that flooding comes with diverse impacts, ranging from significant financial costs (tangible) to social (intangible) impacts on households. However, it is not feasible for government spending on structural flood defences to adequately protect all at risk properties. Hence, the need for homeowners to take action in the form of investing in property level flood risk adaptation (PLFRA) measures to protect their properties has since been the subject of debate. However, the take-up of PLFRA measures remains low, due to factors such as financial constraints, aesthetics, emotional issues, and a lack of information on the actual cost and financial benefit of investing in the measures. Notably, previous research in this area has failed to include the value of intangible impacts such as health effects, meaning that the existing models do not reflect the full benefits of PLFRA measures. This in part is due to the inherent difficulty in monetising such intangible impacts. Nevertheless, evidence from the literature, indicates that knowledge of such impacts may be important in determining whether to invest in PLFRA measures.

Based on a synthesis of the literature, a conceptual framework of the costs and benefits of PLFRA measures was developed. Data was collected through a questionnaire survey of homeowners who had experienced flood damage to their properties during the 2007 summer flood event. This data was combined with secondary data of the actual cost of reinstatement incurred in the aftermath of the 2007 flood event. By analysing these two data sets, the additional costs of resistance and resilience measures for four property types were established. The value of the intangible benefits of investing in PLFRA measures was found to be £653 per household per year representing an increase of 8% for resistance and 9% for resilience measures.

Decision support lookup tables (DSLT) were developed so that homeowners can determine the cost effectiveness of PLFRA measures as pertaining to individual buildings; insurers can assess the level of potential financial benefit of adopting PLFRA measures by their customers, and perhaps offer incentives by way of premium reduction to encourage homeowners to invest in the measure. Flood risk assessment surveyors can determine the benefit cost ratio of taking up of PLFRA measures for their individual clients; thereby, enhancing the robustness of their professional advice. Most importantly, the DSLT has the potential to complement Government's effort in encouraging homeowners to invest in PLFRA measures.

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DEDICATION

This thesis is dedicated to Almighty God for granting me the grace to start and finish this PhD programme. Finally, to my lovely daughter Victoria Omolola Joseph who firmly stood by me throughout the course of the programme.

LIST OF ABBREVIATIONS

ABI	Association of British Insurers
AEP	Annual Exceedance Probability
ARC	Actual Reinstatement Costs
BCIS	Building Cost Information Services
BCR	Benefit Cost Ratio
CASA	Civil Aviation Safety Authority, Australia Government
CBA	Cost Benefit Analysis
CMM	Choice Modelling Methods
CM_{rs}	Cost of Resistance measures
CM_{rt}	Cost of Resilience measures
CPI	Consumer Price Index
CVM	Contingent Valuation Methods
DEFRA	Department for Environment, Food and Rural Affairs
DNRE	Department of Natural Resources and Environment
DSLT	Decision Support Lookup Table
DTLR	Department for Transport, Local Government and Regions
EA	Environment Agency
EAD	Expected Annual Damage
ECD	Expected Cumulative Damage
EIA	Environmental Impact Assessment
EM-DAT	Emergency Event Database
EU	European Union
FDGiA	Flood Defence Grand in Aid
FEPA	Federal Environmental Protection Agency
FHRC	Flood Hazard Research Centre
HMSO	Her Majesty's Stationery Office
IRC	Institute of Research in Construction
IRR	Internal Rate of Return
NAO	National Audit Office
NFF	National Flood Forum
NPV	Net Present Value
OECD	Organisation for Economic Co-operation and Development
OFWAT	Office of Water Services
OPW	Office of Public Works
OST	Office of Science and Technology
PLFRA	Property Level Flood Risk Adaptation
PTSD	Post Traumatic Stress Disorders
RICS	Royal Institution of Chartered Surveyors
RII	Relative Importance Index
RPM	Revealed Preference Methods
SoP	Statement of Principles
SPM	Stated Preference Methods
SRC	Subsequent Reinstatement Cost
TAC	Temporary Alternative Accommodation Costs
TBCS	Treasury Board of Canada Secretariat
UNIDO	United Nations Industrial Development Organisation
UK	United Kingdom
VAT	Value Added Tax
WHO	World Health Organisation
WTP	Willingness to Pay

GLOSSARY

Annual Exceedance Probability is the chance of a flood of a given size (or larger) occurring in any one year, usually expressed as a percentage. For example, if a peak flood discharge of 500 m3/s has an AEP of 5%, it means that there is a 5% chance (i.e. a 1 in 20 chance) of a peak discharge of 500 m3/s (or larger) occurring in any one year.

Benefit Cost Ratio – This is a ratio used in an attempt to identify the relationship between the cost and benefits of a proposed project. Benefit cost ratios are most often used to detail the relationship between possible benefits and costs, both quantitative and qualitative, of undertaking new projects or replacing old ones.

Choice Modelling Methods – Is a family of survey-based methodologies for modelling preferences for goods, where goods are described in terms of their attributes and of the levels that these take. Respondents are presented with various alternative descriptions of a good, differentiated by their attributes and levels, and are asked to rank the various alternatives, to rate them or to choose their most preferred. By including price/cost as one of the attributes of the goods, willingness to pay can be indirectly recovered from people's rankings, ratings or choices.

Contingent Valuation Methods - The contingent valuation method (CVM) is used to estimate economic values for all kinds of ecosystem and environmental services. It can be used to estimate both use and non-use values, and it is the most widely used method for estimating non-use values. The contingent valuation method involves directly asking people, in a survey, how much they would be willing to pay for specific environmental services. In some cases, people are asked for the amount of compensation they would be willing to accept to give up specific environmental services.

Cost Benefit Analysis – This is an analysis of the cost effectiveness of different alternatives in order to see whether the benefits outweigh the costs.

Expected Annual Damage this is the total value of potential damage, which can occur as a result of a flood event on annual basis.

Expected Cumulative Damage this is the aggregate value of potential damage, which can occur as a result of flood event over a certain period of time, for instance, in this research it was assumed to be over 20 years.

Floodplain this is the land adjacent to a river that is periodically inundated due to floods. The floodplain includes all land that is susceptible to inundation by the probable maximum flood event.

Intangible impacts – These are the impacts of flooding, which are not easy to express in monetary terms, for instance, stress of flooding, worrying about future flooding.

PAS 64 – This is a document developed in the UK, to provide the damage management industry with a code of practice and the client with information, guidance and measurable results regarding damage restoration, sanitation and safety. It can be used as a reference document by those involved in recovering water damaged properties to confirm contractor's compliance to accepted industry standards and legal obligations (PAS 64, 2013).

Property Level Flood Risk Adaptation measures – These are combination of structural and non-structural measures, which are installed to reduce or eliminate the damage effect of flooding on property.

Resilience measures – These are measures, which are installed to inside a property to minimise the damage caused by floodwaters entering the building

Resistance measures - These are measures installed to keep flood water out of the property.

Revealed Preference Methods - Revealed preference methods (RP) refer to the observation of preferences revealed by actual market behaviour and represents real-world evidence on the choices that individuals exercise. Revealed-preference methods use the relationship between some forms of individual behaviour (e.g., visiting a park or buying a house) and associated environmental attributes (e.g., of the park or the house) to estimate value.

Stated Preference Methods - Can measure the total economic value; that is, SPM incorporate both non-use value and option value. This characteristic has far-reaching potential as it implies that SPM can be used to value potential future or hypothetical (but realistic) goods and interventions.

Tangible impact – These are the impacts of flooding, which can be expressed in monetary terms, for instance, cost of reinstating flood damage properties, or cost of replacing flood damage personal belongings

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CHAPTER ONE: GENERAL INTRODUCTION

1.1 INTRODUCTION

Flooding is a global phenomenon that causes widespread devastation, economic damages and loss of human life (Jha *et al.,* 2012). During the past decade, reporting of incidents of natural disasters that meet Emergency Event Database (EMDAT) criteria have increased six fold compared to the 1960s due mainly to an increase in small and medium scale disasters (Guha-Sapir *et al*., 2006; Jha *et al.,* 2012). The occurrence of floods is the most frequent among all these natural disasters. 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). For instance, in 2010 alone, 178 million people were affected by floods (Jha *et al.,* 2012). This increase is due to combinations of climate change, population growth and development pressures (Environment Agency, 2003; Crichton, 2007a; Jones *et al*., 2013). Blunden and Arndt (2012), Field *et al*., (2012) asserted that almost 90% of natural disasters are hydro meteorological events such as droughts, storms and floods. Further, scientific evidence suggests that global climate change will only increase the number of extreme events, creating more frequent and intensified environmental emergencies (Field *et al.,* 2012). Bogardi (2004) predicted that, globally, flooding could directly impact on over 54 million people per year by 2050 if mitigation efforts are not stepped up.

The global increase in the frequency of flooding has been reflected in the UK where, currently in England alone, one in six properties or over 5.2 million properties are at risk of flooding (Environment Agency, 2009). This includes 2.4 million properties threatened by coastal and river flooding and a further 2.8 million affected by surface water flooding (Environment Agency, 2009). Nearly half a million properties are at significant risk of riverine or coastal flooding (1 in 75 years), and research has shown that the situation is likely to worsen as average global temperatures increase and if properties are continued to be built on floodplains (Soetanto *et al.*, 2008b; Environment Agency, 2009).

Since 2000, there have been several major flood events in the UK, such as the nationwide flooding in 2000; Boscastle flooding in 2004; Carlisle and North Yorkshire flooding in 2005; the summer flood event in 2007; Cockermouth flooding in 2009 and Cornwall flooding in 2010. These flood events have caused considerable damage to properties, demanding significant financial sums for repairs and replacements. Apart from physical damage to properties, floods have the potential to damage the physical and mental health of households who are affected by them (WHO, 2002; Tapsell *et al.*, 2003; Tunstall *et al.*, 2006; Ranger *et al.*, 2011).

In the aftermath of these flood events, UK insurers have paid out £4.5 billion to customers whose homes or businesses have been hit by flooding (ABI, 2010). This shows an increase of 200% on the £1.5 billion paid in the previous decade (ABI, 2010). For instance, the 2007 summer flood resulted in insurers paying out £3 billion; the 2005 floods in Carlisle cost insurers over £272 million; and the Cumbria floods in November 2009 cost over £174 million. Reasons for the rise in flood costs include the increased frequency and severity of flooding in the UK; inflations affecting construction materials and labour; and the growing problem of surface water flooding (ABI, 2010). It had been previously estimated that the total value of assets under flood risk exceeds £200 billion (Office of Science and Technology, 2003); this is more than the current budget deficit.

Flood risk in the UK today is, therefore, greater than ever before. The UK Government response to the increase in flood risk is reflected in the radical reviews of flood risk management including; the Institution of Civil Engineers *Learning to Live with Rivers*, 2001; Department for Environment, Food and Rural Affairs (DEFRA) *Making Space for Water*, 2005; and the Foresight Project *Future Flooding, 2004*. These reviews have proposed less reliance on hard engineering solutions such as flood defence and a move towards adaptation and resilience to flood risk (OST, 2004). Evans *et al*., (2004) stressed that there is a need for a conceptual shift in which flood risk management relies less on Government intervention and more on an individuals' acceptance of responsibility for managing flood risk at property level.

Whilst the Environment Agency, on behalf of the UK Government, is working on increasing the number of properties protected from flooding by building new structural defences and maintaining existing flood defences, it is estimated that about half of the households currently in areas of significant risk of flooding may remain undefended (Bichard and Kazmierczak, 2009). Therefore, given current government policy, there has been growing support for property adaptation (Ali and Jones, 2013). The installation of property-level flood risk adaptation measures represents a viable approach for these households. In addition, the efficiency of flood protection by structural measures is never absolute (a typical example is seen in New Orleans in the United States of America in 2005) and is likely to decline with the increasing unpredictability and severity of weather systems. It was acknowledged in Lloyd's report of 2008, that if no action is taken to reduce potential flood risk on properties, losses from coastal flooding for high risk properties could double by 2030, therefore, recommending that property adaptation is vital given the potential future rate of climate change (Lloyd, 2008). In view of this statement, Booth (2009) argued that the biggest changes in response to the effect of climate change are happening at the government and insurance industry levels; however, homeowners appear not to be participating in the changes to reduce the impact of flooding on households.

Flood impacts on households are both tangible and intangible in nature. Tangible flood impacts are those impacts that can be monetised, such as the cost of replacing damaged properties (Tapsell *et al.,* 2002); whilst, the intangible impacts are those that cannot readily be valued but can be described in qualitative or quantitative terms, such as loss of irreplaceable items or item of sentimental value (Environment Agency and DEFRA, 2004; Proverbs and Soetanto, 2004; JBA, 2005).

UK Insurers have a key role to play in helping society manage this risk through the provision of cover for flood damage (Crichton, 2007b; Crichton, 2008). The UK is one of the very few countries in the world where flood insurance remains an integral part of property insurance. It has been identified that managing the risk of flooding is not the responsibility of insurers alone (ABI, 2010). Arguably, insurers play an important part of the UK flood risk management strategy, but not the panacea. While insurers are experts at managing the financial risks of flooding, the liabilities of insurers are limited to the reduction of tangible impacts of flooding on households; whilst, the intangible impacts are left for homeowners and in some instances government to deal with.

Individual property owners need to take action by adapting their properties and businesses to mitigate flood risk by taking necessary precautionary measures, such as registering for national flood warning alert (Pitt, 2007; Halcrow, 2009) and by adapting their properties to flood risk through the use of property level flood risk adaptation (PLFRA) measures. There is a high level of uncertainty whether the approaches to adaptation can be effectively integrated into the built asset management framework (Jones, 2012) because it is not considered as part of routine maintenance. Taking up adaptation measures may be by investing in resistance measures, which are designed to keep flood water out of properties, these involve, the use of demountable door guard; airbrick covers; and fixing non-return value. Alternatively, where resistance measures are not a viable option, resilience measures can be installed to protect properties against flood risk; these are installed to reduce the damaging impact on the building fabric (Joseph *et al.,* 2011a), these involve, replacing timber floor with concrete; raising services meters above anticipated flood levels; raising sockets above flood levels.

The responsibility for managing flood risk in the UK must be shared between homeowners, insurers, Government and construction professionals, to keep people, their homes and their livelihoods safe. According to Thurston *et al.,* (2008) a key to flood risk management strategy at households level is the take-up of adaptation measures both in new developments and as part of repair after flood events. However, research has shown that at-risk householders are reluctant to adopt resistance and resilience measures in the aftermath of a flood event (Harries, 2007; ABI, 2010) for reasons such as information barriers, emotional constraints, aesthetic considerations, timing issues and lack of first-hand information on the costs and benefits of the adaptation measures (Proverbs and Lamond, 2008).

Information on the cost and benefits of adaptation measures can be established by applying the concept of cost benefit analysis (CBA) to the study of PLFRA measures. The concept of CBA is such that a project should not be undertaken unless its cost is less than the benefit (Wingfield *et al.,* 2005). In order to determine whether benefits outweigh costs, it is important that the benefits and costs are expressed in a common scale or denominator, so that they can be compared with each other, even when some benefits and costs are not traded on markets and, hence, have no established monetary values (Brinkhuis-Jak *et al.*, 2004). Prior to applying the concept of CBA in the study of PLFRA measures, detailed knowledge of the tangible and intangible impacts of flooding is essential, so that the intangible impacts can be monetised. Due to the difficulty in quantifying the value of intangible impacts, most previous studies have tended to ignore the value of these impacts.

Full knowledge of the costs and benefits of PLFRA measures, which takes into account the intangible impacts, will therefore be valuable for a number of purposes. Homeowners need to know the costs and the subsequent benefits of investing in PLFRA measures; this can encourage them to take action. Finance can be raised by extended borrowing, the Council of Mortgage Lenders policy on the adaptation measures stated that lenders should be sympathetic in this regard (Proverbs and Lamond, 2008).

Conversely, national and local governments and their associated agencies with responsibility for flood risk management and implementation need to understand the full financial implications of their spending decisions, particularly with regards to the uptake of PLFRA measures and, therefore, need to have a national adaptation plan (IPCC, 2012). Availability of a comprehensive CBA model, which includes both the tangible and intangible impacts of flooding on households, has the potential to provide government bodies with the required understanding and to supplement existing knowledge.

Flood risk management at household level is a topic of growing public policy importance. As a result, a better understanding of how to quantify the impacts (tangible and intangible) of flooding on households and subsequent incorporation of these monetised impacts in the CBA model would have the potential to increase the quality of information which homeowners require to make decisions on adaptation measures.

1.2 RESEARCH CONTEXT AND JUSTIFICATION

Flood risk management research cuts across many disciplines, such as physical sciences aspects of short term flood prediction, engineering aspects of flood damage protection, and social science considerations such as studies of vulnerability and economic damage assessment. The current study is located broadly within the area of flood risk management, but more specifically within the socio-technical discipline, with a specific focus on flood impact assessment on households. Flood risk management research in the UK context has focussed on preservation of life, the development of flood defences and towards improving emergency response (Penning-Rowsell and Wilson, 2006). Flood damage prevention is also a primary focus (Hall *et al.*, 2003; Entec, 2005). Research into the impact of flooding in the UK has focused mostly upon the economic costs to the insurer, government and society in general (Clark *et al.*, 2002; JBA, 2005; Environment Agency and DEFRA, 2004; Environment Agency and DEFRA, 2005, Wassell *et al.*, 2009).

Damage to property, infrastructure and business has been studied in some detail by Penning-Rowsell and others (Green *et al.*, 1994; Penning-Rowsell *et al.*, 2005; Penning-Rowsell and Wilson, 2006; Penning-Rowsell *et al.*, 2010) to evaluate the costs and benefits of flood risk management programmes for the purpose of flood protection/defence investment appraisal. Further, there has been a series of studies to investigate the longer term stress and health impacts of flooding on the flooded household (Bennet, 1970; Reacher *et al.*, 2004; Environment Agency and DEFRA, 2004). Some insurance industry-funded study has been undertaken to examine the effect of flooding on the cost of repairing individual properties (Black and Evans, 1999; Soetanto *et al.*, 2002b). Lamond (2008) argued that such studies were commissioned to allow insurers to assess their ultimate financial exposure to flood risk. Research into the costs of flood resilient reinstatement of domestic properties was carried out on behalf of the Association of British Insurers (ABI) (Wassell *et al.*, 2009). The research was commissioned to evaluate the cost implication of Government's proposal of making it compulsory through the use of Building Regulations 2010 in England and Wales to reinstate flooded properties in a resilient manner. The shortcoming of this research is that benefits of resilient measures were not considered, although the authors acknowledged the fact that these measures are beneficial to both homeowners and insurance companies. This current research, therefore, addresses the issues of tangible and intangible benefits of adaptation measures.

In 2007, the Environment Agency and DEFRA jointly commissioned research to investigate the economic benefits of using resistance and resilience measures. The project was titled – '*Developing the evidence base for flood resistance and resilience'* (Thurston *et al.*, 2008). The project was intended to provide analytical information for the wider *Making Space for Water* projects, encouraging and incentivising uptake of resistance products and resilience measures by households and businesses (Thurston *et al.*, 2008). However, the authors acknowledged that the research did not take into account some of the less easily monetised benefits of flood risk adaptation measures, such as reduced anxiety and improved social cohesion. In establishing the total benefits of PLFRA measures for homeowners, these intangible benefits have to be included, because these are impacts that affect households directly as compared to the tangible impacts which in most cases will be paid for by the insurers. Green *et al.*, (1985) argued that the intangible impacts are both large and more important to the households affected than are the direct monetary losses.

The difficulties in the evaluation of intangible impacts of flooding on households have been acknowledged by many authors (Green and Penning-Rowsell, 1989; Lekuthai and Vongvisessomjai, 2001; Environment Agency and DEFRA, 2004; Werritty *et al.*, 2007; Environment Agency, 2010,). For instance, Green and Penning-Rowsell (1989) referred to them as the factors or considerations which are left out of CBA because they are difficult to evaluate. Lekuthai and Vongvisessomjai (2001) argued that the subjective nature of intangible impacts of flooding on households contributed to its difficulty in evaluation.

Research by different stakeholders: industry and practitioners (Flood Repair Forum, 2006; Joseph *et al.*, 2011b; Joseph *et al.*, 2011a), academics (Soetanto *et al.*, 2008b), Government, (Office of the Deputy Prime Minister, 2003; Bowker *et al.*, 2007b; Thurston *et al.*, 2008) and the insurance industry (ABI, 2003; ABI, 2006; Wassell *et al.*, 2009) has examined the costs and effectiveness of installing property level resistance and resilience measures. To some extent, this body of previous research provides a confusing message for stakeholders by using simple illustrations of the fact that some measures will pay back after a single flood. However, it also demonstrates that many measures are not cost effective at certain flood return periods normally considered as representing a significant flood risk. A major shortcoming of this research is a failure to take into consideration the intangible benefits, which may have yielded different results. In the light of these exclusions and with the wider acceptance by different authors that the intangible impacts are large and important (Green and Penning-Rowsell, 1989; Lekuthai and Vongvisessomjai, 2001; Werritty *et al.*, 2007; Environment Agency, 2010), the need to develop a comprehensive systematic quantification of the costs and benefits of PLFRA measures, which incorporate the monetised intangible impacts of flooding on households within the CBA model has been identified.

Private flood insurance is the main source of funding for the reinstatement of flooded residential property in the UK. Currently, there is no state provision for flood reinstatement and, as part of an agreement between the ABI and the UK Government (gentlemans' agreement known as the "Statement of Principles"), flood cover is included as standard in domestic property insurance policy (Huber, 2004; Crichton, 2005a; Lamond *et al.*, 2009a). However, in the light of the high costs of flooding events and the generally accepted view that flood events in the UK are becoming more frequent and are likely to continue to do so (Environment Agency and DEFRA, 2004; ABI, 2005), insurers are becoming less willing to cover properties at risk of flooding (Crichton 2005b).

A majority of the insurance policies in the UK are policy of 'indemnity' (meaning that the insurer's liability is to put the insured back to the same financial position they were prior to the damage/loss). Therefore, financing resistance or resilient measures during reinstatement periods through the insurance provision is considered as 'betterment', and therefore will not be covered under the insurance policy. However, following the summer 2007 flood event in the UK, the ABI (2007) called for a number of government actions to reduce the cost of future flood events among, which is an increased focus on increasing the resilience and reparability of homes and businesses. This is seen by the ABI as an avenue to reduce risk and claim spend for the insurance industry. Therefore, any information, which can be made available to support decision making on investment in PLFRA measures, will be beneficial to all stakeholders in managing flood risks.

In relation to the aim of this research, there is a consensus that intangible impacts of flooding on households are difficult to evaluate, and yet they are large and important. However, there is an absence in the existing studies of a comprehensive CBA model of PLFRA measures which take into consideration both tangible and intangible impacts of flooding on households. Therefore, the major challenge of this project is to evaluate the true benefits of PLFRA measures, not only in financial terms, but also with due regard to the intangible impacts of flooding on households.

1.3 AIM OF THE STUDY

The aim of this research is to develop a CBA model of PLFRA measures.

1.4 OBJECTIVES OF THE STUDY

In order to achieve this aim, the following eight subsidiary objectives are to be achieved:

1. To conduct a comprehensive literature review on the nature of flood events worldwide and specifically in the UK, 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.
2. To critically review the concept of CBA and its applicability to the study of PLFRA measures, with particular emphasis on available methods of valuation of

less monetised impacts (intangible) of flooding on households, with the aim of incorporating it in the CBA model.

3. To develop a conceptual framework, specific to domestic property in the UK, of the costs and benefits of property level flood risk adaptation measures based on a synthesis of the extant literature.
4. To elicit domestic homeowners' willingness to pay (WTP) values in order to reduce the intangible impacts of flooding on their households and subsequently employ appropriate statistical analysis techniques with a view to exploring factors which has potential to influence the WTP values and the adoption of PLFRA measures,
5. To collect data on the actual reinstatement costs of flood damaged properties affected during the 2007 summer flood event and establish the additional cost of adopting PLFRA measures based on different property types, flood depth and floor construction methods.
6. To establish the expected cumulative damage (ECD) avoided of PLFRA measures and to subsequently use appropriate statistical analysis techniques to explore the relationship between costs and benefits of the measures.
7. To test, refine and validate the CBA model towards its potential relevance for practical application in flood risk management at household levels.
8. 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.

1.5 RESEARCH QUESTIONS

From the aim and objectives stated above, the key research questions that this research set out to answer are as follows:

- How to quantify and monetise the intangible impacts of flooding on households?
- What is the value of intangible impacts of flooding on households?
- What is the relationship between costs and benefits of adopting PLFRA measures?
- Do the benefits of PLFRA measures outweigh the associated costs?

1.6 RESEARCH METHODOLOGY

The driving forces for the choice of a research methodology in any study are not the advantages or disadvantages associated with a particular method (Creswell, 2009). The factor that influences the choice of one approach over another is the nature of the research problem or the objectives of the study (Mertens, 2003; Creswell, 2009). For instance, if the nature of the problem is such that the objective of the study is to test or explain an existing theory, then the quantitative method is the best approach. However, Creswell (2009) suggested that if a concept or phenomenon needs to be understood, because minimal research has been done on it, then a qualitative approach should be adopted. Further, due to the interdisciplinary nature of research, there may be a need to combine both quantitative and qualitative methods in order to address the research question and this is termed the mixed approach (Creswell, 2009). The research paradigm for this study is quantitative in nature. The quantitative concept implies that the reasoning of the research is largely deductive, involving the development of a conceptual structure prior to its testing through empirical observation (Loose, 1993).

The research also involves a comprehensive literature review, consisting of relevant journals, books, internet articles, thesis and government reports and papers. This is necessary to identify knowledge gaps in the domain of flood risk management at household levels, and the impacts of flooding on households with the intention to identify measures to reduce the identified impacts and subsequently review costs and benefits of the measures. Particular emphasis was laid on how to quantify intangible impacts of flooding for the purpose of incorporating it in the CBA models of PLFRA measures.

Following the literature review, the development of an appropriate conceptual framework for reinforcing the future direction of the research was undertaken. This conceptual framework was critical in addressing the key research questions and was concerned with the cost of PLFRA measures and the benefit of the measures.

In view of the nature of investigation associated with this research work, and in addition to the theoretical basis of this study involving the collection of data to draw deductive conclusions, a survey technique was adopted for the study. Within the survey research technique, samples were examined through specifically designed questionnaires (survey instrument). Before embarking on the major survey, a pilot survey was undertaken, acting as a ‘trial run’ that can assist in ‘smoothing out’ the survey instrument in order to ensure that participants in the main survey did not experience any difficulties in completing it. The primary aims of the pilot survey are to test the wording of the questionnaire, identify ambiguous questions, test the intended technique for data collection and measure the effectiveness of the potential response. Data was collected through the survey questionnaire, which was distributed to homeowners that were identified through the summer 2007 flood event data base. Secondary data in the form of actual reinstatement costs for the summer 2007 flood event was obtained and used for the analysis. The data collected from the questionnaires in conjunction with the actual reinstatement cost data were then analysed.

The research adopted statistical software (e.g. Statistical Package for the Social Sciences (SPSS) in analysing the research data. Statistical analysis techniques including correlation analysis, multivariate regression analysis and ratio analysis were used to make inferences and draw conclusions on the data. Further inter-rater agreement tests were carried out on the questionnaire data. Appropriate statistical analysis methods were used resulting in the development of CBA models of PLFRA measures.

A process of validation was undertaken to establish whether the concepts and methodologies used in developing the model were sound, and also to establish whether the findings were reliable. Validation is important because it reflects the potential objectivity and reliability of the model. Internal and external validation processes were employed in testing the validity of the findings. External validation involves homeowners to comment on the usefulness of the developed models. Subsequently, flood risk management stakeholders including loss adjusters and surveyors were invited to provide feedback on the usefulness of the findings.

Following the completion of validation process, conclusions were drawn and recommendations made. Conclusions were also drawn to determine the extent to which the research objectives developed in order to collectively satisfy the main research aim, were accomplished or otherwise, further, limitations of the study were provided and scope for further study were identified.

A flow chart summarising the research process and methodology is presented in Figure 1.1. A more detailed discussion of the methodological approach adopted for this research is presented in chapter five of this thesis.

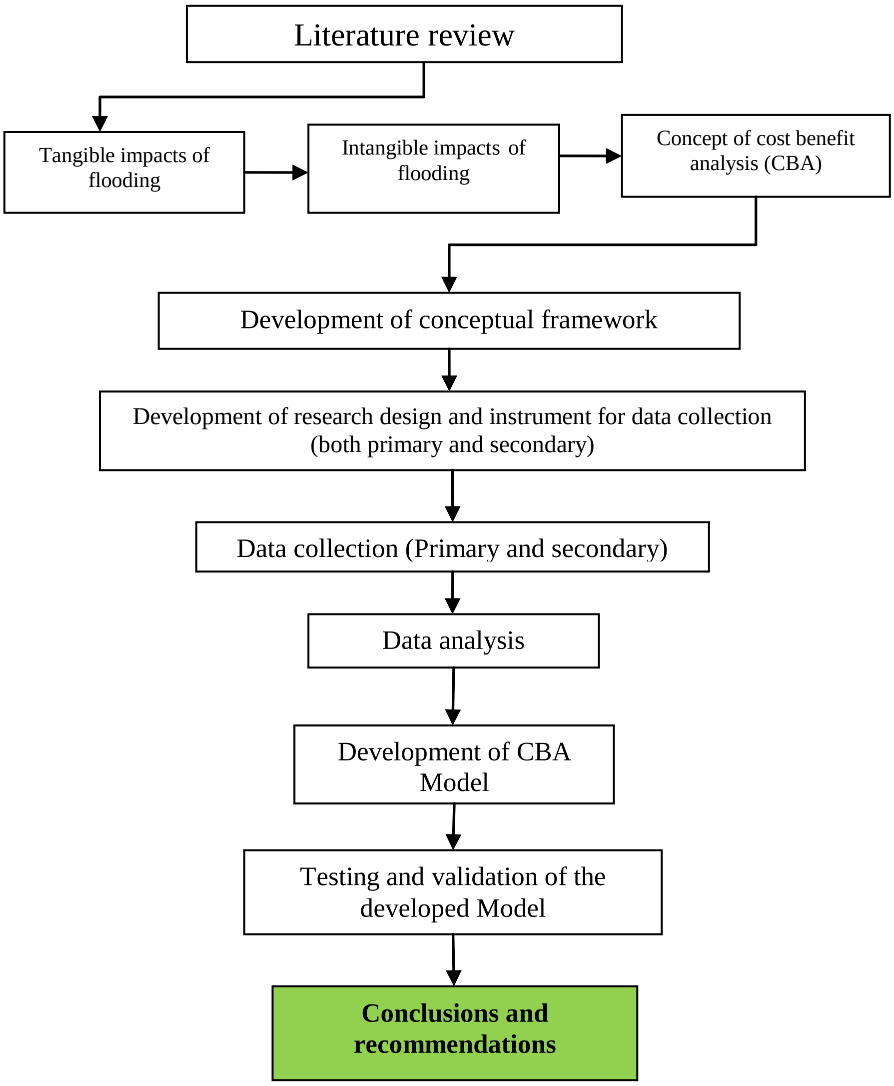


Figure 1.1 Flow chart of research process adopted for the study

1.7 LIMITATIONS OF THE STUDY

This section focuses on the scope of the research project, which was anchored on the literature review and the exploratory phase of the research. For the purpose of this research, Scotland was excluded from data collection for practical and financial reasons of access to participants, particularly with regards to the 2007 summer flood event data, which was used in this research. The 2007 summer flood event did not affect Scotland; therefore, data will not be available for the same period.

This study was set out to develop CBA model of PLFRA measures for residential property in the UK by incorporating the value of intangible benefits of the measures in the CBA model. Only domestic residential property was considered because many business properties are not owner-occupied and it is unlikely that they will suffer similar intangible impact of flooding as the domestic homeowners. Further, business properties are always subject to different insurance provisions and the impacts of flood event on business-occupier are completely different from domestic properties. The review of extant literature has considered a wide range of international studies encompassing different flooding types, flood impact and measures to reduce the impacts; the empirical analysis has been strictly limited to domestic property. Other limitations of the research are presented as follows:

The survey and the analysis were based on data from England, from locations flooded in the summer 2007 event, which was limited to inland flooding, mainly river and surface water flooding. The use of these locations was driven by the desire to use actual event data as against using theoretical approach which is always based on assumptions. It has not been possible in this research to test whether these results will hold true for another flood event. However, a simple and comprehensive conceptual framework developed for this research can allow for similar analysis to be carried out in any part of the country.

It is, therefore acknowledged that due to the targeted samples, the results presented in this research, which relate only to those households who were involved in the 2007 flood event, may be different if households who are at risk of flooding but not yet experienced a flood event were included in the survey, as previous research has shown that at risk residents will be willing to pay less than flooded residents to avoid flood impacts on their households. However, the samples only included 9% who had been flooded more than once and the remaining 91% only experienced flood on their properties in 2007 and this was seen by most of the respondents as one off event. The sample can be said to be a mix of flooded and at risk respondents; therefore, the value of willingness to pay (WTP) by these respondents can be taken as representative of floodplain residents.

The current economic situation in the UK has seen increase in inflation rates with no increase in wages (The Monetary Policy Committee, 2013). This subsequently affects the value of disposable income and may have affected the value of WTP stated by respondents. The value of WTP may be different if there is no economic crisis in the country during the course of carrying out this research.

The resistance and resilience specification used in the development of the costs and benefits of PLFRA measures in this research is seen as another limitation of the research. The ever increasing constant innovation in the development of resilience and resistance materials and a maturing market may result in reduction in costs of resistance and resilience measures due to competition, therefore the CBA presented in this research may vary if other products are used. However, this limitation can be addressed by the use of the developed conceptual framework, as the framework is expected to be used with current and available data for decision making.

1.8 BENEFICIARIES

Walker (1997) has documented various ways to demonstrate originality, such as development of new methodologies, tools and/or techniques, new areas of research, and the application of existing theories to new areas or a new blend of ideas. It was observed from the in-depth review of literature that a comprehensive CBA model of PLFRA measures using real life flood event data, which takes into account the intangible impact of flooding on households, is yet to be developed in England. Whilst extensive research on the impact of flooding on households, communities and the nation at large has been undertaken, together with benefits of flood and coastal risk management at government levels, it would appear that no previous research has focused on the application of CBA model to highlight to households the potential benefits that can be derived from investing in flood risk adaptation measures at property-level in England. This may have contributed to the low take-up of PLFRA measures among the floodplain homeowners.

By focusing on this particular gap, this study is building on the existing body of knowledge on flood risk management by opening up a new area of research through the application of an existing technique CBA to PLFRA measures. This, therefore, represents a significant contribution to knowledge.

This research offers a model, which could be used by homeowners, flood management stakeholders and researchers to systematically capture cost outlays on PLFRA measures and use that as a basis for predicting the potential benefits of investing in PLFRA measures in the following ways:

i. The recent call for the homeowners to take responsibility for flood risk management particularly at household levels has made this study timely as it is expected to provide useful information on the costs and benefits of adapting domestic property to flood risk. It is anticipated that the CBA model developed in this study can be used by homeowners to make informed decisions on adaptation measures to be adopted. This can eventually be used as proof to insurance companies that adaptation measures have been implemented, and could therefore be reflected in their insurance premium.

ii. Malcolm Cooper, director of pricing & underwriting for general insurance at Legal & General (cited in Savage, 2011), explains how those considering improvements to their property to reduce the impact of further flooding could state their case to the insurer — by arranging for a flood risk assessment to be completed and then implementing its recommendations. The result of this study is a contribution to academic research through the development of a new methodology for quantifying the intangible impacts. Therefore, the model can be used by flood risk assessment companies in the UK to establish the costs and benefits of adapting properties to flood risk, thereby enhancing the insurability of their clients' home.

iii. Other stakeholders, such as loss adjusters and surveyors, can use the information provided in this research to advise flood victims of the cost and the eventual benefit of using the opportunity of flood event to adapt their properties to future flood risk. It is expected that the position in the UK insurance market may change in the near future due to the transition from the Statement of Principles (SoP) to the Flood Re agreement (Joseph *et al.*, 2013), albeit the effectiveness of the 'Flood Re' agreement is not yet possible to predict. Under these circumstances the role of any useful information which building professionals can use in encouraging appropriate adaptation measures, at repair stage remains critical, and the findings from this research has provided some insight into the information on cost and benefit of adaptation measures.

iv. Insurers can use the information to advise any potential customer on the benefits of adopting PLFRA measures; however, insurers may need to provide additional incentive to their existing or new customers in order to encourage them to take action to reduce the flood risk to their properties, especially in the light of the recent Flood Re agreement.

v. 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 flood risk management stakeholders. The main contribution to the wider public is that the research has the potential to remove the barrier of information in the decision making process on PLFRA measures. Therefore, it supplements Government policy in encouraging the take-up of PLFRA measures in England.

1.9 THESIS ORGANISATION

The thesis consists of eleven chapters. Chapter 1 provides the detailed context for the study, including the aim and objectives, and specified research questions to be addressed. The research methodology to address these questions is outlined. The key delimitations and benefits of the study are discussed.

The literature review for the study was broadly sectioned into two strands each forming a chapter. The literature on the impacts of flooding on households in the UK is presented in chapter 2 with particular attention on the measures to reduce or eliminate those impacts; the costs of PLFRA measures, as well as benefits of the measures.

In chapter 3 the concept of CBA is considered. The chapter traces the origin of CBA, and then critically investigates how it has been applied in various other contexts. It then explores how the CBA technique may be adapted for application in the context of this study.

Chapter 4 presents the conceptual framework that brings together, in a logical manner, the comprehensive cost variables involved in adapting property to flood risk, and the total benefits (tangible and intangible) of the adaptation measures which are to be investigated in the empirical stage of the research. The discussion addresses the development of the conceptual framework of PLFRA measures. This aids the development of appropriate hypotheses, data collection and subsequent hypotheses testing.

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. Correlation and regression analyses were employed in the analysis. Exploration of the questionnaire data was carried out by using an inter-rater agreement tests and relative importance index. Factors that have potential to influence respondents' WTP values were identified in the analysis. The value of WTP to avoid flood impact and psychological effect of flooding on households are established. Further analyses are carried out to establish the extra expenses incurred on food, travelling, phone calls and unpaid leave by households whilst in alternative accommodation, which were not reimbursed by their various insurers.

Chapter 7 describes the practical steps necessary in the empirical analysis phase of the research based on flood damage reinstatement data from the 2007 summer flood event. The actual costs involved in reinstating properties affected by 2007 flood event are analysed. Subsequently, by employing descriptive statistical analysis, the additional cost of resistance and resilience measures based on different property types, flood depths and floor construction methods are presented. These additional costs being due to the inclusion of resistance and resilience measures in the reinstatement schedule of repairs.

In chapter 8, detailed tangible benefits of PLFRA measures are established, these are expected benefits if adaptation measures have been implemented and functioned correctly. Further, the ECD avoided for each property type over 20 years period is established. In order to assist in examining the effect of the inclusion of intangible benefits in the model to be developed, benefit cost ratios (BCR) are established, these BCRs are without the inclusion of intangible benefits.

In chapter 9 by carrying out ratio analysis, substantive CBA models relating costs of PLFRA measures and the benefits accruing from such measures are developed for different property types, based on varying flood depth and floor construction methods. In order to determine the effect of flexible interest rate as proposed in the model, a sensitivity analysis was carried out; the results are presented in this chapter.

Chapter 10 provides the results of the validation of the CBA model. The chapter describes the validation process, which include both external and internal validation. In carrying out external validation, two categories of respondents are invited to provide feedback on the research findings; these are homeowners who were part of the main survey and loss adjusters/surveyors who are expected to be the potential user of the developed model.

In chapter 11, 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 which could be index linked. The research was brought to an end by making recommendations for further research.

1.10 SUMMARY

This chapter has briefly outlined the context within which the research was undertaken and the justification for the research. It has been shown within this chapter that flood risk management is an important issue, not just in the UK but worldwide. With the effects of climate change and development pressures, flood events are on increasing phenomenon and the importance of increased research into the area of flooding will grow commensurately. Previous research has focused on the impacts of flooding and the costs of adaptation measures in order to reduce flood impacts. Within this substantial body of flood risk management research, there has been minimal or no research carried out towards the development of cost benefits analysis of the adoption of PLFRA measures which includes value of intangible benefits for homeowners' use. The research is timely in that emphasis is being laid on homeowners taking responsibility for flood risk management in the media, by government and the insurance industry. The availability of a CBA model is argued to be useful for a wide range of stakeholders (homeowners, flood risk assessment companies, insurance companies and government).

The aim of this investigation is towards the development of a comprehensive CBA model of PLFRA measures. On the basis of this aim, objectives were set out, and the key research questions have been identified. The research methodology to address these questions has been outlined, and the contributions of the study were stated together with the limitations of the study. Chapter 1 has, thus, laid the foundation for the thesis. On this foundation, the thesis proceeds with the detailed discussion of the research. The next two chapters (2 and 3) constitute the critical literature review section of the thesis, starting with the critical review of the impacts of flooding on households.

CHAPTER TWO: A REVIEW OF HOUSEHOLDS LEVEL FLOOD RISK MANAGEMENT

2.1 INTRODUCTION

A critical review of extant literature on the impacts of flooding on households and properties together with the various adaptation measures to reduce the impacts are presented in this chapter. The chapter also addresses the first key objective of this research, which sought to critically review the literature on different forms of flood impacts on households with the view to understanding the necessary measures, which can be put in place either to eliminate the impacts or to reduce the impacts. The literature review approach is adopted to explore the impacts of flooding affecting the floodplain residents in the UK. Thus, various strands of the literature starting with review of different types of flooding; the major flood impacts affecting households; measures that can be put in place at household levels to eliminate or reduce the impacts; costs of adaptation measures as well as the benefits of adaptation measures are brought together to identify research gaps on the investigation of the costs and benefits of PLFRA measures.

2.2 TYPES OF FLOODING

Often people will say that they have suffered a flood, when in point of fact their washing machine has leaked or there has been a burst pipe, which in insurance terminology will be referred to as an 'escape of water'. Therefore, what is it that differentiates a flood from any other water damage incident? The definition of flood was set out 36 years ago in the case of Young v Sun Alliance (1976) (as cited in Brennan *et al.*, 2007). Flood is usually when a watercourse, such as a river, bursts its banks or sea breaches sea defences. It requires something large, sudden and temporary, not merely seepage, trickling or dripping. This definition will preclude seepage through defective tanking or a gradual rise in the water table over a period of time. Conversely, the EU directive on flood risk management defines a flood as a temporary covering by water of land not normally covered by water (Schanze *et al.,* 2008). Flooding may result from an increasing in the volume of water within a body of water, such as a river or lake, which overflows or breaks levees, with the result that some of the water escapes its usual boundaries (Powell, 2009). However, to an insurance company, to a farmer or to a household the term flood may carry different meanings (Lamond, 2008). Flooding occurs as a result of one or a combination of events such as rainfall filling rivers, streams and ditches, coastal storms resulting in overtopping and breaching of coastal flood defences, blocked or overloaded drainage ditches, drains and sewers, heavy rain resulting in run-off flowing overland, or rain soaking into the ground, thereby, raising ground water levels (Office of the Deputy Prime Minister, 2003).

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 in the UK. Lamond (2008) opined that it is important to be aware of the differences in definition of flooding when comparing estimates of the cost of floods because some types of flooding are more controllable or preventable than others. For the purposes of this research a much simplified grouping of flood types is practical, while recognising that many flood events may combine more than one type of flooding, for instance, some locations experienced more than one type of flooding during the 2007 summer flood event (ABI, 2009). There are five categories of floods, these are, coastal flooding, groundwater flooding, river flooding, surface water flooding and sewer flooding. These categorisations are important because the effectiveness of PLFRA measures depends on the types of flood risk in a particular location.

2.2.1 Coastal flooding

Coastal flooding from the sea at the coast this is usually caused by extreme tidal flows, which can occur due to three main mechanisms (Lamond, 2008; ABI, 2010); high cyclical tides due to the gravitational effects of astral bodies (astronomical tide level); increase in water level due to low barometric pressure and wind (surge); swelling waves due to the wind speed and direction (wave action). Sea defences are often in place to defend against the normal level of such mechanisms but flooding may often occur when several of these mechanisms combined.

2.2.2 Groundwater flooding

Flooding from groundwater can happen when the level of water within the rock or soil that makes up the land surface (known as the water table) rises (ABI, 2011). The level of the water table changes with the seasons due to variations in long term rainfall and water abstraction. When the water table rises and reaches ground level, water starts to emerge on the surface and flooding can happen. One of the key features of groundwater flooding is that it usually occurs days or even weeks after heavy or prolonged rainfall.

2.2.3 River flooding

River flooding (also known as fluvial flooding) occurs when a watercourse cannot accommodate the volume of water draining into it from the surrounding land. It is generally infrequent and can be predicted to some extent. This type of flooding is usually caused by heavy or prolonged rainfall (Lamond, 2008). The resultant runoff overwhelms the natural water courses and exceeds their capacity for transmitting water downstream. Rapid snow melt may also generate the runoff levels which cause fluvial flooding but in the UK this is less common.

Watercourses are more likely to be overwhelmed when rainwater cannot be absorbed into the land onto which it falls. It might be very steep, water logged, or built over. With the use of the state-of- the-art forecasting equipment, river flooding is often predictable during periods of prolonged rainfall but if intense rainfall for a wide area is directed into a narrow watercourse as occurred in Boscastle, in August 2004, (DOE, 2004) flash flooding may occur too fast for monitoring systems to generate warnings (Lamond, 2008), as experienced in some part of UK in 2007. Groundwater saturation also has a part to play during very prolonged rainfall. The ability of the surrounding countryside to allow soak-away to the water table is compromised and so the majority of the water must be discharged through the water courses.

2.2.4 Surface water flooding

Surface water flooding (also known as pluvial flooding) occurs when heavy rainfall overwhelms the capacity of local drainage, rain falling on already saturated ground, where groundwater levels are already high, or in paved areas. The route the water takes and the depth of flooding will depend on local features and can be difficult to predict. Surface water flooding may also be the result of blockages in the drainage system or high river levels backing up along drainage pipes. As a result, properties located in areas where floodwater can accumulate are at risk of being flooded by surface water (Office of the Deputy Prime Minister, 2003).

2.2.5 Sewer flooding

Sewer flooding occurs when sewers are overwhelmed by heavy rainfall or when pipes become blocked. In urban areas, surface water flooding and sewer flooding often combine, polluting the floodwater. Sewer flooding is arguably the second most serious issue facing UK water companies after drinking water quality (OFWAT, 2002). During the period 2005 to 2010, sewerage companies collectively set out to invested nearly £1 billion to reduce significantly the number of properties considered to be at risk of internal flooding from overloaded sewers (OFWAT, 2005; OFWAT, 2007). Data indicates that some 11,600 properties, in England and Wales, were at risk of sewer flooding at least once in ten years (NAO, 2004), and the risk would increase over time with climate change, likewise shown in the 2007 summer flooding that was partially attributed to the unprecedented heavy rainfall (EA, 2007). Sewer flooding is a serious, distressing issue that affects the quality of life of many householders in England and Wales.

2.3 IMPACTS OF FLOODING ON HOUSEHOLDS

The impacts or consequences of flooding depend on both the nature of the flood and on the area affected. Flood impacts have long been recognised as complex and versatile (Werritty *et al.*, 2007). In the worst cases, flooding has the potential to cause loss of life and personal injury. Whatever the severity of a flood event, the results for the people affected can often be complex and far-reaching. Flooding can also have significant financial implications for individuals. For instance, the experience of the Carlisle 2005 flood event in the UK and the summer 2007 floods has shown that major flooding can cause extensive damage to the internal fabric of a property and, at the same time, impact on the well-being of households for many years (Thurston *et al.*, 2008). Occurrence of a flood event often causes considerable damage to properties, demanding huge financial sums for repair works, and in some cases it could lead to relocating of families to alternative accommodation (Proverbs and Soetanto, 2004). According to research by EA/DEFRA (2004) and ABI (2010) these are the greatest flood impacts, which adversely affect households the most.

In the UK the incidence of severe weather events has increased in recent years (DEFRA, 2009). The increase has been attributed to climate change and on this basis the intensity of events is projected to continue to accelerate (Evans *et al.*, 2004). However, even without the increase in weather events the financial risk to property in the UK has increased due to urbanisation (Lamond, 2008) and increasing value of buildings and their contents (Chatterton *et al.*, 2010). The impact of flooding on households can be categorised into two generic groups namely tangible and intangible, with further classification into direct and indirect (Proverbs and Soetanto, 2004; Messner and Meyer, 2005).

2.4 TANGIBLE IMPACTS OF FLOODING ON HOUSEHOLDS

Tangible impacts of flooding are those that can be readily measured in monetary terms. These are further categorised as direct and indirect impacts (Queensland Government, 2002). Damage to buildings and contents is considered tangible because it can be quantified in terms of replacement or reinstatement cost (Queensland Government, 2002). These impacts can arise from almost any source of flooding, including coastal, fluvial as well as from surface water runoff and groundwater and combinations of these sources as discussed in section 2.2. Basic classification of tangible impacts of flooding on households are presented in Table 2.1, its contents are explored in detail in subsequent sections.

Table 2.1 Basic classifications of tangible impact of flooding on households

Direct tangible impacts	Indirect tangible impacts
Physical damages to properties (Building and contents)	Disruption of daily life and normal activities (such as damage to communications networks)
Increase cost of complete restoration	Reduced spending power / financial loss
Unpaid leave and use of holiday entitlement	Increase in insurance premiums or excesses
	Loss of house value
	Loss of utility supplies (e.g. electricity)
	Increase travel cost

2.4.1 Direct tangible impact

Direct tangible impacts of flooding are the physical damage caused to buildings and their contents. The impacts cover all varieties of damage which relate to the immediate physical contact of flood water to humans, property and the community infrastructure (Queensland Government, 2002; Messner *et al.*, 2007). According to Wassell *et al.,* (2009), when considering flood damage to domestic properties, the construction methods and geographical position of the property have to be considered because these have significant impact on reinstatement costs and measures to take to reduce the impact against future flooding.

Physical damage to properties (Building and contents)

Flooding causes damage to the property and disrupts the use of the property, both during and for sometime after the event. The severity of the flood event will have a direct bearing on the amount of damage to a particular property and its contents (Wordsworth and Bithell, 2004). One of the major impacts of flooding on households is the presence of physical damages to properties, which is the first evidence during flood event. The most frequent structural repairs necessary after flooding at any depth are: replastering works to internal walls, repair of electrical wiring systems and replacement of kitchen units and depending on floor construction methods, floor materials may be damaged by flood water in which case it will have to be replaced (Elliott and Leggett, 2002; Wassell *et al.*, 2009). The three most commonly damaged household contents during flood events are: furniture, carpets and electrical goods (Elliott and 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. Flooding at a depth greater than half a metre is expected to cause greater damage than flooding at less than half a metre, because it will require hacking-off of plaster from floor to ceiling height, thereby leading to higher reinstatement costs.

Increase cost of complete restoration

In the UK, the standard flood insurance policy pays for direct physical damage to the insured property up to the replacement cost or actual value of the damaged items (Crichton, 2002); this is true for fully insured homeowners. However, some properties may be underinsured. In the case of underinsured properties, the owner in most cases has to contribute to the cost of reinstatement, such contribution increases the financial effect of flood event on households.

Unpaid leave and use of holiday entitlement

During the recovery phase of flood events, one of the impacts on the household is the need to take an unpaid holiday (if annual leave has been exhausted prior to the flood event) in order to wait at home for loss adjusters, builders or for delivery of replacement items. Taking time off work to recover from flood events can cause problems for people, not least through the loss of income (Whittle *et al.*, 2010). It was recognised that many flood victims may have supportive employers that may allow them some days off work with pay, in order to recover from the event. It was suggested by Whittle *et al.*, (2010) that time off for employees could perhaps be covered as a component of insurance policies for employers. In most cases, if a flood victim had to take an unpaid leave in order to oversee the repair work or to wait for loss adjuster/builders, the costs of unpaid leave are not reimbursed by the insurer. In the empirical stage of this research, information on this will be elicited directly from homeowner because implementation of PLFRA measures has the potential to avoid or reduce such impact.

2.4.2 Indirect tangible impacts of flooding on households

Indirect tangible impacts (ITI) of flooding comprise damage, which occurs as a further consequence of the flood and the disruptions of economic and social activities (Queensland Government, 2002; Environment Agency and DEFRA, 2004). This damage can affect households who may not have been affected directly by the flood. Examples include loss of utility supplies, financial loss, potential for increased insurance premiums, and short-term loss of house values, particularly if homeowners decide to sell their properties immediately or soon after the flood event (Lamond, 2008).

Indirect impacts can also occur as a result of tax increase or payment of levy. A typical example is the recent flood event in Australia (2011), it was reported that the Australian Government levied every households $5 (Australian dollars) in order to finance the recovery process. Other examples are the loss of time due to traffic disruptions (Watts, 2010). For instance, the summer 2007 flood event affected many parts of the UK and caused damages of approximately £674 million to important national infrastructure. The floods also caused substantial disruption to the operation of many essential services (Chatterton *et al.*, 2010). Since the focus of this research is on costs and benefits of measures to reduce impacts of flooding on households, those indirect tangible impacts, which could be reduced or eliminated through the adoption of PLFRA measures, are discussed further in this thesis.

Disruption to daily life and normal activities

Research suggests that disruption to family life is the most difficult aspect of flooding to deal with (ABI and NFF, 2004b). The prime function of investment in flood defence measures and the management of flood risk and floodplains are to protect people, property and precious environments from the damage and disruption that floods can bring. Tapsell *et al*., (2002) found that disruption to daily life was one of the main issues raised by flood affected homeowners, which have high level of impacts on their households. Many were said to have been very upset at the loss of treasured possessions and the disruption of their daily routines.

Reduced spending power / financial loss

Flooding has a potential to reduce spending power or to impose financial loss on households (EA, 2004). If it is necessary to be evacuated during a flood recovery period, then costs of temporary alternative accommodations can amount to a substantial expense that may often be covered by insurance for those victims who are underinsured. However, extra transport costs and increased living expenses resulting from the inaccessibility of the normal amenities of home are harder to quantify and will probably be borne by the flood victim. Some households are not insured or underinsured. An informal survey in Lewes, Sussex UK showed that 15% of residents were underinsured by £5,000 to £20,000 (Kenney *et al.*, 2006). Thereby, when they are faced with flood event, they will have to contribute to the reinstatement cost.

Increase travel costs

The occurrence of a flood event have a serious impact on the transport network (Arkell and Darch, 2006). Research on transport network reliability and resilience to disasters demonstrates that a disruption to a particular section of road network can have various degrees of disruption throughout the community (Sakakibaral *et al.*, 2004). The implication of this is that other regions within the vicinity of the flood area may be affected. In the specific case of flooding, the disruption can affect large continuous areas of the street networks. The impact of this on households is an increase in travel costs. However, where households have been evacuated to a temporary alternative accommodation, there is possibility that the temporary accommodation may add few more miles to their daily routine, either to work or to take children to school. If this is evaluated, the cost could be substantial, especially for households evacuated for up to six months or more.

During the 2009 flood event in Cockermouth UK, six bridges were reported to have been washed away by flood water (Watts, 2010). The loss of bridges meant that people had to find alternative routes to get to their destinations (such as work, school, and shops). It was reported that the alternative routes could add as much as 55 miles per journey on a daily basis for some residents, which equates to approximately extra travel costs of £24.75 per trip (assuming 45p per mile). This had a massive impact on the already strained resources of local businesses and households in general.

Potential for an increase in insurance premiums / policy excess

Floods account for approximately one third of economic losses worldwide from all natural disasters, but only about 10% of economic insured losses because, in many markets, flood cover is conservative or unavailable (Kenney *et al.*, 2006). In the UK, flood insurance is offered as part of the household domestic insurance policy and is provided entirely by the private insurance market (Crichton, 2008). Wordsworth *et al.*, (2005) found that several major insurers had started to link flood risk to postal codes and many have started to set premiums on that basis. According to the ABI, currently, where the level of flood risk is known, insurers are increasing premiums to more accurately reflect the risk (Thurston *et al.*, 2008). This is somewhat contrary to the state of affairs in the past decade where a premium rise was normally as a result of direct effect of claiming under the insurance policy.

Of course, not everyone is insured, and those who claim under their insurance policy may face an increase in premiums (Thieken *et al.*, 2006) or refusal of renewal (Elliott and Leggett, 2002). Mitchell (2006) raised concern that, despite the ABI's assurances, in areas of flood risk, securing adequate insurance cover is becoming increasingly difficult. In contrast to Mitchell's concern, Lamond (2008) found that the variation in insurance premium rates for low, moderate and significant risk areas was not significant. Further, Lamond and Proverbs (2009a), in their survey of the flood insurance market from the consumer's point of view, found that availability of insurance is still strong in both at-risk and previously flooded locations, and this was attributed to the competitive nature of the UK insurance market and households shopping around to gain cover.

It can be concluded that there is no significant difference in the long run average premium charged for flood insurance whether properties are at risk or not, though, a minority of flooded households may experience some increases in their policy excess when they come to renew their insurance policy and some may experience some increase in their premium. The replacement of the SoP with the Flood Re agreement signal that domestic insurance cover will still be widely available in the UK, even to those properties located in high flood risk area, however, for how long this will last is still a subject of debate. Therefore, the need to take action by homeowners to reduce the potential flood damage to their property cannot be over emphasised.

Potential for reduction in property values

A flood event in a particular region / area may adversely affect the value of a residential property, depending on the local property and the particular property in question. Wordsworth *et al.* (2003) showed that this may typically involve a temporary discounted value of some 12%, but depends very much on the individual circumstances of the property. Wordsworth *et al.* (2005) found that the ability to obtain buildings insurance cover, and the nature of any conditions attached, will be key determinants of value and saleability of a particular property which is located in a floodplain area.

Inevitably, houses in the worst category, are those where no defence improvements are planned, such households may face the situation that insurance cover is withdrawn or maintained at a penalising premium rate (Elliott and Leggett, 2002); thereby, severely restricting the ability to sell such property (Lamond, 2008), because it would either be expensive to obtain cover for such properties or may be practically impossible to obtain cover.

The results of research commissioned by the RICS showed that flood events adversely affects the value of a residential property, though the degree of discounting is not consistent between valuers, and depends on their personal perceptions of the local residential property market and the particular property in question (RICS Foundation, 2004). Further, Samwinga *et al.* (2004) reported that homeowners interviewed expressed concern regarding the potential reduction in property values due to flooding. However, Lamond (2008) concluded that, in most cases, there is no long term loss of property value due to flooding in the UK, the loss of value may appear to be temporary in nature (i.e. immediately after the flooding). These will only affect homeowners who decide to sell their properties immediately after a flood event or who may want to borrow money against the property. Studies have shown that flood event can trigger temporary property value loss. Further, the loss of value can be on paper rather than actual loss, however, it is still widely believe that there is a potential for discounting value of floodplain properties, this is as a result of negative effect of media coverage or report as part of post flood recovery phase.

2.5 INTANGIBLE IMPACTS OF FLOODING ON HOUSEHOLDS

The intangible impacts are those that cannot readily be valued but can be described in qualitative or quantitative terms such as loss of irreplaceable item or item of sentimental values, and health impact of flooding (Tapsell *et al.*, 2002; Environment Agency and DEFRA, 2004; Proverbs and Soetanto, 2004; JBA, 2005). The health impact of flooding can include both physical and stress-related symptoms, for example loss of sleep, anxiety, a reduced immune system response and increased susceptibility to certain illnesses (Environment Agency and DEFRA, 2004). Ahern *et al.* (2005) argued that the impacts of flood on health and livelihood vary between populations for reasons relating to population vulnerability and the type of flood event. The intangible impacts of flooding directly affect those households who are vulnerable to flooding; these are the impacts which are not ordinarily insurable, thus any information on how to avoid or reduce its impact is expected to be useful to floodplain residents in general.

2.5.1 Direct intangible impacts of flooding on households

Direct health impacts of flooding on households occur during the flood itself and are caused by coming in contact with flood water (these are the impacts normally felt immediately the flood event occurs), it could also result from direct exposure to the flooded environment, these include: mortality from drowning, heart attacks, injuries from debris, chemical contamination and hypothermia (WHO, 2002; Ahern and Sari, 2006; Du *et al.*, 2010). As illustrated in Table 2.2 direct impact of flooding on households are sub divided into three, these are: immediate, medium term and long term impacts. These are discussed in detail in the following sections.

Table 2.2 Intangible losses/impact of flooding on households

Immediate (flood onset phase)	**Medium term - (flood recovery phase)**	**Long term (post flood recovery phase)**
Mortality due to flooding	Stress of flood itself	Time and effort to return to normal
Injuries due to flooding	Having to leave home	Worry about future flooding
Chemical contamination	Dealing with insurers	Strains between family
Hypothermia	Living in temporary accommodation	Loss of community spirit
	Dealing with builders	Deterioration to physical health
	Being stranded in/out of home	Deterioration to mental health
	Out break of infectious diseases	Loss of irreplaceable/ sentimental items

Sources: WHO, 2002; Du et al. 2010)

Immediate direct health impacts of flooding on households

These are impacts which could be felt during the onset of the flood event, such as mortality, injuries, out-break of infectious disease, chemical contamination and hypothermia. In the UK, the risk of flood related mortality was very low in the last two decades; this is due to government investment in flood risk management, such as structural defences and flood alert warnings (Halcrow, 2009). For the purpose of this thesis only those impacts which can be avoided or reduced by the adoption of PLFRA measures are discussed further.

Injuries due to flooding

Flood related injuries may occur as individuals attempt to escape from objects being carried by a fast-flowing waters, as a result of the collapse of buildings or other structures and, as a result of individual trying to relocate expensive personal items to save area of the property under intense pressure (Du *et al.*, 2010). Injuries can be relatively minor and self-treated, such as cuts and abrasions, or may be more serious, such as straining of arms, legs or backbone (Ahern and Sari, 2006). Flood related injuries may occur in the pre-onset, onset and post-onset phases of the flood events (Few *et al.*, 2004). In the pre-onset and onset phases, injuries may be sustained when individuals are attempting to remove themselves, their family or valued possessions from the approaching waters (Ahern *et al.*, 2005). The post-onset injuries are likely to occur in the aftermath of a flood disaster as residents return to their home and businesses and begin the clean-up process (WHO, 2002; Few *et al.*, 2004; Ahern and Sari, 2006). Few *et al.* (2004) noted that a lack of coordinated monitoring of injuries related to flooding, including from clean up activities, meant that it was difficult to assess the true burden of ill health due to flood events. The most commonly reported flood related injuries are sprains/strains, lacerations and contusions/abrasions.

Presently, minimal information is available on the frequency of non fatal flood injuries, as they are mostly not routinely reported or identified as flood related. Further, in the UK the availability of flood warning systems, which inform people of the potential flood event and allow both the authorities and the households to take necessary precautionary measures before the flood water comes, could be seen as a contributing factor for the reduction in the number of reported flood related injuries.

Medium term direct health impacts of flooding on households

These are impacts felt after the flood water has receded and the recovery process has began, such as having to go through the psychological stress of having to leave home, dealing with insurers and builders and living in alternative accommodation. Whittle *et al.* (2010) argued that much of the emotional trauma experienced by households following flood events are related to the stresses and strains of dealing with the practicalities of flood recovery. This ranges from the loss of personal possessions to coping with insurance companies and the experience of being displaced into temporary alternative accommodation. Longer term research shows that people's emotional recovery does not have a clear beginning or end (Pitt, 2008; Tapsell and Tunstall, 2008). Research shows that women are placed under a particular strain in the months following flood events, as the stresses of managing the recovery process often appears to fall on them, many of them end up taking on the responsibility of project managing the repairs process (Enarson and Fordham, 2001). This can be attributed to the fact that in most cases some women work part-time or are at home looking after the children and, as a result, they are expected to be available to supervise workmen, receive deliveries and make phone calls to the insurance company. In the empirical stage of this research, data will be collected on the level of stress in which respondents experienced during the 2007 flood event. There is a potential for the adopting of PLFRA measures to reduce such effect of flooding on households.

Long term direct health impacts of flooding on households

These are impacts which could be felt during the post flood recovery stage; these could last longer in some cases, it may last for months or years, such as worrying about future flooding, strains between families, loss of community spirit and deterioration to mental health.

Deterioration to mental health

Flooding can lead to a range of adverse outcomes on physical health and many of these can in turn lead to impacts on mental health status. There are three aspects of mental health, these are: common mental health disorders; post traumatic stress disorders (PTSD); and suicide (Ahern and Sari, 2006). For the purpose of this research, only the first two aspect of mental health will be explored, because there is no epidemiological evidence to support any link between suicide rates and flooding.

Common mental health disorders

There have been several studies on the effects of flooding or natural disasters on common mental health disorders, particularly in the USA (Ginexi *et al.*, 2000; Ferraro, 2003). Conceivably, it has been established that there are correlations between common mental health disorder and victims of natural disasters (e.g. flooding). Bennet (1970) found a significant increase in the number of new psychiatric symptoms (considered to comprise anxiety, depression, irritability and sleeplessness) reported by flooded female respondents compared with the non-flooded group. Norris *et al.* (2001) reviewed 177 articles comprising samples of over fifty thousand individuals who experienced eighty different types of disasters (62 per cent of which were natural disasters, mostly in the US). Chronic problems identified were: troubled family and interpersonal relationships, social disruption, occupational and financial stress, concerns about general living conditions and the wider community, and obligations to provide support to others. In the UK, there is no doubt that flooding, in common with other traumatic life events, is associated with increased rates of the most common mental disorders (Tapsell and Tunstall, 2006), especially for those people who has experienced flood damage to their properties.

Reacher *et al.* (2004) found that adults in a flooded household have a four-fold higher risk of psychological distress than non-flooded households. The autumn 2000 flood event in Lewes it was reported to be highly associated with common mental disorders ten months after the flood event and there was a strong indication that displacement was an important factor in this psychological distress, this is in addition to loss and damage to property and possessions and financial concerns (Tapsell and Tunstall, 2008). Post-flood disruption to life has been reported in the UK as the most significant of all the intangibles flood impacts which affect people's health. The aftermath of flooding, the disruption and long recovery process, appear to generate the most severe stress, with people's lives being 'put on hold' until the home is back in order. This in most cases can lead to post traumatic stress disorder.

Post Traumatic Stress Disorder (PTSD)

Post traumatic stress disorder. PTSD *''arises after a stressful event of an exceptionally threatening or catastrophic nature and is characterised by intrusive memories, avoidance of circumstances associated with the stressor, sleep disturbances, irritability and anger, lack of concentration and excessive vigilance [and the specific diagnosis of PTSD] has been questioned as being culture-specific, and may be over diagnosed''* (WHO, 2001). Nonetheless, studies have shown that there are increases in PTSD following floods events (Norris *et al.*, 2001; Reacher *et al.*, 2004; Kreibich *et al.*, 2005).

Pre-existing health conditions appear to lead to increase susceptibility to health problems among some people, particularly the very elderly. The majority of any physical health effects associated with the experience of being flooded tended to be in the early weeks and months following the flood and generally receded over time. The majority of longer-term health problems attributed to flood events were not the physical but the psychological impacts. These impacts appear to have led to increased and prolonged physical health problems, which in turn exacerbated and prolonged the psychological effects. Tunstall *et al*. (2006) reported that psychological effects were much more commonly reported after flooding than physical ones, with anxiety when it rains the most frequently mentioned symptom. The extent of exposure to a flood related disaster is probably the most important risk factor for the development of flood disaster related post traumatic disorders. This means that persons who are direct victims of flood disaster have a greater likelihood of developing post traumatic disorders than other groups who have not experience similar disaster. It is against this background that the empirical stage of the research will focussed on those households who had experienced flood event in the past (summer 2007 flood event). However, the extent and magnitude of flood damage and impact on properties and households depend on the characteristics of flood itself.

2.6 IMPACT OF FLOOD CHARACTERISTICS ON DAMAGE TO PROPERTY

As described in section 2.5, the impact of flooding on households is great and causes distress to households. However, flood losses arise to the extent to which the elements and structure of a building, and its contents, are susceptible to different characteristics of a flood. There are a number of different characteristics of a flood which could cause damage these are, flood depth, duration, velocity of flow, and floodwater contaminants (Kelman, 2002; Kok *et al.*, 2004; Messner *et al.*, 2007; Samwinga and Proverbs, 2003). Conventionally, the most important characteristic is understood to be the depth of flooding. Hence, it is usual to estimate flood losses by reference to a depth-damage curve (Messner *et al.*, 2007; Penning-Rowsell *et al.*, 2010). Concurring to this, the result of the study which was carried out by Soetanto *et al.* (2002a) reveals that surveyors perceive the depth of floodwater to be the most important factor in determining the flood damage potential (i.e. the most destructive and costly). Other characteristics of floods that can affect flood losses and impact include the velocity of flow, the duration of the flood, flood contaminant materials, and materials entrained in the flood water (that is the volume of debris).

The extent of damage to a property by flood depends on the property characteristics, which include the building construction material and drying characteristics, its condition prior to flooding and the frequency of flooding incidence (Soetanto *et al.*, 2002a). Flood characteristics are major factors which determine the extent of damages suffered by properties and the subsequent economic impact on the household. For the purpose of this thesis, flood depth and duration will be discussed further, as these are the two flood characteristics which can significantly affect flood damage and subsequent reinstatement costs.

2.6.1 Flood depth

In the UK, flood depth is often considered as the key factor influencing the extent of flood damage (DTLR, 2002). For example, very shallow floods, which do not rise above floor level; the damage caused is unlikely to be significant for most properties, unless the property contains a cellar. On the other hand, flood depths greater than one metre above floor level may damage the building's structure through hydraulic pressure and abrasion or scouring (Soetanto and Proverbs, 2004; Proverbs and Lamond, 2008). Typically, up to 900mm of floodwater within a modern house (terraced, semi-detached or detached) will result in an average cost of £35,000 to reinstate the property back to its pre-damage condition, this cost excludes professional fees (Wassell *et al.*, 2009) and around £14,000 to replace damaged belongings (Penning-Rowsell *et al.*, 2010). Therefore, flood depth is a major variable to be considered in this research when developing conceptual model in chapter 4 and estimating the additional cost of PLFRA measures.

2.6.2 Flood duration

As described in section 2.6, flood duration is another major characteristic which has potential to affect the extent of flood damage. Generally, the longer the floodwater remains in contact with the fabric of buildings, the more extensive is the damage caused. This is mainly due to the fact that the structures of many UK properties are made of porous solid materials, such as bricks, blocks and concrete (Soetanto and Proverbs, 2004). Particularly, kitchen units, which are traditionally constructed from chipboard, offers little, if any, resilience against flood damage (Wassell *et al.*, 2009).

Hence, the longer the flood duration, the greater the amount of floodwater absorbed by the building materials; hence, prolonging subsequent drying and repair works and subsequently increasing the cost of reinstatement. Concurring to this, Messner *et al.* (2007), argue that the duration of flooding is important for instance when calculating production losses but could also influence direct impact of flooding on properties. USACE 1996, cited by Messner *et al.,* (2007) argue that duration may be the most significant factor in the destruction of building fabric. This may be true for properties in the UK because there is potential increase damages from longer duration of flooding, for example, mortar, drains, timbers, plasterworks and tiles will be affected and subsequently require to be replaced, thereby increasing the cost of reinstatement.

The impacts of flooding on households and flood characteristic, which can have significant impacts on the extent of flood damage and looses experience by households, have been discussed. In the next section of this chapter, measures which have the potential to reduce or eliminate the identified impacts are discussed.

2.7 PROPERTY-LEVEL FLOOD RISK ADAPTATION (PLFRA) MEASURES

As outlined in Chapter 1 section 1.4, one of the objectives of the research is to review and identify measures which are capable of reducing or eliminating flood impacts as described in section 2.5.1. PLFRA measures entails all actions taken by homeowner to adapt their properties and households behavioural changes to flood risk (Joseph *et al.*, 2011a). These include collective process of either keeping water out - resistance measure or allowing the water into the property but reducing the damage caused to the fabric of the property - resilience measure (ABI, 2003; Thurston *et al.*, 2008; Beddoes and Booth, 2008; Wassell *et al.*, 2009; Joseph *et al.*, 2011a; Warren *et al.*, 2011; JBA, 2012; Royal Haskoning, 2012). Further property can be adapted to flood risk by relocating expensive items from ground floor to first floor or by register for flood alert warning (Walker *et al.*, 2008; Priest *et al.*, 2008).

As discussed in sections 2.5 and 2.6, if a home is flooded it can be costly, not just in terms of money and time but also inconvenience and this can impact adversely on people's health. The experience of flooded homeowners in having household member(s) move out of the home, for example, to stay with relatives, in rest centres, in rented property, or confined in caravans in the front garden also added to the health and stress effects EA/DEFRA (2004). The length of time it took to get the house back to normal after the flood was another good reason why the adoption of PLFRA measures can lead to a significant reduction in the intangible impact of flooding on households. Mark (2008) argues that measures that minimize population displacement and favour an early return of victims to routine activities of daily living are known to lessen the adverse impact of flooding.

DEFRA, in its 'Making Space for Water' (DEFRA, 2005), encourages uptake of flood resilience and resistance measures for individual properties especially where publicly-funded community defences are impractical. As discussed in section 2.6, one of the factors that either mitigate or aggravate the mental health of flood affected victims following a flood event is the length of time it normally took to reinstate their properties back to the pre-flood conditions, it can be concluded that adoption of PLFRA measures by floodplain residents has the potential to reduce the intangible impact of flooding on households as the adoption of such measures means that their properties would be returned to normal quicker. The two main flood adaptation measures are discussed.

2.7.1 Flood resistance measures

As previously discussed, resistance measures are designed to keep out, or at least minimise, the amount of water that enters a building (DEFRA, 2005). There are temporary and permanent resistance measures which householders can implement. Temporary measures involve the installation of barriers which prevent flood water from reaching the property (Wingfield *et al.*, 2005). Permanent measures include waterproof doors and windows, automatically sealing airbricks – which use devices such as flotation valves to seal the bricks (see Figure 2.1) – and automatic barriers. A further categorisation of resistance measures can be made in accordance with the deployment method; these are manual and automatic deployed resistance measures.

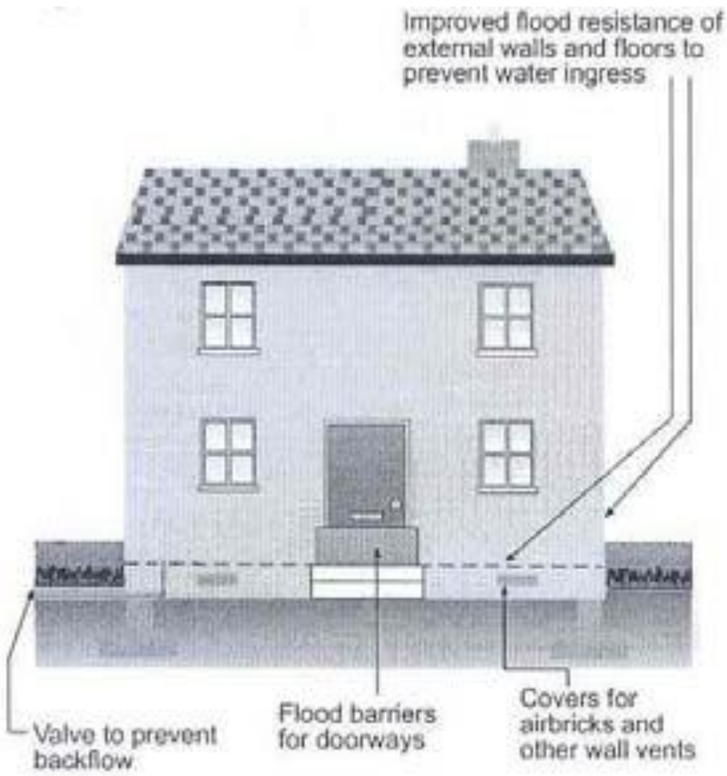


Figure 2.1 Installations of resistance flood protection measures

Developing flood resistance specifications

Grant *et al.* (2011) established two packages of resistance measures, Manual Activation and Fit and Forget. These were named in terms of how the measures are to be deployed or installed to achieve the required protection against flood risk. However, Royal Haskoning (2012) identified that there were some items that are usually included in these types of resistance packages that were not included in Grant *et al.* (2011) resistance package; therefore, the package was updated accordingly. This research will adopt the updated version of the resistance package. Table 2.3 shows the resistance measures categorised in accordance with methods of deployment.

Table 2.3 Resistance specification adopted for the research

Flood resistance specification	**Itemised measure**
Manual Specification	Singular panel demountable door guard
	Demountable panelled system fitted into channels – for patio doors
	Airbrick Cover
	Sewerage bung
	Toilet pan seal
	waterproofing work on external walls (up to 1.2m high)
	Apply silicone gel sealant around cables
	Supply and install sump pump
Automatic specification	Supply and install automatic door guards
	Supply and fix self-closing airbrick
	Supply and fix non-return valves 110mm soil waste pipe
	waterproofing work on external walls (up to 1.2m high)
	Apply silicone gel sealant around cables
	Supply and install sump pump

Both resistance measures (i.e. manual and automatic) are set at a height of protection of 0.6m above the threshold of the property, which is the current industry standard (Royal Haskoning, 2012), the rationale for selecting this flood threshold is that according to the ABI (2003), the level of flooding currently being experience in the UK at the moment is between 100 to 600mm deep, therefore, it is prudent to put this into consideration when estimating the costs of the measure, further, approximately 35% of properties flooded in 2007 summer flood event were inundated up to 900mm deep (Wassell *et al.*, 2009). The other 65% were inundated up to 600mm.

The specification presented in Table 2.3 will be used in chapter 4 for the development of the conceptual model for the CBA model of resistance measure to be developed in chapter 9. However, where installation of flood resistance measures is not practicable or viable, for instance, in terrace properties where the adjacent neighbour is not taking similar adaptation measures; property can be made flood resilient by installing resilience measures.

2.7.2 Flood resilience measures

Resilience has been defined as the ability of a building to resist exterior and interior damage as a result of flooding (Wingfield *et al.*, 2005; Joseph *et al.*, 2011a); resilience measures aim to reduce the consequence of flooding by, for example, facilitating the early recovery of buildings, infrastructure or other vulnerable sites following a flooding event (DEFRA, 2005; Proverbs and Lamond, 2008). Flood resilience measures reduce the cost of repairs after deep and prolonged floods, and can speed up restoration times. Due to the additional cost involved in implementing such measures, they are generally recommended for buildings with exceptionally high risk of flooding and are usually installed when restoring a building after it has been flooded or as part of planned renovations in order to reduce the cost of installation.

Developing flood resilience specifications

In developing the resilience specification for this research (illustrated in Table 2.4), guidance was drawn from a range of publications and previous research including (Bowker, 2002), (DTLR, 2002b), (ABI and NFF, 2004a), (Proverbs and Soetanto, 2004), (Garvin *et al.*, 2005), (Bowker *et al.*, 2007a), and (Soetanto *et al.*, 2008a). The following resilient specifications were adopted for this research work:

- Renewing external timber doors with UPVC (upd – upvc door)
- Replacing timber sub floors with concrete sub floors (cf – concrete floor)

- Replacing gypsum plaster with water resistant materials such as sand/cement render and lime plaster (scr – sand cement render)
- Fixing UPVC wall boarding in place of plasterboard (upw – upvc wall boarding)
- Replacing timber skirting with a UPVC equivalent (ups – upvc skirting)
- Replacing architraves with a UPVC equivalent (upa – upvc architraves)
- Renewing internal doors with solid hardwood (shd – solid hardwood door)
- Painting of hardwood doors with water resistance paint (wrp – water resistance paint)
- Sealing of door frames with water resistance materials (wrs – water resistance sealant)
- Hanging internal doors with rising butt hinges to facilitate removal on flood warning (rbh – rising butt hinges)
- Re-wiring of ground floor electrics to allow cables to run down from ceiling void where previously within timber sub floor (ddw – drop down wiring)
- Mount boiler on wall (mvw –mount boiler on wall)
- Move service meters well above likely flood level (sma – service meters above)
- New ceilings and decoration to allow rewiring (cd – ceiling decoration)
- Replacing chipboard kitchen/bathroom units with plastic units or water resistant panels

These specifications were grouped into two different packages of adaptation measures, the grouping was based on whether resilient measures were taken with resilient flooring or not (Thurston *et al.*, 2008; Royal Haskoning, 2012). The categorisation was adopted so that the existing floor construction can be put into consideration when estimating the costs of resilience measures. According to Royal Haskoning (2012), the decision whether or not to install resilient flooring has a significant impact on the costs of resilient measures (Royal Haskoning, 2012). Table 2.4 shows the resilience measures adopted in this research.

Table 2.4 Resilience measures

Resilience package	Individual Resilience measures
Resilience without flooring	Replace gypsum plaster with water resistant material, such as lime Replace doors, windows and frames with water-resistant alternatives Hanging internal doors with rising butt hinges Mount boilers on wall Move electrics well above likely flood level Move service meters well above likely flood level Replace chipboard kitchen/bathroom units with plastic units of water resistant panels Replace MDF panel with water resistant panels Decoration to allow re-wiring
Resilience with flooring	All measures above and Replace timber floor with solid concrete

Source: Adapted from Royal Haskoning (2012)

Despite the extra cost of these measures, it has been suggested that the implementation of resilient measures will reduce the repair costs in the long-term assuming repeat flooding (Thurston *et al.*, 2008).

Making property resilient or resistant to floods is not a universal remedy for all ills. Some floods will cause structural damage or sweep away well protected homes (Lamond and Proverbs, 2009). The effectiveness of the resilient measures taken would be greatly dependent on the expected depth and duration of the flood water as described in section 2.6 and it has been established that in some cases these measures are not always cost effective (Thurston *et al.*, 2008; Lamond and Proverbs, 2009); therefore, proper flood risk assessment should be carried out before investing in resilient reinstatement. Hence, the need for a study which provides detail information of costs and benefits of PLFRA measures to assist homeowners in decision making.

2.7.3 Review of Government Property level flood adaptation grant scheme

The UK Government, through DEFRA, ran a property-level flood protection scheme between 2009 and 2011. The scheme was instituted in order to increase the uptake of flood adaptation measures at household levels. The grant was made available to selected at risk residents and can be spent on property surveys to determine the most appropriate measures to protect individual properties, as well as pay for the full cost or a proportion of the cost for the measures and their installation. By the close of the two year programme £5 million had been allocated to local authorities who delivered property-level flood protection to over 1,000 households in over 60 communities across England.

Follow the completion of the DEFRA grant scheme in March 2011, the Environment Agency in April 2011 made £2 million of Flood Defence Grant in Aid (FDGiA) funding available to property level flood protection projects, such as flood barriers for doors or airbrick covers. The funding was available for groups of residential properties in areas that are at high risk from flooding and where there is no prospect of a community flood defence in the foreseeable future. The report produced following the completion of the scheme shows that residents overwhelmingly agreed to the scheme, since Government was paying for it. Therefore, it can be concluded that one of the barriers to uptake of PLFRA measures by floodplain residents is non-willingness to pay for the measure.

2.7.4 Barriers to uptake of resistance and resilience measures

The adoption of flood resilient and resistant construction may have a long-term positive benefit by reducing both the tangible and intangible losses experienced by households during flood events; cognisance has to be taken of other drivers, such as liveability, and most importantly the acceptability of any change in construction methods to the homeowner. According to the homeowner's survey conducted on behalf of the

Association of British Insurer (ABI, 2009), it was identified that there may be some resistance by the homeowners to any reinstatement method, which varies from the status quo that existed pre flood (Lamond and Proverbs, 2009).

Cost perception was identified as a major factor limiting the uptake of flood resistance and resilience measures by individual homeowners (Proverbs and Lamond, 2008; Thurston *et al.*, 2008). A survey of householders and businesses carried out on behalf of DEFRA/EA (Thurston *et al.*, 2008) revealed a number of factors that deter people from taking mitigation measures. These are:

- feelings that they are expensive,
- the belief that collective measures have already reduced the risk,
- concerns about impacts on the appearance of the property,
- lack of experience of flood event (Proverbs and Lamond, 2008),
- concern that such measures might adversely affect property values (Proverbs and Lamond, 2008) or make properties harder to sell (Thurston *et al.*, 2008),
- Lack of clear communication strategy to enhance individual understanding of the benefits of using flood resistance and/or resilience measures.

As discussed, lack of information on the cost of the measure and subsequent benefit in financial terms is a major barrier militating against uptake of PLFRA measures by floodplain residents.

2.7.5 Costs of property-level flood risk adaptation measures

Previous research carried out on behalf of the ABI (2009), revealed that, on average, resilient reinstatement costs over 40% (£12,000) more than traditional reinstatement. It was stressed that there are significant variations around this 40% average, both between house types (i.e. bungalow, detached, semi-detached and terraced) and within house types. Although, the authors further reiterate that resilient reinstatement could costs as little as 15% or as much as 70% more than traditional reinstatement (ABI, 2009). The reasons for the wide variation in percentage extra over cost were property owners' individual preferences and different approaches to reinstatement methods adopted by different surveyors, despite the available guidance such as Proverbs and Soetanto, (2004), Garvin *et al.,* (2005) and (PAS 64, 2013).

Some resilient measures can be introduced on a cost neutral basis, and therefore not all aspects of resilient reinstatement measures increase the cost of reinstatement. According to the economic modelling study, which was conducted on behalf of DEFRA and EA, resilience measures are most cost effective when conducted as part of a programme of resilient repair following a flood (Thurston *et al.*, 2008). Table 2.5 shows the cost comparison of some traditional building / reinstatement materials against their resilient alternatives.

Table 2.5 Comparison of material cost of traditional and resilient reinstatement

	Material		**Costing**		
Component	**Traditional**	**Resilient**	**Unit**	**Traditional**	**Resilient**
Plaster	Gypsum	Cement/sand	M2	£14	£21
Plasterboard	Plasterboard	UPVC cladding	M2	£18	£45
Staircases	Softwood	Hardwood	Item	£900	£1,500
Skirting - shallow profile	Softwood	UPVC	M	£6	£11
Skirting - deep profile	Hardwood	UPVC	M	£34	£21
Doors and frames	Softwood/Hollow	Removable	Nr	£160	£330
Floor construction	Timber (including floor joist and board)	Concrete	M2	£91	£140
Floor Finishes	Laminate (including underlay)	Tile	M2	£37	£60

Source: ABI Research Paper 14, 2009 (Resilient reinstatement: the costs of flood resilient reinstatement of domestic properties)

For example, replacing hardwood skirting with Upvc will cost approximately 62% less. However, other materials show percentage cost increases ranging from 50% to 150%

over the traditional reinstatement costs. One other major factor which determines the extra over cost of resilient reinstatement over the like-for-like reinstatement is the expected flood depth as discussed in section 2.6.1 (ABI, 2009, ABI and NFF, 2004a, Broadbent, 2004). Understandably, as the depth of the floodwater increases, so does the cost of necessary repair works. Getting this wrong may invalidate the resilient measures, which were taken, and at times it may lead to even higher reinstatement costs. For example, the cost of replacing a cement sand render in a property with expected flood level of 900mm is expected to be greater than when doing the same to a property with expected flood level of 300mm. Therefore, it is always advisable to obtain full information of the expected flood level prior to the adoption of resilient measures.

2.7.6 Benefits of property level flood risk adaptation measures

According to Brent (2003) benefit is any gain to individual. Benefits of investing in PLFRA measures can be gained by different flood risk management stakeholders, such as homeowners in terms of reduction in intangible impacts such as stress of living in alternative accommodation for months (Warren *et al.*, 2011); tangible benefit to the insurer in terms of reduction in claim spend following future flood event (Joseph *et al.*, 2011a). The adoption of property-level flood adaptation measures can be taken into consideration by the insurer when quoting for flood insurance (DEFRA, 2011); thereby, making it possible to obtain insurance cover at affordable price. Other benefits are the reduction or elimination of intangible impacts such as:

- Reduction in the deterioration of physical health
- Reduction in depression cases following flood event (Reacher *et al.*, 2004)
- Reduction in anxiety rate
- Reduction in stress
- Loss of irreplaceable items

- Worrying about future flooding
- Potential to reduce strains between families
- Loss of community spirit
- Reduction in the deterioration of mental health
- Reduce worrying about loss of borrowing power
- Inability to move house immediately after flooding

Flood resistance measures help in reducing the vulnerability of a building to excess water. For instance, the use of simple solutions such as one-way valves on pipes and drainage prevent water back-up into buildings. The largest percentage savings are for residential properties with an annual risk of flooding of 4% or greater (25 year return period). Research shows that for households that flood more than once in every ten years, the benefits (both financial and non-financial) outweigh the up-front investment by a factor of between five and ten, while for the average office-based business they outweigh the up-front investment by between six and eleven times (Thurston *et al.*, 2008).

Research has demonstrated clearly that adopting resistance and resilience adaptation measures is beneficial in financial as well as psychological terms. However, homeowners need to be convinced of these benefits in order to assist in their decision making on investing in PLFRA measures. It may, therefore, be argued that to demonstrate these benefits, it would be useful to undertake a review of the concept of CBA and its applicability to the study of PLFRA within the context of flood risk management at household levels.

2.8 SUMMARY

This chapter has presented a review of literature focusing on different types of flooding and the particular flooding relevant to the current study has been defined. This study focus on domestic properties at risk from fluvial flooding in England. Critically, the review also focuses on the impacts of flooding on household, with particular attention to the intangible impacts. Measures to reduce the identified impacts are critically discussed. Cost of measures to reduce or eliminate the impacts are also discussed and the theoretical benefits of the measures are presented in the chapter, it shows that the benefits of adopting the measures can also be reaped by insurance companies in terms of reduced claim spent following future flooding. To consider this theme of the research there is a need to carry out comparative analysis of the costs and benefits deriving from adoption of PLFRA measures through the application of the concept of CBA. Therefore, a critical review of the concepts of CBA and justification for its applicability in the context of PLFRA measures in England is presented in the next chapter.

CHAPTER THREE: THEORETICAL REVIEW OF THE CONCEPT OF COST BENEFIT ANALYSIS

3.1 INTRODUCTION

The theory behind cost benefit analysis (CBA) is relatively well developed; however, its application to real world problems is not always easy. The main aim of this research is to develop a comprehensive CBA model of property level flood risk adaptation (PLFRA) measures. Therefore, a consideration of the theory of CBA, the underlying decision making theory in project / investment appraisal is, therefore, relevant to the research. Further, and in line with the underlying research philosophy, the quantification of the different impacts of flood on households will require the use of different cost estimation methodologies for the purpose of developing a comprehensive costs and benefits models.

To this end, an appreciation of the full concept of CBA and its application in flood risk adaptation appraisal and investment at the individual property level will be critical to this research. In line with objective two of the research, the critical review of the principles of CBA and argument for its full applicability in decision making on investing in flood mitigating measures at property level are presented in this chapter. Further, the origin of CBA and how it has been applied in various other contexts including flood risk alleviation schemes are presented. Following which, exploration of how the concept of CBA may be adapted for potential application in the financial appraisal of flood adaptation measures at individual property levels is discussed. The chapter argues that the application of CBA in decision making on PLFRA measures can potentially offer an opportunity to understand the relationships between the costs and benefits of investing in such adaptation measures. This chapter, therefore, serves as the pivot for this research work and will lead to the development of a CBA conceptual framework to investigate the development of the CBA model of PLFRA measures.

3.2 THE CONCEPT OF COST BENEFIT ANALYSIS (CBA)

CBA was described by Snell (2011) as a formal technique adopted for clear systematic and rational decision making, especially when faced with complex alternatives or uncertain data. It is a quantitative analysis of probable outcomes of alternative courses of action, which diminishes the uncertainty and improves the decision-making process (TBCS, 1998). It was suggested by the Canadian Institute for Research in Construction (IRC) that the use of CBA as a technique for economic justification for any flood proofing measure should be encouraged among floodplain residents (Wingfield *et al.*, 2005).

CBA is used to undertake an economic evaluation of an investment proposal, change in policy or regulatory arrangement and is specifically concerned with identifying and measuring (where practical), and then discounting future costs and benefits to present values to enable the calculation of the net economic worth of project options (CASA, 2007). There is usually an existing strong presumption that an act should not be undertaken unless its benefits outweigh its costs (Hanley and Spash, 1995). In order to determine whether benefits outweigh costs, it is desirable to attempt to express all benefits and costs in a common scale or denominator, so that they can be compared with each other, even when some benefits and costs are not traded in the market and, hence, have no established monetary values.

The basic principle of CBA requires that a project results in an increase of economic, financial and societal welfare, i.e. the benefits generated by the project should exceed the costs of it (Brinkhuis-Jak *et al.*, 2004). Every effect of an investment project should be systemically estimated and, wherever possible, can be given a monetary value. Application of concept of CBA can give an overview of distribution effects of a project or resources; alternatives and uncertainties inherent in the project; this is possible because, overall assessment on project or resources costs will always requires complete information. This requires that all relevant effects/costs (both tangible and intangible costs/impacts) are taken into account when carrying out such project appraisal. However, in practice, according to Thurston *et al.* (2008) and Ikpe (2009) the analysis of the costs and benefits of projects is often narrowed to the consideration of tangible monetary impacts, with intangible impacts often excluded.

In flood risk management at national level, this means that the costs of measures for increasing the safety against flooding (for example, construction of flood defence) are compared with the decrease in expected flood damage (i.e. to property) in the area. However, in the evaluation of costs, different types of costs have to be included: costs of investment, which are both fixed and variable costs (fixed costs are not subject to change throughout the life span of the project while variable costs are subject to change throughout the life span of the project); and the costs of maintenance and management (Penning-Rowsell *et al.*, 2005). The benefits include the reduction of damage costs, which are often subdivided in direct costs (repair of buildings and interior damage), costs of business interruption of companies in the flooded area, and indirect costs outside the flooded area mainly due to business interruption (Pearce *et al.*, 2006). Penning-Rowsell *et al.* (2005) argued that companies outside the flooded area may benefit from the flood due to transition effects (Penning-Rowsell *et al.*, 2005). Therefore, the potential economic growth due to improved flood defence should be taken into account in a full CBA; however, the spatial scale of measurement is critical when carrying out economic CBA at a national level.

3.2.1Criticism of cost benefit analysis

It is important to note that while CBA is an extremely useful project appraisal tool, it has been heavily criticised for a number of shortcomings. Most of these issues are extremely common in the economic literature and, as such, there is little need to go into great detail here (Hanley and Spash, 1993; Zerbe and Dively, 1994; Edwards-Jones *et al.*, 2000). However, one notable criticism, which is peculiar to this study, was asserted by Joubert *et al.,* (1997) that the concept of CBA necessitates quantification of all costs and benefits in monetary terms, even when not all benefits are traded in the market, therefore, posing problems to economist in the evaluation stage.

Another notable criticism of CBA which is relevant to the study of PLFRA measures as argued by Ackerman (2008), is that costs and benefits of public policies do not always occur simultaneously. Both cost and benefits do occur over a period of years, the benefits of investing in PLFRA measures often extend much farther into the future than the costs. Therefore, in addition to presenting all costs and benefits in monetary terms, cost-benefit analysis follows standard economic practice in discounting future benefits, converting them to their equivalent value today, or present value. In Economist views, when the time span is so great that different generations are involved in costs today and benefits tomorrow, the analogy to an individual investment decision breaks down (Hanley and Splash, 1993; Ackerman, 2008). However, it was suggested that when setting discount rate for a project, it must be set to a very low level, so generate enhanced benefits (Stern, 2006; Ackerman, 2008).

However, application of the concept of CBA in the study of PLFRA measures requires that the intangible benefits are monetised to assist in comparing the cost with benefit for decision making. In order to guide against the critiques discussed earlier, appropriate evaluation method will be used to estimate the value of intangible benefits. Having introduced the concept and the critiques of CBA as related to the study of PLFRA measures, it is considered important to trace the origins of the CBA prior to discussing its application in the study of PLFRA measures.

3.3 ORIGIN OF COST BENEFIT ANALYSIS

The theory of CBA is primitive and its origin can be more precisely set in the 1840s with the writings of the French Engineer and Economist Jules Dupuit (Little and Mirrlees, 1974; Brent, 1996; Pearce, 2002). The concern of Dupuit was the issue of how to make public choices about investments that had no necessary commercial returns, such as roads and bridges. He established the notion of what today is being called ‘consumer’s surplus’, the consumer’s net benefit from consuming something and measured by excess of willingness to pay over the cost of acquiring the good (Brouwer and Pearce, 2005). Prior to this period, the theory and practice of CBA remained divergent, however, until the formal requirement that costs and benefits be compared entered into water-related investments in the USA in the late 1930s (Pearce, 1988; Brouwer and Pearce, 2005).

After World War II, there was pressure for efficiency in government and there was a requirement to find ways to ensure that public funds were efficiently utilised in major public investments (OECD, 2006). This resulted in the beginnings of the fusion of the new welfare economics, which was essentially CBA, and practical decision-making. Harberger and Jekins (2002) observed that since the 1960s CBA has enjoyed fluctuating fortunes, but is now recognised as the major appraisal technique for public investments and its application rapidly expanded to a variety of public sector activities in all parts of the world (Preez, 2004, OECD, 2006). Ikpe (2009) argued that the earlier uses of CBA were concerned to bring quantitative appraisal into the process of the allocation of public resources in an attempt to realise greater economic efficiency.

The UK government in 1967 gave formal recognition to the existence of CBA and assigned a limited role for nationalised industries. While in 1972, the United Nations industrial development organisation (UNIDO) published its own guidelines different in detail but essentially with the same philosophy (Mishan, 1982). This implies that the CBA has been applied in many countries and in different contexts. In the context of flood protection investment appraisal, applying CBA is similar to any other method of investment appraisal where there are scarce resources to be allocated and, therefore, decisions have to be guided in order to achieve maximum benefit from their investment (Brent, 1996; TBCS, 1998; Penning-Rowsell *et al.*, 2005; Campbell and Brown, 2007). Therefore, this technique has the potential to be applied to help compare the costs and benefits of property-level flood risk adaptation measures. However, Snell (2011) argued that CBA are differentiated according to the identity of the group of people on whose behalf they are carried out, or whose interests are to be taken into account in making decisions. Therefore, it is necessary to identify different types of CBA. There are three main categories of CBA, these are economic, financial and social.

3.3.1 Economic cost benefit analysis

An economic CBA concerns the welfare of a defined group of people, usually a nation (Penning-Rowsell *et al.*, 2005; Snell, 2011). There is general perception that market prices and money flows, which are usually the starting points for quantification of costs and benefits, are imperfect representation of the group's best interests, therefore they have to be adjusted by what is refer to as shadow pricing (Layard and Glaister, 1994; Belli *et al.*, 2001; Brent, 2006). Snell (2011) argued that the adjustments are often towards efficiency prices, corresponding to the concept of perfect market that achieves the best possible allocation of resources by the interaction of supply and demand. It can be inferred that in economic CBA, the purpose of economic pricing is to adjust market or financial prices in order to correct for these distortions and arrive at the prices that a perfect market would arrive at. However, Snell (2011) concluded that this leads to one of the main sources of subjectivity, and hence dispute, in economic CBA. In the domain of national flood risk management and investment in major flood alleviation schemes, economic CBA is the main means of assessing national economic losses caused by floods and their indirect consequences. This will be discussed in more detail later in the chapter.

3.3.2 Social cost benefit analysis

Social cost-benefit analysis refers to cases where the project has a broad impact across society and, as such, is usually carried out by the government (Pollock, 2008; Fujiwara and Campbell, 2011). The HM Treasury (2009) described social CBA, as a way of expressing the value of a proposed government policy to society. It seeks to express the full social costs and full social benefits of policies in monetary terms so that the consequences of a diverse range of policies can be compared using a common metric (Fujiwara and Campbell, 2011). In a social CBA the analyst adjusts the prices by which costs and benefits are valued by applying discount rates, so as to reflect priorities that no market would reflect, not even a perfect market (Snell, 2011). It could be argued that there is no implication that such prices are anything but subjective applications of value judgments, usually of an explicitly political nature. However, in practice, there is no clear distinction between economic CBA and social CBA, both kinds in most cases are being referred to as economic analysis (Irvin, 1978; Van Pelt, 1993; Snell, 2011).

3.3.3 Financial cost benefit analysis

Snell (2011) asserted that financial CBA concerns the financial position of a person, firm or organisation, so that both costs and benefits are measured in terms of money spent or received by that party, regardless of whether the prices are a good reflection of true value. This kind of analysis includes VAT, subsides and is not concerned with price distortions (Penning-Rowsell *et al.*, 2005). A financial CBA is made from the perspective of a person, group or unit directly involved in the project which is being appraised, for example flood protection to individual properties. In this case only the expenses that will be made by the homeowner and benefits that will accrue to the homeowners (i.e. not including the externalities) are taken into account in a financial analysis; this makes a financial CBA much simpler to calculate. In financial CBA, the actual money transfer involved is used to evaluate the loss or gain, for instance, if a household has a new-for-old insurance policy and they claim for a ten year old television, the loss is counted as the market price of a new television. According to Penning-Rowsell *et al.* (2005), the major distinction between economic CBA and financial CBA is that, any taxation element within the potential flood losses is always deducted when carrying out economic CBA; however, this is always included when carrying out financial CBA.

This research is based on providing decision making information on investing in PLFRA measures for homeowners; therefore, the financial CBA approach is adopted to compare cost and benefits of PLFRA measures for decision making. As the decision whether to invest in PLFRA measures is expected to be made by homeowners based on their disposable income, this then led the research to focus on financial CBA.

3.3.4 The decision-making perspective

The purpose of carrying out CBA is to guide decision making on the most cost effective way of achieving a common goal. According to Preez (2004), there are three techniques used in decision making. These are Net Present Value (NPV), Internal Rate of Return (IRR) and Benefit Cost Ratio (BCR). The choice of criteria to use in decision making depends on the purpose for which the CBA was carried out, however, one or more of these criteria can be used for decision making (Preez, 2004). For the purpose of this thesis, only two of the criteria will be discussed (NPV and BCR), this is because IRR is not relevant to the study. As it cannot be used to estimate the costs and benefits because the IRR has potential to yield results that are inconsistent with a ranking based on the NPV method.

Net Present Value

Net Present Value is the difference between the present value of all of the flow of benefits and the present value of the flow of costs (Penning-Rowsell *et al.*, 2005), otherwise expressed as the sum of discounted net cashflows over the period. When properly calculated, the NPV is a relatively objective method of determining the improvement in national wealth resulting from a proposal (CASA, 2007). One of the criteria for reducing benefits and costs to a unique value is the net present value (NPV) or "net benefits" criterion (Penning-Rowsell *et al.*, 2005; OECD, 2006), this is represented by equation 1:

$$\text{NPV} = \sum_{t=0}^{n} \frac{B_t - C_t}{(1+r)^t} = 0 \quad \text{Equation 1}$$

Where:

NPV = net present value

B_t = benefit after t years

C_t = cost after t years

N = number of years

$(1 + r)^t$ = factor which the difference between B_t and C_t is discounted by

r = the discount rate

Harrison (2010) argued that the higher the net present value, the more valuable the project. Where budget constraints exist, however, the criteria become more complex. The NPV measure profits only and has its own drawback such as the selected discount rate (Penning-Rowsell *et al.*, 2005). This shortcoming is somewhat irrelevant in this research because the choice of discount rate can be flexible, thereby, allowing users of the model to decide on the appropriate discount rate to use. However, NPV will not be adopted as a decision making criterion in this study because benefit cost ratio (BCR) is the preferred decision making criterion in the domain of flood risk management research.

Benefit-cost ratio (BCR)

The BCR is defined as the ratio of the present value of benefits over the present value of costs (Preez, 2004; Penning-Rowsell *et al.*, 2005). Benefit cost ratio can provide a sophisticated means of comparing different investments and outcomes once they are both expressed in a common monetary unit. It is limited to consideration of those impacts to which a value can be attached but it leads to a simple parameter on which choices can be made (Penning-Rowsell *et al.*, 2005). Therefore, the use of benefit cost ratio will require quantifications and monetisation of all impacts to a common unit, which is one of the objectives of this research. Benefit cost ratio (BCR) is represented by equation 2:

$$\text{BCR} = \frac{\sum_{t=0}^{n} \frac{B_t}{(1+r)^t}}{\sum_{t=0}^{n} \frac{C_t}{(1+r)^t}} = B/C \quad \text{……………………………………………………Equation 2}$$

BCR = Benefit Cost Ratio (see equation 1 for the definition of the other letters)

The ratio is used to measure both quantitative and qualitative factors. Snell (2011) suggested that in cases where possible, qualitative factors should be translated to quantitative terms in order for the results to be easily understandable and tangible. Perkins (1994) argued that the decision rule of the BCR is that a project should be accepted if its BCR is greater than or equal to one, that is, if its discounted benefits exceed its discounted costs. Advantages of benefit cost ratio are that it is easily understood by non-economists and easy to show the impact of a percentage rise in costs or fall in benefits on the projects viability (Perkins, 1994). Further it is the criteria used for decision making when appraising flood defence investment at government levels. The CBA model of PLFRA measures to be developed in chapter 9 will be presented in the form of BCR as a final decision making criteria.

Time Preference - Discounting

As discussed in section 3.2.1, one of the criticism of CBA is the need to apply discount rate to both cost and benefits. Discounting is used in CBA to compare costs and benefits over time. All costs and benefits are “brought back” to the starting time. Sugden and Williams (1988) argued that most important decisions about whether or not to undertake projects are not simply decisions about the use of resources at one point in time. They involve some commitment of resources or promise of returns in the future as well as in the present. Very often decisions have to be made about whether to incur costs in the present, in return for benefits in the future; as in the case of investing in PLFRA measures, every investment project requires a decision of this kind.

Since individuals have preferences for when they receive benefits or incur costs, these "time preferences" also have to be accounted for through the process of discounting. However, there is some level of unacceptability with regards to discounting, this unacceptability arises from the fact that distant future costs and benefits may appear as insignificant present values when discounting is practised. In turn, this appears to be inconsistent with notions of intergenerational fairness (Brent, 2006).

In the UK, before 2003, the Treasury (the *Green Book*) required a discount rate of 6%. (HM Treasury, 1997). However, from 1st April 2003, a new version of the *Green Book* (HM Treasury, 2003) introduced lower discount rates of 3.5% (0-30 years), 3.0% (31-75 years) and 2.5% (76-125 years). The impact of lower discount rates is to increase present values (PVs). For example, with the lower discount rate of 3.5%, £100 spent in 10 years will be an equivalent to £71 spent today. DEFRA (2012) has advised that the guidance on discounting in the new *Green Book* should be applied to the economic appraisal of all new flood and coastal defence projects in the UK. The implication of this, is that, the result of any appraisal with low discount rate would show an enhanced benefit. The introduction of lower discount rate in the UK concurred with the view of many environmental economists that have argued for the use of a lower discount rate for environmental projects. The advantages of discounting are that it enforces consistency and it makes the assumptions explicit (Penning-Rowsell *et al.*, 2005). In this research a discount rate of 8% is used in the development of the CBA model of PLFRA measures, however, the use of discount rate for individuals could be flexible and set by the user of the model without loss of generalisation of the developed model.

3.4 THE USE OF COST BENEFIT ANALYSIS (CBA) IN THE UK

CBA has had a long history in the United Kingdom. Its first real life application was project-based and was to road transport. Britain's first motorway was the M1 from London to Birmingham. The application of CBA on the project was, in fact, experimental rather than an integral part of the assessment. This is because, according to Coburn *et al.* (1960), had the CBA shown expected construction costs to outweigh the benefits, the construction of the motorway would still have proceeded. The cost of construction was compared with the benefits in terms of working and non-working time saved, reduced accidents, and changes in fuel consumption and vehicle wear and tear Coburn *et al.* (1960), as cited in Pearce, (1998) and Snell, (1997).

Following the successful completion of the M1 motorway project, it was the turn of the London Victoria underground railway to be evaluated in CBA terms (Foester and Beesley, (1963), as cited by Pearce, (1998). Interestingly, the CBA assessment of the project was not justified in purely economic terms, but was found to be profitable from a social standpoint once all time savings had been included. A consistent feature of these early studies was the total neglect of environmental impacts; the successful application of the concept of CBA at these early stages of the transport sector marked the coming of age of CBA in the UK. During this early stage, for instance, a government appointed research team concluded that an inland site was preferred on cost-benefit grounds. Most significantly, apart from savings in air and ground travel time, which together dominated the analysis, the team attempted to value noise nuisance and disamenity through an estimation of impacts on house prices (the hedonic property price approach). Although, by today's standards, the study was primitive it was the first significant attempt to estimate environmental impacts in monetary terms. However, the environmental opposition to the study was intense, this is because it was concluded that the environmental costs amounted to less than 0.5 per cent of total social costs at preferred sites, and only 1.5 per cent at the worst site (Pearce, 1998).

As discussed above, CBA in the UK began with project applications, reflecting the way in which the underlying theory itself developed, and only later came to be applied to policy. Other areas where CBA had an influence on project decisions include the following:

- The Aldburgh sea flood defence wall. The significance here was that this was the first use of contingent valuation results commissioned by the Ministry of Agriculture and accepted by HM Treasury. The Treasury had always shown scepticism towards the results of questionnaire based approached (Pearce, 1988);
- The conservation plan for the Norfolk Broads. The economic valuation study commissioned by the Ministry of Agriculture notably included an assessment of non-use values which were shown to dominate the overall valuation of benefits. Aside from the controversy over contingent valuation, there is a separate debate about the relevance of non-use values to CBA (Bateman *et al.*, 2003); and
- A cluster of local authority issues such as local sea defence schemes.

The modern period of CBA in British Government dates from the late 1980s with the first effective environment 'White Paper' (HMSO, 1990). One of the central features of sustainable development is the pervasive role of environment in all decisions.

Environmental issues had, therefore, to be treated seriously and formally, there was a need to know how they could be incorporated into decision-making.

The Environment Agency has shown considerable interest in CBA, reflecting the requirements of the Environment Act of 1995 to take into account the likely costs and benefits of its actions, and to be excused from this requirement only if it is unreasonable to do so. While the requirement does not formally mandate any particular form of CBA, considerable effort in the EA has gone into devising guidelines on the use of unit monetary values for assessing schemes and policies based on benefit transfer. Generally in the UK, substantially greater use is made of CBA and benefit estimation than probably realised.

Apart from the large scale application of CBA in the UK, the technique has also been applied on a smaller scale, such as the evaluation of local authority housing investments and the local provision of car parks and recreation facilities (Snell, 1997). Thus, CBA has been widely used in the UK to assist government decision making on social investment.

Apart from the UK, CBA has also been widely used in Asia (Anand and Nalebuff, 1987) and USA (Griffiths and Wheeler, 2005) and has even gained recognition at government level to simplify decision making. Its effective use led to preserve environment or health in the USA through the Federal Environmental Protection Agency (FEPA) and also has been introduced in other contexts such as agricultural projects, health contexts, water, electricity and gas supplies, and in education and transport (Snell, 1997).

In the UK, the Flood Hazard Research Centre (FHRC) at Middlesex University has carried out a series of research projects on flood damage estimation based on CBA concepts. These findings are published in the form of a series of manuals. The Blue manual was published in 1977, giving a detailed procedure for valuing damage loss resulting from flooding of residential, commercial, industrial and agricultural areas (Penning-Rowsell and Chatterton, 1977). In 1987, this was updated by the Red manual, which also refined and extended the treatment of types of property and extended the treatment of indirect losses (Parker *et al.*, 1987). In 1992, the FHRC issued the Yellow Manual, which was primarily concerned with coastal defences but also refined the methodology of the first two manuals (Penning-Rowsell *et al.*, 1992). In 2003, following series of research and updates, the Multi-Coloured Manual and associated handbook was published (Penning-Rowsell *et al.*, 2003). In 2005, an updated copy of the Multi-Coloured Manual and associated handbook was published, this was meant to guide the appraisal of most flood and coastal risk management schemes in England and Wales (Penning-Rowsell *et al.*, 2005). The aims of these manuals are two folds, namely:

a. to provide a range of techniques and data that can be used in a practical way to assess the benefits of fluvial flood risk management schemes and policies; and
b. to provide a range of techniques that can be used in a practical way to assess the benefits of plans and schemes to alleviate the impact of coast erosion.

The focus of these manuals was on CBA to aid the allocation of the nation’s scarce economic resources; therefore, it was based on economic CBA as discussed in section 3.3.1. The result of the manual cannot be used for financial CBA from the individual point of view as acknowledged by the authors (Penning-Rowsell *et al.*, 2005). However, the results of the manuals have been used extensively in the UK for flood risk management appraisal schemes.

With evidence from various applications of CBA as stated above, it is argued that CBA can be applied to PLFRA measures and improve homeowners' decision making in flood risk management at household levels in England. However, in order to apply CBA to flood risk adaptation measures, there is a need to carry out a comprehensive financial CBA to establish whether it is desirable or acceptable from the individual financial point of view. This may help to provide additional information on the viability of carrying out flood risk adaptation at an individual property level. In order to carry out a financial CBA, there is a need to establish both cost and benefits of PLFRA measures.

The main tasks involved in undertaking a financial CBA are to identify the right costs and benefits to be considered in the analysis and to estimate the various prices to be assigned to them (Perkins, 1994; Snell, 1997). Harvey (1987) suggested that this can be done by identifying all the relevant costs and benefits of a particular scheme and quantifying them in monetary terms so that each can be aggregated and then compare. Therefore, the first step in CBA is to identify all relevant costs and benefits (Briscoe, 1993; Perkins, 1994; Snell, 1997; Snell, 2011).

3.5 CLASSIFICATION OF COSTS IN CBA STUDY

The key issue in carrying out financial CBA is the identification and measurement of all relevant costs and benefits associated with the proposed investment (Irvin, 1978; Mishan, 1982; Briscoe, 1993; Snell, 2011). Cost has been defined as anything that imparts a loss and benefit as any gain to individual (Brent, 2003, Little and Mirrlees, 2003). Lindqist and Lindholm (2001) described costs as the values of the real resources used. There are different types of costs that are relevant to this research, these are; financial costs, social and opportunity costs.

3.5.1 Financial costs

Financial costs are the expenditures that are actually incurred by individual as a result of undertaken a project (Perkins, 1994). The financial costs of PLFRA measures are the tangible costs of installation of resilience or resistance measures, which is the additional cost of installing adaptation measure during flood recovery period, as discussed in chapter 2, the cost of like-for-like reinstatement will be paid by the insurer (Lamond, 2012). These financial costs are the direct costs to the homeowner of taking the decision to adapt their properties to flood risk.

3.5.2 Social costs

The social costs in relation to flood risk management at household levels account for the losses attributable to factors such as loss of life, both physical and stress-related symptoms, for example loss of sleep, anxiety, a reduced immune system response and increased susceptibility to certain illnesses (Environment Agency and DEFRA, 2004). These costs can be categorised as intangible costs. Other social costs include loss of irreplaceable personal belongings and the stress of dealing with insurers, builders and loss adjusters (Lamond, 2012). As discussed in Chapter 2, section 2.5 the intangible costs of flooding are difficult to quantify and some of them are ethically problematic to monetise. The social costs of flooding can be divided into short and long term costs and also with further classification into direct and indirect costs. In order to carry out a comprehensive CBA of PLFRA measures, these social costs will need to be quantified in this research (see chapter 6).

3.5.3 Opportunity costs

Harberger and Jenikins (2002) and Snell (2011) described opportunity cost as something that is given up in order to obtain something. Mishan (1982) described opportunity cost analysis as an important concept in company's financial decision-making processes. Pindyck (1992) argued that opportunity cost is useful when evaluating the cost and benefit of choices. Harberger and Jenikins (2002) reinforced this argument in stating that the principle of opportunity cost can be applied to both costs and benefits. Snell (2011) asserted that opportunity cost is a powerful concept with many applications. It is being used in daily decisions, particularly when there is a need to make financial investment choices. Perkins (1994) noted that economist favours opportunity cost as appropriate costs for decision-making. It follows that opportunity cost is the cost of passing up the next best choice when making a decision. For example, if an asset, such as capital, is used for one purpose, the opportunity cost is the value of the next best purpose the asset could have been used for. Therefore, it can be argued that the opportunity cost is a relevant cost concept, which can be applied to the study of property level flood risk adaptation when the problem facing the homeowners may be a problem of choice and proper allocation of their scarce resources.

Following the identification of different types of costs that are relevant to this research, it is important to discuss how this costs and benefits are measured.

3.6 REVIEW OF CBA VALUATION METHODS

As discussed in section 3.2, costs and benefits have to be measured and weighed up against each other in order to generate criteria for decision making. Arguably, if all the costs and benefits of PLFRA measures could be measured and assigned a money value, then the appraisal would involve no more than a simple exercise in monetary arithmetic. However, in measuring costs, two concepts of cost are important in CBA and these are financial costs and resources costs (Carley, 1987). As discussed in section 3.5.1, financial costs are the monetary values of actual goods and services such as costs of purchasing flood resistance and resilience materials and installation costs, which often have market values and are easily expressed in monetary terms (Perkins, 1994; Novozhilov, 1997). Resources costs in contrast involve opportunity forgone as discussed in section 3.5.3, which refer to the benefit which might have been gained had the resources been employed in their next best alternative use (Carley, 1987; Pearce, 1988; Sugden and Williams, 1988; Penning-Rowsell *et al.*, 2005; Snell, 2011). Many of the benefits of adopting PLFRA measures are intangibles and, therefore, not easily measured in monetary terms; however, for the CBA to be carried, as explained in section 3.2, both costs and benefits have to be in the same unit. Therefore, it is necessary to assign some monetary value to the intangible benefits of PLFRA measures so that the costs of the measures can be compared with the benefits in monetary terms. There are two methods of assigning monetary value to intangible benefits, these are revealed and stated preference methods (Folmer and Ierland, 1989; Environment Agency and DEFRA, 2004; Penning-Rowsell *et al.*, 2005; CASA, 2007; Botzen *et al.*, 2009).

The reveal preference methods (RPM) are also known as indirect valuation methods, the RPMs look for related or substitute markets in which the environmental good is implicitly traded, the information derived from observed behaviour in the substitute markets is used to estimate willingness to pay (WTP), which represents individual's valuation of, or the benefits derived from, the investment in flood protection measures (Penning-Rowsell *et al.*, 2005). The RPM have the advantage of producing estimates of the value for a particular good from actual market behaviour; however, care must be taken in extrapolation to market conditions which have not been observed in practice. The two most popular examples of RPM, which are prevalent in the environmental economics literature, are the hedonic pricing and the travel cost methods (Penning-

Rowsell *et al.*, 2005; Birol *et al.*, 2006; Lamond, 2008; Markantonis and Meyer, 2011). In the context of quantifying the intangible impacts / losses of flooding on households, neither of the two examples of RPM will be considered further in this thesis as they both cannot be used to value the intangible impact of flooding on households.

3.7 STATED PREFERENCE METHODS (SPM)

Stated preference methods (SPM), also called direct valuation methods or inferential methods, have been developed to solve the problem of valuing intangible impacts/losses that have no obvious market value (Penning-Rowsell *et al.*, 2005; Birol *et al.*, 2006). The SPMs use survey techniques to elicit the value of something that does not have an observable price (Penning-Rowsell *et al.*, 2005). They are survey or experiment-based approaches that elicit people's preference directly. The contingent valuation method (CVM), and the Choice Modelling method (CMM) are the two main examples of SPM. Both methods use structured questionnaires but differ in the way they define the non-market effect of concern. The most important feature of these valuation methods is their ability to evaluate outside the observed market conditions. In addition to their ability to estimate use costs / values of any environmental impact on people, they can be used to infer the value of intangible impacts/losses on households; thereby, enabling the incorporation of the cost associated with intangible impacts within the CBA decision making model. Therefore, in order to evaluate the value intangible impact of flooding on households, the CVM of SPM is adopted in this research.

3.7.1 Contingent valuation methods (CVM)

The CVM is a widely used nonmarket valuation method especially in the areas of environmental CBA and environmental impact assessment (EIA) (Cummings *et al.*, 1986; Mitchell and Carson, 1989). Its application in environmental economics includes estimation of non-use values (Brookshire *et al.*, 1983; Walsh *et al.*, 1984), nonmarket use values (Choe *et al.*, 1996) or both (Niklitschek and Leon, 1996) of environmental resources. According to Merrett (2002), this method is commonly used in developing countries to elicit the individuals' preferences for the basic infrastructural projects such as water supply and sanitation.

CVM is a method of estimating the value that a person places on a good or service (Venkatachalam, 2004). Rather than inferring from observed behaviours in regular market places as in the case of RPM, the CVM approach asks people to directly state their willingness to pay (WTP) to obtain a specified good or service, or willingness to accept (WTA) compensation to give up a good or service (Penning-Rowsell *et al.*, 2005; Fujiwara and Campbell, 2011). In the context of PLFRA measures at household levels, this approach has the potential to help identify the amount homeowners are willing and able to pay to avoid or reduce the intangible impacts of flooding on households.

According to Mitchell and Carson (1989), the CV method is a social survey approach; therefore, it is very important to pay attention to the design and implementation of the survey questions and sample design. The pre-requisites for a successful use of CV method in estimating the financial value of the intangible impacts of flooding on households are, individual survey of flooded residents, consultations with relevant experts, and pre-testing of the survey questionnaires (Hanemann, 1994). Further, decisions need to be taken regarding how to conduct the interviews such as in-person, via mail or via telephone surveys. If the sample can be shown to be representative of the flooded residents population, the mean WTP that have been obtained from the sample can then be extrapolated across the population to obtain the combined WTP (Hanemann, 1994; Environment Agency and DEFRA, 2004). The major strength of the

CVM is that respondents are given the opportunity to state what they are willing to pay or what compensation they are willing to accept in order to reduce or eliminate the intangible impacts of flooding. Therefore, if conducted appropriately the CVM will arrive at a measurement of equivalent financial value that is unambiguous and pertains only to the intangibles. However, this valuation method is not without its criticism and biases.

3.7.2 The biases of CVM

According to Wattage (2002), the CVM approach suffers from a variety of theoretical and practical difficulties. There are several potential sources of bias given the nature of the CVM and the survey instrument. Among the most important biases are hypothetical and strategic biases. These two types of biases are discussed below:

1. ***Hypothetical bias***

The nature of the market created in a contingent valuation survey is mainly hypothetical, and therefore, it may attract a bias called 'hypothetical bias' (Neill *et al.*, 1994). Cummings *et al.* (1986) defined hypothetical bias as the potential divergence between the real and hypothetical payments. Many CVM studies have reported that the hypothetical WTP values are found to be greater than the real WTP values (Bishop and Heberlein, 1979; Kealy *et al.*, 1990; Neill *et al.*, 1994; Brown *et al.*, 1996). For instance, Duffield and Paterson (1991) in an experiment estimate the WTP for maintaining the river flow that would facilitate protection of two rare fish species. Two independent samples were used to estimate the non-use value of the fish species in this case. Respondents in one sample group were asked to state their hypothetical WTP for the Montana Nature Conservancy, a body that would maintain the stream flow in the river and respondents in the other sample group were asked to actually contribute to the same organisation. The results of this study show that the amount of hypothetical WTP exceeds the actual WTP by 25%. In another study, by Seip and Strand (1992), hypothetical WTP value was elicited from a sample group for membership fee for a Norwegian environmental organisation. The same sample group then was asked to contribute 'actual payment' towards the membership fee. In this case, it was reported that the hypothetical WTP value was greater than the actual contribution. Further, Foster *et al.* (1997) study compares the actual donations to environmental preservation and the hypothetical WTP values derived from six UK CVM studies for comparable environmental amenities. The important finding of the study is that there exists a divergence between the actual and hypothetical WTP values, with the hypothetical value being greater than the actual value by ratio 3 to 1 (Foster *et al.*, 1997).

Mitchell and Carson (1989) and Whittington *et al.* (1991) argued that the more a respondent is familiar with the goods, the less will be the level of hypothetical bias in a CVM. This implies that the WTP values elicited for those public goods, which are traded in the markets or which the individuals are familiar with, would be free from hypothetical bias. In this research the effect of hypothetical bias is reduced because the target population are those who had experience flood damage to their properties and therefore familiar with the intangible impacts in question.

2. ***Strategic bias***

The possibility of strategic bias was another main objection to the use of CVM among most economists. For instance, Hausman (1993) criticised the CVM severely for not being a proper method of estimating the nonmarket values. Mitchell and Carton (1989) and Hanemann (1994), stated that there are two forms of strategic behaviour, namely, free riding and over pledging. Free riding would occur if an individual understates her true WTP for a public goods on the expectation that others would pay enough for that goods, and therefore, he/she need not have to pay. For example, a rational response to the current flood risk management policy might be a tendency for respondents to understate the WTP in expectation that this will limit their future liability to contribute towards defence spending. In evaluating individual property level measures which is not a public goods, respondents may understate their WTP on the prospect that insurance company or government will pay for it.

Conversely, over pledging occurs when an individual assumes that their stated WTP value would influence the provision of goods under question, provided that the stated WTP would not form any basis for the future pricing policy (Venkatachalam, 2004). For instance, the situation in the past when decisions to build a flood defence from the public purse may have been based on the findings of research commissioned by the Government.

There are some empirical studies which have reported strategic bias in their results. For instance, Whittington *et al*. (1992) designed a study to test the impact of time given to the respondents on WTP value for improved services of water supply. Two independent sample households were selected from three villages of Nigeria. One set of sample households was given an opportunity (one day) to 'think' about their WTP value; whereas, the other set of sample households was not given this opportunity. The results suggest that the WTP values for improved water services elicited from those households who were provided time to think about their stated WTP are found to be less than that of the households who were not provided the time to think. This implies that the households who were given time to think about the WTP values might have behaved strategically (by understating their true WTP) on the assumption that their stated WTP value would form the basis for the future water tariff policy. However, the authors claim that the respondents provided genuine reasons for their comparatively lower level of WTP values, in an informal discussion after the main survey was over. This, according to the authors, implies that it is not the strategic bias but other factors, such as socio, economic variables, that affected the WTP values.

There are very few CVM studies that exclusively deal with addressing the issue of strategic bias. Many of the CVM studies take a stand that the strategic bias is not a major problem in CVM experiments (Griffin *et al.*, 1995; Schulze *et al.*, 1996). Mitchell and Carson (1989) concluded that the following reasons make the strategic behaviour very weak for most of the CVM respondents:

1. The amount of information required for strategic behaviour are great;
2. CVM surveys convey to the respondents that a larger number of people are interviewed, and therefore, respondents get the impression that their stated WTP would not influence the overall outcome;
3. The payment vehicles used in CVM studies remind the respondents about the budget constraint so that the respondents could not overstate their true WTP; and
4. The understatement of true willingness to pay might be discouraged given the respondents' impression that the good under investigation may not be provided.

Apart from these aspects, it has been found that using incentive compatible elicitation techniques (such as dichotomous choice technique) would minimise the impact of strategic bias (Carson *et al.*, 2001). Having reviewed different kinds of experiments on strategic bias, Mitchell and Carson (1989) suggest that the CVM questionnaires should be designed such that it would not give any 'hint' to the respondents that makes them behave strategically.

As discussed, one of the weaknesses of using the contingent valuation method in the domain of property level flood risk management is that questions are often problematic, because of the devastating effect of flood event which affected respondents may be trying to forget. Asking questions which are capable of bringing back the memory of the flood event(s) may be too emotional. However, a well designed questionnaire should be able to address this weakness by clearly state the reason for the research and the potential advantage to the respondent. It is recognised that the WTP by individual is subject to their disposable income as there are income differential among the floodplain residents, this is another inherent bias towards the preferences of the better off. In order to address these drawbacks, a careful survey design is needed for income and age as suggested by Mitchell and Carson, (1989).

3.7.3 Choice modelling method (CMM)

Choice modelling method (CMM) is concerned with the individual attributes of, say, a flood and estimates WTP for these individual attributes. CMM is a family of survey-based methodologies for modelling preferences for goods, where goods are described in terms of their attributes and of the levels that these attributes take (Pearce *et al.*, 2006). This method assumes that each respondent has a perfect discrimination capability, whereas the analyst has incomplete information and must therefore take account of uncertainty (Birol *et al.*, 2006). Respondents are presented with various alternative descriptions of a good, differentiated by their attributes and levels, and are asked to rank the various alternatives, to rate them or to choose their most preferred. By including price/cost as one of the attributes of the good, WTP can be indirectly recovered from people's rankings, ratings or choices. As with contingent valuation, CMM can also measure all forms of value including non-use values (Pearce *et al.*, 2006). In the case of PLFRA measures, respondents could be presented with different bundles of flood impacts, which can be reduced by implementation of property level flood alleviation measures at a certain price among which they are asked to make a choice.

Similar to CVM, the CMM can estimate financial values for any environmental resource, and can be used to estimate tangible as well as intangible values. The CMM, however, enables estimation not only of the value of the environmental resource as a whole, but also of the inherent value of its attributes, their implied ranking and the value of changing more than one attribute at once (Hanley *et al.*, 1998; Bateman *et al.*, 2003). There are a number of variants to choice modelling which differ in the way they present the respondent with the choice task. According to Fajiwara and Campbell (2011), only two of these comply with the requirements of economic theory: choice experiments and contingent ranking. Choice experiments require the respondents to choose their most preferred scenario. Contingent ranking requires the respondents to rank the given scenarios according to their preference.

It is generally accepted among economists and policy makers that the CVM is the most adaptable and dominant methodology for estimating the monetary value of changes in non-market goods. The embrace of CVM does not mean that its drawbacks are no longer recognised. Arguably, the CVM is the most familiar valuation technique in the family of stated preferences method; however, there has been growing interest in CMM approaches. For many years, CMM has been widely used in the market research and transport studies (Green and Srinivasan, 1978; Henchser, 1994), and in the last decade, it has been applied to other areas such as the environment (Pearce *et al.*, 2006; Fujiwara and Campbell, 2011). According to Pearce *et al*. (2006), this is due to the fact that most non-market goods can be described by their attributes.

Arguably, in the environmental context, at least some of this emerging interest in CMM has arisen as a response to the problems of contingent valuation. Pearce *et al.* (2006) argued that some of the arguments behind claims that CMM can overcome some of the problems associated with CVM are largely, at this time, a matter of speculation. However, a clear strength of CMM lies in its ability to value changes which are multidimensional: that is, entailing changes in a number of attributes of interest (Pearce *et al.*, 2006). There have been problem associated with the application of CMM to value non market environmental goods.

3.7.4 Problems of CMM

The main disadvantage of CMM approaches lies in the cognitive difficulty associated with multiple complex choices or rankings between bundles with many attributes and levels. Both experimental economists and psychologists have found evidence that there is a limit to how much information respondents can meaningfully handle while making a decision (Carson *et al.*, 2001). One common finding is that the choice complexity or depth of a ranking task can lead to greater random errors or at least imprecision in responses. More generally, since respondents are typically presented with a large number of choice sets there is scope for both learning and fatigue effects and an important issue is which on average will be predominant. Further, the problems with handling repeated answers per respondents have been identified by Adamowicz *et al.* (1998) as posing statistical issues during analysis stage and the need to take into consideration and properly modelled correlation between variables is very important.

This implies that, whilst the researcher might want to include many attributes as much as possible, unless very large samples are collected, respondents will be faced with a overwhelming choice of tasks (Foster and Mourato, 2002). The consequence is that, in the presence of complex choices, respondents use rules of thumb to simplify the decision task. These filtering rules lead to options being chosen that are good enough although not necessarily the best, avoiding the need to solve the underlying utility-maximisation problem (Pearce *et al.*, 2006), that is a satisfying approach rather than a maximising one. This is one of the major problems which make the application of CMM not practicable in this research, further there is no pre-knowledge of the price/cost to be allocated to each of the intangible flood impact attributes for respondents to choose from. For instance, respondents will have to be provided with different intangible impact scenario and cost/price to reduce the impact; however, this will require researcher's prior knowledge of the price to be allocated to each of the intangible impacts. Since there is no market price to be allocated to each of the intangible impacts, it is considered not viable to use arbitrary values; therefore, the use of CMM in the research was rejected on this basis.

3.7.5 Choice modelling method (CMM) versus contingent valuation method (CVM)

CMM has become more popular due to several advantages over CVM. These include: the ease of estimating values of single attributes of a flood impact on households; avoidance of part-whole bias problem since different levels of the impacts can easily be built into the experimental design; and that respondents are more familiar with making choices rather than generating spontaneous valuations. Moreover, CMM can solve some of the biases that are present in CVM; the strategic bias which is associated with CVM is minimised in the CMM since the prices of the different intangible flood impacts are already defined in the choice sets. However, the choice approach does limit the valuation to predefined options and does not allow for the respondent to state a zero value for the resource even if they do not value it, however, in order to eliminate the limitation, *no change no expense* can be an option within the choice set.

While it is likely that on some criteria, CMM is likely to perform better than CVM and *vice versa* the evidence for such assertions is largely lacking at present. Moreover, while those few studies that have sought to compare the findings of CMM and CVM appear to find that the total value of changes in the provision of the same environmental good in the former exceeds that of the latter, the reasons for this are not altogether clear. Intellectual curiosity doubtless will ensure that more research emerges to cast light about both of these sources of uncertainty and about the relative merits of CMM and CVM. However, whether the two methods should be seen as always competing against one another in the sense of say CMM being a more general and thereby superior method is debatable. Both approaches are likely to have their role in cost-benefit appraisals and a useful contribution of any future research would also be to aid understanding of when one approach should be used rather than the other. As discussed earlier, CVM is adopted in this research as it provides basis for which respondents can state the value of WTP to avoid impact of flooding on their households as against providing them with choices.

3.8 CBA RESEARCH APPLICATIONS

In order to establish the costs and benefits of flood risk adaptation measures, particularly with regards to flood risk investment appraisal at government level, researchers and practitioners have adopted different methods to estimate the costs and benefits of the measures (Penning-Rowsell *et al.*, 2005). However, considerably fewer efforts have focussed on the application of CBA to the development of comprehensive costs and benefits of PLFRA measures. The application of the concept of CBA to evaluate the potential benefits to homeowners of investing in PLFRA measures represents a potentially novel development towards improving the resilience of homes not only in the UK but in other international locations. The concept of CBA typically involves estimating costs and benefits in order to choose the best or more profitable action (Snell, 2011). Thus, it can provide useful information for homeowners when considering adapting their properties to flood risks. Some of the research applications are thus, discussed below.

3.8.1 Review of existing studies of CBA of PLFRA measures

There have been few studies in the UK that have examined the cost benefit of investing in PLFRA measures. Some of these results indicate that it is cost beneficial for property owners living in a floodplain with a 1 to 75% annual exceedence probability (AEP) of 1.33%, which means that there is a 1.33% chance of a similar flood (or larger) occurring in any one year to invest in the measures (Thurston *et al.,* 2008; Joseph *et al.,* 2011; Royal Haskoning, 2012). As this has the potential to reduce households' exposure to flood risk and to improve their recovery when they experience flood events.

Thurston *et al.* (2008) investigated the economic benefits of using resistance and resilience measures. A key element of the study was to examine the effectiveness of property based resilience and resistance measures in reducing flood risk. In the study, new spreadsheet models for both residential and selected commercial properties were developed and these models were used in the quantification of property-scale benefits and costs for different packages of flood resistance and resilience measures. According to Thurston *et al.* (2008) by using benefit-cost ratio, it was established that resistance measures are economically worthwhile for properties with an annual chance of flooding of 2% or above. It was reported for households that flood more than once in every ten years, the benefits outweigh the up-front investment by a factor or between five and ten. In contrast, the study found that a full package of resilience measures will only be economically worthwhile when installed in a building that has a greater that 4% annual risk of flooding or that has a greater than 2% annual risk and is in need of repair or refurbishment.

Thurston *et al's* (2008) study aimed to provide analytical information for the wider "Making Space for Water" projects (as discussed in Chapter 2) and to encourage and incentivise uptake of resistance products and resilience measures to existing properties by households and businesses in England and Wales. The study concentrated on properties located in areas designated as having significant risk of flooding (i.e. with a return period of 1:75 or higher), and was based on the quantification of tangible costs and benefits. A major exclusion from the study is that the less easily monetised benefits of flood risk adaptation measures such as reduced anxiety and improved social cohesion (the intangible benefits) were not included in the model. While the findings of the study provides an insight into the quantification of costs and benefits of flood risk adaptation measures at household levels, the non inclusion of intangible benefits in the model, could makes its application less robust. That is, the most important benefits of flood risk adaptation at household levels is the intangible benefits (Green and Penning-Rowsell, 1989; Environment Agency and DEFRA, 2004; Joseph *et al.*, 2011b) and the inclusion of the intangible benefits has the potential to provide a more robust decision making information for homeowners and flood risk management stakeholders. However, the authors acknowledged non inclusion of intangible impacts in the model as a limitation of the research and it was recommended that further research should consider intangible benefits.

Joseph *et al.* (2011a) conducted an investigation into the costs of resilient reinstatement of flood affected properties, using the 2009 flood event in Cockermouth as a case study. The CBA adopted in the research was based on the return period on investment and payback period. The authors concluded that resilient reinstatement will help in limiting the costs of repairs following a subsequent flood event by approximately 73% for properties located in an area with 5 years flood return period (20% annual chance). This indicates that the up-front investment would be recovered fully following one subsequent flood event. However, for properties located in an area with a 100 years flood return period (1% annual chance) adopting resilience measure was not considered economical because for full recovery to be made, such properties will be required to experience up to 12 flood events. This result mirrors the findings of Thurston *et al.* (2008) in that adoption of resilient repairs following flood event is more beneficial for properties located in an area with significant risk of flooding.

Similar to the exclusion in Thurston *et al's* (2008) study, Joseph *et al.* (2011a) did not consider the intangible benefits of flood risk adaptation measures in the analysis, though it was acknowledged that the inclusion of intangible benefits may make the adoption of resilience measures more worthwhile for properties located in low flood risk areas, even when the results of the analysis showed that for properties with a 1% annual chance of flooding, the adoption of resilience measures was not cost effective.

Grant *et al.* (2011) carried out research to identify 'low-regrets' adaptation options within the residential buildings sector associated with three types of hazards: flood, water stress and overheating. 'Low-regrets' measures are defined in the research as having a cost-benefit ratio lower than what is currently being reported. The objectives of the research was to investigate the utility of the cost-curve methodology for adaptation planning and to inform government policy on adaptation planning related to low-regrets options in the building sector.

The range of adaptation options considered was limited to those that can be implemented within the home and (largely) to those applicable to existing buildings as well as new buildings. Cost-curves show the cost-benefit ratio of measures versus their total economic benefit (in terms of a defined metric) and are presented in the societal and householders perspectives. Cost curves differentiate between applications to new builds and existing buildings (during repair or retrofit). Similar to earlier studies discussed, the definition of economic costs and benefits is limited to tangible costs and benefits, and no attempt was made to quantify and incorporate the intangible benefits in the cost-curves.

In 2012, Royal Haskoning undertakes a research to identify the type and level of adaptation action that could cost-effectively manage current and future flood risk in England. One of the objectives of the research was to estimate the scale of property-level action that would be cost-effective for society to take in England today given current conditions; and when accounting for future climate uncertainty, future flood defence investment scenarios and future development. The research concluded that generally, manual resistance measures are cost-beneficial for properties with the onset of flooding of 2% annual exceedence probability (AEP) or greater, whilst the automatic resistance measures are cost-beneficial for properties with an onset of flooding of 3-5% AEP or greater. It was found that in the repair and new build scenarios resilience packages are more cost-beneficial than the retrofit case, although they do not provide the same level of cost benefit ratio as the resistance packages. Unlike the earlier CBA research of PLFRA discussed, the Royal Haskoning (2012) research included the value of intangible impacts in the analysis, although, the value of intangible benefit of £200 was used, this was based on the EA/DEFRA, (2004) research findings.

The first three studies (Thurston *et al.*, 2008; Joseph *et al.*, 2011a; Grant *et al*., 2011) acknowledged the importance of incorporating the intangible benefits within the costs benefits analysis their omission represents a major shortcoming in knowledge and understanding of PLFRA measures. For instance, the property level flood adaptation projects funded by the "Flood Defence Grant in Aid" as discussed in section 2.7.3, are reported to achieve a benefit cost ratio of 5 to 1 (JBA, 2012). However, other intangible benefits were not included in this benefit cost ratio, implying that the benefit cost ratio achieved on these projects is likely to be more than the reported 5:1 were intangible benefits included. It can be argued further that even though these studies highlighted useful applications of CBA, there is limited evidence that it has been applied for decision making at household levels on investing in PLFRA measures.

3.8.2 Review of existing study of assessment of intangible benefits of flood protection measures

While many authors agreed with the fact that the intangible impacts of flooding are significant particularly on households (Proverbs and Soetanto, 2004; Tunstall *et al.*, 2004; JBA, 2005; Messner and Meyer, 2005; Penning-Rowsell *et al.*, 2005; Werritty *et al.*, 2007; Thurston *et al.*, 2008; Joseph *et al.*, 2011b), there has been a dearth of research in quantifying the intangible impacts of flooding on households (Lekuthai and Vongvisessomjai, 2001). However, in 2004, the Department for Environment, Food and Rural Affairs (DEFRA) and the Environment Agency (EA) "Flood and Coastal Erosion Risk Management Research and Development" programme, jointly commissioned a study to improve understanding of the impact of flooding on people in terms of health and stress and to consider how this major area of intangible impacts might be incorporated routinely into the economic appraisal of flood alleviation projects in England and Wales. The studies used the CVM to elicit WTP values to avoid health impact of flooding on households. The WTP values were elicited from both those households who had been flooded and those at risk but not yet flooded. The results demonstrate that flooding causes short-term physical effects and, more significantly, short and long-term psychological effects. More than 60% of flooded and at risk respondents expressed a WTP to avoid the health impacts associated with flooding. Based on the analysis of the survey, the authors recommended that a value of £200 per household per year be taken as representing the benefits of reduced health impacts as a consequence of a significant reduction in the risk of flooding.

This can be seen as a positive development with regards to the quantification of intangible flood impacts on households; however, the value of £200 may be questionable in light of conclusions from other authors (Green and Penning-Rowsell, 1989; Adamson, 2003) with regards to the relationship between tangible and intangible losses. For instance, Green and Penning-Rowsell (1989) carried out experimental work by using a bootstrapping procedure to relate known tangible losses to intangible losses by deriving equivalent values. This method was based upon an extensive interview survey with flood victims. In conducting the interview, affected households were asked about the nature of the flood which they have experienced what effects it had and how much it cost to repair or replace the damage. Most importantly, respondents were asked if they recovered all their costs from insurances companies and other sources. The study found that the monetary equivalents of the intangible impacts far exceeded the tangible impacts. Additionally, Adamson (2003) concluded that the intangible impacts are currently set as equivalent to the residential property damage in the evaluation of potential flood damage in the Republic of Ireland. Further, Penning-Rowsell and Green (2000) asserted that the intangible effects of flooding are recognised to be substantial and are considered to be greater in impact than the tangible effects.

Even though, EA/DEFRA (2004) study provides a value for the intangible losses which have been used extensively within the flood alleviation appraisal methodology, the emphases of the author was laid on the health impacts of flooding on households. Werritty *et al.* (2007) found that damage to and loss of memorabilia items was ranked as major impacts by respondents in their research in Scotland, it was ranked above health impact, this was contrary to the EA/DEFRA (2004) findings in England and Wales. Other major impacts highlighted by Werritty *et al*. (2007) research which respondents considered important when considering impact of flooding on households are: effort of getting a house back to normal, having to leave home, and anxiety about future flooding. Considering this statement, it can be inferred that the value of intangible impacts of flooding on household could potentially be much greater than £200 per year if other intangible impacts are included in the analysis.

3.9 QUANTIFICATION OF COSTS AND BENEFITS

Considerably fewer research efforts have focussed on the application of CBA to the adoption of PLFRA measures. The use of CBA methodological approach to evaluate maximum benefits of flood adaptation measures can be of fundamental importance to lessen the impacts of flooding on households. The calculations of CBA, as discussed in section 3.2, typically, involve quantifying costs and benefits in order to choose the best or more profitable action (Penning-Rowsell *et al.*, 2005; Black *et al.*, 2008; Snell, 2011). Thus, it can provide useful decision making information to homeowners on investing in PLFRA measures. Arguably, CBA of PLFRA measures is based on assumptions and probability, it was asserted by different authors such as (Penning-Rowsell and Chatterton, 1977; Mishan, 1982; Pearce, 1988; Pindyck, 1992; Perkins, 1994; Harberger and Jenkins, 2002; Snell, 2011) that it is a good practice to be explicit about the underlying assumptions used to arrive at estimates of future benefits and costs.

In the course of quantifying the intangible benefits of flood risk adaptation measures, such as reducing stress, reducing flood related health problems and reducing anxiety. There are inherent difficulties in putting value against these intangible benefits. However, the focus of the research is to provide homeowners with a robust account of the costs/benefits of PLFRA measures. This will enable them to compare different adaptation solutions towards making more informed decisions, which might include decision not to adapt. Arguably, quantifying only the tangible benefits aspect such as reducing repair costs following subsequent flood event, reducing alternative accommodation costs and the number of day households spend in alternative accommodation will not provide such robust account of the costs/benefits of the measures. It can be concluded that these principles need to be merged into a framework, which would provide a systematic base for the comprehensive quantification of costs and benefits of PLFRA measures.

3.10 SUMMARY

This chapter has considered the origin of CBA and its development over several decades with particular attention to the application of CBA to the study area. The applications of CBA in various research contexts were reviewed and the potential for how this technique may be adapted for application in the study area was considered. Previous studies of the intangible impacts of flooding on households were identified, which highlighted the consensus in the literature that the intangible impacts are significant to households but they are difficult to quantify in monetary terms. Different methods of quantifying these intangible impacts were reviewed. The problems associated with each of the methods were identified and suggestions on how to mitigate the effects of these problems have also been discussed. Previous attempts to apply the concept of CBA to PLFRA measures have been reviewed. The quantification of the costs and benefits of PLFRA measures can help improve the information available to homeowners and, for example, facilitate a comparative evaluation of a range of different adaptation solutions for their own property. The next chapter presents the development of a CBA conceptual framework of PLFRA measures for fully insured homeowners; this framework captures the benefits of PLFRA measures and contrasts these with the costs of the measures, this will be presented as BCR.

CHAPTER FOUR: CBA OF PROPERTY LEVEL FLOOD RISK ADAPTATION MEASURES: A CONCEPTUAL FRAMEWORK

4.1 INTRODUCTION

This chapter describes the conceptual model developed in light of the extensive review of extant literature on the impacts and costs of flooding on households in the UK and the application of the concept of the CBA to the study of property-level flood risk adaptation (PLFRA) measures. From the literature review, it was identified that the adoption of PLFRA measures for those households living in areas vulnerable to frequent flooding will lead to additional costs, and subsequently generates benefits to such households. In order to apply the concept of CBA to PLFRA measures, the conceptual framework will bring together the key parameters of costs and benefits of adapting properties to flood risk, to inform the data collection phase of the research was developed. Thus, addressing objective 3 of the research. In chapter 3, it was established that the principles of CBA could be developed to provide a decision support tool for homeowners during the flood recovery period or during a planned renovation work; thereby, assisting in making an informed decision on the adoption and investment in PLFRA measures. This chapter seeks to strengthen that argument by putting forward a framework that theoretically establishes the additional costs and benefits of the measures at household level. To put the chapter in context, summary of the review of existing CBA model of PLFRA measures is presented.

4.1.1 A review of the existing PLFRA models

As discussed in chapter 3, section 3.8.1 work investigating the relationship between costs and benefits of PLFRA measures in England has been carried out on behalf of DEFRA and the EA. Therefore, in the development of a new CBA conceptual model, which takes into consideration the intangible benefits, it is essential to bear in mind the shortcomings of the existing CBA models. Four existing models have been extensively reviewed in section 3.8.1. The limitations in these developed models by various researchers have been identified. While the models can partially be used to compare costs and benefits of flood risk adaptation measures at household level, none inclusion of the intangible benefits in the models represents a significant omission given the nature of such intangible impacts, in conjunction with the costs of the measures. Knowledge of these intangibles will help in the development of a comprehensive understanding of the full costs and benefits of the PLFRA measures. This provides the compelling justification for a framework, which includes all the parameters affecting the costs and benefits involved in PLFRA measures.

4.2 COST MODEL OF PLFRA MEASURES

From the literature review, it was evident that the available cost model of PLFRA measures and other sources of costs information on PLFRA measures were not adequate for decision making by homeowners when considering the adoption of PLFRA measures. The available cost models take no account of intangible benefits of adopting the measures, which could enable the identification of benefits to homeowners of investing in PLFRA measures. As discussed in chapter 3, without the identification of the intangible benefits, in conjunction with the costs of the measures, consideration of the cost effectiveness of the measures may be more difficult. Hence, it was concluded that the application of the concept of CBA could provide useful information and better understanding of the costs and benefits of PLFRA measures, which are required to enhance decision making at household levels on investment in PLFRA measures.

The concept of CBA focuses on the future, and is based on the expected benefits of proposed alternatives (Snell, 2011). Based on this, it transpired that information on investment on PLFRA measures may be used when making decisions on investment on the measures. Snell (2011) argued that where all benefits and costs can be expressed in common units, CBA is an excellent tool for providing decision makers with a clear indication of the most efficient alternative that generates the largest net benefits. Therefore, it is important to consider the assignment of monetary values to costs and benefits of PLFRA measures.

One method for estimating additional costs of the measures is to proceed step-by-step from the beginning to the end of the estimation activity. This involves developing resilient and resistant specifications, and then identifying the cost components at each stage of the estimation process. A schematic representation of these steps, in the form of a flow chart describing different variables, which are relevant for the estimation process, is presented in Figure 4.1.

This approach requires that for each property, the expected flood depths are known. The property type and method of floor construction are also required to be determined (i.e. bungalow, detached, semi-detached, and terraced; suspended timber floor or concrete floors). According to Merz *et al.* (2004), estimating the adaptation costs of properties by building type categories has the potential to lead to better results. Therefore, the additional costs of the measures are established based on the two available measures (i.e. resilient and resistant measures). These were quantified by itemised adaptation specification for resistance and resilience measures as discussed in section 2.7, items were scheduled and priced using average market (including tendered rates) repair prices.

The costs of resilient and resistant measures are denoted as CM_{rt} and CM_{rs}, respectively, in Figure 4.1 below.

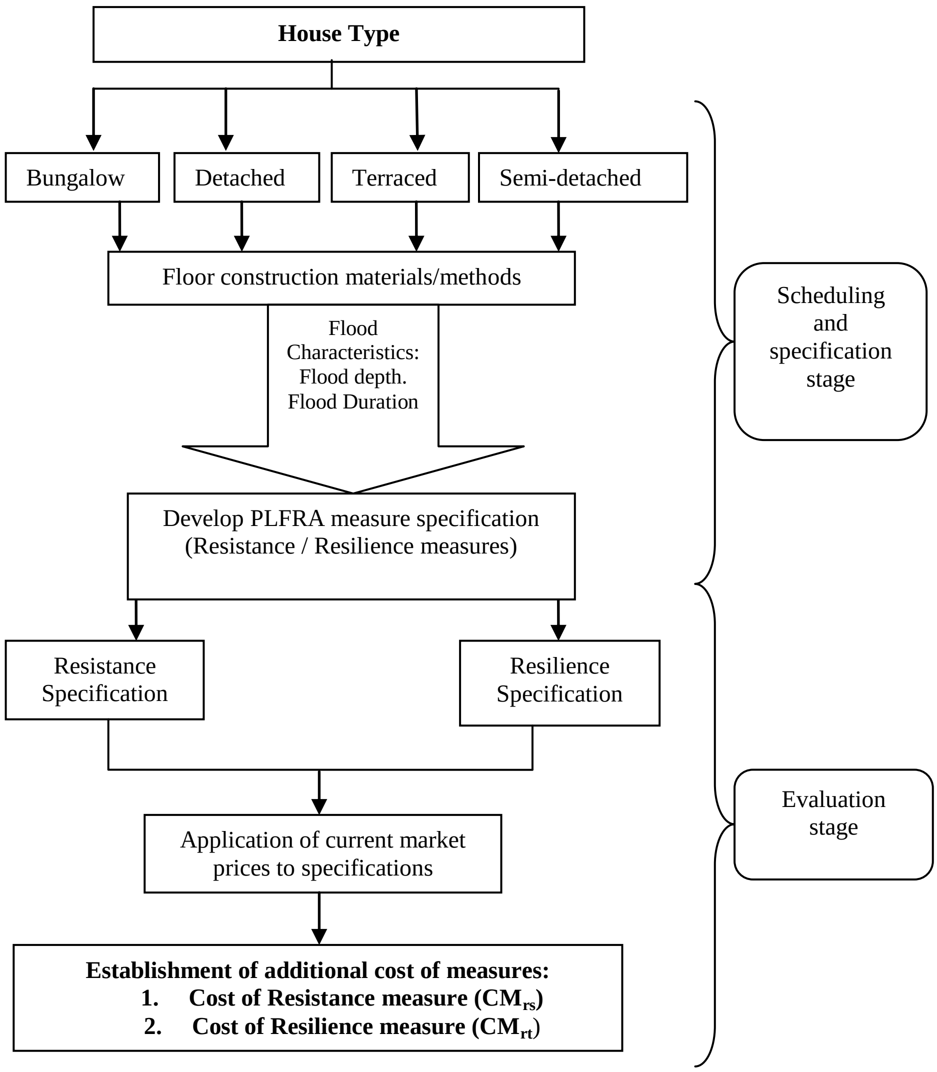


Figure 4.1 Estimation of additional cost of property level flood risk adaptation measures including flood characteristics variables

4.2.1 The impact of flood characteristics on flood damage

As discussed in chapter 2 section 2.6, flood characteristics that influence the extent of damage include depth, velocity, contaminant and duration (Proverbs and Soetanto, 2004). Among these flood characteristics, depth and duration of flooding are most influential on the extent of damage and they are relevant elements in any flood damage assessment procedure (Penning-Rowsell *et al.*, 2005; Thurston *et al.*, 2008; Snell, 2011). Flood depths for resilience measures have been categorised into five different levels in this research, these are flood level up to 150mm, 300mm, 500mm, 1000mm and over 1000mm. However, flood depth for resistance measures is limited to flood up to 600mm. The rationale for the choice of flood depth is that these are the levels to which adoption of the two types of PLFRA measures can be effective. According to the ABI (2003), these levels of flooding are currently being experienced more often in the UK. Wassell *et al.* (2009) argued that at flooding of less than 100mm, theoretically it requires removal of wall plaster under 500mm above the flood line.

4.2.2 Expected flood damage

Expected flood damage is the frequency weighted sum of damage for the full range of possible damaging flood events and can be viewed as what might be expected to occur in present or any future year (DEFRA, 2010). According to EMA (2002), expected damage can be calculated by plotting the estimated damages for a given flood at a range of magnitudes, against the probability of occurrence of the flood event. The expected flood damage can be established by aggregating the weighted expected tangible and intangible flood damage. The expected flood damage is a function of flood probability and flood characteristics. This means that the deeper the flood depth the greater the expected flood damage and the higher the frequency of flooding the greater the expected flood damage. The decision on whether to invest in PLFRA measures will to some extent depend on level of flood risk being faced by individual property owners.

4.3 BENEFITS OF PLFRA MEASURES

The benefits of PLFRA measures from an individual financial perspective involves several considerations, such as taking into account all the benefits accruing and all the costs incurred by households as a whole (Penning-Rowsell *et al.*, 2005); selecting appropriate prices for evaluating the benefits and costs in monetary terms; and adjusting the future prices of benefits to present values to make them comparable with the costs (Campbell and Brown, 2007). That is, as these benefits and costs stem from many different effects, a systematic procedure is required to make sure that each is considered and evaluated properly. Additionally, as discussed in chapter 2, section 2.7.6, the benefits are both tangible and intangible in nature.

The tangible benefits of PLFRA measures includes, reduction in alterative accommodation cost, significant reduction in reinstatement costs following subsequent flooding (Thurston *et al.*, 2008; Joseph *et al.*, 2011a) and elimination in cost of replacing personal possessions, these benefits are accrued to both insurance companies and homeowners. However, the intangible benefits are derived primarily by homeowners from the reduction or elimination of intangible impacts/losses of flooding, such as reduction in flood related health problems; reduction in psychological problems of having to relocate to temporary alternative accommodation; reduction in anxiety about future flooding. These losses are not covered under the domestic flood insurance policy.

Figure 4.2 shows graphical representations of both tangible and intangible losses that could be prevented by the adoption of PLFRA measures, it also shows the stages involved in estimating the value of benefits that will accrue following the adoption of the measures. This is considered very important because the application of the concept of CBA requires that both the costs and benefits have to be monetised before any decision can be made on whether a project is cost beneficial or not (Campbell and Brown, 2007). Further flood probability, severity of flood impacts and discount rates variables were included in the estimation process.

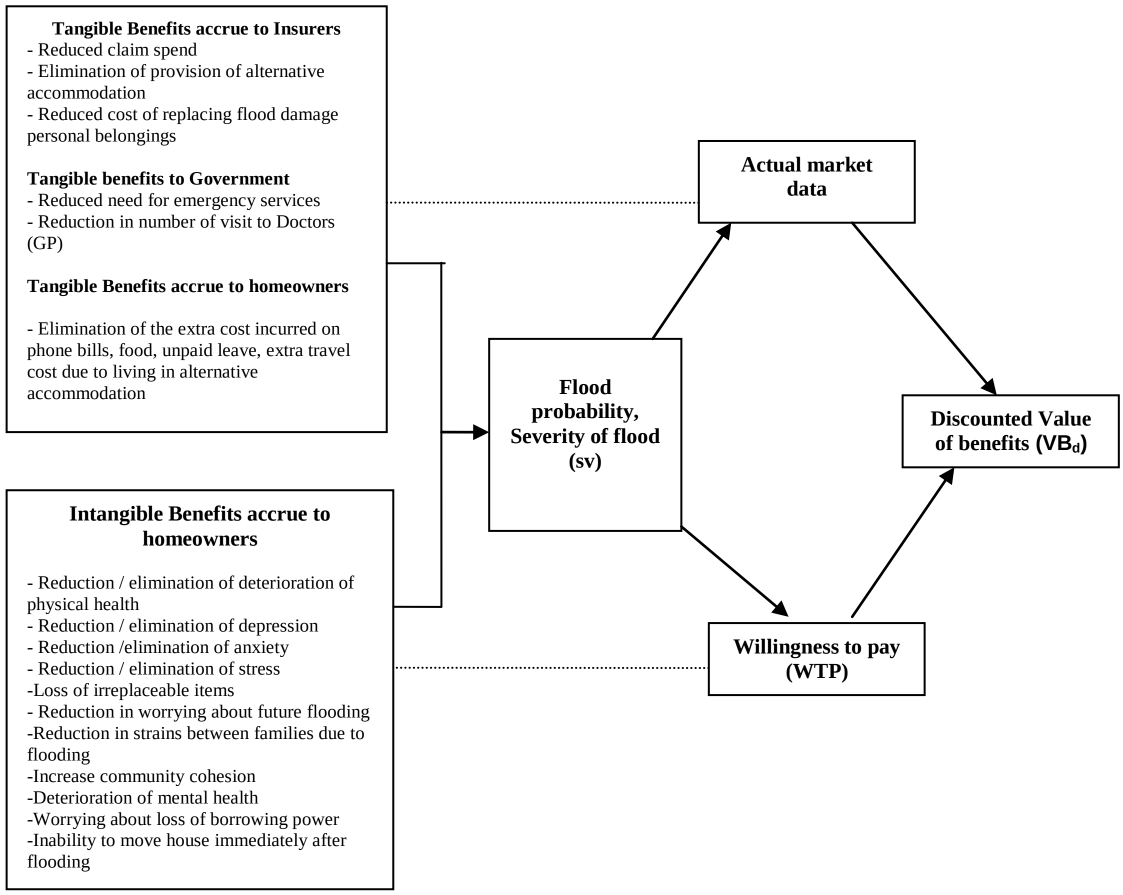


Figure 4.2 Valuation of benefits of measure using contingency valuation method

4.3.1 Flood probability variable

Figure 4.2 includes flood probability variables because the cost effectiveness of PLFRA measures has been shown to depend on the flood return period. For instance, Thurston *et al*. (2008) concluded that resistance measures designed are economically worthwhile for properties with a 50 year return period, however, for households that flood more than once in every ten years, the benefits outweigh the up-front investment by a factor of between five and ten.

On the contrary, a full package of resilience measures was established only to be economically worthwhile when installed in a building that has a greater than 25 years return period or that has a greater than 50 years return period. In support of this finding, Joseph *et al.* (2011a) found that the adoption of resilience measures will be more economical for properties, which are located in area with up to 25 years return period. However, for households that floods more than once in every five years, the benefits were established to outweigh the up-front investment. Therefore, flood probability (flood return period) is an important variable, which will be considered when quantifying the value of benefits of adopting PLFRA measures.

4.3.2 Flood severity variable

Another major variable, which has significant impact on the benefits of PLFRA measures, is the severity of flood (sv). According to DNRE (2000), the maximum depth and duration of inundation, as well as the rate of rise in flood level, are the major factors that determine the flood severity (DNRE, 2000). Qualitative descriptions of how severe a possible flood could be are in three categories, these are: high, medium and low. High severity would be associated with structures being destroyed, medium severity would indicate that a moderate rise of flood water is anticipated, whilst, low severity would indicate that a slow, gradual rise of flood waters is anticipated. Krewski *et al.* (1995) opined that perceived severity of flooding is important factor to take into consideration when making decisions on flood adaptation measures. Further, DNRE (2000) opined that anxiety and stress are likely to relate in some extent to the severity of flood and the physical impacts of flood upon owned or treasured property. Green and Penning-Rowsell (1989) argued that the magnitude and severity of different impacts of flooding on households will depend upon three key factors: flood characteristics; the property itself and the household experience of flood events. Therefore, prediction of the severity of the intangible impacts to be anticipated must be based upon development of flood onset and anxiety / stress level. The greater the flood onset, there is an increase in the level of anxiety / stress experienced by flood victim and subsequently this leads to these impacted severely on the households, thereby increasing the severity of flood event on households. In the empirical stage of the research respondents were asked to rate the relative severity of each of the individual intangible impacts on households.

Green and Penning-Rowsell (1989) concluded that the importance of the direct damages to house fabric and contents is the degree to which they determine households' judgements of the severity of the intangible impacts of flooding on households. However, they have no direct effect upon households' judgements as to the overall severity of flood, but affect this judgement indirectly through their effect upon judgements about other impacts such as stress level, anxiety levels, worrying and loss of memorabilia. Therefore, both direct and indirect impacts of flooding, the intangible impacts are as important in determining the overall severity of flood event.

In this study, in order to determine the severity level of flood risk being faced by households living in flood prone areas, the probability and onset levels of flooding together with the severity of flood were combined, this depends on how extreme the flood is, level of onset and available warning time. Subsequently, the benefits of PLFRA measures to reduce the level of risk can be determined with the combination of the probability and severity of flooding in the benefit equation.

4.3.3 Choice of the discounting rate

As discussed in chapter 3, section 3.3.4, the most important decisions about whether or not to undertake projects are not simply decisions about the use of resources at one point in time. They involve some commitment of resources or promise of returns in the future as well as in the present. In the case of investing in PLFRA measures, benefits of the investment depend on flood return period, therefore in quantifying the benefits, it is necessary to discount the value of the benefits to present value (pv) in order to be able to compare the present cost of the measures with the anticipated value of benefits over the measures life span. A discount rate of 8% was used in this research, the rationale behind this decision is that lower discount rate will make the benefits more than it actually is, this could be misleading. However, the discount rate can be flexible and set by the user without loss of generalisation of the conceptual model.

4.4 COMPARING COST AND BENEFITS OF PLFRA MEASURES

As discussed in chapter 3, CBA is a project appraisal technique that adds up the equivalent monetary values for all the costs and benefits of a project. In doing so, one can weigh the costs against the benefits and assess if a project is worthwhile. Therefore, in order to carry out a CBA, it is necessary to express both the costs and benefits in monetary terms. As explained in chapter 3, section 3.8.1, different studies have been carried out that established the additional costs of flood adaptation measures (Thurston *et al.*, 2008; Joseph, *et al.*, 2011a; Grant, *et al.*, 2011; Royal Haskoning, 2012); conversely, establishing the values of benefits are not in most cases very straight forward, particularly when the benefits are intangible in nature. However, in order to extract the relevant elements of costs and benefits, as outlined in sections 4.2 and 4.3 above, it is possible to develop a conceptual framework that reflects the hypothesised relationship between additional costs of flood adaptation measures and benefits of the measures, and identifies all the key parameters that will aid the primary data collection at the empirical stage of the research.

Figure 4.3 shows the comparison between costs of adopting PLFRA measures and the benefits of the measures. As discussed in Chapter 3, the concept of CBA is such that a project should not be undertaken if the benefits do not outweigh the costs. Therefore, the benefits of the adaptation measures for different stakeholders, as shown in Figure 4.3, can be expressed as:

$VB_{Ins} = \sum \left(VB_{TangIns}\right) dt \times p$ ……………………………………………………equation 3

$VB_{Gov} = \sum \left(VB_{TangGov}\right) dt \times p \times sv$ ………………………………………………..equation 4

$VB_{Hom} = \sum \left(VB_{TangHom} + VB_{IntagHom}\right) dt \times p \times sv$ ……………………………………equation 5

Where; $VB_{TangIns}$ - denotes value of tangible benefits accrue to Insurer,

$VB_{TangGov}$ - denotes value of tangible benefits accrue to Government,

$VB_{TangHom}$ - denotes value of tangible benefits accrue to Homeowner,

$VB_{IntagHom}$ - denotes value of intangible benefits to Homeowner, and

dt - denotes discounted rate over time period

p – denotes flood probability / return period

sv – denotes severity of flood impact on households

Once the cost of the measures have been established in conjunction with the value of benefits, as detailed in equations 3 to 5 above, the benefit cost ratio can be determined by comparing the costs of adaptation measures with the discounted value of the benefits. Therefore, benefit cost ratio (BCR) can be computed for each of the adaptation measures (i.e. resilience and resistance) and for different stakeholders as follows:

Resilience measures:

BCR for Insurer = VB_{Ins} / CM_{rt} ……………………………………………………equation 6

BCR for Government = VB_{Gov} / CM_{rt} …………………………………………..equation 7

BCR for Homeowner = VB_{Hom} / CM_{rt} …………………………………………..equation 8

Similar equation can be derived for the adoption of resistance measures as follows:

BCR for Insurer = VB_{Ins} / CM_{rs} ……………………………………………………equation 9

BCR for Government = VB_{Gov} / CM_{rs} ……………………………………………equation 10

BCR for Homeowner = VB_{Hom} / CM_{rs} ……………………………………………equation 11

From the above equations it can be inferred that the relationship between the costs of measures and the associated benefits of measures is such that the costs of the measures must be less than the value of the benefits for it to be cost effective. This relationship will be tested statistically at the empirical stage of the research. This conceptual framework, thus, provides a robust platform for data collection for the purpose of developing CBA models of PLFRA measures.

Based on the framework in Figure 4.3, a number of hypotheses can be developed and tested at the empirical stage of the research. These are as follows:

H_0: That the benefits of adopting PLFRA measures outweigh the additional costs of the measures.

H_0: That the greater the probability of flooding, the more cost effective the adoption of PLFRA measures by households.

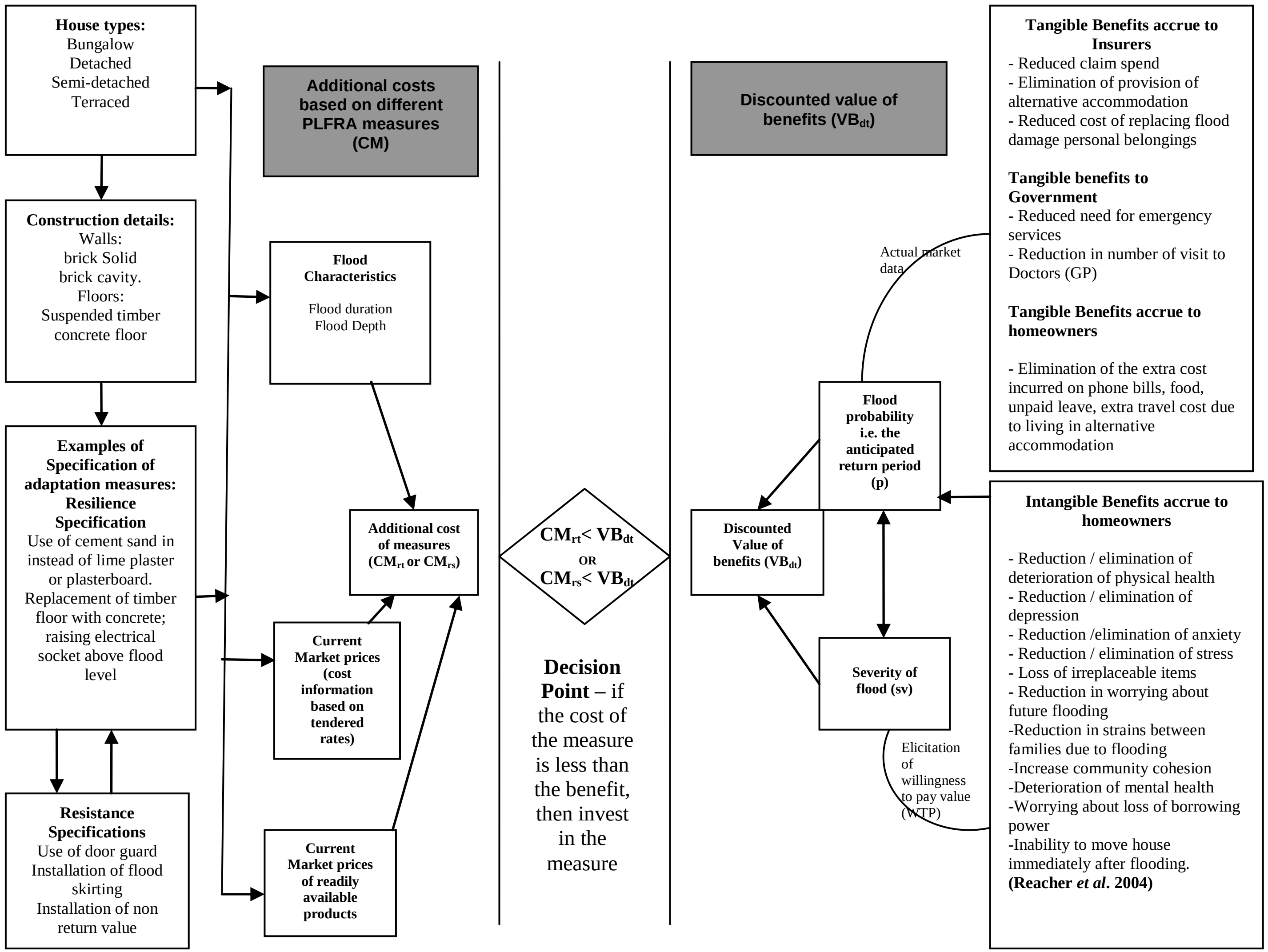


Figure 4.3 Conceptual Framework of CBA Model of PLFRA measures

H_0: That the greater the expected flood damage, the higher the chances of adopting property level flood adaptation by homeowner

The above outlined hypothesis will be tested during the empirical stage of this research. For comparison of costs and benefits, benefits will be transformed into their present value (PV), as discussed in chapter 3, section 3.3.4, which is defined as: the value of benefits or costs when discounted back to the present time. This is necessary because the benefit of investing in PLFRA measure will depend on any future flooding.

4.5 QUANTIFYING COSTS OF PLFRA MEASURES

Cost assessment of adaptation measures, particularly the resistance measures, is often done following a whole life cycle costs approach (Bouwer *et al.*, 2011), this includes costs for purchasing the product and in some cases installation costs and maintenance costs. The costs of PLFRA measures have been established by various authors. For instance, ABI (2003) established the resilience unit costs in order to advise homeowners of the costs and potential benefits of adopting the PLFRA measures. Thurston *et al.,* (2008) assessed the cost of six packages of resistance and resilience measures for residential properties, based upon a typical semi-detached house. Wassell *et al.* (2009) established the costs of resilient reinstatement of flooded property by using a real life event data (Wassell *et al.*, 2009). In 2011, Grant *et al.* (2011) used the resilience unit costs from the ABI (2003) project and resistance cost information on readily available products to establish the cost effectiveness of PLFRA measures.

The establishment of the additional costs of PLFRA measures in this research was based on four property types, these are: bungalow, detached, semi-detached and terraced. This is based on the fact that the list reflects property types contained within the UK domestic housing stock and, therefore, considered to be representative of the proportions of different property types that may be subject to flooding in the private housing stock in England. In quantifying the cost of the measures, both the ABI (2003) and Wassell *et al.* (2009) methods of estimations was adopted. The rationale for this important decision is that the ABI methodology provides a robust system of estimating different forms of resilience and resistance measures; however, the actual cost as contained in the ABI (2003) guide will not be used as it is approximately 9 years old. Although the costs could be adjusted to the current day prices by using the consumer price index (CPI). This option is rejected because of the potential for over estimation of the cost, as observed by Royal Haskoning (2012). Wassell *et al.* (2009) method of cost estimation is considered relevant because it was based on floor construction methods for each of the property types included in the study. This is considered important particularly when establishing the cost of resilient measures because, according to the ABI (2003), there is a relationship between the construction methods (i.e. whether suspended timber floor construction) and the costs of adaptation measures.

In this research, only the repair to existing properties after a flood event scenario will be considered, the rationale for this decision is that there are consensus in the literature that it is more cost beneficial to install measures during planned refurbishment or during a flood repair process than it is to retrofit measures to properties which are at risk but not flooded and that installation during repair will minimise disruption and be more desirable to the occupier of the property (Soetanto *et al.,* 2008; Thurston *et al.,* 2008; Joseph *et al.,* 2011a). Further, the research was set out to make use of the 2007 summer flood event data set which was based on repair cost data of flooded properties.

4.6 QUANTIFYING VALUE OF BENEFITS OF PROPERTY LEVEL FLOOD ADAPTATION MEASURES

There are two types of benefits of PLFRA measures. They are tangible such as avoided flood damage to building fabrics and content (Lee, 2004); reduced claim spend in the form of reduction in time spend in alternative accommodation (Joseph *et al.*, 2011a) and intangible. The larger proportion of tangible benefits are accrued to insurance companies in the form of reduce claim spend following subsequent flooding. The intangible benefits on the other hand, such as reduction in worries, stress, are difficult to quantify due to its subjective nature. The quantifications of these two benefits are discussed in section 4.6.1 and 4.6.2.

The process of estimating benefits of PLFRA measures requires estimation of damage frequency relationship after the flood measures are implemented. That is, establishing the relationship between flood probability and expected damages both with and without measures as shown in Figure 4.4.

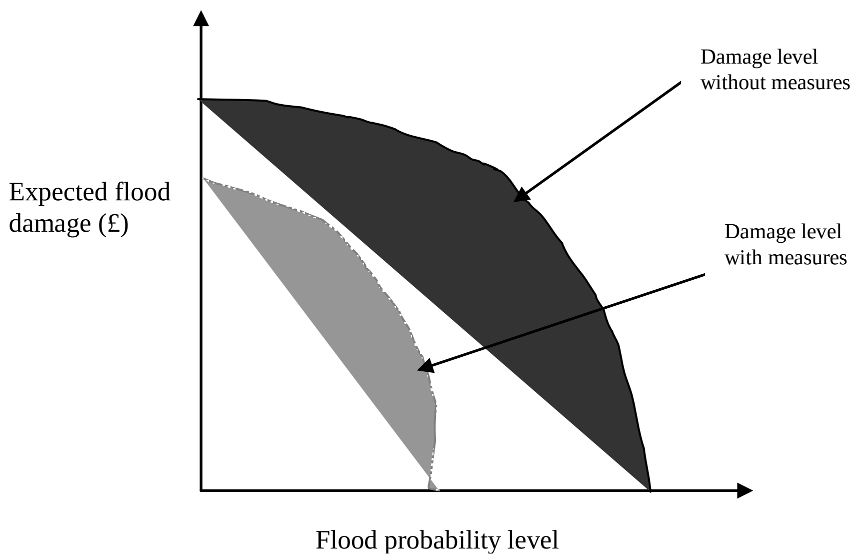


Figure 4.4 Theoretical expected flood damage curves profiles with and without measures

Figure 4.4 is a graphical representation (not from any data) of the difference in damage levels between property, which has been adapted to flood risk and another property which was not adapted to flood risk. The area under each curve corresponds to the expected flood damages with and without the measures. That is, the area shaded grey shows a reduction in damage (property where PLFRA measures have been implemented) when compared to the area shaded black, which represents property with where PLFRA measures have not been implemented. Therefore, the difference between the two areas is the expected damage avoided, which by definition corresponds to the average benefits of adopting PLFRA measures.

4.6.1 Tangible benefits quantification

The financial costs of tangible impacts are values that can be observed in the marketplace. For example, with flood damages, property must be repaired or replaced at market prices for materials and labour (Environment Agency and DEFRA, 2004). As shown in Figure 4.3, actual market data will be used to quantify the cost of tangible benefits of adopting PLFRA measures, such as reduction in alternative accommodation cost, reduced claim spend and costs of replacing flood damaged personal belongings (contents). The rationale behind using actual market prices for the quantification of tangible benefits of flood adaptation measures is based on the assumption that individuals' behaviour in actual markets and the prices they pay for goods and services are at least a minimum reflection of their preferences or WTP (Environment Agency and DEFRA, 2004).

4.6.2 Intangible benefits quantification

Intangible impacts, by virtue of their subjective nature, are far more difficult to quantify, as they are often more personal to the victim of flood event, with the severity of the impact dependent upon the individual's specific relationship with the loss or damage resulting from the flood. Due to the difficulties involve in assessing and calculating intangible impacts, some organisations such as 'the Office of Public Works Dublin has adopted a conservative approach by measuring the intangible impacts as the equivalent of residential property damage (OPW, 2009).

Further, establishing the financial values of intangible benefits of flood adaptation measures are more difficult to measure because there are no existing markets where these impacts are being traded (Environment Agency and DEFRA, 2004; Joseph *et al.*, 2011b; Markantonis and Meyer, 2011). As discussed in chapter 3, section 3.7.1, the intangible benefits of PLFRA measures can be quantified by using one of the stated preference methods of valuation refer to as contingent valuation method, this can be used to elicit WTP values from flood plain residents. The maximum amounts of money floodplain residents are willing and able to pay to avoid or reduce the intangible impacts of flooding, as discussed in section 2.5, were elicited at the empirical stage of the research. The value of benefits of PLFRA measures are the average of all willingness to pay values, taking into consideration the socio demographic distribution of respondents and their income level (see chapter 5 for detail discussion on survey instrument and analysis).

4.7 SUMMARY

The chapter addresses the development of a CBA conceptual framework of PLFRA measures for homeowners. The developed framework brings together all the essential aspects of costs and benefits to be examined, and provides appropriate parameters and points of reference for investigating the actual costs and benefits of the PLFRA measures. The CBA framework, thus, provides a context for this research to identify costs and benefits of PLFRA measures and compare the difference between these benefits and costs by calculating the benefit cost ratio of each of the adaptation measures (i.e. resilient and resistant measures). The information derived from the analysis is critical to providing homeowner adequate decision making information when face with the problem of choosing whether to invest in PLFRA measures or not.

The conceptual framework reveals relationships between the costs of adopting PLFRA measures and the associated benefits of reducing tangible and intangible losses / impacts of flooding on households. 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

The research methodology is an important aspect of any research project and essential to the research process. It provides the procedural approaches used in a study, shows how appropriate the chosen methods were, and puts forward a rationalisation of their use over other methods. A methodology also provides a good link between the literature reviewed and the sets of data collection (primary and secondary in the case of this research project). The aim and objectives of the research were presented in chapter one. The critique from the extant literature review in chapters 2 and 3 led to the development of conceptual framework in chapter 4. This chapter analyses the different methods available for undertaking the research towards achieving the stated aim. It explains the proposed and up to date methodology for the research coupled with the reason for using the various methodologies. Thus, this chapter provides the platform on which objective 4 will be achieved.

A brief discussion of the research approach, which is based on analysis of locations flooded in the summer 2007 is presented. Details of the 2007 flood event and site selection criteria are described. This is followed by data collection methods and justification for choosing the method. The nature of secondary data, which was collected for the study, is also explained within the relevant sections. The primary survey data collection strategy is discussed and different statistical analysis methods used are presented. Ethical issues pertaining to the research are also described and steps taken to comply with relevant ethical procedures are discussed.

5.2 RESEARCH APPROACH

The research has been driven from the onset by the search to derive largely quantitative measures of costs and benefits of PLFRA measures for floodplain resident in England. This dictates the choice of a largely quantitative approach and research method as the foremost paradigm for this study. According to Creswell (2009), quantitative research method is all about quantifying relationships between variables. The driving forces for the choice of a research methodology in any study are not the advantages or disadvantages associated with a particular method. According to Creswell (2009), one of the factors that influence the choice of research approach over another is the nature of the research problem or the objectives of the study. For instance, if the nature of the problem is such that the objective of the study is to test or explain an existing theory, then the quantitative method is the best approach. However, Creswell (2009) suggested that if a concept or phenomenon needs to be understood because little research has been done on it then a qualitative approach should be adopted. Further, due to the interdisciplinary nature of research, there may be a need to combine both quantitative and qualitative methods in order to address the research question and this is termed mixed approach (Mertens, 2003; Creswell, 2009).

The research concept for the study is quantitative in nature. The quantitative concept implies that the reasoning of the research is largely deductive involving the development of a conceptual (theoretical) framework prior to its testing through empirical observation (Loose, 1993). The research approach employed in the empirical stage of the research combined a quantitative analysis based on the actual flood reinstatement costs data, a bottom up approach based on individual households' perception of intangible impacts of flooding and triangulation approaches. Primary and secondary data were combined via the inclusion of questionnaire survey data within the research programme with secondary data sources for actual reinstatement costs of flooded properties on the basis of different house type categories.

5.2.1 Choice of questionnaire survey

In dealing with the issue of assessing the value of intangible impact on households, as discussed in Chapter 4, the most appropriate source of data for the analysis was the collection of primary data from floodplain residents who had been flooded before. This is because; obtaining first hand information on their willingness to pay to avoid or reduce the intangible impacts of flooding on the households cannot be elicited through other means apart from eliciting it directly from the homeowners. As it has been established that willingness to pay is a function of households' disposable income Penning-Rowsell *et al.* (2005); therefore, such information can only be reliably obtained from the homeowner. The data collection was effected in the form of a questionnaire survey. The output from the survey was analysed in order to determine each individual's perception of the extent of intangible impacts/losses of flooding on their households and the homeowners' willingness to pay to avoid or reduce the impacts. The data was combined with the tangible benefits data to establish total benefits of investing in PLFRA measures.

5.3 THE SUMMER 2007 FLOOD EVENT

The flood sites used in the empirical stage of the research were selected from locations flooded during the summer 2007 flood event, which was reported to be widespread and catastrophic in nature (Chatterton *et al.*, 2010).

The major advantages of choosing this large scale national flood event as the basis for the empirical study was that the number of properties affected was large in UK terms, therefore, if well dispersed, would provide maximum data for the research. According to Stuart-Menteth (2007), the estimated insured losses were the largest flood losses in insurance history for the U.K. and the largest U.K. natural catastrophe since the destructive Windstorm Daria in 1990. Further, the event served as a ‘wake-up call’ for flood risk management stakeholders, such as insurance companies, government departments and homeowners. Following which different reviews have been carried out, such as Pitt Review, resilient reinstatement cost report by ABI; and flood forum establishment. The 2007 summer was the wettest summer since records began in over 250 years (EA, 2007), with extreme levels of rainfall compressed in relatively short periods of time. The flood events were linked to a pattern of very wet and unstable weather across the U.K. over the course of several months. The unseasonably wet weather began in May and continued throughout the summer, with record-breaking rainfall totals in June and July (Stuart-Menteth, 2007; EA, 2007).

There is wide variance in the estimates of number of properties affected by the flood event, according to Stuart-Menteth (2007), over 55,000 properties were flooded (both residential and commercial), EFRA (2008) puts the number of properties at 46,000, while Pitt (2008) reported that approximately 48,000 flooded homes were flooded. Estimates made after the floods put the total losses at about £4 billion (Chatterton *et al.*, 2010), of which insurable losses were about £3 billion (Wassell *et al.*, 2009). Around 7,000 people were rescued from the flood waters by the emergency services and 13 people tragically lost their life (Chatterton *et al.*, 2010). Tens of thousands of people were rendered homeless, and some businesses were put out of action for months on end, Table 5.1 shows the most affected regions and the number of flooded properties in each regions.

Table 5.1 Towns and Cities most affected by the summer 2007 flood event

Region	**Number of domestic flooded buildings**	**Number of commercial flooded buildings**	**Total**
East Midlands	4,581	290	4,871
London	1,108	302	1,410
South East	5,896	129	6,025
South West	4,915	1,000	5,915
Welsh	32	4	36
West Midlands	8,450	1,453	9,903
Yorks/ Humberside	23,479	3,718	27,197
Total	48,461	6,896	55,357

Source: Adapted from: Environment Agency, (2007) and Stuart-Menteth, (2007)

5.4 CASE STUDY SITE SELECTION

While the research focus was on the summer 2007 flood event, which was reported to be widespread, it was considered necessary to select sites for the analysis, because it is impractical to include all the flooded locations in the sample size due to time constraint and availability of secondary data to be used in the analysis. However, the selected sites can be said to be representative of flooded regions during the summer 2007 flood event. The selected sites and their main features are summarised in Table 5.2. The types of reported flooding was also given consideration, the reported sites experienced flash flooding, river flooding and surface water flooding due to extensive rainfall during the period, as discussed in section 5.3. Selection of the analysis sites from the locations flooded during the 2007 event was based on the need to represent the widest possible variation both geographical and flood typology while retaining minimum numbers of properties within each selected site. To that end only sites with greater than 50 affected properties were considered.

Table 5.2 Selected locations for empirical analysis

Location/Region	Sources	No of Properties sampled
Barnsley/Yorkshire	Flash/River flooding	90
Beverley/ Yorkshire	Surface water flooding	106
Cheltenham/South West	Flash/River flooding	143
Chesterfield/East Midlands	Flash/River flooding	84
Doncaster/ Yorkshire	Surface water flooding	230
Evesham/West Midlands	Flash/River flooding	52
Gloucester/South West	Flash/River flooding	171
Grimsby/ Yorkshire	Surface water flooding	121
Hull/ Yorkshire	Surface water flooding	124
Pontefract/ Yorkshire	Flash/River flooding	57
Retford/East Midlands	Flash/River flooding	54
Rotherham/ Yorkshire	Flash/River flooding	87
Sheffield/ Yorkshire	Flash/River flooding	204
Swindon/South West	Flash/River flooding	116
Tewkesbury/South West	Flash/River flooding	183
Thatcham/South East	Flash/River flooding	418

Figure 5.1 shows the survey locations, this includes samples from the Northern part of the country (Yorkshire and the Humberside); the South West and South East, and East and West Midlands of the country. This shows that the conclusion drawn from this research can be generalised to the population in other parts of the country.

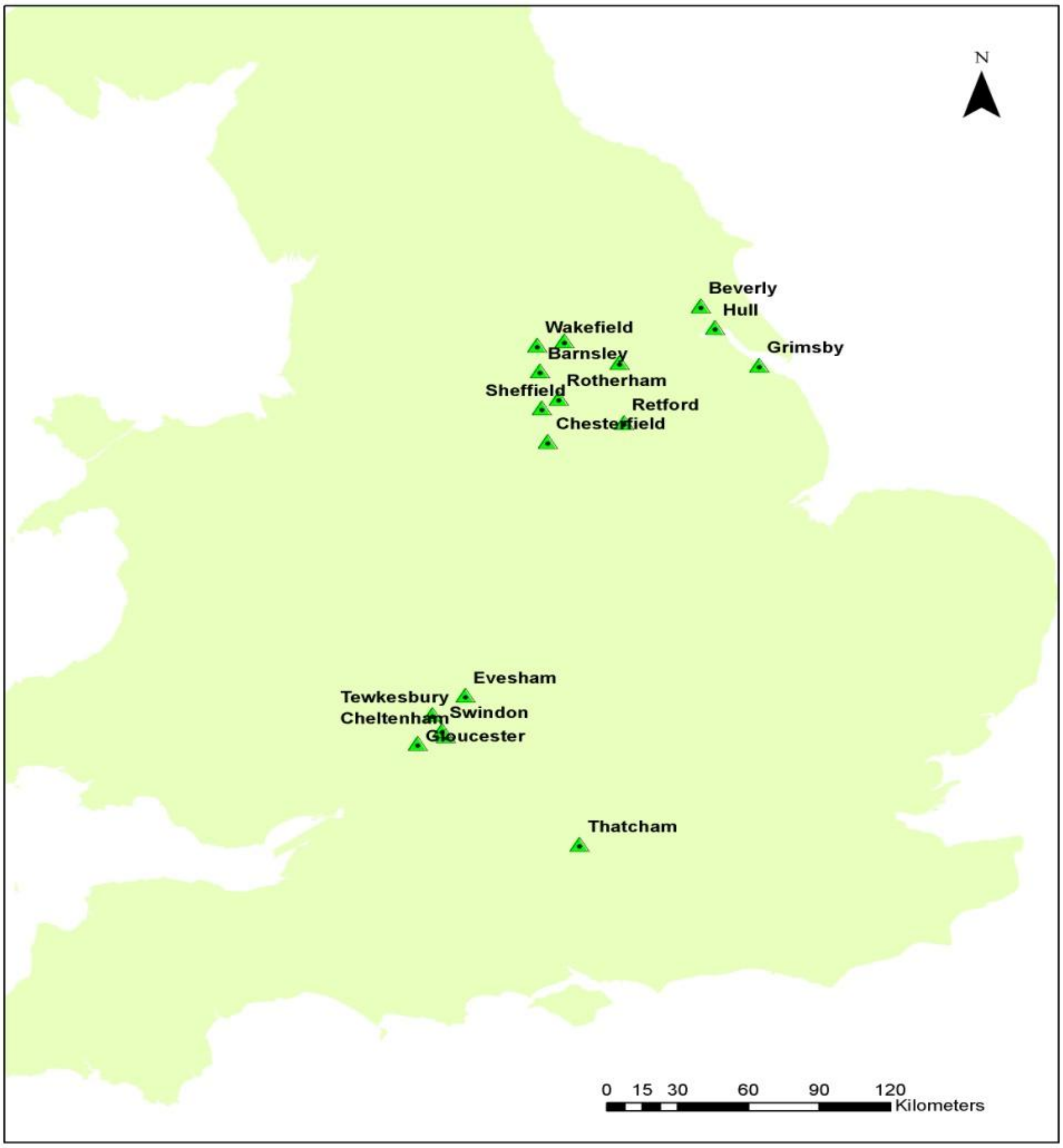


Figure 5.1 Survey Site Locations

5.5 SECONDARY DATA COLLECTION

According to the ABI (2010), flood hazard and flood risk data is critical to the effective management of flood risk. Accurate data is needed to plan and adopt appropriate flood adaptation measures, to enable insurance companies to price flood risk accurately, and to allow homeowners to make informed choices about their investments in flood adaptation measures. A priority of this research is, therefore, to ensure that reliable and robust actual flood reinstatement cost data were used.

As discussed in section 5.2.1, questionnaire survey was used to collect data on households WTP to avoid the intangible impacts of flooding, however, the initial data sources for the empirical stage of this research were designed to rely heavily on existing secondary sources. The secondary data in the form of actual reinstatement schedule of repairs and schedule costs of flooded properties, shown in Table 5.2, were obtained from insurance loss adjuster's claim database. Anticipated flood frequency information was obtained from the Environment Agency website.

5.5.1 Data collection on actual reinstatement schedule of repairs for flood damaged properties

The insurance loss adjuster were engaged by different insurance companies to determine the validity of each claims, following the acceptance of the claim, the insurance loss adjuster then project managed the reinstatement work, which involve the three traditional phases of strip-out, drying and reinstatement work. Data on the actual costs of reinstatement in the form of complete repair schedule (both building and contents) are collected and maintained by insurance loss adjuster on behalf of insurance companies. The Loss Adjuster's Data Register holds details of over 2,300 claims data emanating from the summer 2007 flood event. The Data Register holds details such as residential address of each of the flooded properties, flood depth, duration of flooding, house types, walls and floor construction method, schedule of repairs and traditional reinstatement costs. This data is not publicly available due to data protection.

During 2009, the ownership of the data was transferred to the Association of British Insurers (ABI) following the completion of research into 'the costs of flood resilient reinstatement of domestic properties' by Wassell *et al.* (2009) which was commissioned by the ABI. Therefore, the permission to use the claim data register in this research was formally obtained from the ABI (see Appendix A-1 for copy of permission letter).

Table 5.3 shows the details of information contained in the claim dataset. These data are considered to be most complete record of actual reinstatement dataset available to any academic researcher in the UK. And it is considered, for these research purposes, to be representative of the proportions of different house types that may be subject to flooding within the whole UK domestic housing stock, except that it do not include examples of modern timber frame properties, which form a large proportion of recently built properties in some areas of the country, particularly in Scotland, this therefore does not affect the validity of the dataset as the research primary focus is England.

Table 5.3 Loss Adjuster's insurance claim dataset

Claims Detail	**Detail information**
Detail Address	Homeowner, Street, Postcode Town, county
Date of loss	25/06/2007
House types	Detached Semi-detached Terraced Bungalow
Year of construction	Ranges from 1921 to 1995
Wall construction	Cavity and solid wall
Floor construction	Solid concrete, suspended concrete and suspended timber
Flood depth	Ranges from 0-150 to 500 -1000
Flood duration	Ranges from <24 to 73>
Reinstatement schedule	Details of traditional like for like reinstatement work carried out in each properties
Total reinstatement costs	£,000.00

The major advantage of using the data source described above over other related research, such as Penning-Rowsell (2005), DEFRA (2007), Thurston *et al.* (2008), Grant *et al.* (2011) and Royal Haskoning (2012), was that the data source was based on actual event data as against developing model of different house types, which always comes with various assumptions about the flooded houses. It was acknowledged in the ABI *'cost of resilient reinstatement project'* by Wassell *et al.* (2009), that some of these assumptions are unlikely to hold in certain instances under the real life event. Further, the cost associated with reinstatement during a flood event such as 2007 were reported to have been affected due to the forces of demand and supply, this will not be put into consideration if the pricing exercise was based on model design as against real life event.

Data collection on costs of resistance measures

Data on the installation and maintenance costs for each packages of flood resistance measures, as described in chapter 2, section 2.7.1, was initially proposed to be estimated from information of the costs of 'Kitemark' approved products, which was to be collected from flood protection product manufacturers and from the Defra flood resilience pilot projects (Harries, 2009) and previous research (ABI, 2003; Norwich Union., 2005). These cost information data were readily available on the internet.

Due to the wide difference in these cost information, it was decided to obtain the unit costs from damage management contractors who have the experience of installing the products because majority of the online cost information, do not include installation cost. The danger in using this kind of cost information is that assumptions will have to be made on the installation cost; therefore, a robust and reliable alternative was to obtain the information directly from the contractors. A small survey of 24 damage management contractors was undertaken to elicit estimated unit costs for the various resistance measures. These are contractors that are fully involved in repair of flood damaged properties on behalf of the insurers, and have experience in this type of repair work.

Data collection on costs of resilience measures

According to Royal Haskoning (2012), readily available sole comprehensive source for the cost of resilience measures is the ABI (2003) study report, which is freely available on the internet. These costs are 9 years old, the actual costs of the measures is expected to have become cheaper over the years due to the maturity of the market, therefore using the ABI data source, which could be updated to current market rate by applying the Consumer Price Index (CPI) in this research could lead to over estimation. It was decided to use the current market reinstatement cost data obtained from insurance loss adjusting firm the author’s employer. The advantage of obtaining the cost data from this source is that the data is based on current market prices, which have been tendered, and therefore it was considered to be robust than the ABI cost data. Permission to use the cost data has been granted by the author's employer. However, due to competitive nature of the insurance loss adjusting market, no further reference will be made in this thesis to the source of the cost data for the resilience measures.

Flood frequency data from Environment Agency

The probability or likelihood of flooding is described as the chance that a location will flood in any one year (DEFRA, 2010). For instance, if a location has a 1.3% chance of flooding each year, this can also be expressed as having a 1 in 75 chance of flooding in that location in any year. As discussed in chapter 4, section 4.3.1, flood probability variable is very important in determining the cost effectiveness of PLFRA measures. The flood property variable for each location, which was included in the empirical stage of this research, was obtained from the Environment Agency website. The website hosts the floodplain maps for England and Wales. The flood probability was categorised into three, these are: significant (the chance of flooding in any year is greater than 1.3%, i.e. 1 in 75); moderate (the chance of flooding in any year is 1.3%, i.e. 1 in 75 or less, but greater than 0.5% i.e. 1 in 200) and low (the chance of flooding in any year is 0.5%, i.e. 1 in 200 or less). However, in this research the flood probability data was converted into percentages (%), this was used to generate the flood return period, which was used in the development of the CBA model of PLFRA measures.

5.6 QUESTIONNAIRE SURVEY DESIGN

Gray (2004) described the questionnaire survey as a research tool through which people are asked to respond to the same set of questions. Surveys as defined from Henn *et al*. (2008) are usually used to collect data, which are then used in quantitative ways in order for them to be added or analysed together, or to gain a view of the sector and the people concerned. Blaikie (2010) emphasises the wide use of questionnaires for descriptive and analytical purposes and to find out facts, opinions, and views. Surveys can be used for both descriptive and explanatory needs within the research to a degree as emphasised by Naoum (1998). In this research, the questionnaire survey was designed primarily to elicit information from homeowners on their perspective of the benefits of PLFRA measures, particularly the homeowners' willingness to pay to avoid or reduce the intangible impacts of flooding on households so that the relationship between costs and benefits could be explored using appropriate statistical techniques. Homeowners were chosen because they are responsible for taking decisions on investment in adaptation measures and, therefore, are in the best position to determine the severity of flood impact on their households. They are able to know the amount of money they are willing to pay to avoid or reduce impact of flooding on their individual households.

5.6.1 Questionnaire design

Blaikie (2010) asserted that questionnaires have to be prepared in such a way that respondents can complete them without any assistance other than built-in and/or separate written instruction. In view of the nature of the information required for the research, it was decided to design the questionnaire with both open-ended and closed-ended questions. Each of these formats has distinct advantages and disadvantages so combining them was essential in reducing or eliminating the disadvantage of each whilst gaining their advantages.

Nesbary (2000) stated that there are five routes that the quantitative researcher can adopt to administer questionnaires, these are; postal, fax, phone, web-based or internal surveys and personal face-face interview. The self administered postal option was used in this research as suggested by Pearce and Ozdemiroglu (2002). This method was selected in order to minimise cost since it has been established by Dillman (2000) that the costs of a postal questionnaire are generally lower than face to face or telephone interviews. While, postal questionnaire surveys are synonymous with low response rate (Creswell, 2003; Creswell, 2009), it was decided that postal method is suitable for this research due to the nature of information required, which in most cases would require respondents to cast their mind back to the past flood event before they can provide answer to some of the questions. Further, online survey distribution system was considered at the outset of the research. This was dismissed because the mixed of the targeted population, which comprises of young and elderly people. It was anticipated that not all of them would have easy access to the internet in order to be able to complete the questionnaire, most especially the elderly ones. Further the email addresses to be used for this method of distribution were not available

The decision to use postal survey method was drawn from some CVM research where this method of elicitation has been used successfully. For instance, a CVM survey to assess demand for improved water supply in the River Ganges in India used a postal survey administered to middle-class Indian families located in major cities throughout India (Markandya, 1997). The results of the survey showed that WTP to clean up the River was very high and the survey yielded a 25% response rate.

Hashimoto *et al.* (2006) carried out research to evaluate the burden on families with a family member suffering traumatic brain injury sequelae in Japan. A national survey among 1707 members of the Japan Traumatic Brain Injury Association was conducted by postal questionnaire with open-ended questions. The survey yielded a total of 29.8% response rates. Further, a recent study of cultural ecosystem services in marine landscapes by Gee and Burkhard (2010) used an extensive postal questionnaire to explore, in part, the aesthetic controversies surrounding offshore windfarm development in the German North Sea. A response rate of 27% was achieved.

Following the successful use of postal survey as discussed above, it was expected that adopting postal method in this research will yield a reasonable response rate, particularly as this method allows respondents to complete the questionnaires at their leisure as against face to face interview or telephone interview, which in most cases put respondents on the spot.

The survey was aimed at eliciting the value of WTP and the extent of severity of flood impact data at individual property level. The section on how to reduce intangible impacts of flooding was, therefore, the most important aspect of the questionnaire. For instance, respondents were asked about the financial value of their uninsured losses (in the form of extra expenses incurred while in temporary alternative accommodation) and to rate the overall severity of the flood in terms of its impact on their households general wellbeing. Additionally, respondents were asked to rate the relative severity of the each of the individual flood impacts on a subjective severity 1 to 5 scale, 1 being not severe, while 5 being extremely severe. Impacts such as, damage to house structure, damage to replaceable contents, loss of memorabilia, health effect of flooding, stress of flood event, disruption to daily life, anxiety, worry about future flooding and worry about temporary loss of house value were included. Data on how long respondents' households lived in the temporary alternative accommodation was also included. This is necessary in order to determine the benefit to the insurance companies, if the lengths of time spend in temporary alternative accommodation is reduced or eliminated by the adoption of PLFRA measures.

It was also considered necessary to collect information on socio-economic data of respondents, such as: age by adopting the EA/DEFRA (2004) categories; 18-39, 40- 64, 65-74, 75+; sex (Male or Female), occupation of the respondents. This is considered necessary so that the respondents can be grouped into socio-economic classes. The EA/DEFRA (2004) socio-economic class grade categories were adopted in this research (e.g. Professional and managerial, Clerical and other white collar, Skilled Manual and Semi skilled/unskilled manual) (Environment Agency and DEFRA, 2004). Further data on length of time in which respondents have lived in the property was also collected. The most sensitive questions, about households income, which some respondents may not want to disclose, 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 established that households' willingness to pay is a subject of their disposable income, therefore income is an important variable to be tested in the research.

Data on respondents' awareness of available adaptation measure was collected. Other questions were included to identify policyholders who have used the opportunity of the 2007 flood event to adapt their properties. Questions on what motivational factors which are require by homeowners to take preventative measures were also included. Analysis of this particular question will provide better information for insurer as to the expectation of homeowners if they are to reduce the level of flood damage to their property, which will subsequently benefit insurers in any future flooding.

The questionnaire was intended to be fairly short and simple to be completed in less than 30 minutes. To that end most of the questions consisted of multiple choice questions requiring ticked-box responses and open ended questions were used for the valuation section of the questionnaire. Provisions were also made for respondents to contribute in free text forms any further comments or views they have in respect of each question. The questionnaire was accompanied by a letter of introduction explaining the purpose of the questionnaire (see Appendices A-2 and A-3).

5.6.2 Elicitation of WTP using CVM

It should be noted that different elicitation techniques have different kinds of advantages and disadvantages, as discussed in chapter 3. This being the case, the question one has to address in a CVM survey is which one of these techniques should be used to elicit the value of intangible impact of flooding. Mitchell and Carson (1989) report that the open-ended method works smoothly in situations where the respondents are familiar with paying for the goods under question. Hanemann (1994) concluded that dichotomy approach is more incentive compatible than other elicitation techniques especially in the case of non-use values. However, one of the important questions still needs to be answered is: if the value differs among different elicitation formats, then what to do? Hanemann and Kanninen (1999) provide the answer by arguing that the cognitive demands of the individuals are not identical, and therefore, one should not expect that the values across different elicitation techniques should converge. It can be concluded that, selection of an elicitation technique in a CVM survey depends on different factors, such as the nature of the good investigated, cost of the survey, nature of the respondents targeted and nature of the statistical technique used.

Mitchell and Carson (1989) and Whittington *et al.* (1991) argued that the more a respondent is familiar with the good, the less will be the level of hypothetical bias in a CVM. This implies that the WTP values elicited for those public goods, which are traded in the markets or which the individuals are familiar with, would be free from hypothetical bias, as discussed in chapter 3, section 3.7.2. Therefore, by targeting respondents who have been flooded before and are familiar with the intangible impacts, hypothetical bias is reduced. The value of benefits of PLFRA measures will be the average of all WTP values, taking into consideration the socio demographic distribution of respondents and their income level.

5.6.3 Administering pilot survey

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 pilot survey was conducted prior to the major survey. According to Creswell (2009), the aim of the pilot study is to test the wording of the questionnaire, identify unclear questions, test the intended method for data collection, test respondents' understanding of the questions and measure the effectiveness of the potential response. The pilot questionnaire survey was administered among two sets of homeowners; those that had previous flood experience and those that had no flood experience. However, these were not part of the main questionnaire survey.

A total of 20 survey questionnaires were issued, 10 for each set of homeowners. Seven completed questionnaire were returned, four from those who had previous flood experience and the remaining three were from those homeowners who had no previous flood experience. Respondents were asked to evaluate the layout, question design and content of the questionnaire after completing the main questions and how long it takes to complete the questionnaire. The benefit of this is that respondents can provide valuable feedback to assist in improving the main questionnaire prior to embarking on larger survey.

Exploratory analysis of the data revealed that some majority of the questions were well understood. However, questions on the awareness and implementation of the adaptation measures were found to be confusing. These questions were then reviewed with further assistance from the supervisory team. This helped to sharpen the final version of the questionnaire for the main survey. Following the completion of pilot study, the main questionnaire was modified based on the feedback received.

5.6.4 Administering main questionnaire survey for the study

In order to boost response rate in the main questionnaire survey, following the completion of pilot study, the result was analysed. Lessons from the pilot study were used to improve the main survey questionnaire prior to distribution to wider respondents. Particular attention was paid to respondents' feedback on income categories and their willingness to pay values. This was deemed necessary because the willingness to pay question are open-ended questions where respondents were given the free hand to state how much they are willing to pay instead of providing them with series of value options to pick from, as in the case of EA/DEFRA (2004) research project.

The address list of the full study locations that experienced flood event in summer 2007 was selected for the main survey. Lamond (2008) in her pilot study tested whether there will be any difference in response rate due to postage class, the result of the study shows that there was no difference in response rate, therefore, it was decided to use second class postage stamp to distribute the main survey questionnaire in this research due to financial constraint as this has been shown not to have detrimental effect on response rate.

According to past researchers such as Lamond (2008) and Ikpe (2009), distributing questionnaires with self address and prepaid envelops, together with a personalised accompany letter, has potential to increase response rates; therefore, it was decided to adopt similar mailing strategy in this research.

The modified questionnaire was issued to the 16 full study sites on 8th February 2013. Three weeks later a reminder postcard was sent to those who had not responded (sample of the reminder postcard is in Appendix A-4). The decision to issue a postcard instead of issuing another set of questionnaires was hinged on the premises that it is possible that some of those who were yet to respond may have decided not to participate, in which case by sending another set of questionnaire to them may upset them. The data collection stage of the research was brought to an end by the end of April 2013. Following the completion of data collection phase of the research, which lasted for 10 weeks, the next research activity is to analyse the collected data.

5.7 DATA ANALYSIS

Following completion of the questionnaire survey, a range of descriptive and inferential statistical analysis was carried out by using the Statistical Package for the Social Sciences (SPSS 20). The analysis was divided into two strands: the first strand was the descriptive analysis of the secondary data, while the second strand involved detail descriptive and inferential analysis of the questionnaire survey data.

5.7.1 Analysis of the actual reinstatement costs

Prior to carrying out detail analysis of the actual reinstatement costs data, it was necessary to check the data for any obvious error due to the fact that the data was not initially collected for the purpose for which it is being used for in this research, therefore checking the data for error is very important, as suggested by Pallant (2005). There are three distinct steps for screening data for statistical analysis, these are: checking for errors, finding the error and correcting the error in the data file. These steps were employed on the data prior to carrying out detail analysis in order to correct any anomalies in the dataset. This is to prevent skewing the result of the analysis. Statistic tool used for identifying obvious error in the dataset are frequency distribution together with minimum and maximum value analysis, as used by Samwinga (2009).

Following the identification and correction of error in the dataset, descriptive analysis was conducted on the actual reinstatement cost data by using different property types, such as bungalow, detached, semi-detached and terraced, as variables. Based on this analysis, the most typical values (mean, median and mode) were adopted. According to Burns (2000), descriptive analysis is an aspect of statistics, which allows researchers to summarise large quantities of data using measures that are easily understood by an observer. The results of the descriptive statistics were categorised by property types, floor constructions method, flood depth and flood return period.

5.7.2 Analysis of the additional costs of PLFRA measures

Similar to what was described in section 5.7.1, the additional costs of PLFRA measures were checked for error and corrected prior to carrying out detail analysis of the dataset. Any potential outliers were identified and adjusted accordingly. According to Creswell (2009) outliers is a term used to refer to cases with values that lie above or below the majority of others cases. As asserted by Tabachnick and Fidell (2001) outliers are important factor to consider in data preparation because they have the potential to distort statistic results.

Descriptive analysis was employed to estimate the mean and median of the dataset; this was based on variables such as property types, floor construction methods, flood depth, and flood probability. The result of the analysis was combined with the result of the analysis of the actual reinstatement costs. The results were presented as a percentage of the actual reinstatement cost; this was to establish the relationship between the actual reinstatement costs and the additional cost of PLFRA measures. The results obtained were used to determine the cost benefit ratio once the values of intangible benefits are established through the analysis of questionnaire surveys.

5.7.3 Analysis of willingness to pay questionnaire

Frequencies of responses for the main variables of interest were examined, particularly the willingness to pay value. The mean scores for categories of respondents were examined by using multivariate regression analysis as used by Soane *et al.* (2010) in their study of the 'flood perception and mitigation: the role of severity, agency and experience in the purchase of flood protection, and the communication of flood information'.

A validity test was carried out. One way to test validity is to examine whether the measures produced by the estimated model relate to other measures as predicted by theory. According to Mitchell and Carson (1989) the CVM measure should conform to theoretical expectations (theoretical validity) and should also be correctly correlated with other measures of the model (convergent validity) (Mitchell and Carson, 1989). Bateman and Turner (1993) suggested a further variant of this approach is to examine the explanatory power of the bid functions. However, Kealy *et al.* (1990) observed that the large number of zero WTP values and the high variance associated with CV, could result in a low R^2 value (Kealy *et al.*, 1990). Mitchell and Carson (1989) suggest an R^2

value of 0.15 as minimum. Therefore, regression analysis was carried out on the dataset to explain the reliability of the dataset.

Descriptive analysis was carried out to establish the mean and median values of willingness to pay elicited from respondents. The results were compared between different locations. Other variables such as income level, occupation of the main income earner, age of respondents, previous flood experience and number of people in households were used to compare respondents' willingness to pay values; this is in accordance with EA/DEFRA (2004). The result obtained were combined with other tangible benefits in order to establish the total benefits of adopting PLFRA adaptation measures, this is in preparation for the development of the CBA model of PLFRA measures in the form of benefit/cost ratio (BCR).

5.7.4 Benefit Cost Ratio (BCR) analysis

The purpose of the BCR analysis is to provide an assessment of the extent to which a project or program may achieve its ultimate goal. The BCR analysis ultimately provides a means of selecting the most cost-effective countermeasure(s) for any given project. The BCR is estimated by dividing the benefit of measure by the value of cost. As noted by Pizzey (1994), absolute figures in an accounting statement are made more meaningful when they are put into perspective by comparison. Therefore, BCR was adopted in this research to obtain insight into the costs and benefits of PLFRA measures and to provide a uniform basis for comparing the costs as well as the benefits of adopting PLFRA measures.

BCR analysis has been successfully applied in the domain of flood protection measures both at government level and at individual property levels by different authors, such as

Thurston *et al*. (2008), Penning-Rowsell (2010), Joseph *et al*. (2011a). The mean or median value of additional cost of adaptation measures were compared with the total discounted benefits (tangible and intangible) of the measures. The benefits were discounted over 20 years as used by Royal Haskoning (2012).

5.7.5 Correlation analysis

Fleming and Nellis (1994) described correlation analysis as a statistical technique, which measures the relationship among variables. Bryman and Cramer (1999) and Field (2009) asserted that correlation indicates both the strength and the direction of the relationship between a pair of variables. It is widely use in the social science research. The intensity of the correlation among variables is usually expressed by a number called the coefficient of correlation which is always denoted by the letter *'r',* this is called the Pearson coefficient of correlation (Motulsky, 1995). The correlation coefficient is a measure of linear association between two variables. Values of the correlation coefficient are always between -1 and +1 (Bryman and Cramer, 1999; Blaike, 2003). Field (2009) concluded that both the strength and direction of the relationship are assessed by making reference to the correlation coefficient 'r' and this can be calculated mathematically as follows:

$$r = \frac{\sum (x_i - \bar{x})(y_i - \bar{y})}{(N-1) s_x y_y} \qquad \text{……Equation 12}$$

Where

S_X is the standard deviation of the first variable

S_Y is the standard deviation of the second variable

x_i and y_i are the data points in question

x and $\bar{x}$ are the means of the sample

N is the number of observation

The correlation coefficient is usually produced with its significance level in SPSS software. For instance, a correlation coefficient of +1 indicates that two variables are perfectly related in a positive linear sense; a correlation coefficient of -1 indicates that two variables are perfectly related in a negative linear sense, and a correlation coefficient of 0 indicates that there is no linear relationship between the two variables. The importance of significance level in correlation equation is that it helps in identifying which of the coefficient are significant or not. According to Field (2009) a significance level that is less than 0.05 is considered indicative of a genuine relationship, which does not just occur by chance. Correlation analysis was performed on the questionnaire data to establish the relationship between various variables.

5.7.6 Regression analysis of the developed model

Regression analysis is a statistical tool for the investigation of relationships between variables (Freund and Wilson, 1998). It is usually used when a researcher is seeking to ascertain the causal effect of one variable upon another or the effect of a price increase upon demand, for example, in relation to this research, it was used to test the hypothesis for the study, such as exploring the relationship between reduction in intangible flood impacts on households and the adoption of PLFRA measures.

According to Field (2009), the regression analysis procedure tests the null hypothesis that the slope parameter of the independent variable is 0 against the alternative hypothesis that the slope parameter is different, that is, more than 0. If the p-value for the test is less than 0.05 (level of significance), the null hypothesis is rejected and it is concluded that there is a statistically significant association between the dependent variable and the independent variable. In that case, the model may be used to make predictions of the dependent variable.

There are two categories of regression analysis, these are simple linear regression used to determine the influence of one independent variable on a dependent variable, and a multiple regression use to determine the influence of more than one independent variable on a dependent variable (Free, 1996). Multiple regression analysis is an extension of bivariate of simple linear regression. Another family of multiple regression analysis is called logistic regression analysis. This is a technique for modelling the probability of an event in terms of suitable explanatory or predictor variables (Loh, 2006). In this research, multivariate regression analyses were carried out on the WTP data to determine variables with potential to influence WTP values. This accords with Green and Penning-Rowsell's (1988) analysis. Further, test of the relationship between flood adaptation awareness and adaptation measures was carried out.

5.8 ETHICAL CONSIDERATIONS

Research into impact of flooding on households in the UK is a very sensitive area given the devastating and catastrophic effect of floods on households. Coupled with the fact that reminding flood affected people of the event again may bring back the bad memory of the event. Therefore, the data collection method adopted for this research has undergone rigorous ethical approvals. The key ethical concerns, thus, presented by this research was ensuring integrity and confidentiality and ensuring that no harm (especially emotional distress) was caused to the respondents and their households. Another important ethical concern was the storage of data and the disposal of data (Fellows and Lui, 2008). Since it was expected that this research will continue to yield publications and possibly discussions beyond the actual completion and examination of the research work, the original data 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. As mentioned by Fellows and Lui (2008), data may 'decay' in usefulness from a user's perspective, and so when the stored data from this research becomes no more useful it will be disposed irretrievably.

In conforming to the established trend, the University of the West of England (UWE) put in place a rigorous ethical validation procedure to assist researchers conform to a reasonably accepted standard. Among others, the code designed by UWE is to ensure that the respondents will be made fully aware of the aim and objectives of the study and will only be asked to participate on a voluntary basis. Any sensitive information provided by the respondents shall remain confidential.

Full ethic approval was granted by the author's University Ethic committee prior to embarking on the nationwide survey. Further, a copy of the questionnaire used in this research was sent to the Association of British Insurer (ABI) for their approval prior to embarking on the main survey of floodplain resident, this was the main condition for granting the permission to use the data for this research.

5.9 SUMMARY

The Chapter has presented a detailed outline of the research methodology adopted for undertaking this research. The adopted research method was largely quantitative method. This was chosen based on the evidence from the literature and on the need to obtain quantitative measures for analysis. A quantitative approach to this study was considered appropriate to provide comprehensive quantification of cost and benefits of PLFRA measures. Data collection strategy employ in the empirical stage of the research involves both primary and secondary, sources of the data have been described in detail in the chapter. The targeted population for questionnaire administration are homeowners who had experienced flood events in summer 2007. Details of different statistic data analysis techniques to be used are also presented in the chapter. Chapter six presents results of data analyses of the questionnaire survey.

CHAPTER SIX: QUANTITATIVE DATA ANALYSES

6.1 INTRODUCTION

In the first part of this chapter, the descriptive analysis and findings of the primary data collected through the questionnaire survey are presented. This includes information regarding the response rate and social demographic representation 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 initial analysis is to provide a detailed examination to the background information of the dataset in order to establish the validity of the conclusions to be drawn from the respondents' information. Further, this initial analysis examined the respondent's characteristics, prior to subjecting the dataset to further analysis which is used in chapter 9 as part of the CBA model development.

In the second part of the chapter, detailed analysis of the dataset is carried out by employing appropriate statistical techniques, such as inter-rater agreement test, correlation and multiple regression analysis. The perceptions of homeowners on the intangible benefits of PLFRA measures were explored and analysed. Also findings from detailed analysis of the factors which can influence the adoption of PLFRA measures are presented. In addition to these, detailed analysis of the factors that influence the stated WTP values is presented. The chapter concludes by establishing the mean value of WTP to be used in the development of CBA of PLFRA measures. This chapter, thus, addresses the fourth research objective in terms of presenting the results of data analysis in relation to the assessment of floodplain residents' willingness to pay to reduce the flood impacts and psychological effect of flooding on households. The overview of the quantitative data analysis is presented below.

6.2 SYNOPSIS OF DETAILED QUANTITATIVE DATA ANALYSES APPROACH

Using the preliminary data analysis strategies presented in part one of the chapter, the screened survey data was analysed. First, descriptive statistics were conducted on the respondents' background information to obtain the overall demographic information in support of the validity of the findings. Following which, further descriptive statistics, correlation analysis, inter-rater agreement tests (rWG)**,** Relative Importance Index (RII) and multivariate regression analysis were conducted on the responses regarding the impacts of flooding; the degree of these impacts to influence respondents' willingness to pay (WTP) values; the respondents' view on the benefits of investing in PLFRA measures; the aggregated value of extra expenses incurred by respondents while in alternative accommodation. An outline of the data analyses with reference to the questionnaire is presented in Figure 6.1.

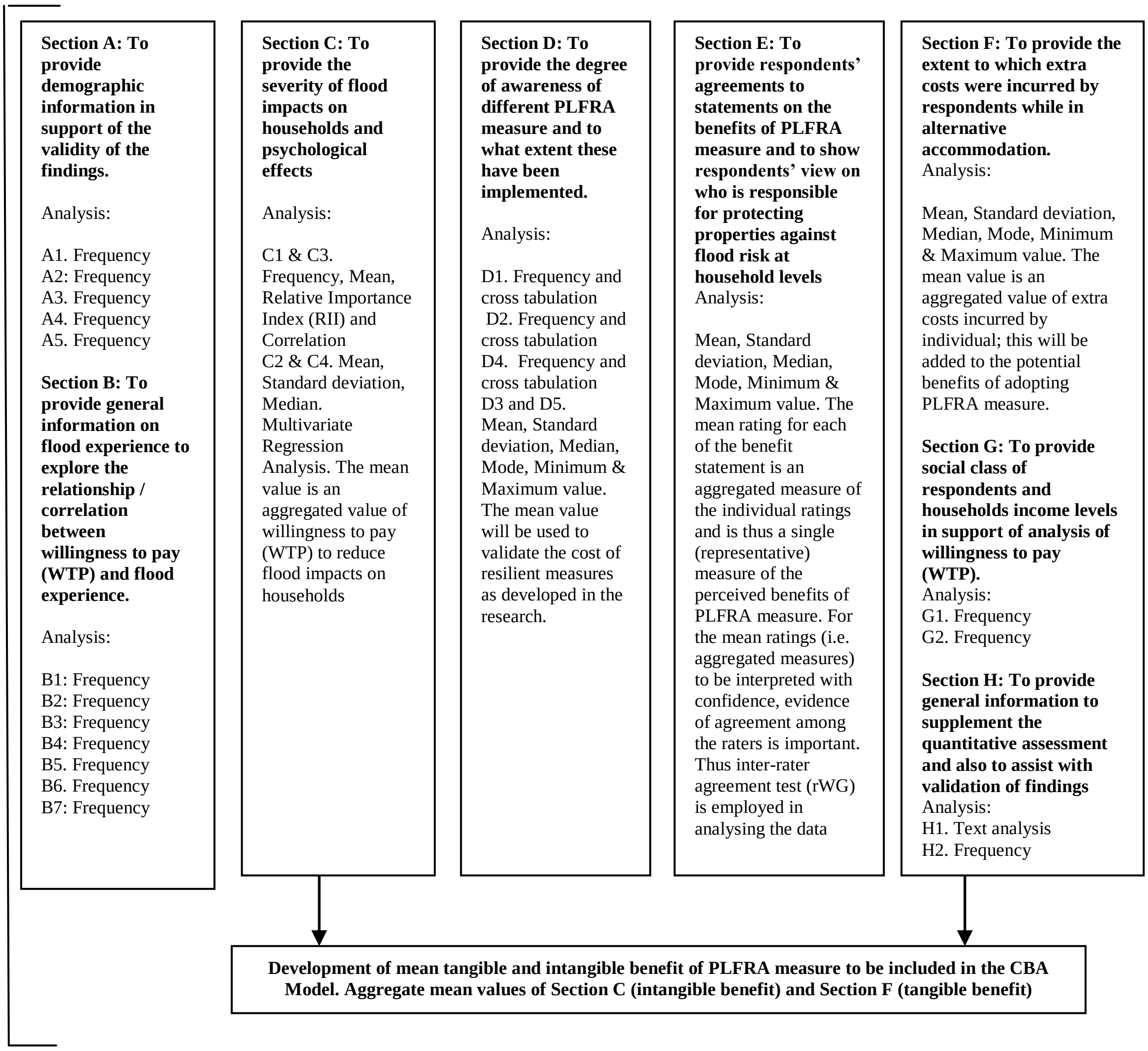


Figure 6.1 Outline of Quantitative data analysis

6.3 QUESTIONNAIRE RESPONSE RATE

Table 6.1 shows the response rate by survey locations. While these response rates are lower than the ideal for survey analysis they are not unusual rates for voluntary postal questionnaire surveys given that no incentive apart from providing respondents with the summary findings was offered. A sizeable sample of 280 responses, representing a response rate of approximately 12.1% was yielded. 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.

Table 6.1 Questionnaire response rates by survey locations

Location	Issued	Returned	Percentage Return
Barnsley	90	17	19%
Beverley	106	17	16%
Cheltenham	143	14	10%
Chesterfield	84	9	11%
Doncaster	230	20	9%
Evesham	52	6	12%
Gloucester	171	21	12%
Grimsby	121	17	14%
Hull	124	28	23%
Pontefract	57	8	14%
Retford	54	6	11%
Rotherham	87	5	6%
Sheffield	204	33	16%
Swindon	116	9	8%
Tewkesbury	183	18	10%
Thatcham	418	39	9%
Wakefield	69	13	19%
Total	**2309**	**280**	**12.10%**

Although, the response rate obtained in this survey appears to be lower compared to the standard response rate for postal questionnaires, indeed, 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, a response rate of 12.1% can be considered adequate and valid for the purposes of analysis.

During the course of administering the survey, many respondents contacted the researcher by email and telephone to explain why they would not be participating in the survey. The reasons provided ranges from, *'just moving into the area within the last one year' and 'to being too old to complete the questionnaire'*. This shows that respondents were interested in the research work, although some of them were unable to participate due to various reasons.

6.3.1 Socio-demographic Characteristics

Socio-demographic assessments were carried out to ascertain the level of representation in terms of age, occupation and income levels offered by the respondents. This was intended to provide a context within which the findings of the survey and subsequent analyses can be taken as valid, to ensure that any inferences extended to the population from the sample are valid and to determine the level of bias in responses provided by different respondents. Table 6.2 shows the age distribution of respondents. Over 52% of respondents were in the age bracket 39-64 years; this is followed by age bracket 65-74 years (30%), people over 75 years only accounted for approximately 12% of the respondents. It can be inferred from Table 6.2 that the result is heavily weighted towards older people. According to Foster Wheeler Environmental Corporation and Harris (2001) concentration of respondents in the older age categories is a fairly common experience for questionnaire surveys. This result is also not surprising because most people owning their own homes are heavily weighted into this category of age bracket.

Table 6. 2 Respondents age

		No of Responses	Percent	Valid Percent	Cumulative Percent
Valid	18-38	16	5.7	5.7	5.7
	39-64	147	52.5	52.5	58.2
	65-74	84	30	30	88.2
	Over 75	33	11.8	11.8	100
	Total	280	100	100	

The profile of respondents' occupations presented in Table 6.3 shows that 40.7% of respondents were retired; this is consistent with the number of respondents in the age bracket of retired people (65-74 and Over 75 years).

29% of respondents were in professional / managerial occupational categories while the rest were engaged in various other occupations. Less than 1% of the entire respondents were unemployed, despite the fact that they are not employed, they are still included in the main analysis because, genuine zero WTP were stated by these respondents, this is not unexpected.

Table 6.3 Statistic of respondents' occupation

		No of Responses	Percent	Valid Percent	Cumulative Percent
Valid	Professional/managerial	81	28.9	29	29
	Clerical and other white collar	37	13.2	13.3	42.3
	Skilled manual	31	11.1	11.1	53.4
	Semi-skilled/unskilled manual	14	5	5	58.4
	Unemployed	2	0.7	0.7	59.1
	Retired	114	40.7	40.9	100
	Total	279	99.6	100	
Missing	System	1	0.4		
	Total	280	100		

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. Only one respondent refused to provide household income information. Of those who provided household income data information (Table 6.4), almost half (49%) earned less than £25,000, while the rest earned between £25,000 and £55,000. In addition 7.5% of the respondents earned over £55,000. It cannot be said that this is typical of national picture of income levels of people living in floodplain areas because currently there is no national data to compare this data with. However, further analysis will be carried out later in the chapter to determine the correlation between income level and willingness to pay to reduce flood impact on households.

Table 6.4 Household income level

		No of Responses	Percent	Valid Percent	Cumulative Percent
Valid	<£5000	15	5.4	5.4	5.4
	£5000-£14999	47	16.8	16.8	22.2
	£15000-£24999	75	26.8	26.9	49.1
	£25000-£34999	51	18.2	18.3	67.4
	£35000-£44999	37	13.2	13.3	80.6
	£45000-£54999	33	11.8	11.8	92.5
	Over £55000	21	7.5	7.5	100
	Total	279	99.6	100	
Missing	System	1	0.4		
	Total	280	100		

6.4 OTHER DESCRIPTIVE DATA ANALYSIS

Further descriptive data analysis was carried out on the survey data to explore the residential characteristics and flood experience of the respondents. Residential characteristics involve the distribution of property types, property ownership, how long respondents have lived in their individual properties, flood depth and duration in the properties. Flood experience of respondents explored include, distribution of flood warning received, how many months each household lived in temporary alternative accommodation whilst their properties were being repaired and how many times each household have been flooded pre and post 2007.

6.4.1 Residential characteristics of respondents

The survey included four main property types (building typology details is in Appendix B-1), 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. Semi-detached were the most common property types represented in the survey responses at just over 41% of the sample. This is closely followed by terraced property types at just over 38%, while bungalows and detached properties are 8% and 13%, respectively. The spread of property types represented in the sample can be said to represent UK housing stock (Wassell *et al.*, 2009; Joseph *et al.*, 2011a); therefore, conclusion drawn on the sample can be representative of UK housing stock exposed to different levels of flood risk.

Table 6.5 Property Types

		No of Responses	Percent	Valid Percent	Cumulative Percent
Valid	Bungalow	22	7.9	7.9	7.9
	Detached	36	12.9	12.9	20.7
	Semi-Detached	115	41.1	41.1	61.8
	Terraced	107	38.2	38.2	100
	Total	280	100	100	

Respondents were asked to indicate their status of ownership of their properties, from Table 6.6 it can be inferred that 98% of the respondents were homeowners. This shows that the targeted populations actually completed the questionnaire; therefore, the findings from the analysis that will follow can be interpreted with confidence. However, some 2% (5) of the returned questionnaires were completed by tenants. These 2% completed by tenants were removed from the main analysis.

Table 6.6 Property Tenure

		No of Responses	Percent	Valid Percent	Cumulative Percent
Valid	Homeowner	275	98.2	98.2	98.2
	Tenant	5	1.8	1.8	100
	Total	280	100	100	

Respondents were asked to indicate how long they have lived in their various properties. Table 6.7 shows that over 93% of the respondents have lived in their properties for over seven years, this implies that they were resident during the 2007 flood. However, the remaining 7% of the respondents have lived in their properties between 1 to 6 years; these people moved to the area after the 2007 flood event. Further interrogation of the data revealed that the 2% completed by tenants as discussed above were actually among those who have lived in the area for less than seven years. Therefore, these 7% were excluded from the main analysis.

Table 6.7 Time live in the property

		No of Responses	Percent	Valid Percent	Cumulative Percent
Valid	1-2years	1	0.4	0.4	0.4
	3-4years	2	0.7	0.7	1.1
	5-6years	15	5.4	5.4	6.4
	7-8years	60	21.4	21.4	27.9
	Over 8 years	202	72.1	72.1	100
	Total	280	100	100	

From Table 6.8, the majority of the properties experienced inundation to their properties on average of less than 1m deep (86.8%). Thirty seven (13.2%) properties experienced flooding above 1m and these were frequently flooded properties.

Table 6.8 Distribution of Flood depth in the sampled property

		No of Responses	Percent	Valid Percent	Cumulative Percent
Valid	0-150	46	16.4	16.4	16.4
	151-300	72	25.7	25.7	42.1
	301-500	59	21.1	21.1	63.2
	501-1000	66	23.6	23.6	86.8
	Over 1000	37	13.2	13.2	100
	Total	280	100	100	

Table 6.9 shows that the flood duration for most properties was less than 24 hours (62.5%). The typical flooding experience was, therefore, a short duration shallow flooding. Further, 28.6% properties were inundated for 24-48 hours. Thus, considering the nature of flooding being experienced in the UK, which is shallow and mostly short duration flooding, this is also supported by the result presented in Table 6.9. Based on this, it can be inferred that the implementation of flood adaptation measures has the potential to be more effective in a flood of this nature.

Table 6.9 Distribution of flood duration in the samples property

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	<24	175	62.5	62.5	62.5
	25-48	80	28.6	28.6	91.1
	49-72	11	3.9	3.9	95
	73>	14	5	5	100
	Total	280	100	100	

6.4.2 Flood experience of respondents

Respondents were asked if they received a flood warning prior to the 2007 flood event (Table 6.10). More than 80% of respondents stated that they did not receive a flood warning, while just over 17% stated that they received flood warning and less than 3% could not remember. Due to the fact that these areas are not listed as high flood risk areas on the Environment Agency database, they are less likely to have received a warning than the general at risk population.

Table 6.10 Flood Warning system

		No of Responses	Percent	Valid Percent	Cumulative Percent
Valid	Yes	47	16.8	16.8	16.8
	No	226	80.7	80.7	97.5
	Don't know	7	2.5	2.5	100
	Total	280	100	100	

Table 6.11 shows the warning time received by the respondents. For flood warning to be of use in terms of reducing flood losses, the warning has to be provided early enough so that action can be taken, such as relocating vulnerable items and implementing any flood protection measures. Table 6.11 shows that almost 10% of those that received flood warning received it less than one hour in advance, giving them little time to prepare and evacuate.

11.4% of those that received flood warning actually received the warning between 1-3hours. An effective flood warning system is very important for successful implementation of some flood resistant products such as door guards and other temporary devices (Garvin *et al*., 2005).

Table 6.11 Flood Warning Duration

		No of Responses	Percent	Valid Percent	Cumulative Percent
Valid	<1hr	27	9.6	9.7	9.7
	1-3hrs	32	11.4	11.5	21.1
	4-7hrs	12	4.3	4.3	25.4
	8-12hrs	2	0.7	0.7	26.2
	13+hrs	4	1.4	1.4	27.6
	Not applicable	202	72.1	72.4	100
	Total	279	99.6	100	
Missing	System	1	0.4		
Total		280	100		

Table 6.12 shows that a majority of the respondents were relocated to an alternative accommodation (68.2%) after the flood. The need to evacuate some 68% of respondents to an alternative accommodation is reflected in the total claim cost as presented in this research. This also can have a significant impact on cost of the 2007 summer flood event if it was reflected in the entire floodplain population.

Table 6.12 Temporary Alternative Accommodation

		No of Responses	Percent	Valid Percent	Cumulative Percent
Valid	yes	191	68.2	68.2	68.2
	no	89	31.8	31.8	100
	Total	280	100	100	

Some of those respondents who reported not having been relocated to temporary alternative accommodation actually either lived in a caravan on their drive or chose to live with relatives. These respondents still had to vacate their properties for repair work to be carried out. Table 6.13 shows the duration spent in alternative accommodations. These durations vary depending on the extent of the damage and the speed of reinstatement.

The majority of those who were relocated to temporary alternative accommodation spent between 4-12 months 61.8% (n=173), less than 3% (n=8) spent 1-3 months, whilst 5.4% (n=15) spent over 12 months in temporary alternative accommodation. This is consistent with the findings of the Pitt review survey that after 9-months 57% of claims were completed (Pitt, 2007).

Table 6.13 Time Spent in Alternative accommodation

		No of Responses	Percent	Valid Percent	Cumulative Percent
Valid	1-3 months	8	2.9	2.9	2.9
	4-6 months	63	22.5	22.5	25.4
	7-9 months	75	26.8	26.8	52.1
	10-12 months	35	12.5	12.5	64.6
	Over 12 months	15	5.4	5.4	70
	Not applicable	84	30	30	100
	Total	280	100	100	

Respondents were asked if they had experienced flood damage to their properties pre 2007. The result presented in Table 6.14 shows that 77.9% (n=218) of the respondents had no previous flood experience prior to the 2007 flood event; 16.1% (n=45) reported that they had experienced one previous flood damage to their properties prior to the 2007 event; and 3.6% (n=10) had been flooded twice and 2.5% (n=7) had been flooded more than twice. This information is important because it is anticipated that the value of WTP stated by respondents would relate to their individual flood experiences.

Table 6.14 Number of times being flooded pre 2007

		No of Responses	Percent	Valid Percent	Cumulative Percent
Valid	None	218	77.9	77.9	77.9
	One	45	16.1	16.1	93.9
	Two	10	3.6	3.6	97.5
	Other	7	2.5	2.5	100
	Total	280	100	100	

Respondents were also asked if they had experienced at least a flood event following the 2007 flood event. Table 6.15 shows that approximately 91% of respondents had not experienced a further flood event. This means that only 9% of respondents had experienced further flood event after 2007 flooding. It is anticipated that this finding would not have significant impact on the value of WTP derived from this research because most of the respondents have been flooded at least once, therefore they are in a best position to make judgement on WTP to avoid similar flood impacts experienced when they were flooded in 2007.

Table 6.15 Number of times being flooded post 2007

		No of Responses	Percent	Valid Percent	Cumulative Percent
Valid	None	256	91.4	91.4	91.4
	One	18	6.4	6.4	97.9
	Two	2	0.7	0.7	98.6
	Other	4	1.4	1.4	100
	Total	280	100	100	

6.4.3 Respondents' interest in research findings

Approximately 65% of the respondents were interested in receiving a summary of the research findings (Table 6.16). This suggests a good deal of interest in the subject under investigation and its relevance to flood risk management as a whole.

Table 6. 16 Respondents who want summary findings

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Yes	183	65.4	65.4	65.4
	No	97	34.6	34.6	100
	Total	280	100	100	

6.4.4 Descriptive statistics of mean raw willingness to pay (WTP) values

More than 89% of respondents expressed a WTP to avoid intangible flood impacts and psychological effects of flooding on their households. The value of WTP to avoid flood impact on households provided by respondents ranges from as low as £0.00 (n = 13) to as much as £5000 (n = 1). While the value of WTP to avoid psychological effect of flooding on households ranges from £0.00 (n = 33) to £10,000 (n = 1). Of those that did not provide a value, some provided genuine zero WTP value, for instance, on the grounds of not being able to afford to pay extra amounts because they are retired person with minimal disposable income. These genuine zero WTP values were included in the mean and median calculation as shown in Table 6.17. The mean of the raw sample responses of WTP values to avoid impacts and psychological effects of flooding on households are £404 and £300 per household per year, respectively.

Kolmogorov-Smirnov normality test was carried out on the data, to determine if the values of WTP are normally distributed. From the result in Appendix B-2, the value of p=0.000 was recorded for both WTP to reduce impact and psychological effect of flooding on households, this means that the WTP values are not normally distributed. Further, from Table 6.17, considering the value of mean (£404) and median (£300), which are far apart, this shows that the raw WTP values are not normally distributed, in a case such as this; median is the better representation of the respondents WTP values. From the raw WTP data, an equal number of respondents n = 42 (15%) expressed a WTP of £500 to avoid flood impact and psychological effects of flooding on their households; this represents the mode of the WTP.

Table 6.17 Statistics of raw sample Willingness to Pay (WTP)

		WTP to reduce impact of flooding	**WTP to reduce psychological effects**
N	Valid	251	251
	Missing	29	29
Mean		£404	£300
Median		£300	£200
Std. Deviation		£460	£685
Minimum		£0	£0
Maximum		£5,000	£10,000

6.4.5 Descriptive statistics of extra expenses incurred by respondents

Respondents were asked to indicate how much extra they spent, while in alternative accommodation, which was not reimbursed by their insurer as part of their flood insurance claims. Table 6.18 shows that the mean extra expenses on food was £231.65, on travelling was £185.00, on phone bills was £150.35 and for unpaid leave it was £302.70.

Table 6.18 Statistics of extra expenses incurred while in alternative accommodation

		Extra food expenses (EFX)	Extra cost incurred on travelling (ETX)	Extra phone expenses (EPX)	Extra cost due to unpaid leave (EULX)	Overall extra expenses (EFX + ETX+EPX + EULX)
N	Valid	79	40	141	37	
	Missing	201	240	139	243	
Mean		£232	£185	£150	£303	£869
Std. Error of Mean		£23	£20	£9	£41	
Median		£100	£100	£100	£100	£400
Mode		£100	£100	£100	£100	£400
Std. Deviation		£202	£127	£104	£249	
Minimum		£100	£100	£100	£100	£400
Maximum		£800	£500	£800	£900	£3000

This finding will be explored in detail in chapter 9 as part of the potential tangible benefits to homeowners of adapting properties to flood risk. It is quite important to note that most respondents were fully reimbursed by their insurers on other expenses provided they (respondents) were able to provide evidence of spending to their loss adjusters, however, approximately 50% of respondents incurred extra telephone expenses while in alternative accommodation, which was not reimbursed by their individual insurers.

Having presented the descriptive statistics of the raw sample responses, the next sections present detailed statistical analysis of the survey data. This will lead to the establishment of actual WTP value to be used in the development of CBA model of PLFRA measures.

6.5 HOMEOWNER'S PERCEPTION OF BENEFITS OF PLFRA MEASURES

Data on the potential benefits of PLFRA measures 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 agree' = 5, 'agree' = 4, 'uncertain' = 3, 'disagree' = 2, 'strongly disagree' = 1. An inter-rater agreement (rWG) test was carried out on the responses received.

Inter-rater agreement represents the extent to which different respondents tend to make exactly the same judgments about the rated subject (Tinsley and Weiss, 1975). 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 estimates whether a response from one respondent is "similar" to the responses of others rating the same subject; thus, reflecting the degree of "agreement" among the respondents. 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) and Manu (2012). An Inter-rate agreement test was, thus, carried out on respondents' perceived intangible benefits of PLFRA measures.

6.5.1 Analysis of respondent's perceived intangible benefits of PLFRA measures

The result of the analysis of homeowners' perception of the intangible benefits of PLFRA measures is presented in Table 6.19. 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 generally the same and the fact that the mean ratings are also approximately the same as the median and mode 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.

Agreement test was conducted using the single-item inter-rater agreement index (rWG) (James *et al.*, 1984). Such tests demonstrate the degree of consensus or "agreement" among raters of the same subject. 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' perceptions of benefits of PLFRA measures. The calculated rWG value for each of the statement is shown in Table 6.19.

Table 6.19 Descriptive statistics and inter-rater agreement indices for benefits of PLFRA measures

Statement on intangible benefits of PLFRA measures	*Mean	Std. Dev.	Std. Error	Median	Mode	Min.	Max.	**rWG
Adapting reduces worrying	4.00	.91	.054	4.00	4.00	1	5	0.59
Adapting can reduce stress of dealing with builders	3.94	.91	.054	4.00	4.00	1	5	0.59
Adapting reduces health effect	3.75	.97	.058	4.00	4.00	1	5	0.53
Adapting can maintained house value	3.61	1.14	.068	4.00	4.00	1	5	0.35
Adapting can reduce strain between family	3.61	.95	.057	4.00	4.00	1	5	0.55
Adapting can increase community cohesion	3.50	.93	.056	4.00	3.00	1	5	0.57
Adapting can reduce insurance premium/cost	3.41	1.11	.067	3.00	3.00	1	5	0.38

* Mean ratings are based on a 5 point scale (1 = strongly disagree, 2= disagree, 3= uncertain, 4 = agree, 5 = strongly agree).
**rWG = Single-item inter-rater agreement index. rWG indices are based on a uniform null distribution. Based on 10,000 simulation runs, rWG values of 0.06, 0.08 and 0.11 are the 90%, 95% & 99% confidence interval estimates respectively for group size of n=280 and 5 response options (i.e. 5 point scale). Hence, rWG values > 0.11 are evidence of significant agreement at p < 0.01 (99% confidence level).

Typically, rWG values $\geq$ 0.70 are considered as evidence of significant agreement. Cohen *et al*. (2001), however found that rWG values vary considerably as a function of group size and number of response items and thus implying that the conventional value of 0.70 may be a reasonable cut-off value for significant agreement with some configurations of group sizes and number of response items, but may not be reasonable for others. Therefore, following the recommendation by Cohen *et al*. (2001), the rWG values for significant agreement were, thus, estimated based on a sample size (i.e. group size) of 280 and a number of response items of 5 (i.e. the 5-point scale). Based on 10,000 simulation runs, rWG values of 0.06, 0.08 and 0.11 are the 90%, 95% and 99% confidence interval estimates respectively for group size of 280 and 5 response options. rWG values > 0.11 are, thus, evidence of significant agreement at $p < 0.01$. From Table 6.19, it is evident that all the rWG values for each of the statements exceed 0.11. This means that there is significant agreement amongst the respondents on the potential benefits of PLFRA measures. The mean ratings are, therefore, credible representations of the respondents' assessments and can be interpreted with confidence.

6.5.2 Discussion

In view of the findings presented in section 6.5.1, several key inferences can be made in relation to the perception of homeowners on the intangible benefits of PLFRA measures. It can be seen that there was greater consensus among respondents on the potential intangible benefits of adaptation measures. Intangible benefits such as reduce worrying, stress of dealing with builders and reduction of other health related impact of flooding were ranked higher by respondents. This is not surprising because the majority of the respondents had first-hand experience of flood damage to their properties; thereby, they were able to fully assess how the flood event impacted on their households in terms of intangible impacts. Research has shown that the effect of flooding on house value in the UK is usually of a temporary nature (Lamond, 2008); however, result of the analysis as shown in Table 6.19 indicates that respondents perceived that adapting properties to flood risk has potential to maintain house values. It can be inferred that despite the findings from previous research that the effect of flooding on property value is of a temporary nature; there is still a perception among homeowners that house value will be affected by the presence of flood risk, hence the general agreement that adaptation measures can help in maintaining house values.

The high level of neutral view recorded in the survey on the potential benefits of adaptation measures to reduce insurance premiums is not surprising. Currently insurance companies are not generally incentivising homeowners by way of a reduction in premium or excess (Thurston *et al.*, 2008; Joseph *et al*., 2011b; Joseph *et al*., 2011a and Wedawatta *et al.*, 2013). *It was stated by one insurer that 'there could be a positive effect on the terms of a homeowner's insurance'* if PLFRA measures have been implemented, but there is no evidence that this has actually been put into consideration by any insurer when quoting for domestic building insurance policy as found in the literature and evidence from some isolated examples in this research.

6.6 ANALYSIS OF FACTORS THAT CAN INFLUENCE THE ADOPTION OF PLFRA MEASURES

Respondents were asked to state the extent to which they agree on what can influence their decision on investing in adaptation measures. Table 6.20 shows the summary of the result of the analysis. For each of the statements the ratings by the respondents ranged from 1 (strongly disagree) to 5 (i.e. strongly agree). The aggregated ratings by individual respondents (i.e. mean ratings) indicate that knowledge of frequency of flooding can encourage adapting property with a mean rating of 4.02 (with Std. dev. = 0.83). It was perceived by most respondents that it is not the responsibility of the insurer to adapt properties against flood risk with a mean rating of 2.39 (with Std. dev. = 1.02).

Rounding the mean ratings to the nearest point on the 5-point scale to ensure conformity with the scale so as to aid interpretation, the eventual overall agreement to the statements is shown in Table 6.20. It can be inferred that there is general consensus that knowledge of frequency of flooding can encourage adapting property to flood risk. Further, knowledge of expected flood damage was generally agreed by respondents to encourage adapting property to flood risk.

Table 6.20 Descriptive statistics and inter-rater agreement indices for factors that can influence implementation of PLFRA measures

Statement on factors which can influence the adoption of PLFRA measures	*Mean (Rounding)	Std. Dev.	Std. Error	Median	Mode	Min	Max	**rWG
Knowledge of frequency of flooding can encourage adapting property	4.02(4)	0.83	0.049	4.00	4.00	1	5	0.66
Knowledge of expected flood damage can encourage adapting property	3.95(4)	0.87	0.052	4.00	4.00	1	5	0.62
In Favour of adapting property to flood risk	3.76(4)	0.93	0.056	4.00	4.00	1	5	0.59
It is not possible to prevent flood damage to property	2.94(3)	1.08	0.065	3.00	3.00	1	5	0.41
Respondents cannot afford the cost of adaptation measures	2.71(3)	1.08	0.065	3.00	3.00	1	5	0.42
Not my responsibility to adapt property to flood risk	2.56(3)	1.06	0.063	2.00	2.00	1	5	0.44
Adapting property is a waste of money	2.50(3)	0.98	0.059	2.00	2.00	1	5	0.52
Responsibility of insurer to adapt my property because I am fully insured	2.39(2)	1.02	0.061	2.00	2.00	1	5	0.48

* Mean ratings are based on a 5 point scale (1 = strongly disagree, 2= disagree, 3= uncertain, 4 = agree, 5 = strongly agree).
**rWG = Single-item inter-rater agreement index. rWG indices are based on a uniform null distribution. Based on 10,000 simulation runs, rWG values of 0.06, 0.08 and 0.11 are the 90%, 95% & 99% confidence interval estimates respectively for group size of n=280 and 5 response options (i.e. 5 point scale). Hence, rWG values > 0.11 are evidence of significant agreement at $p < 0.01$ (99% confidence level).

A high percentage of respondents were in favour of implementing adaptation measures in their properties; however, this result appears contradictory when compared with the number of people who have actually implemented one form of adaptation measures as indicated by responses received on level of awareness and implementation of the measures. Financial concerns are of course a primary factor. However, research has shown that other factors such as informational barriers, emotional constraints, aesthetic considerations and timing issues contributed to the low uptake of adaptation measures (Harries, 2007; Lamond and Proverbs, 2008).

Respondents were unsure as to whether it is possible to prevent flood damage to properties; this can be linked to the low level of knowledge of the effectiveness of adaptation measures. From Table 6.20, the level of neutrality on the affordability of the cost of adaptation measures appears high (mean 2.71). Some respondents are still on the border line when it comes to who is responsible to protect properties against flood risk, for instance, one of the respondents stated that (in text column box);

"…Why should I pay to protect my property? What is our Government doing? It is the job of my Local Authority to make sure that the drainage was clear of debris, if this had been done, we would not have suffered what we suffered in 2007" **(Respondent).**

Some of the respondents were uncertain as to whether adapting properties to flood risk is a waste of money or not, for instance one of the respondents stated that;

"… no matter what you do flood water will still get into your property, why then do you have to do anything when you will end up ripping them off later?" **(Respondent).**

Statements such as the above show that the respondent's knowledge of the effectiveness of available adaptation measures is very limited. It has been suggested by Lamond and Proverbs (2009) among others that the adoption of flood adaptation measures is not always the best strategy or completely effective in preventing damage, however the degree of effectiveness of adaptation measures varies greatly, therefore, there is a potential to increase level of homeowners' knowledge of the effectiveness of different adaptation measures by evidencing the advantages of already implemented measures.

The majority of the respondents disagreed that it was the responsibility of the insurer to adapt properties to flood risk. However, 24% of respondents were neutral in their responses as to where the responsibility should be placed. Some 13% of respondents were of the opinion that it is the responsibility of the insurer to adapt properties to flood risk. This result is not surprising because it is expected that there will be mixed responses on this particular question because of the perception of risk transfer mechanism through insurance provisions (Crichton, 2008).

6.6.1 Discussion

Two factors were ranked highest by respondents as the factors that have the potential to influence decision on adaptation measures. These are knowledge of frequency of flooding and expected flood damage. However, awareness of flood risk is just one step; taking action to reduce its impact on households goes beyond awareness. The Environment Agency have produced hazard maps which can be used to assess the potential flood risk being faced by a particular region, but people need specific information about their individual risk. However, knowledge of flood risk may not necessarily lead to action. A greater understanding of the intangible benefits of adopting PLFRA measures might help in this respect.

There is a wide agreement among respondents that they are in favour of adapting their properties to flood risk, this can be linked to the potential benefits associated with the adoption of PLFRA measures. Despite the agreement, the result of the analysis shows that majority of respondents did not seize the opportunity of the 2007 flood event to adapt their properties to flood risk. *If this is the case, the next question to address is why are homeowners not adapting their properties to flood risk when they appear to be in favour of it?* This question can be explored by looking at the level of uncertainty among respondents with regards to the effectiveness of adaptation measures to prevent flood damage, coupled with the fact that there was mild disagreement among respondents on the issue of affordability of the cost of the measures. Other factors with high level of uncertainty are 'whether it is the responsibility of the homeowners to adapt properties to flood risk or not and the fact that respondents are not certain whether it is a waste of money or not. These results concur with the previous research on barriers to adaptation measures (Proverbs and Lamond, 2008). Financial barriers are seen as one of the reasons why at-risk homeowners are not taking up adaptation measures despite the fact that they are in favour of the measures. This suggests that, if government grants were made available to the wider at-risk population, there is the potential to increase the take-up of adaptation measures. Evidence from the recently concluded Government adaptation grant scheme shows that 93% of homeowners in the surveyed location participated in the scheme (JBA, 2012).

The analysis of the question on “who is responsible for adapting property to flood risks” shows that some respondents are uncertain as to who is responsible. However, there was greater agreement among respondents that insurers are not responsible for adapting properties to flood risk. Perhaps, the thought was that it is the responsibility of the Government to adapt their properties to flood risk by way of increasing spending on flood defences. Therefore, to succeed in generating change it is important for at-risk population to be aware of the limit of the responsibilities of others. Currently, it appears that most at risk populations are receiving conflicting messages about the potential flood risk and most will choose to hope for others to take the responsibility. Hence, the need to provide clear information on who is responsible with regards to flood risks management at household levels is of a paramount importance.

6.7 ANALYSIS OF THE SEVERITY OF IMPACTS AND PSYCHOLOGICAL EFFECT OF FLOODING ON HOUSEHOLDS

The decision to invest in PLFRA measures will to some extent depend on the flood experience of households and the extent of any psychological effects that members of households may have been exposed, to as discussed in sections 2.5 and 4.3.2. It is also expected that this experience is likely to influence how much homeowners are willing to pay to reduce such impact/effect on households. This section, therefore, presents the analyses of responses received on severity of flood impacts and psychological effect of flooding on households.

6.7.1 Analysis of severity of intangible impact of flooding on households

Information on severity of the intangible impact of flooding on households and the extent of this was gathered using a five-point Likert scale ranging from 'extreme impact' to 'no impact'. A weighting was allocated to each extent; where ''extreme impact' = 5, 'high impact' = 4, 'moderate impact' = 3, 'marginal impact' = 2, 'no impact' = 1'. The relative importance index (RII) method was used to rank the responses obtained from the Likert scale questions. RII is a method used to evaluate the comparative importance of a single item to others (Yang and Wei, 2010) and has been used successfully to rank factors according to their relative importance in construction research (Ramanathan *et al.,* 2012) and flood related research (Wedawatta *et al.,* 2013). In this research the relative importance index (RII) was calculated for each item by using equation 13.

RII = $\frac{5n1 + 4n2 + 3n3 + 2n4 + 1n5}{5N}$ **…………………………………………..**Equation 13

Where;

n1 = number of respondents for 'extreme impact';

n2 = number of respondents for 'high impact';

n3 = number of respondents for 'moderate impact';

n4 = number of respondents for 'marginal impact';

n5 = number of respondents for 'no impact' and;

N = Total number of respondents.

Table 6.21 presents the RII values for effects and the consequent ranking of factors. Accordingly, 'stress of flood event' (0.80) was the top-ranked impact, closely followed by 'worrying about loss of house value' (0.77). Low ranked impact was 'deterioration of physical health' (0.44). This result agreed completely with the conclusion drawn in section 6.5.1 where the top ranked benefit of adaptation measure was to reduce stress and worrying. The result also concurred with other related studies, such as EA/DEFRA (2004); Bichard and Kazmierczak (2009); and Joseph *et al.* (2011a). Apart from the intangible impact of flooding on households, other serious long term effects are the psychological effect of flooding on households. The RII values will be used to apportion the value of intangible benefits based on the severity of impacts of flooding on households.

Table 6.21 Ranking of severity of flood impacts according to relative importance index (RII) values

Flood Impacts	Number of Responses with the highest weight	Number of responses with no impact	Mean Impact weight	Relative Importance Index (RII)	Ranks* R (Based on RII value)
Stress of flood	206	2	4.01	0.80	1
Worry about loss of house value	192	14	3.83	0.77	2
Worry about future flooding	183	16	3.79	0.76	3
Destruction of property	171	16	3.71	0.74	4
Increase in insurance premium	167	25	3.64	0.73	5
Time to return to normal household activity	160	17	3.63	0.73	6
Dealing with insurers	154	9	3.56	0.71	7
Dealing with builders	142	21	3.48	0.69	8
Having to leave home for longer period	151	70	3.22	0.64	9
Loss of irreplaceable/sentimental items	130	55	3.16	0.63	10
Inability to obtain insurance cover	100	99	2.72	0.54	11
Disruption of livelihood and income	73	113	2.38	0.48	12
Strains between family	57	100	2.33	0.47	13
Deterioration to mental health	63	122	2.26	0.45	14
Deterioration to physical health	53	115	2.18	0.44	15

*Equal RII values ranked according to the number of responses with the highest weight

6.7.2 Analysis of psychological effect of flooding on households

Information on how often members of households have been affected by psychological effects due to the experience of 2007 flood event was gathered using a five-point Likert scale ranging from 'always' to 'never'. A weighting was allocated to each extent; where 'always' = 5, 'very often' = 4, 'sometimes' = 3, 'rarely' = 2, 'never' = 1'. The relative importance index (RII) method was used to rank the responses obtained from the Likert scale questions. Table 6.22 presents the RII values for effects and the consequent ranking of factors. Accordingly, 'anxiety when it rains or when river levels rise' (0.77) was the top-ranked psychological effect, closely followed by 'increased stress levels (0.65). Low effect was 'increase use of alcohol (0.29), this means that increase use of alcohol is not related to the effect of flood experience. As can be seen stress of flood event is a major problem faced by flooded respondents. Based on this, the question can be raised; will information on adapting property to flood risk help in reducing flood related stress? There is a potential for information on adaptation measures to assist homeowners in making a decision on investing in the measure, this can subsequently assist in reducing flood related stress if the measures are implemented and functioned as expected. Therefore, monetisation of intangible impact and its incorporation in the CBA model of PLFRA measure for decision making has the potential to provide much needed information in decision making on PLFRA measures.

Table 6.22 Ranking of the frequency of psychological effect of flooding on household according to relative importance index (RII) values

Psychological effect	Number of Responses with the highest weight	Number of responses with no impact	Mean Impact weight	(Relative Importance Index (RII)	Ranks R (Based on RII value)
Anxiety when it rains or when river levels rise	181	11	3.84	0.77	1
Increased stress levels	108	28	3.27	0.65	2
Flashbacks to the flood event	66	102	2.46	0.49	3
Sleeplessness	52	98	2.31	0.46	4
Depression	47	114	2.21	0.44	5
Increased anger	32	126	2.06	0.41	6
Difficulty concentrating on everyday tasks	25	141	1.95	0.39	7
Increased tensions in relationships for example, more arguing	25	155	1.81	0.36	8
Nightmares	27	169	1.74	0.35	9
Increased visits to the GP	16	174	1.66	0.33	10
Increased use of alcohol	13	203	1.46	0.29	11

6.8 ANALYSIS OF WILLINGNESS TO PAY (WTP) VALUES

Having established in the earlier sections different factors perceived to influence homeowners' decision on investing in adaptation measures and the raw mean WTP values to avoid impact and psychological effect of flooding on households, detail analyses of the WTP values are presented in this section. Therefore, prior to taking the raw WTP values forward as valid WTP to be used in the development of CBA model of PLFRA measures, there is a need to subject the data to further analysis in order to determine if these values can be taken as representative. Therefore, in this section, the review of highest and zero WTP values are analysed in detail, analyses of factors that affect or determine WTP values and subsequently the actual WTP values to be used in development of the CBA model for this research are presented.

Out of the 280 homeowners surveyed 251 (89.6%) provided WTP values which ranged from £0 to £5,000 to avoid impact of flooding on households and £0 to £10,000 to avoid psychological effect of flooding on households. As in other contingent valuation method studies, such as Özbafli (2011), there is always a potential for a protest WTP values stated by respondents; therefore, it was considered necessary to carry out a proper screening of the WTP values for protest bids.

Review of highest willingness to pay (WTP) values

The results of the review suggested that there were two potentially invalid WTP responses on the basis that the WTP values represented 13.3% and 32.9% of households incomes for the two respondents, using the top end of the income brackets in calculating the percentage (Based on these commentaries, the two respondents will be referred to as Respondent 1 and Respondent 2).

Respondent 1, (Age 65-74; income £35,000-£44,999) was flooded to moderate depth of 500mm. Respondent 1 had a considerably bad experience during the 2007 flood event as detailed in the text box as:

> *'I was away working; speed of rise of waters meant I could not get home before flood, leaving my wife to deal with emergencies. Now fearful of being away when flood waters rise, which is now more frequent'*

Based on the above statement, it is obvious that this respondent was negatively affected by the flood event; the WTP values stated by the respondents are £5,000 (to avoid flood impact on his household) and £1,000 (to avoid psychological effect of flooding on his household) producing a combined WTP of £6,000. This appears unrealistic when considering the respondent's income. On this basis, the WTP values were deemed to be invalid and were not included in subsequent analysis.

Respondent 2, (Age 39-64; income £25,000-£34.999) was also flooded to moderate depth of 500mm. However, the respondent also had a considerably bad experience with builders and increase insurance premiums. These two impacts of flooding were indicated by the respondent as 'extreme impact'. Further the respondent indicated that the flood event had a 'high impact' on stress levels. It was, therefore, inferred that the respondent's judgement of WTP values was adversely affected. The WTP values offered of £1,500 (to avoid flood impact on her household) and £10,000 (to avoid psychological effect of flooding on her household) producing a combined WTP value of £11,500, this appears unrealistic when it was compared with the respondent's income. On this basis the WTP values were deemed to be invalid and were not included in subsequent analysis.

Review of zero willingness to pay (WTP) values

Out of the 251 respondents who stated their WTP values to avoid impact of flooding on households, 13 (5.2%) stated a value of zero, whilst out of the 251 respondents who stated WTP values to avoid psychological effect of flooding on households, 33 (13.1%) stated a zero value. A detailed review of the completed questionnaire by those respondents who stated zero WTP values was undertaken. It was concluded that six respondents actually stated zero values as a protest bid, based on the following statement provided by those six respondents:

Respondent A:

> *'in my opinion no property except for rising on steel can be protected to flooding unless all of the properties are surrounded to stop the water from finding its level. Water enters houses mainly through the damp course not through doors and windows. Insurance claims would not be as high if builders were checked on their quotes and not allowed to invent works that was not needed to be carried out'*

Respondent B:

> *'nothing. Building company who built estate should be the ones to pay. And council for giving planning permission'*

Respondent C:

> *'It's better to spend money on stopping properties flooding than making them flood resilient. Fix the cause not the effects. My property is a coach house so I was not too badly affected by the flooding, which may explain some of my answers'*

Respondent D:

> *'nothin. Authorities should make flood defences'*

Respondent E:

> *'nothing. The insurers refused to pay out on damaged items because they said they were in the wrong place'*

Respondent F:

> *'already paying high council tax. Problem caused by excess building. Also council allowing building on flood plain'*

Based on these statements and in order to avoid introducing a bias in the WTP values by including invalid zero value in both sets of WTP (i.e. on impacts and psychological effects), the usual practice was followed by removing the 6 protest responses from the WTP analysis (O'Garra *et al.* (2007), Birol *et al.* (2008) and Özbafli (2011) for a similar treatment of protest responses).

Within the remaining 243 responses on WTP to reduce flood impact on households, 7 (3%) were true zero WTP value, whilst on WTP to reduce psychological effect of flooding on households, 27 (11.1%) were true zero WTP value. Therefore, the analysis that follows was based on 243 responses for avoiding impact of flooding and psychological effect of flooding on households.

6.9 FACTORS AFFECTING WILLINGNESS TO PAY (WTP) VALUES

The initial analysis, as discussed in section 6.4.4, suggested that, as for the intangible impact of flooding, there were numerous factors influencing the WTP value provided by a particular household and that the overall pattern of values would be difficult to explain. Previous studies in this area have suggested that factors such as site location, household income levels, age of respondents, and occupational characteristic of the respondents and perhaps number of people in the household, to some extent affect individual willingness to pay values (EA/DEFRA, 2004).

It is important to test for construct validity of the contingent valuation method (CVM) used in this research. This is typically done by estimating a stated WTP value function relating how WTP responds to a variety of covariates collected in the survey. In particular, in this research, the researcher is interested in whether variables for which there are prior expectations are both significant in determining WTP and affect values in the expected way. Conversely, if key variables (such as income level, age, stress levels) are found to be either insignificant or, most importantly, to affect WTP in unexpected and illogical ways, this casts doubt on the theoretical validity of the results. Appendix B-3 shows the developed correlation matrix, which identifies possible relationships that exist between flood impacts and WTP values. Individual factors are hereby discussed in subsequent sections.

6.9.1 WTP values by Location

One finding that emerged from the review of extant literature is that WTP values are likely to be influenced by flood location (EA/DEFRA, 2004). With this in mind, Table 6.23 presents a list of the sampled areas with the highest and lowest mean WTP values to provide a backdrop to the analysis which follows. Rotherham with four respondents produced the highest combined (flood impact + psychological effect) the mean values are influenced by the presence of high values particularly where there are relatively few respondents. It is acknowledged that location may be related to severity of flood impacts experienced by respondents.

Table 6.23 Analysis of mean WTP values by surveyed location

Location	Number of respondents (N)	Mean WTP (Value) Flood impact	Mean WTP (Value) Psychological effect	Rank*
Rotherham	4	£858	£258	1
Barnsley	16	£454	£466	2
Wakefield	12	£419	£421	3
Cheltenham	12	£486	£265	4
Swindon	7	£429	£330	5
Pontefract	7	£436	£307	6
Sheffield	28	£416	£293	7
Doncaster	19	£426	£279	8
Gloucester	16	£414	£280	9
Grimsby	16	£413	£216	10
Tewkesbury	15	£349	£237	11
Hull	25	£317	£227	12
Thatcham	34	£352	£183	13
Beverley	13	£292	£227	14
Evesham	5	£366	£106	15
Chesterfield	8	£267	£183	16
Retford	6	£225	£158	17

Rank* is the summation of the values of respondents WTP to reduce both flood impacts and psychological effects

There is some consistency between WTP values and the degree of stress of flood event as discussed in section 6.7.1. The cross tabulation of site location and severity of flood event analysis carried out indicates that the first four flooded towns (Rotherham, Barnsley, Wakefield and Cheltenham) in Table 6.23 indicated that stress of flood on their households ranged from moderate impact to extreme impact with no indication that the stress was either no impact or marginal impact. Generally, the degree of stress of flood event was found to be a significant explanatory factor for determining respondents' WTP values. This finding also reinforces the significance of intangible impacts of flooding on households.

6.9.2 Willingness to pay (WTP) by household income levels

Many CVM studies found low income effects due to the difficulties in measuring households income. For instance, high non-response rate, intentional misrepresentation of respondent's income, failing to include income from all sources (Alberini, 2004). In addition to this, the likelihood of having a significant income effect has also been related to the sample size and the design choices made in the study (Aiew *et al.,* 2004; Broberg, 2010). According to Field (2009) and Blaikie (2010), Pearson's Correlation Coefficient is sensitive to skewed distribution and outliers, as indicated in section 6.8 there are outliers in the WTP data, therefore in order to reduce the effect of outliers, Spearman's rank correlation coefficient is used.

Table 6.24 shows the result of Spearman's rank correlation coefficient investigating the relationship between household's income and the value of WTP by respondents. From Table 6.24 the size of the correlation coefficient between household income level and the value of WTP to avoid impact of flooding is not significant ($R_s = 0.032$). Further, WTP to avoid psychological effect of flooding is negatively correlated to household income level ($R_s = -0.078$). The result presented in Table 6.24 is contrary to the result of EA/DEFRA (2004), which found that household income level was significantly correlated with the value of WTP.

Table 6. 24 Correlation matrix for household income level and WTP values

			Household income level	**WTP to reduce impact of flooding**	**WTP to reduce psychological effects**
Spearman's rho	Household income level	Correlation Coefficient	1.000	0.032	-0.078
		Sig. (2-tailed)		0.624	0.228
		N	243	243	243
	Willingness to pay to reduce impact of flooding	Correlation Coefficient	0.032	1.000	0.619**
		Sig. (2-tailed)	0.624		0.905
		N	243	243	243
	Willingness to pay to reduce psychological effects	Correlation Coefficient	-0.078	0.619**	1.000
		Sig. (2-tailed)	0.228	0	
		N	243	243	243

**Correlation is significant at the 0.01 level (2-tailed).

In order to explore the result presented in Table 6.24 further, the mean WTP value based on income levels of each of the respondents was analysed. Figure 6.2 shows the result of this analysis. This result concurs favourably with the result presented in Table 6.24 showing that higher income does not necessary means higher WTP values. Meaning that the WTP values stated by respondents appear not to have significant relationship with households' income. When compared, the WTP to reduce impact and psychological effect of flooding for respondents that earn less than £5,000 with those that earn over £55,000, there were 15.7% and 20.4% difference in the mean WTP values for both income levels. Based on these findings, it can be inferred that the stated WTP values by flooded respondents are not influence by the household income level. This can be linked to the fact that higher income earners may have better insurance cover than low income earners, by having additions to their normal domestic insurance policy in which case the premium they pay will reflect this. Based on this, they may be of the opinion that they are fully covered, and this can have significant influence on their stated willingness to pay values. Equally high income earners may likely consider themselves 'self insured' because they could afford to replace things and pay extra phone bills. This assumption can influence the stated WTP by high income earners. Further, it can be argued that high earners are most likely to be less stressed about flooding because they are more resilient.

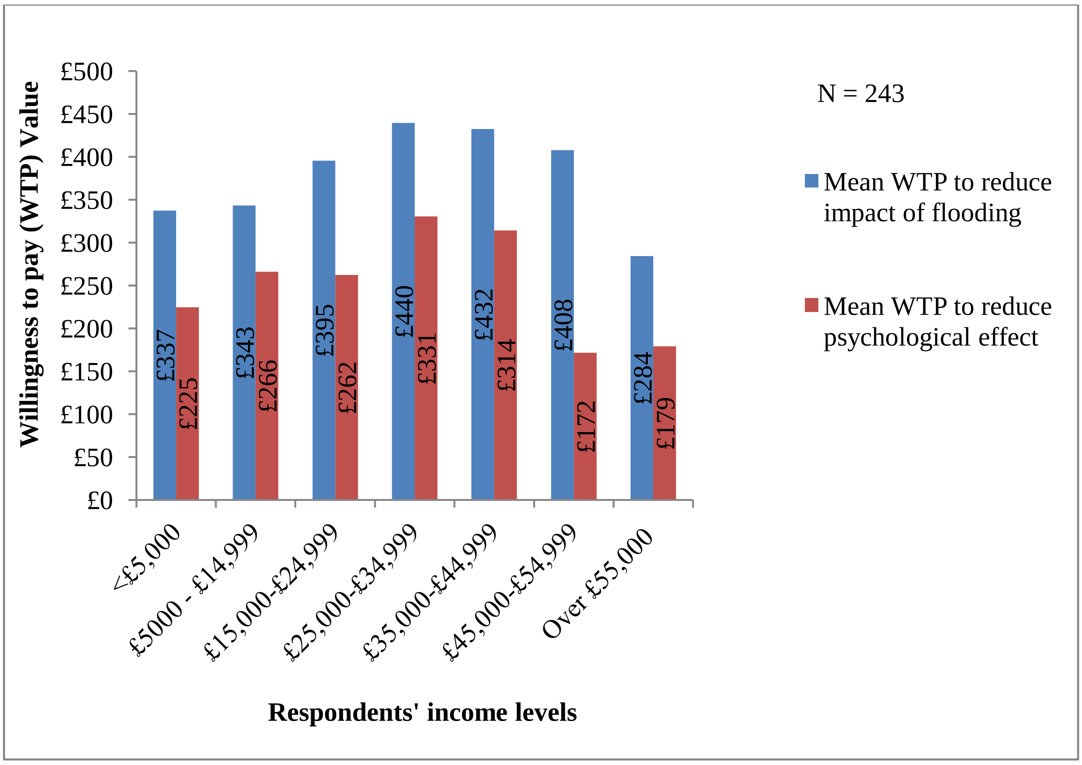


Figure 6. 2 Mean WTP values based income level of household income earner

6.9.3 Willingness to pay (WTP) by occupation of respondents

The mean WTP values based on occupation of respondents were analysed. Figure 6.3 shows that respondents in professional/managerial occupation recorded lowest mean WTP value (£355) to avoid impact of flooding. Clerical and other white collar occupational category recorded the highest mean WTP values (£449), whilst semi-skilled and retired respondents showed mean WTP to avoid impact of flooding of £407 and £387, respectively. Respondents with skilled manual occupation recorded highest mean WTP value to avoid psychological effect of flooding. The pattern of distribution of mean WTP values to avoid psychological effect of flooding by occupation of respondents is not similar to the recorded mean WTP value to avoid impact of flooding.

It can be inferred from this result that respondent's stated WTP value is not strongly related to the occupation of household income earners.

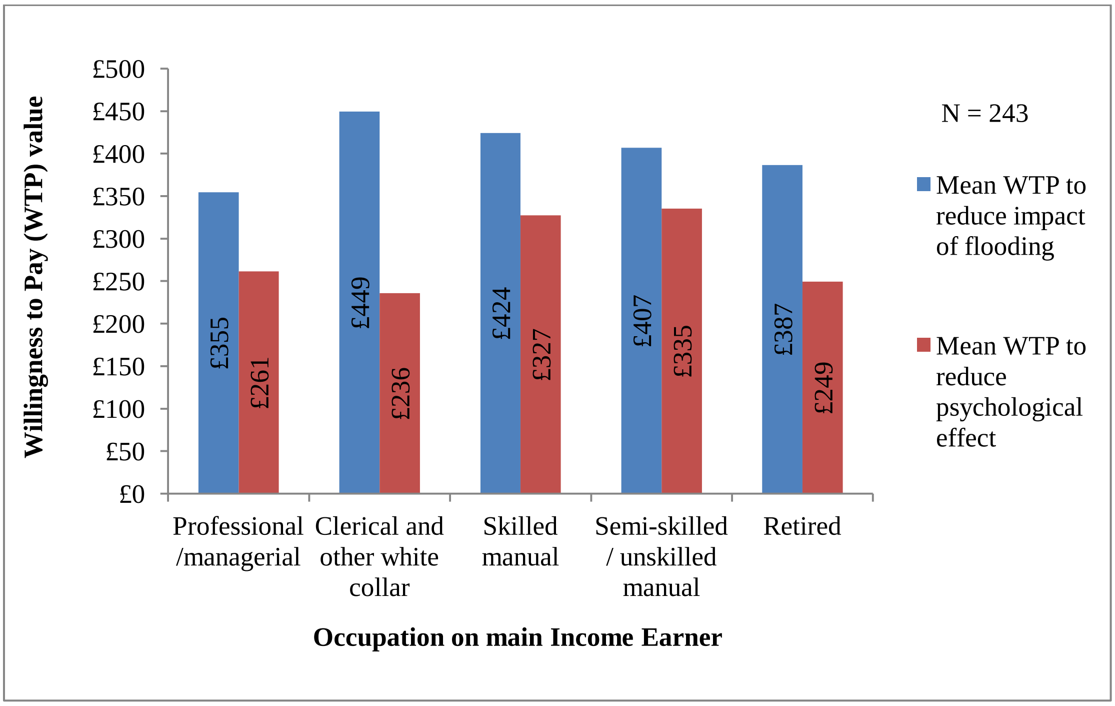


Figure 6.3 Mean WTP values based on respondents' occupation

6.9.4 Willingness to pay (WTP) by age

From the result of correlation analysis shown in Table 6.25, there are weak negative correlations between the age of respondents and the value of WTP to avoid impact and psychological effect of flooding on households with correlation coefficients (R_s) being -0.063 and -0.092, respectively. However, further analysis was carried out by comparing the mean WTP values across age brackets.

Table 6. 25 Correlation matrix for respondents' age bracket and WTP values

			Respondent age	WTP to reduce impact of flooding	WTP to reduce psychological effects
Spearman's rho	Respondent age	Correlation Coefficient	1.000	-0.063	-0.092
		Sig. (2-tailed)		0.21	0.155
		N	243	243	243
	WTP to reduce impact of flooding	Correlation Coefficient	-0.063	1.000	0.080
		Sig. (2-tailed)	0.330		0.905
		N	243	243	243
	WTP to reduce psychological effects	Correlation Coefficient	-0.092	0.080	1.000
		Sig. (2-tailed)	0.155	0.905	
		N	243	243	243

Figure 6.4 shows that younger people are willing to pay less to avoid impact and psychological effect of flooding on households. This shows that as the respondents' age increases the WTP value also increases up to the age bracket 65-74. However, the over 75 age bracket recorded lowest WTP values, which can be linked to the fact that over 75 years old homeowners may have little disposable money and they are more likely to be retired, which can affect how much money they can afford to pay (EA/DEFRA, 2004). Further, the young age group are more likely to have less disposable income because they have more financial commitments, such as mortgages and car loans. Further, young group may be drawn to housing because of schools and therefore, unlikely to move out of a good catchment areas. The highest mean WTP values based on age brackets were recorded by respondents in age brackets 65-74 (£444 and £278 to avoid flood impact and psychological effect, respectively). It can be inferred from Figure 6.4 that age is a determining factor of WTP values stated by respondents, further it can be inferred that there is a linear relationship between age and WTP values up to age 74 years). This result is what would be expected because, older people are less likely to want to relocate from one end of the town to the other, whereas younger people in the age bracket 18-39 can easily decide to relocate to a flood risk free areas. However, the result could also be linked to attitude to risk by different age groups, for instance, due to school catchments,

younger age group may not want to move away from a particular are, even, when the area is prone to flood risk.

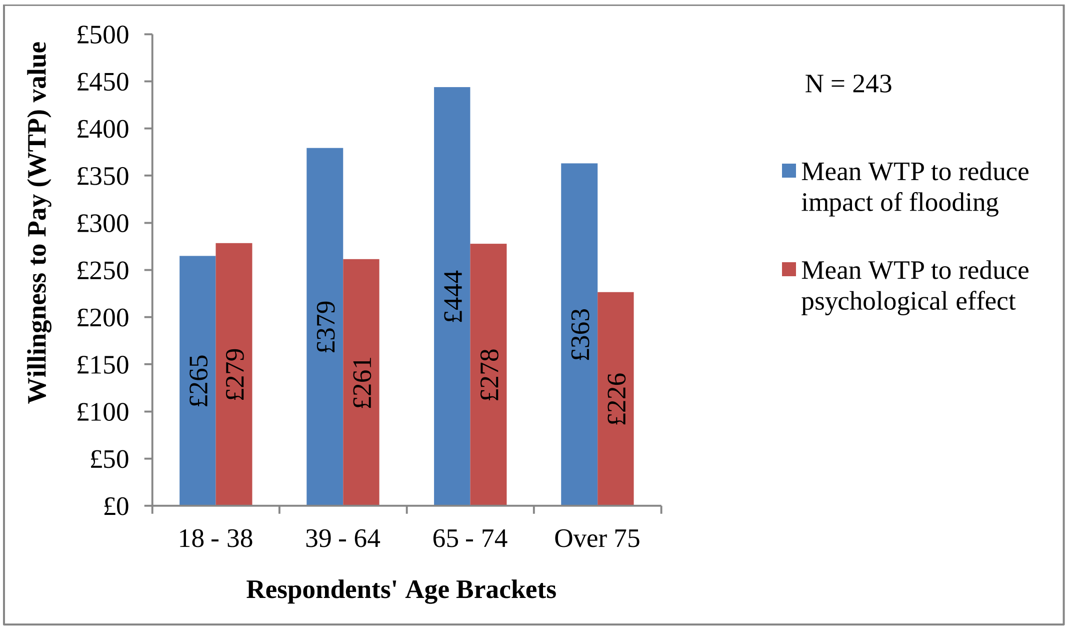


Figure 6.4 Mean WTP values based on respondents' age

6.9.5 Willingness to pay (WTP) by number of people in household

From the correlation results presented in Table 6.26 it can be seen that there are weak relationships between WTP values to avoid flood impact and psychological effect of flooding and the number of household members. The correlation coefficients (R_s) are 0.002 and 0.095 for the reduction of impact of flooding and psychological effect of flooding, respectively. Further analysis was carried out by comparing the mean value of WTP.

Table 6.26 Correlation matrix for respondents' based on number of people in household and WTP values

			No of people living in the household	WTP to reduce impact of flooding	WTP to reduce psychological effects
Spearman's rho	No of people living in the household	Correlation Coefficient	1.000	0.002	0.095
		Sig. (2-tailed)		0.980	0.140
		N	243	243	243
	WTP to reduce impact of flooding	Correlation Coefficient	0.002	1.000	0.008
		Sig. (2-tailed)	0.980		0.905
		N	243	243	243
	WTP to reduce psychological effects	Correlation Coefficient	0.095	0.008	1.000
		Sig. (2-tailed)	0.150	0.905	
		N	243	243	243

As indicated in Figure 6.5 the mean WTP values to avoid flood impacts for each household increases progressively from a single parent family to two or more adults. Such a progression may be the result of both an ability to pay (single parent families might be expected to be amongst the least able to pay) and concern over the presence of children (those with children are WTP more). However, the result is different when compared with the mean WTP value to avoid psychological effect of flooding on household. Mean WTP values for households with 2-3 and 4-6 persons are in the same range (£263 and £268, respectively), the mean WTP value for household with over 6 members was the least (£40). Further interrogation was carried out on this particular case and it was discovered that the low value result (£40) was due to low sample in this category (n=2). Additionally, the result shows that one-person households have the highest mean WTP to reduce psychological effect of flooding, this can be as a result of the fact that such households may suffer more psychological effect because of non availability of household members to discuss and share the burden that comes along with flood events, as identified by Tapsell and Tunstall (2008).

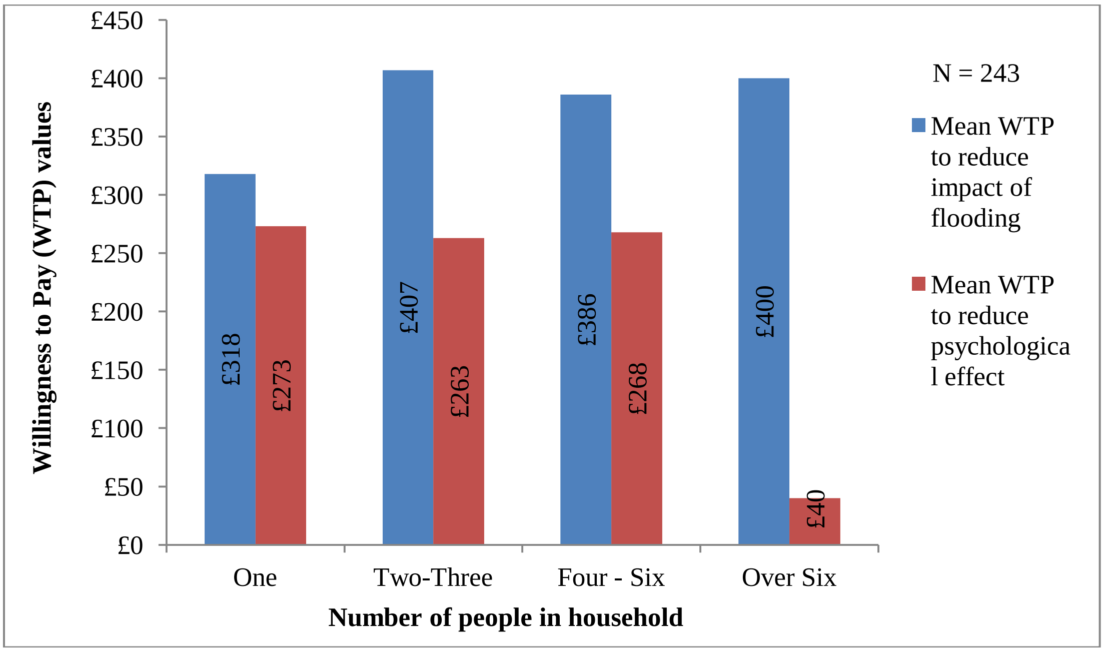


Figure 6.5 Mean WTP values based on number of people in each household

6.10 ANALYSIS OF THE REVISED WILLINGNESS TO PAY (WTP) VALUES

In section 6.4.4 raw sampled mean WTP values were stated as £404 and £300 per household per year to avoid impact and psychological effect of flooding on households respectively. From the detailed analyses carried out in sections 6.7 and 6.9 it was revealed that stress of flood event, age of respondents, number of people living in the households and the flood location were shown to influence WTP values. Among these factors, it was established that stress of flood event ranked the highest in both flood impact and psychological effect of flooding. It can be inferred that the stated WTP by respondents is a function of the extent of the stress effects experienced during the 2007 flood event couple with the age of respondents. These findings support the proposition that WTP to avoid impact of flooding on households is indeed influenced by flood experience and the psychological effects of flooding on households.

6.10.1 Determinants of WTP values

In order to evaluate the credibility of empirical methodologies, such as CVM, objective rules must be employed. According to Bateman *et al.* (2002) and Champ *et al.* (2003), the validity of estimated values from CVM studies is commonly assessed by examining their construct or theoretical validity. Construct or theoretical validity examines whether the relationship between WTP values and other indicators/factors is in accordance with expectations. Atkinson *et al.* (2008) asserted that some of these indicators are predictors from economic theory, this includes examining the relationship between the value of WTP and income (as discussed in section 6.9.2), while others reflect empirical regularities, which seem naturally correct, and hold across a large number of studies. This concerns the effect of responses on indicators such as characteristics of the goods in question and a range of socio-demographic information such as age, occupation and number of people living in households as discussed in the preceding sections. In order to statistically determine the factors that are important in determining WTP values, multivariate regression analysis was employed as used by EA/DEFRA (2004).

Multivariate regression analysis can be expressed mathematically as:

$y = a_0+a_1x_1+a_2x_2+a_3x_3 + ... a_nx_n+\sigma$……………………………………………equation 14

Where;

y = denotes the dependent variable (i.e. the variable to be explained WTP values),

a_0 = intercepts,

a_1 = constants,

x_1 - explanatory or independent variables (i.e. the variables that principally determine the level of y, such as income, stress level, age, number of people in households), and σ = a random error term capturing all other factors (including the pure randomness of human behaviour) that affect y.

By adopting equation 14 above, the associated 'multiple coefficient of determination', R^2, will lie in the range 0 - 1, or 0% - 100%, where 1 (100%) represents a perfect fit, i.e. y (the dependent variables can be completely explained by the variables in the equation). According to Alexopoulos (2010), increasing the number of variables will lead to a better fit that is a higher value of R^2, however, if there are k variables and n observations, n should be greater than 4k to avoid 'overfitting' because there is potential to be using an excessive number of variables to generate a good fit. This aspect is reflected in the use of R_{adj}^2, which accounts for the numbers of observations (n) and variables (k) (EA/DEFRA, 2004).

A direct indication of the relative significance of the variables is the t-test. The importance of each variable in the analysis is reflected by the t-test values, which is the ratio of the associated coefficient to the standard error, this ratio being larger, the smaller the probability that the dependent variable is not systematically related to the independent variable concerned (EA/DEFRA, 2004; Field, 2009; Blaikie, 2010). Therefore, it was suggested that t-values >2.07 will indicate significance with a 95% confidence although the precise values will depend on the degrees of freedom = n-(k+1).

A stepwise multivariate regression analysis was undertaken based on the combined WTP values elicited from respondents. The individual WTP value was used as the dependent variable and 33 respondents' explanatory/independent variables for impact and psychological effect of flooding on households. SPSS was used to carry out the analysis. (Detail output of the regression model can be seen in Appendix B-4).

Table 6.27 Model Summary of regression analysis

Model	R	R^2	R_{adj}^2	Std. Error of the Estimate	Change Statistics					Durbin-Watson
					R^2 Change	F Change	df1	df2	Sig. F Change	
1	0.412	0.170	0.156	501.366	0.017	4.757	1	238	0.030	1.971

Number of times being flooded post the 2007 flood event appears to be the most significant factor, which affects the WTP values. There were a number of other factors that produced overall degree of explanation (R^2 = 0.17 and the R^2_{adj} = 0.16). Other factors such as stress of dealing with builders, having to leave home and stress of flood impact all appear to be significant factors in influencing the respondents stated WTP. The low R^2_{adj} recorded in this analysis shows that there are other factors, which have greater influence on respondents' stated WTP values, factors such as attitude of respondents towards the item being values, in which case attitude test will have to be carried out, however, this research was not aimed at carrying out attitude test. Other research such as EA/DEFRA (2004) recorded R^2 as low as 17; this does not, however, affect the results of the analysis. Thus, the low R_{adj}^2 recorded in this analysis will have no impact on the CBA model to be developed.

In testing for independence of the error terms, the Durbin-Watson statistic was produced (Table 6.27). This shows a value of 1.971, which is less than 2 (greater than 1). The Durbin-Watson test of serial correlation of the residuals can be used to check the assumption of normality (Norusis, 2003; Field, 2009). The Durbin statistic shows whether the assumption of independent errors is tenable: less than 1 or greater than 3 raises alarm (Field, 2009). The closer to 2 the value is the better. Therefore, the value of 1.971 obtained in this analysis indicates that this assumption has not been violated.

Another direct way of checking normality is to create a dot plot or histogram of the standardized residuals (Free, 1996). The histogram of standardized residuals should not be skewed but rather be bell-shaped, or at least symmetric. Field (2009) asserted that it is only when all these assumptions are met that the model result can be accurately applied to the population. Figure 6.6 shows the histogram with a bell-shaped distribution indicating that the assumption of normality has not been violated.

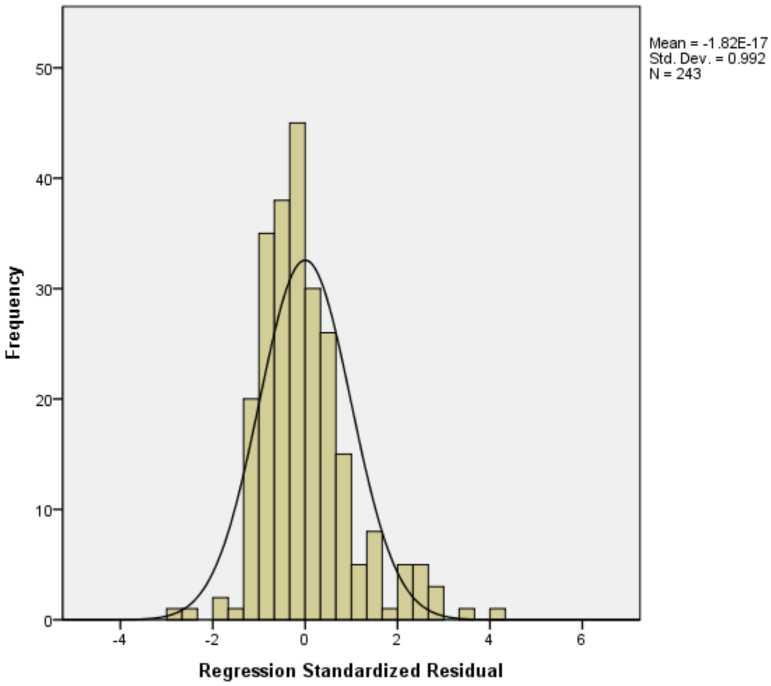
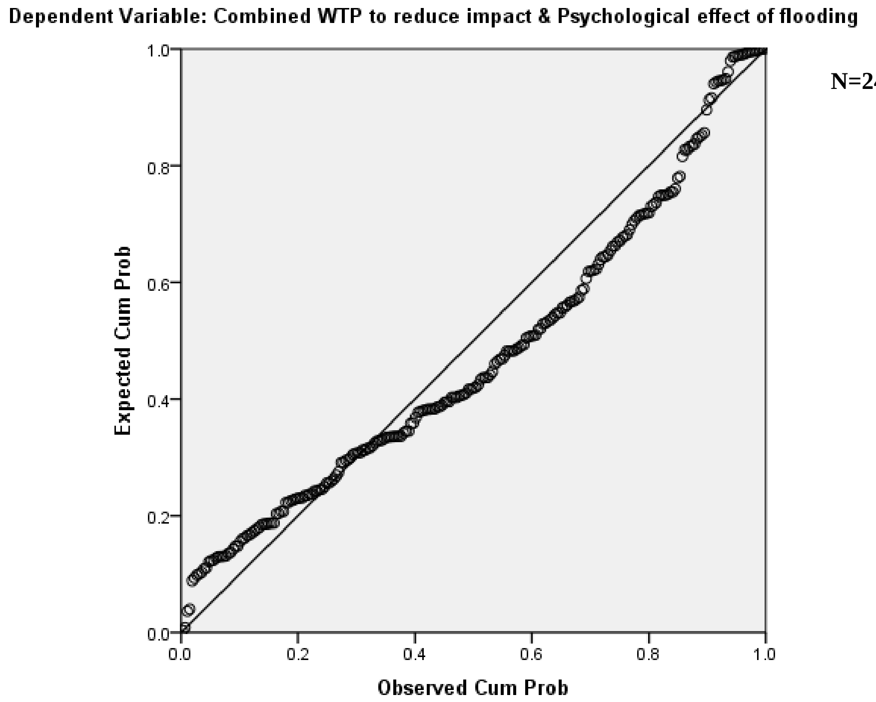


Figure 6. 6 Histogram of standardised residual

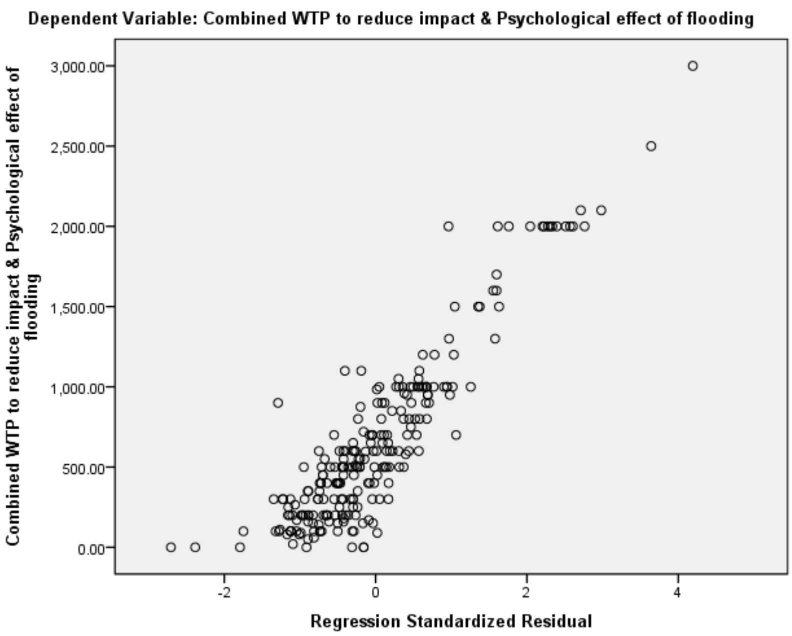
Figure 6.7 shows the normal probability plot of standardised residual which shows points generally lying close to the straight line. This indicates that the assumption of normality has not been violated.



N=243

Figure 6. 7 Normal P-P Plot of standardised Residuals

Linearity of the relationship between variables was assessed by examining Figure 6.8. The random distribution of data points indicates that there is no evidence of a non-linear relationship and, therefore, this assumption has also not been violated.



N=243

Figure 6. 8 ScatterPlot of Standardised Residuals

Having established the validity of the factors which can influence the value of WTP, Table 6.28 presents the summary of the non-parametric median and mean WTP values obtained from the survey. The median WTP value to avoid impact of flooding on households is £300/household per year; while the mean WTP is £390/household per year. Conversely, the median WTP value to avoid psychological effect of flooding on household is £200/household per year and the mean WTP to avoid impact of flooding on household is £263/household per year. The combined median and mean WTP values to avoid impact and psychological effect of flooding on household are £500 and £653 per household per year.

In CVM research of environmental and cultural goods, it is not uncommon to find that the distribution of WTP is skewed in that, for example, there are a small number of respondents stating large values and, conversely, a large number of respondents stating small or even zero values. In other words, the problem in such cases is that mean WTP gives 'excessive' weight to respondents who have stated larger values. However, in a CBA, mean WTP is still preferred to median WTP as an indicator of a project's cost benefit. Therefore, for the purpose of development of CBA model of PLFRA measures, coupled with the fact that the standard deviation is not large (Table 6.28); the combined mean WTP value of £653 per household per year will be used as the value of intangible benefits of PLFRA measures in the development of CBA model of PLFRA measures in chapter 9. The adoption of mean WTP in this research is in line with other related study, although these related studies, such as Vaughhan *et al.* (1999), EA/DEFRA (2004) and Atkinson *et al.* (2008), were based on a project level as against individual household level, which is the focus of this research.

Table 6.28 Summary Statistics for WTP to avoid impact and psychological effect of flooding on households

		Non-parametric statistics		
		Willingness to pay to reduce impact of flooding/year	Willingness to pay to reduce psychological effects/year	Combined WTP per household per year
N	Valid	243	243	
	Missing	0	0	
Mean		£390	£263	£653
Std. Error of Mean		22.40	17.84	
Median		£300	£200	£500
Std. Deviation		£349	£278	
Maximum		2,000	2,000	

6.11 SUMMARY

The descriptive data analysis of questionnaire inquiry has been presented in this chapter. Emphasis was laid on the demographic representation of the respondents. It is quite important to establish the distribution of respondents to 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 importance to the society of the topic under investigation. Analysis of extra expenses incurred, while in alternative accommodation, revealed that the respondents spent average of £232, £185, £150 and £302 on food, travelling, phone calls and unpaid leave, respectively, which were not reimbursed by their various insurers. Findings from the analyses clearly indicate that these are part of the potential benefits of PLFRA measures, such that the adoption of the measure can reduce or completely eliminate the need to incur such extra costs. Additionally, in this chapter, the results of detailed analysis of the WTP values were presented. Statistical significant factors that influence these WTP values have been identified. This finding, therefore, concurred with the expectation; thereby, indicating the validity of the data collection and analyses method employed in this research.

It was concluded in this chapter that the mean WTP values to avoid impact and psychological effect of flooding on households are £390 and £263 per household per year, respectively; thereby, producing a combined mean WTP values of £653 per household per year. This combined mean WTP value is the intangible benefit of investing in adaptation measures which will be used in the development of CBA model of PLFRA measures in chapter 9.

CHAPTER SEVEN: ANALYSIS OF THE ADDITIONAL COST OF PLFRA MEASURES

7.1 INTRODUCTION

In this chapter, the analysis of the additional cost of PLFRA measures is presented. This is in line with objective five of the research, which is to collect data on the actual reinstatement costs and to establish the additional costs of PLFRA measures for flood damaged properties affected during the 2007 summer flood event. The data provided information on the house type, extent of the damage, flood depth, scope and costs of repair. Subsequently, the additional costs of adopting PLFRA measures base on different house types, flood depth and floor construction methods were estimated. These additional costs being due to the inclusion of resilience measures in the reinstatement schedule of repairs. In additional, the cost of temporary alternative accommodation and cost of subsequent reinstatement assuming adaptation measures have been put in placed were estimated and analysed. Descriptive statistics including frequency distribution, measures of central tendency (including means, medians and modes) and measures of dispersion are first used to summarise and explore the data. Further, a normality test was performed on the data to ascertain the distribution pattern of the data for validity and inference purposes. This chapter, thus, establishes the additional costs of PLFRA measures, which will then be used in subsequent chapters to develop the CBA models of PLFRA measures.

7.2 ESTIMATION OF ADDITIONAL COST OF PLFRA MEASURES

In the development of the new CBA conceptual model, (as discussed in chapter 5) the method for estimating additional costs of the measures is to proceed stage-by-stage from the beginning to the end of the estimation activity (Wassell *et al.*, 2009). This method can be time consuming, but it has the potential to produce a more accurate estimate of the cost of the measures. This involves developing resilience and resistance specifications and then identifying the cost components at each stage of the estimation process. In the subsequent sections, a detailed analysis of the additional costs of resistance (CM_{rs}) and resilience (CM_{rt}) measures are presented; thereby, establishing the additional costs for each measure.

The process adopted in this research to estimate and analyse the additional cost of adaptation measures is presented in Figure 7.1. For each of the measures (resistance and resilience), three distinct stages are involved and these have to be followed sequentially in order to accurately estimate the additional costs. As shown in Figure 7.1, stage 3, involves establishing the additional cost of resilience measures based on property types and floor construction, the rationale behind floor construction categorisation was based on the fact that, existing floor construction method has a significant influence on the additional cost of implementing resilience measures.

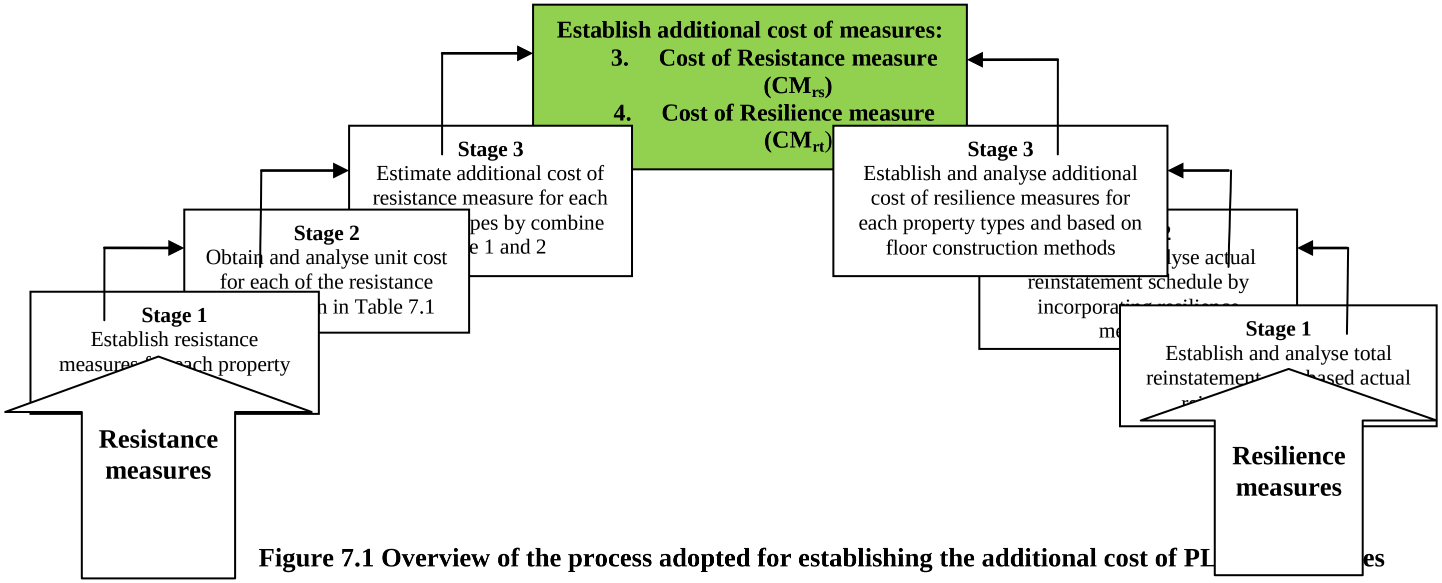


Figure 7.1 Overview of the process adopted for establishing the additional cost of PL es

7.3 ESTIMATION OF THE ADDITIONAL COST OF RESISTANCE MEASURES (CM_{rs})

As outlined in section 7.2, three stages are involved in evaluating the additional costs of resistance measures. Stage 1 involves the determination of the number of resistance measures required by different property types (bungalow, detached, semi-detached and terraced). Stage 2 involves obtaining the unit cost for each of the resistance measures and in stage 3 of the process; the unit costs were used to estimate the additional cost of all resistance measures based on the different property types. In order to evaluate the additional cost of resistance measures for each of the property types in consideration in this research, the resistance specification presented in chapter 2, section 2.7.1 is used (the resistance specification is re-produce in Table 7.1). As shown in Table 7.1, two different specifications are proposed to be used in this model, based on their method of deployment, namely, manually or automatically deployed. This is in line with studies carried out by Grant *et al*. (2011) and Royal Haskoning (2012).

Table 7. 1 Resistance specification adopted for the research

Flood resistance specification	**Itemised measure**
Manual Specification	Singular panel demountable door guard
	Demountable panelled system fitted into channels – for patio doors
	Airbrick Cover
	Sewerage bung
	Toilet pan seal
	waterproofing work on external walls (up to 1.2m high)
	Apply silicone gel sealant around cables
	Supply and install sump pump
Automatic specification	Supply and install automatic door guards
	Supply and fix self-closing airbrick
	Supply and fix non-return valves 110mm soil waste pipe
	waterproofing work on external walls (up to 1.2m high)
	Apply silicone gel sealant around cables
	Supply and install sump pump

In this research, resistance measures to be implemented (apart from waterproofing external walls) have been assumed to have a height of protection of 0.6m above the threshold of the property. This limiting depth has been adopted as it has become the industry standard (Royal Haskoning, 2012). This is based on evidence that above this level, brick and concrete block walls may fail due to the hydrostatic loading of flood water (Garvin *et al.,* 2005). The recently completed DEFRA grant scheme includes this assumption (Grant *et al.,* 2011). Thurston *et al.* (2008) asserted that one important consideration for resistance measures is the fact that they need to be applied to all ground floor homes in any one block. If they are not, water can leak from unprotected properties into protected ones, thereby reducing the effectiveness of the measure. Resistance measures are, therefore, most suitable for detached and bungalow properties or for terraced / semi-detached properties where owners are able to agree a common approach to flood resistance. In this study, it is assumed that resistance measure will be applied to all the properties apart from those that were flooded above 0.6m.

7.3.1 Stage 1: Resistance measures required per property

Four different property types were considered in this research, these are bungalows, detached, semi-detached and terraced. These property types are of different sizes and construction methods; in particular number of potential flood water entry points for each of the property types varies and depends on the construction material used (Garvin *et al.,* 2005). Based on this, to adapt each property to flood risk through the adoption of resistance measures will require a different number of the various measures. This means that the additional cost of resistance measures depends greatly on property types and types of measures adopted (i.e. manual or automatic as mentioned in section 7.3).

Table 7.2 shows the components of resistance measures for different property types. This was derived by considering the size and form of construction for each property as suggested by Garvin *et al.* (2005).

Table 7.2 Component of resistance measures based on property types

Resistance Measure	Property Type			
	Bungalow	**Detached**	**Semi-detached**	**Terraced**
	No of Manually Operated Measures			
Singular panel demountable type	2	2	2	2
Demountable panelled system fitted into channels	1	1	1	2
Supply and airbrick Cover	27	23	14	12
Supply and fix sewerage bung	3	3	2	2
Supply and fix toilet pan seal	1	1	1	1
Supply and install sump pump	1	1	1	1
Carefully apply silicone gel around openings such as cables, doors, windows etc	1	1	1	1
Carry out waterproofing work on external walls (up to 1.2m high) - Water sealant spray to external elevation up to 1.2m high	1	1	1	1
Supply and install garage/driveway Barrier	1	1	0	0
	No of Automatically Operated Measures			
Supply and install automatic door guards	3	3	3	2
Supply and fix self-closing airbrick	27	23	14	12
Supply and fix non-return valves 110mm soil waste pipe	1	1	1	1
Supply and fix non-return valves 40mm utility waste pipe	3	3	3	3
Supply and fix non-return valves 12mm overflow pipe	1	1	1	1
Supply and install sump pump	1	1	1	1

Source: *Adapted from Royal Haskoning (2012)*

In developing Table 7.2, a guide was also taken from Royal Haskoning (2012) recently completed research *Assessing the Economic Case for Property Level Measures in England.* However, the Royal Haskoning (2012) study did not consider bungalows; therefore, the required number of unit of measures for a bungalow property was derived from the literature (Garvin *et al.*, 2005). The components are presented in accordance with individual deployment method in line with Table 7.1. The unit cost per property type for the resistance measure was developed based on the number of units presented in Table 7.2.

One of the routes where flood water can easily enter property without notice is through the airbrick vents (Proverbs and Soetanto, 2004; Garvin *et al.*, 2005). As can be observed in Table 7.2, airbrick cover constitutes the highest number of resistance measures required by each property to prevent water entry into the property. A bungalow, due to its large area size, typically requires 27 airbrick covers; a detached property requires 23 airbrick covers; a semi-detached requires 14 airbrick covers and a terraced property requires 12 airbrick covers (Royal Haskoning, 2012).

7.3.2 Stage 2: Unit cost of resistance measures

Having determined the number of resistance measures required per property type, the next stage in the estimation process is to establish the unit costs for individual components. The unit costs were obtained from damage management contractors as discussed in chapter 5 section 5.5.1. A small survey of 24 damage management contractors was undertaken to elicit estimated unit costs for the various resistance measures. These are contractors that are fully involved in repair of flood damaged properties on behalf of the insurers, and have experience in this type of repair work. A total of 18 completed questionnaires were received, this equates to 75% response rate. Based on the responses from contractors, lower, mean and upper rate unit cost databases have been developed for resistance measures (Table 7.3). The presentation of the unit cost in three different rate levels allows for a robust assessment of the variability in the individual rate of the measures.

Table 7.3 Mean unit cost of resistance measures

Item	Description Flood Resistance Measure	Unit	Lower rate (£)	Mean Rate (£)	Upper Rate (£)
1	Supply and fix demountable door guards				
	Singular panel demountable type	nr	250	330	410
	Demountable panelled system fitted into channels	nr	540	690	840
2	Supply and airbrick Cover	nr	45	55	65
3	Supply and fix sewerage bung	nr	50	60	70
4	Supply and fix toilet pan seal	nr	83	98	113
5	Supply and install sump pump	nr	920	1,070	1,270
6	Carefully apply silicone gel around openings such as cables, doors, windows etc.	m	5	5	5
7	Carry out waterproofing work on external walls (up to 1.2m high) - Water sealant spray to external elevation up to 1.2m high	m	20.5	23	30
8	Supply and install automatic door guards	nr	850	1,200	1,600
9	Supply and fix self-closing airbrick	nr	72	92	110
10	Supply and fix non-return valves 110mm soil waste pipe	nr	99	119	140
11	Supply and fix non-return valves 40mm utility waste pipe	nr	60	80	100
12	Supply and fix non-return valves 12mm overflow pipe	nr	40	50	70
13	Supply and install garage/driveway Barrier	nr	1,250	1,650	2,000
14	Supply and install garage/driveway Barrier (automatic)	nr	2000	2500	3000

The figures were compared with published databases such as the DEFRA grant scheme 2011 (JBA, 2012), and found to be broadly consistent with the exception of the cost of sump pumps. The DEFRA grant scheme allows £400, £500 and £600 for lower, mean and upper estimate costs, respectively (Royal Haskoning, 2012) compared to £920, £1,070 and £1270. For the purpose of this research, the costs obtained from contractors will be used as these are more recent and include overheads (such as office administrative costs) which were not included in the DEFRA estimates. The unit cost data presented in Table 7.3 was used to establish the additional cost of resistance measures for different property types as discussed in the next section.

7.3.3 Stage 3: The additional cost of resistance measures (CM_{rs})

Having established the number of resistance measures required per property (stage 1) and the unit cost for each of the measures (stage 2), the final stage in the estimation process is to establish the additional cost of the measures based on each property type. The mean unit costs (discussed in section 7.3.2) were then applied to the specific resistance measures for each property type to establish the additional costs. Table 7.4 illustrates the total cost for different resistance measures based on the deployment methods.

As would be expected the cost of manually deployed resistance measures are lower than the cost of automatically deployed measures. For example, the manually deployed resistance measures for bungalow and detached properties are 51% less expensive when compared with the cost of automatically deployed measures. Further, for semi-detached and terraced properties, the percentage difference in cost of manual and automatic deployed resistance measures are 60% and 43%, respectively. Thurston, *et al.* (2008) acknowledged that due to the high cost of automatically deployed resistance measures, they are more likely to be less cost-beneficial; however, automatically deployed measures provide advantages in not needing to be deployed. Further, automatically deployed measures are more suitable for areas that are prone to flash-flooding; where there is high proportion of elderly or disabled persons and where the deployment of temporary resistance measures is not possible prior to the onset of flooding. Where the application of resistance measures is not practicable or not cost beneficial, resilience measures can then be considered.

Table 7.4 Cost of Resistance measures (CM_{rs}) based on specification and unit costs in Tables 7.2 & 7.3 for each property types

Flood resistance specification	Itemised measures	Cost based on specification for each property type (£)			
		Bungalow	Detached	Semi-detached	Terraced
Manual Specification	Singular panel demountable door guard	660	660	660	660
	Demountable panelled system fitted into channels – for patio doors	690	690	690	690
	Airbrick Cover	1485	1265	770	660
	Sewerage bung	180	180	120	120
	Toilet pan seal	98	98	98	98
	waterproofing work on external walls (up to 1.2m high)	966	782	552	483
	Apply silicone gel sealant around cables	25	25	25	25
	Supply and install sump pump	1070	1070	1070	1070
	Supply and install garage door barrier	1650	1650	0	0
	Total cost for different house types (CM_{rs})	**6,799**	**6,420**	**3,985**	**3,806**
Automatic specification	Supply and install automatic door guards	3600	3600	3600	2400
	Supply and fix self-closing airbrick	2484	2116	1288	1104
	Supply and fix non-return valves 110mm soil waste pipe	119	119	119	119
	waterproofing work on external walls (up to 1.2m high)	966	782	552	483
	Apply silicone gel sealant around cables	50	50	50	50
	Supply and install sump pump	1070	1070	1070	1070
	Supply and install garage door barrier (Automatic)	2500	2500	0	0
	Total cost resistance measures for different property types (CM_{rs})	**10,789**	**10,237**	**6,679**	**5,226**

7.4 ESTIMATION OF THE ADDITIONAL COST OF RESILIENCE MEASURES (CM_{rt})

The process of estimating additional cost of resilience measures, involves making sure that necessary cost variables are included in the estimation process. There are several variables that can influence the additional cost of resilience measures. It was considered necessary to ascertain these variables at the initial stage of estimation. This is important because the developed model, which is expected to be used in determining the costs and benefits of adaptation measures, could become very complex and difficult to understand by the users if too many irrelevant variables are included in the model. It was also recognised that oversimplification of the model is likely to lead to inaccurate estimations. Therefore, a balance must be drawn between excessive complexity and accuracy in order that the models will be both user friendly and sufficiently reliable to provide useful information which can assist in decision making on adaptation measures. Detail review of existing flood protection models such as (ABI, 2003; Penning-Rowsell, *et al.,* 2005; Thurston, *et al.,* 2008; Joseph *et al.,* 2011a; JBA, 2012; Royal Haskoning, 2012) were carried out, the review revealed that property types, floor construction methods/material and flood depths are three main variables which can significantly influence the costs and benefits of adaptation measures.

7.4.1 Additional cost of resilience measures

As outlined in section 7.2, the estimation process of additional cost of resilience measures is in three stages. Stage 1 of the process involves establishing the actual reinstatement costs which comprises of strip-out; drying and repair costs. These costs are extracted directly from the final account schedule of repairs prepared by surveyors on behalf of insurance companies. The analysis involved categorising of costs based on property types, flood depths and floor construction. Stage 2 involves re-pricing of the actual schedule of traditional repair specification with a resilience specification for each property type. The re-pricing exercise represents the cost of repair using flood resilient measures which would have been incurred had these measures been adopted at the time. The results of this re-pricing work was used to establish the additional cost of resilience measures based on different property types, flood depths and floor construction methods. The third and final stage in the estimation process is to determine the difference between the actual reinstatement cost (stage 1) and the cost obtained from the re-pricing work (stage 2). This, thereby, establishing the additional cost of resilience measures used in the development of CBA models of PLFRA measures in chapter 9.

The analysis discussed in this section is based on the respondents to the major survey as discussed in chapter 6, section 6.8. The claims database used in this study did not include repair schedules for some of the respondents and were excluded from the analysis. It was observed that this seemed to be relatively small value claims (usually under £15,000), which appear to have been settled directly by insurers because the repair schedule of work for those claims were not available. Within the 280 responses received, 33 were excluded on this basis. Wassell *et al.* (2009) asserted that the 2007 flood event includes many such claims. The cost implication for implementing resistance or resilience measures to these properties may be higher and not cost effective. Arguably, resilient reinstatement is not appropriate when very little reinstatement is needed, thereby limiting the applicability of the model to be developed to claims above £15,000. Therefore, the analysis in this section excludes such small value claims because of the lack of detailed information on the reinstatement specifications and costs.

The total number of properties used for the analysis in this section is 247, this comprises of 20 (9%) bungalows; 33 (13%) detached; 98 (40%) semi-detached and 96 (38%) terraced. The distributions by flood depth are as follows: 50 (20%) 0-150mm; 54 (22%) 151-300mm; 55 (22%) 301-500mm; 59 (24%) 501-1000mm and over 1000mm 29 (12%). The spread of property types reflects the summer 2007 flood locations (as discussed in chapter 6) and, in view of the geographical extent, is considered a good spread of each property types widely encountered in the England housing stock when compared with the English Housing Stock survey report (DCLG, 2010). It can be concluded that most of the property types encountered in the UK housing market are represented in the database and, therefore, inferences drawn from this data can be extended to the population. The samples are uniformly distributed in terms of the flood depth, however, in terms of the property types, terraced and semi-detached houses were heavily represented.

Based on this, a normality test was carried out on the data before further analysis was performed. The result of the Kolmogorov-Smirnov normality test (0.192, sig 0.000) shows that the data is not normally distributed. Further, the *p*-value < 0.05 shown indicates a deviation from normality. According to Field (2009) in a normal distribution, significance value must be greater than 0.05 (sig > 0.05), this test confirms that the data is not normally distributed; therefore, the mean is not an accurate representation of actual reinstatement cost. Mann (2003) and Field (2009) suggested that in cases such as this, the median is preferable; therefore, the median values will be used in the subsequent analysis.

7.4.2 Stage 1: Analysis of total reinstatement costs

The total value of the reinstatement cost, which is based on the total spent on 247 properties in the sample, was around £12.8 million, giving a mean spend per property of £51,979. The reinstatement costs include strip-out, drying, repair cost and loss adjuster/surveyor professional fees. Table 7.5 shows the summary statistics of reinstatement costs. The minimum actual reinstatement cost was £18,548 and the maximum was £184,134, with a median cost of £48,546. The wide range in these costs reflects the varieties inherit in the housing stock in England.

Table 7. 5 Statistics of actual traditional reinstatement costs

N	Valid	247
	Missing	0
Mean		51,979
Std. Error of Mean		1,559
Median		48,546
Mode		65,412
Std. Deviation		21,962
Skewness		2.468
Std. Error of Skewness		0.16
Kurtosis		10.306
Std. Error of Kurtosis		0.309
Minimum		18,548
Maximum		184,134

Actual reinstatement cost (ARC) by depth of flooding and property types

Figure 7.2 presents the values of actual reinstatement costs for each of the property types; this is based on the actual flood depth experienced by each household during the 2007 flood event. The data represents all properties in the sample which experienced flood depth from 0 to over 1000mm. Wassell *et al.* (2009), acknowledged that the summer 2007 flood event placed significant strain on all parts of the reinstatement supply chain. Therefore, the actual costings as presented in Figure 7.2 include an uplift factor, or repair premium, which was incurred (Wassell *et al.,* 2009). This covers such things as more expensive labour, materials, site overheads and also enhanced scopes of repair which come about when dealing with major events. Whilst these figures may be considered excessive for some property types when compared to other published data, these are the actual cost incurred by insurers in reinstating these properties back to their pre-flood condition.

As discussed in chapter 5, section 5.5.1, the major advantage of using actual data sources is that the value of costs derived was not based on assumptions, which is normally the case when using other sources such as stage damage curves to estimate flood damage. As acknowledged by Wassell, *et al.* (2009), some of these assumptions such as flood depth, availability of labour force to carry out repair work at normal labour rates, are unlikely to hold in certain instances under the real life event. Therefore, the use of actual cost as presented in Figure 7.2 is seen as a major contribution to the robustness of the developed CBA models of PLFRA measures.

From Figure 7.2, it can be seen that to reinstate a bungalow to its pre-flood condition is more expensive than any other property types for flood depths 0-150, 301-500 and 501-1000mm. There are factors that may contribute to the expensive nature of reinstating a bungalow property when compared to other property types, these include: (1) no upper floor for storage of personal belongings or where households can relocate while repair work is ongoing; (2) additional cost of temporary accommodation likely to be needed as no upper floors to be used (unlike other property types); and (3) larger ground floor areas compared to other property types (Penning-Rowsell *et al.*, 2010).

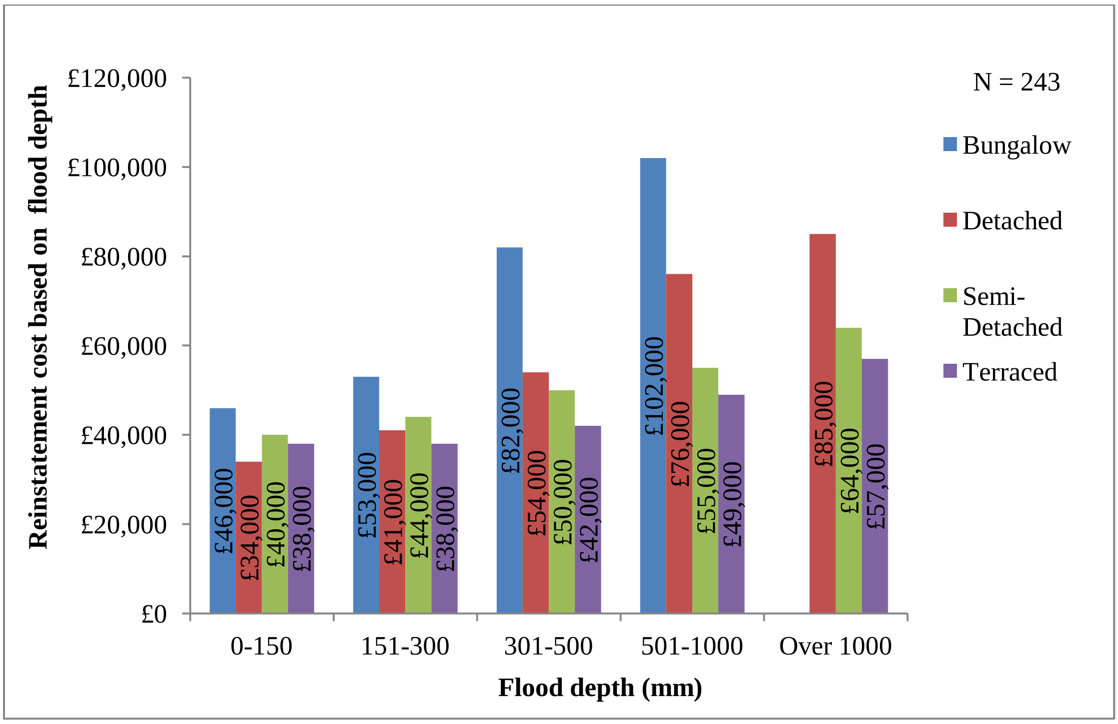


Figure 7.2 Median of Actual Traditional like for like Reinstatement Costs (ARC)

These results concur with the literature review (as discussed in section 2.6.1) in that depth is a major cost driver in reinstating property to its pre-flood condition. For each property types as the flood depth increases, there is also subsequent increase in the reinstatement cost. Although for terraced property the median cost of actual reinstatement for flood depth 0-150 and 151-300mm are the same (£38,000). The main reason for this may be that terraced property damage is less sensitive to changes in flood depth up to 300mm. Following the establishment of the actual cost of reinstatement, the next stage of the estimation process is to develop the additional cost of resilience measures.

7.4.3 Stage 2: Re-pricing of actual schedule of repair for resilience measure

From the sample of 247 properties with flood depth ranges from 0 to over 1000mm, as discussed in section 7.4.2, the schedule of actual reinstatement work carried out were re-priced on a resilience basis. In determining the depth of flooding for the re-pricing aspect of the analysis, the current depths of flooding as experienced by individual property were adopted as the basis, these were increased by 500mm in accordance with the suggestion by Garvin *et al.* (2005) and as adopted by Wassell *et al.* (2009). This approach makes it possible to implement resilience measures above the original flood line; additionally, it takes into account the capillary action of some building materials. Figure 7.3 shows the cost of repair using flood resilience materials and techniques, which would have been incurred had these measures been adopted at the time of reinstating these properties to their pre-flood condition in 2007. As expected, the inclusion of resilience measures in the actual schedule brings an increase in costs, shown in Figure 7.3 relative to what is presented in Figure 7.2. This concurs with various authors in that adoption of resilience measure will always lead to additional costs (ABI, 2003; Thurston *et al.* 2008; Wassell *et al.* 2009; Joseph *et al.* 2011a; JBA, 2012; Royal Haskoning, 2012).

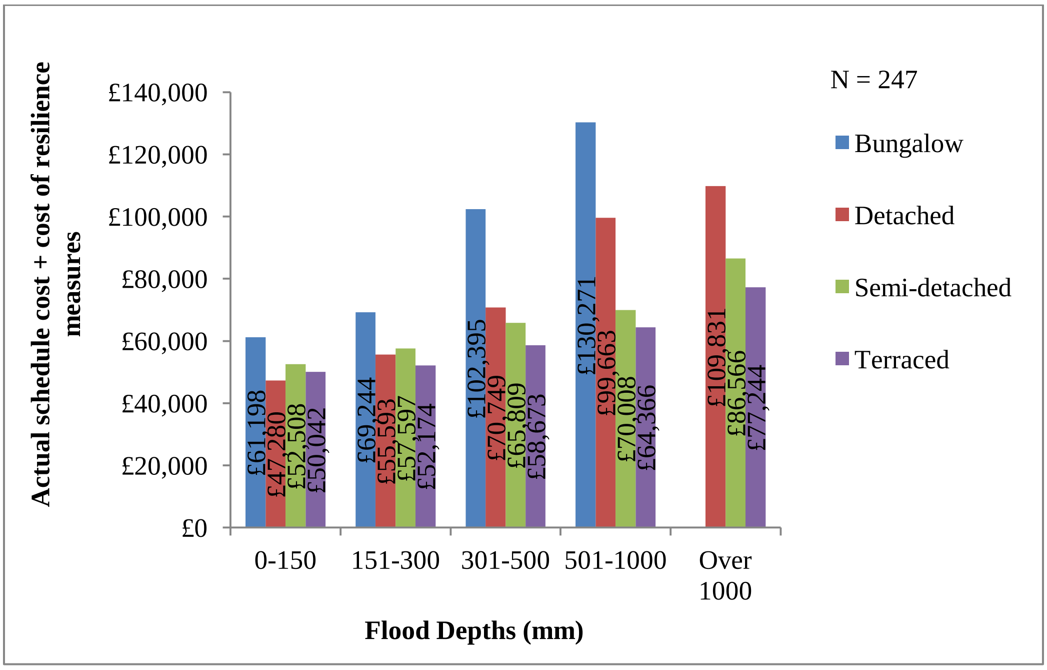


Figure 7.3 Median of actual cost of repair by incorporating resilience measures into the schedules

Bungalows still incurs higher costs compared to other property types; however, in order to establish the additional cost of resilience measures over and above the traditional like for like reinstatement, it is necessary to carry out further cost analysis.

7.4.4 Stage 3: Analysis of additional cost of resilience measure (CM_{rt})

In this section, the results of the analysis of the additional cost of resilience measures were presented based on the three variables discussed in section 7.4. This is in preparation for the next series of analysis in chapters eight and nine. Figure 7.4 shows the median additional resilience reinstatement costs based on concrete floor construction. When these costs are compared across different categories of property types and flood depths, it can be seen that the costs of additional resilience reinstatement are within the same range with the exception of flood depth 501-1000mm where bungalow incurred high costs (£28,271) compared to other property types. The reason for the consistency in the additional cost of resilience measures for flood depth 0-500 across the four property types is as a result of the fact that most flood resilience measures are specified with the assumption that the expected flood level will be around 500mm mark, which will necessitate installing resilience measures over and above the expected flood level without taking cognisance of the lower flood depth. Based on the median costs, it can be seen that bungalows are more costly to be adapted to flood risk when compared to other property types. The additional cost of adapting bungalow to flood risk is not proportional to total reinstatement cost when compared to other property types. This findings support previous research such as Wassell *et al.* (2009), Joseph *et al.* (2011a) and Royal Haskoning (2012).

Further from Figure 7.4, it can be inferred that depth of flooding is a major cost driver in determining the additional cost of resilience measure because across different property types, the additional cost increases as the flood depth increases, the range of cost increase over depth of flooding ranges between 15% to 58%, the higher percentage is achieved in flood depths over 300mm. The main reason for this could be the influence of surveyor's original decision on strip out and initial reinstatement.

By using the median figure presented in Figure 7.4, the percentage additional cost to install a concrete floor was calculated. The result of the analysis shows percentage increase ranges from as low as 22% and as high as 38% across different property types. From the analysis, bungalow appears to be less expensive based on flood depth in percentage terms to be made flood resilient, if the cost is related back to the original cost of conventional reinstatement to its pre-flood condition. However, this does not necessarily means that a bungalow will be less expensive in financial terms to adapt to flood risk when compared to other property types, if the percentage is related back to the actual cost of reinstating each property to flood risk, it will be apparent that a bungalow is the most expensive property to adapt to flood risk. The percentage increase for bungalow over actual reinstatement cost based on varying flood depth ranges from 22-35% and for detached property it ranges from 28-36%. For semi-detached property it ranges from 30-33% and for terraced property it ranges from 32-38%.

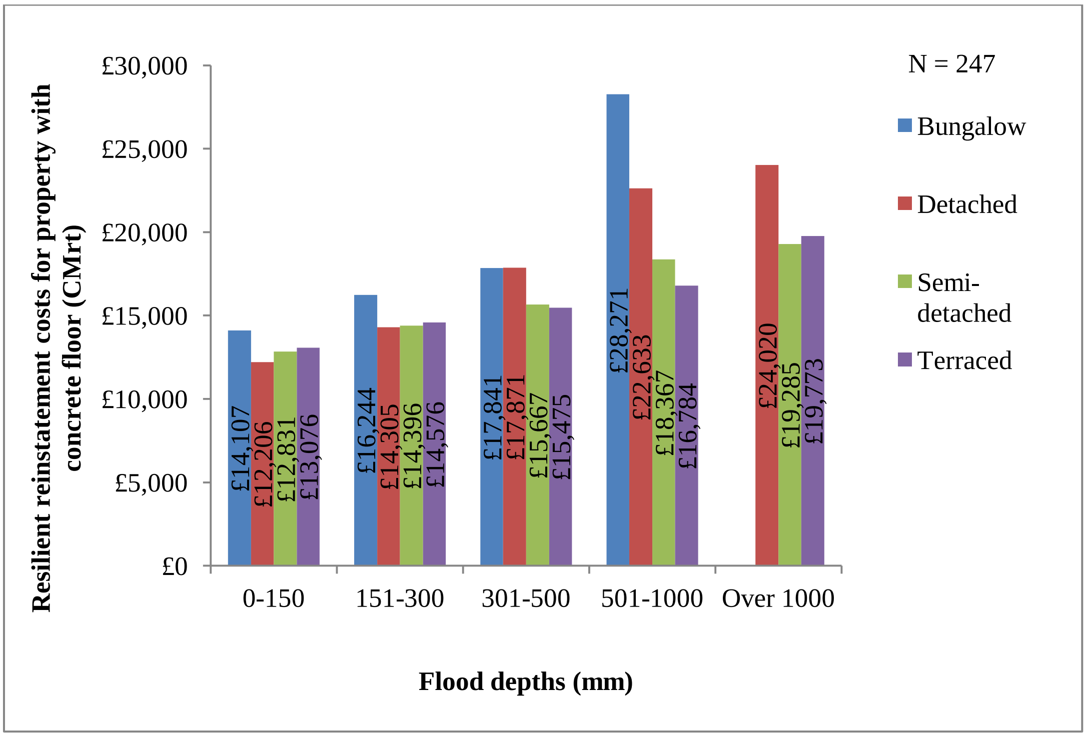


Figure 7.4 Median resilient reinstatement costs (CM_{rt}) based on flood depth and property types

The results of the analysis of additional cost of resilience measure for properties with suspended timber floor are presented in Figure 7.5. As expected, the additional cost of making a property with timber floor construction flood resilient should be higher when compared with property with concrete floor. This is due to the extra cost incurred in replacing timber floors with concrete. From Figure 7.5, it can be inferred that depth of flooding is also an important variable in determining the additional cost of resilience measure because the additional cost of the measures appear to be increasing as the flood depth increases. Further analysis was carried to calculate the percentage increase in the additional cost over the actual cost. The percentage increase over the actual reinstatement cost to make a bungalow with suspended timber floor flood resilient ranges from 35-43% and for detached property it ranges from 31-41%. For semi-detached property it ranges from 36-39% and for terraced property it ranges from 39-47%.

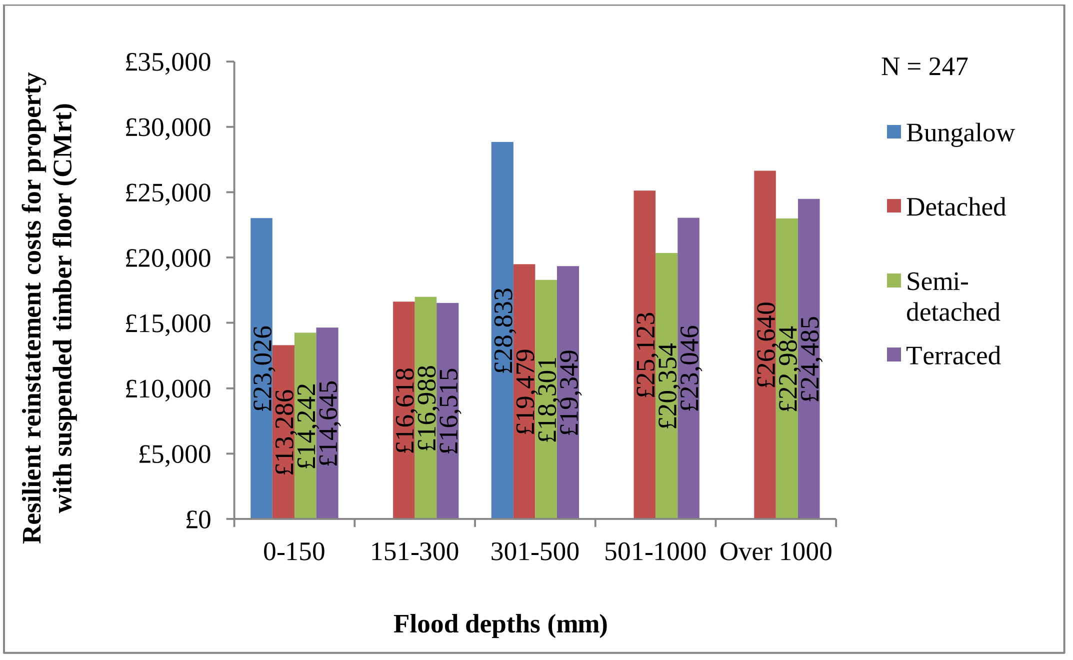


Figure 7.5 Median resilient reinstatement costs (CM_{rt}) based on flood depth and property types

When the results of the percentage difference between the additional costs of resilience measures for a concrete floor property and suspended timber floor property were compared, it shows that there is a percentage increase of between 3% and 16% to make a suspended timber property flood resilient compared to concrete floor property.

It can be concluded that these wide ranges in percentage increase of additional resilience reinstatement cost over actual reinstatement values is typical of the ranges encountered in practice and reflect the actual varieties in house sizes, layouts and specification, including quality, seen within categories of similar types of properties. It also reflects the different approaches different surveyors take to similar cases.

7.5 ANALYSIS OF OTHER ASSOCIATED COSTS

In CBA studies, the robustness of the CBA model centres on the fact that all costs and benefits should be accounted for in the model (Snell, 2011). Failure to include all relevant costs and benefits parameters in the model has the potential to lead to making decisions on incomplete information. The additional costs of the measures have been established, however, there are two other costs which are important in developing CBA model of PLFRA measures. These are subsequent reinstatement cost (SRC) and the cost of temporary alternative accommodation (TAC) which is the costs of avoided loss. These two costs components have to be accounted for when developing CBA model of property level flood risk adaptation (PLFRA) measures.

7.5.1 Analysis of the subsequent reinstatement cost (SRC)

The costs of reinstatement following a subsequent flood event were estimated by creating model schedules of anticipated flood damage, the schedules mostly include drying, cleaning and decoration works. In preparing the model schedules, it was assumed that adaptation measures (resilience measures) were implemented when a property was in need of repair or refurbishment following a previous flood. It is expected that the extra cost of a resilient repair will be relatively low. This was based on the assumption that adaptation measures had been implemented correctly and the flood level is less or equal to what was experienced previously.

It is also assumed that the SRC will only be incurred if resilience measures were in place; however, if resistance measures were installed, deployed correctly and functioned as expected, it is assumed that no reinstatement cost will be incurred during future flooding. Therefore the analysis that follows only relates to resilience measures and it is assumed that for resistance measure the cost of future flooding will be limited to cleaning of external hard standing. In most cases homeowners may carry out the cleaning without making a claim under their domestic insurance policy.

The same property data variables, such as the quantities in the actual reinstatement schedules (discussed in chapter 7), were used with the same unit rates. The subsequent reinstatement costs were estimated for the 247 properties in the data set, and then entered into Statistical Package for the Social Sciences **(**SPSS) version 20 software for analysis.

Prior to carrying out detailed analysis of the data, it was decided to examine the distribution of the data. Table 7.6 shows the descriptive statistics of the SRC. It was observed that there is a large difference between the minimum (£3,050.54) and maximum values (£17,399.54). These reflect differences in property types and individual finishings. However, the standard deviation is rather large and the result of the Kolmogorov-Smirnov normality test (0.099, sig. 0.000) shows that the data is not normally distributed, therefore the median is used as the best measure of central tendency (Field, 2005), which in this case is £6,575.68.

Table 7. 6 Descriptive statistics of the subsequent reinstatement cost (SRC)

			Statistic	Std. Error
Cost of subsequent reinstatement	Mean		7,099.60	144.08
	95% Confidence Interval for Mean	Lower Bound	6,815.80	
		Upper Bound	7,383.40	
	Median		6,575.68	
	Variance		5127799.78	
	Std. Deviation		2,264.46	
	Minimum		3,050.54	
	Maximum		17,399.54	
	Skewness		1.33	0.15
	Kurtosis		2.94	0.30

The SRC presented in Figure 7.6 includes an allowance for three weeks alternative accommodation at £500/week, this was based on the experience of the residents of Derwent Housing Association Cockermouth in 2009 (Watts, 2010). It can be observed from Figure 7.6 that flood depth appears not to have significance influence on the cost of subsequent reinstatement. This is because decoration work will be carried out on to the full height of each of the property irrespective of the flood depth (Joseph *et al.* 2011a; Royal Haskoning, 2012), which appears to be the most expensive work to be carried out in each of the property.

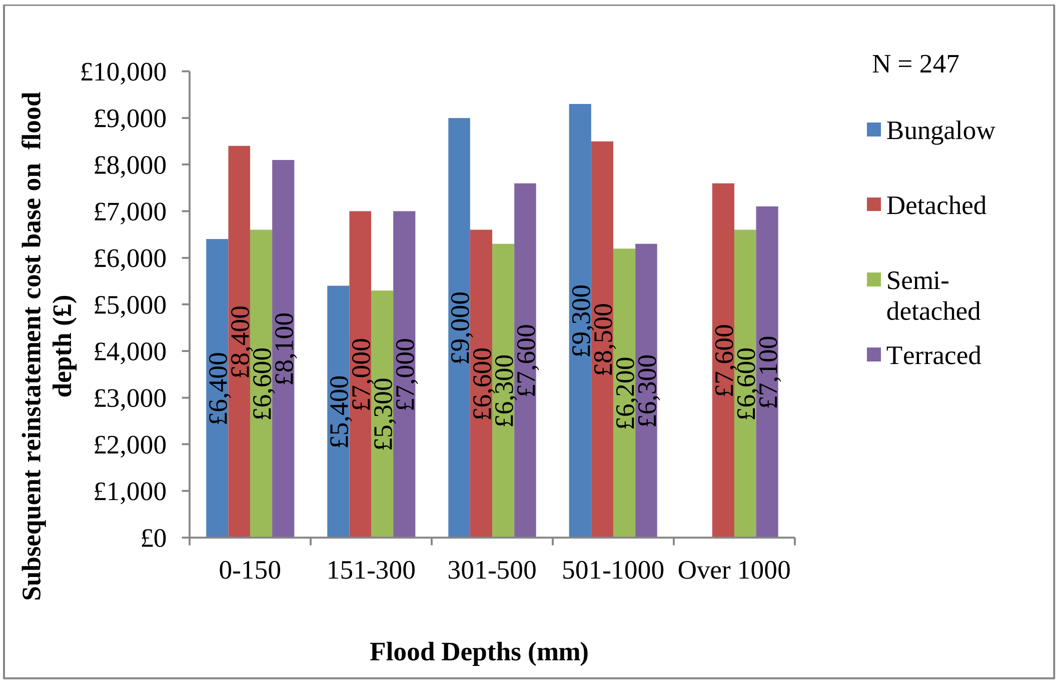


Figure 7.6 Median of subsequent reinstatement costs (SRC) assuming resilience measures had been implemented

From Figure 7.6, terraced property with flood depth 0-150mm and 151-300mm incurred higher costs (£8,100; £7,000) when compared to either bungalow (£6,400; £5,400) or semi-detached (£6,600; £5,300). This shows that the cost of subsequent reinstatement for a terraced property flooded up to 150mm is approximately 21% more than the cost of reinstating a bungalow and 18.5% for a semi-detached property flooded to the same depth. However, for higher flood levels (301-500 and 501-1000mm) bungalows incurred higher cost when compared to other property types. The main reason for these differences in cost of subsequent reinstatement for different property types can be linked to the varieties in wall and floor finishings.

7.5.2 Analysis of the cost of temporary alternative accommodation (TAC)

When a property has been severely inundated by flood water, an extensive drying and repair program will be necessary; this means that households may need to vacate their home for a significant period, whilst reinstatement works are being carried out. In most cases, the cost of relocating to a temporary alternative accommodation will be covered under individual household's insurance provisions (ABI, 2009). In chapter six, it was established that typically a large proportion of householders experience evacuation after a flood for long periods. This is consistent with the experience of households in the research database where out of 247 households 200 were relocated, equating to 81%, these are the severely flooded household.

From Table 7.7 it can be seen that the minimum temporary alternative accommodation cost (TAC) was £1,250 and the maximum was £29,625. It can be inferred from the values of Skewness (1.590) that the data is not normally distributed (Field, 2009), therefore it is not appropriate to use the mean as a measure of central tendency, and instead the median value will be used.

Table 7.7 Statistics of actual temporary alternative accommodation cost (TAC)

N	Valid	200
	Missing	47
Mean		7,765.41
Std. Error of Mean		357.65
Median		6,545.00
Mode		6,000.00
Std. Deviation		5,057.99
Skewness		1.590
Std. Error of Skewness		0.17
Kurtosis		3.03
Std. Error of Kurtosis		0.34
Minimum		1,250.00
Maximum		29,625.19

Figure 7.7 shows the median cost of alternative accommodation based on flood depth and different property types. It can be inferred from the analysis that the cost of alternative accommodation is not actually flood depth related as the range of median

values across flood depths appear not to differ significantly from one depth to the other; with the exception of flood depth 501-1000mm where the median of TAC for a household residing in bungalow was £17,300. Closer examination of the data for bungalow with flood depth 501-1000mm shows that there are only three households in this category. Each of them was in alternative accommodation for up to 9-months and each household contained three people, these therefore affected the median value for bungalow.

In the development of the CBA model for property level flood risk adaption measures, the median value of £6,545 will be used. This figure is in the same bulk pack as the mean cost of £6,695 obtained by Environment Agency (2010) from Weathernet insurance-based data as the cost of temporary alternative accommodation for those households that were temporarily relocated in 2007. Having established the median costs of subsequent reinstatement and temporary alternative accommodation.

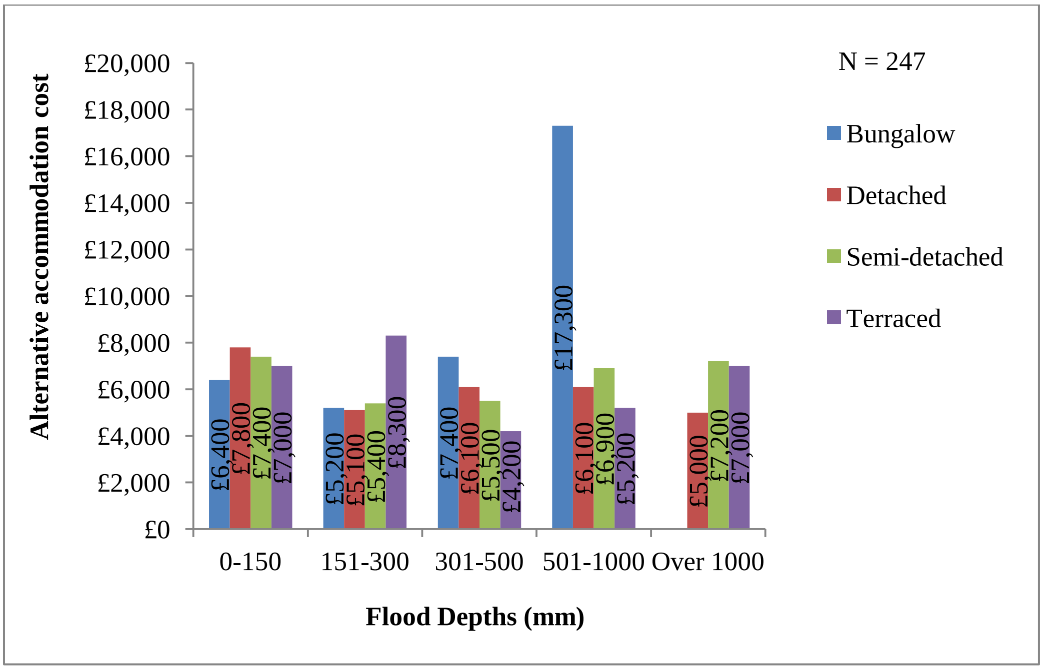


Figure 7.7 Median of alternative accommodation cost (AAC) based on flood depths and property types

7.5 OVERVIEW OF COMBINED COST SUMMARY OF PLRFA MEASURES

One of the aims of the conceptual framework developed for this research (discussed in chapter 4) was to bring together the costs and benefits of PLFRA measures in a unified manner. Therefore, to summarise the additional cost content of this chapter, Table 7.8 is presented as the overview of the additional costs of PLFRA measures. It can be seen from Table 7.8 that the additional cost of resistance measures ranges from £3,800 to £10,800 depending on property types and deployment methods. Whilst the additional cost of resilience measure ranges from £12,200 to £28,300 and £13,300 to £28,800 for concrete and suspended floor properties, respectively, the additional costs to be incurred depend greatly on property types and flood depths. This brings together the additional costs of adaptation measures and demonstrates that the research has covered the full range of properties and flood depths typical in England.

Table 7.8 Summary of additional costs of PLFRA measures based on different house types, flood depths and deployment methods

Floor construction	Property type	Cost of resilience measures (CM_{rt}) in flood depth (mm) categories					Cost of resistance measures (CM_{rs})	
		0-150	151-300	301-500	501-1000	Over 1000	Manual	Automatic
Concrete solid floor	Bungalow	£14,100	£16,200	£17,800	£28,300	N/A	£6,800	£10,800
	Detached	£12,200	£14,300	£17,900	£22,600	£24,000	£6,400	£10,200
	Semi-detached	£12,800	£14,400	£15,700	£18,400	£19,300	£4,000	£6,700
	Terraced	£13,100	£14,600	£15,500	£16,800	£19,800	£3,800	£5,200
Suspended timber floor	Bungalow	£23,000	N/A	£28,800	N/A	N/A	£6,800	£10,800
	Detached	£13,300	£16,600	£19,500	£25,100	£26,600	£6,400	£10,200
	Semi-detached	£14,200	£17,000	£18,300	£20,400	£23,000	£4,000	£6,700
	Terraced	£14,700	£16,500	£19,400	£23,100	£24,500	£3,800	£5,200

7.6 SUMMARY

This chapter has presented the first part of the data analysis to establish the costs of different adaptation measures. In doing this, the unit costs of resistance measures were fully analysed and used to estimate the additional cost of resistance measures based on property types. Further, actual reinstatement schedules were reviewed and analysed in the process of establishing additional cost of resilience measures. Actual schedules of repairs were re-priced by incorporating a resilience specification in the schedules and then analysed based on different property types and flood depth to establish the additional cost of resilience measure.

The results presented in this chapter shows that the additional cost of resistance measures ranges from £3,800 to £10,800 depending on property types and deployment methods. Equally, the additional cost of resilience measure ranges from £12,200 to £28,300 and £13,300 to £28,800 for concrete and suspended floor properties, respectively, depending on property types and flood depths. In addition, the cost of subsequent reinstatement was established based on different property types, these costs ranges from £5,300 to £9,300 depends on the property types. Having established the costs of different adaptation measures in line with objectives 4 and 5 of the research, the next stage is to establish the gross benefits of investing in adaptation measures; this forms the focus of the next chapter.

CHAPTER EIGHT: ANALYSIS OF THE TANGIBLE BENEFITS OF PROPERTY LEVEL FLOOD RISK ADAPTATION MEASURES

8.1 INTRODUCTION

In chapter six the preliminary analysis of the survey data was presented, whilst the additional costs involved in adopting property level risk adaptation measures based on different property types, flood depths and floor construction methods were presented in chapter 7. In this chapter the expected annual damage (EAD) avoided was established, this was followed by evaluation of the expected cumulative damage (ECD) avoided over twenty years period. This is in line with objective six of the research which is to establish the expected cumulative damaged (ECD) avoided of PLFRA measures and to subsequently use appropriate statistical analysis techniques to explore the relationship between costs and benefits of the measures.

One of the decision making criteria of CBA is the BCR. This chapter presents the BCR analysis of PLFRA measures in order to provide a uniform basis for comparing the costs as well as the benefits of the measures across different property types, flood depths and floor construction methods. The comparison makes it possible to rank the benefits in terms of flood return periods and flood probabilities when the costs of the adaptation measures are taken into account. However, prior to establishing the benefit of the measure, cost of subsequent reinstatement and alternative accommodation costs were established. This chapter, thus, establishes the tangible benefits and BCR of PLFRA measures, which will then be used in chapter nine in developing the CBA model of the measures.

8.2 ANALYSIS OF THE TANGIBLE BENEFITS OF RESISTANCE AND RESILIENCE MEASURES

The tangible benefits of implementing PLFRA measures are the sum of the total cost incurred by different stakeholders during a flood event (such as reinstatement cost, alternative accommodation cost and emergency service / evacuation costs) that are averted as a result of the adaptation measures implemented in comparison to those experienced by a property that has not been adapted. As discussed in section 2.7.6, the benefits of PLFRA measures can be grouped into two categories, these are: tangible and intangible benefits (Lee, 2004; Penning-Rowsell *et al.* 2005). Irrespective of who covers the cost of PLFRA measures, Joseph *et al.* (2013) asserted that the tangible benefits of the measures are shared among three stakeholders, homeowners, insurers and government. In establishing the benefits of PLFRA measures, an 8% discount rate was used instead of the 3.5% rate, which is normally used in the economic benefit appraisal (HM Treasury, 2003). A lower discount rate is normally used when evaluating economic benefit of investment as against a financial benefit, which is the focal point of this research. As discussed in section 3.3.4, the use of the discount rate for individuals could easily be set by the user of the model without loss of the general principle and rigour of the developed model.

In this section, the gross benefits of the measures are estimated based on the resistance and resilience measures implemented. As discussed in section 4.6, the gross benefit is the value of expected annual damage (EAD) avoided by implementing adaptation measures over 20-years. A scheme life of 20-years has been used to assess the costs and benefits of the PLFRA measures because it is expected that most properties would be refurbished within 20-years and this assumption accords with other research, such as Thurston *et al.* (2008), JBA (2012) and Royal Haskoning (2012). Prior to establishing these benefits, which are the avoided losses, a damage profile for resilience measure based on different property types and flood depth for a single flood event was estimated, this is the EAD avoided. Figure 8.1 shows the damage profiles, these are the costs of damage to be avoided for a single flood event if resilience measures have been implemented and worked effectively.

As expected, the damage profile for a bungalow is higher when compared with other property types; this is followed closely by detached, semi-detached and terraced properties. For all the property types, the value of damage profiles increases as the depths of flooding increase. This implies that flood depth is a major factor, which can influence the damage cost of flood event on properties. For a bungalow, there is a an increase in damage of approximately 11% when compared flood depth up to 150mm with depth of 300mm. However, for other property types, the level of increase from one flood depth to another is relatively consistent; this could be as a result of the various approaches to strip-out adopted by different surveyors.

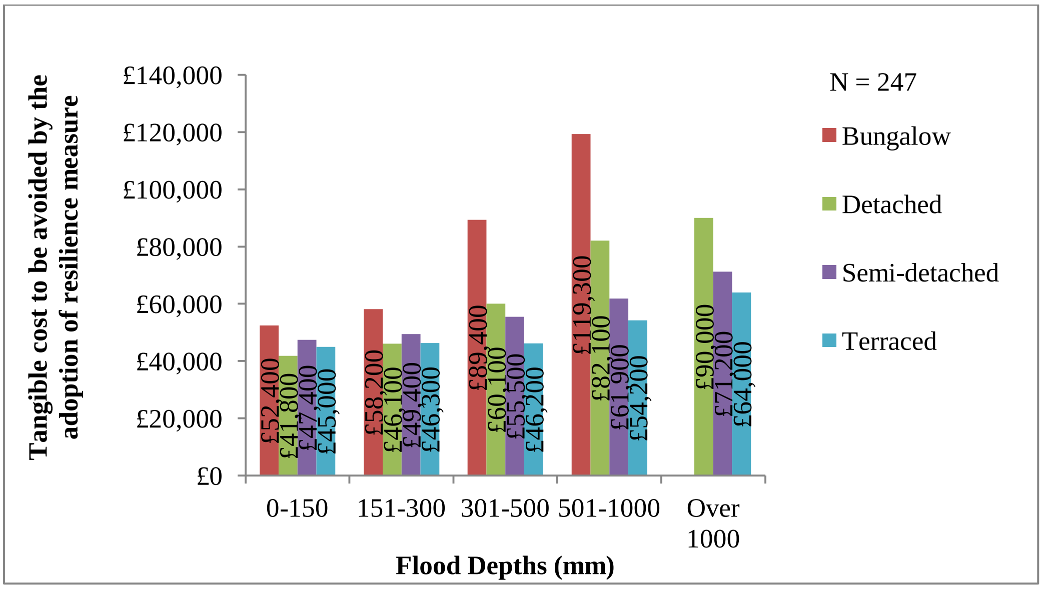


Figure 8.1 Expected damage to be avoided based on a single flood event

Having established a damage profile for a single flood event, the analysis of the expected cumulative damage (ECD) avoided is presented for resistance and resilience measures.

8.2.1 Analysis of expected cumulative damage (ECD) avoided for resistance measures

The calculation of ECD avoided involves the integration of a damage probability distribution (Goldman, 1997). The damage probability distribution is usually estimated from a set of distributing variables, which most typically consists of flood probability (p). In calculating the ECD avoided for resistance measures, of the 247 samples, only 159 (64%) were considered suitable for the analysis. This is because the flood threshold at which resistance measures are suitable and advisable as discussed in section 7.3 is 600mm. Therefore, properties flooded above 600mm were excluded from this analysis. The ECD avoided established in this section is also referred to as gross benefits of resistance measures because these are the benefits to be achieved if resistance measures are installed and deployed correctly. In establishing the ECD avoided, the following steps were taken:

(1) The do nothing option is taken as the actual traditional claim cost, shown in Figure 8.1 as the damage profile. The 'do nothing option', is based on conservative assumption that the total claim cost will remain the same following a subsequent flood event, although this is a conservative hypothesis considering the growth of financial and economic losses due to natural disasters (Mill *et al.* 2005; Munich Re, 2005). Therefore, no inflationary effect was taken into consideration.

(2) The results obtained from step (1) are then discounted to present value by applying 8% discount rate ( ) and flood return period (n). The results are then summed up over 20-years to establish expected cumulative damage (ECD) avoided for each property type.

The ECD avoided, which is the gross benefit (GB) of resistance measures, is expressed mathematically as:

$$GB_f = \sum p * \left(\frac{1}{1+\delta}\right)^y * d_y \text{ ......equation 15}$$

Where;

GB_f, denotes the avoided damage at flood return period f

'p' denotes the annual flood probability for return period f

'f' denotes the flood return period in year

'y' varies from 1 to 20-years (the rationale behind the 20-years is that, it is anticipated that renovation would have been carried out within 20-years, for instance kitchen units would have been replaced within this period)

d_y denotes the value of avoidable damages in the year 'y'

By applying equation 15, the ECD avoided for adopting resistance measures were calculated for each property type based on two deployment (manual and automatic) methods as discussed in chapter 7, section 7.3. Table 8.1 shows the results of the analysis. The results show direct relationship between ECD avoided and flood probability. Thus, the ECD avoided decreases as flood probability decreases for both deployments methods. This means that property located in high flood risk areas are expected to suffer more damage compared to property in low flood risk areas, therefore installation of resistance measures in high flood risk areas will avoid greater flood damage. The ECD avoided for automatic resistance measures is greater than manually deployed measures, this is because the effectiveness of manually deployed measure is anchored on the fact that someone must be on hand to deploy the measures when they are required, and failure to do this will result in higher damage. Alternatively, automatic measures do not require such assistance in order to perform, hence the reason for its higher cost as discussed in section 7.3.3. The assumption taken was based on the result of Thurston *et al*. (2008) study, which shows that automatically deployed resistance measures will reduce damaged caused by flooding to a property by approximately 24.5% when compared to the manually deployed method.

Table 8.1 Expected Cumulative Damage (ECD) avoided over 20 years for resistance measures

Flood return period / Flood probability (p)	Bungalow		Detached		Semi-detached		Terraced	
	Manual	Auto	Manual	Auto	Manual	Auto	Manual	Auto
5 year (0.20)	£98,356	£122,453	£63,002	£78,438	£62,835	£78,229	£56,503	£70,347
10 year (0.10)	£49,178	£61,226	£31,501	£39,219	£31,417	£39,115	£28,252	£35,173
20 year (0.05)	£24,589	£30,613	£15,751	£19,609	£15,709	£19,557	£14,126	£17,587
25 year (0.04)	£19,671	£24,491	£12,600	£15,688	£12,567	£15,646	£11,301	£14,069
40 year (0.025)	£12,294	£15,307	£7,875	£9,805	£7,854	£9,779	£7,063	£8,793
50 year (0.02)	£9,836	£12,245	£6,300	£7,844	£6,283	£7,823	£5,650	£7,035

8.2.2 Analysis of expected Cumulative damage (ECD) avoided for resilience measures

The 247 properties in the sample (as discussed in section 7.4.1) were used in calculating the ECD avoided for resilience measures. Equation 15 presented in section 8.2.1 was used for the calculation; the ECD avoided were derived for different property types, based on varying flood depth and the results are presented based on floor construction methods as discussed in section 7.4.2. The detailed results of the ECD avoided based on the premise that resilience measures have been implemented are presented in Tables 8.2 to 8.5.

Table 8.2 presents the ECD avoided for a bungalow property (concrete and timber floor), it can be seen that the value of damage avoided for a shorter flood return period

(5-years) across flood depth are significantly higher when compared to other flood return periods. The percentage difference between the ECD avoided across flood depths ranges from 11% (0-150-1 to 151-300mm) to 54% (151-300 to 301-500mm) for concrete and suspended floor properties. The high value of ECD avoided for higher flood depths is not unexpected, because at higher flood depth, it is expected that households will be relocated to temporary alternative accommodations and the repair period for such level of flooding is expected to be higher when compared to how long it normally takes to repair property that suffered shallow flooding.

The value of ECD avoided for suspended timber floor properties are higher than that of concrete floor properties, this is because following flood event, during reinstatement, concrete flood property will only need to be dried prior to reinstatement which means that there will not be a requirement to replace the concrete floor. For a suspended timber floor property, during reinstatement, the timber floor in most cases will need to be replaced, hence the higher ECD avoided for a suspended timber floor property when compared to concrete floor property. The overall trends that are seen in the ECD avoided for bungalow are repeated for other property types (detached, semi-detached and terraced as shown in Tables 8.3-8.5).

Table 8.2 Expected Cumulative Damage (ECD) avoided for bungalow based on resilience measures

Floor Construction	Flood return period (year) / Flood probability (p)	Flood depths (mm)			
		0-150	151-300	301-500	501-1000
Concrete Solid floor	5 year (0.20)	£87,265	£96,924	£148,883	£198,677
	10 year (0.10)	£43,632	£48,462	£74,441	£99,339
	20 year (0.05)	£21,816	£24,231	£37,221	£49,669
	25 year (0.04)	£17,453	£19,385	£29,777	£39,735
	40 year (0.025)	£10,908	£12,115	£18,610	£24,835
	50 year (0.02)	£8,726	£9,692	£14,888	£19,868
Suspended timber floor	5 year (0.20)	£95,991	£106,616	£163,771	£218,544
	10 year (0.10)	£47,995	£53,308	£81,885	£109,272
	20 year (0.05)	£23,997	£26,654	£40,942	£54,636
	25 year (0.04)	£19,198	£21,323	£32,754	£43,708
	40 year (0.025)	£11,998	£13,327	£20,471	£27,318
	50 year (0.02)	£9,599	£10,661	£16,377	£21,854

Table 8.3 Expected Cumulative Damage (ECD) avoided for detached properties based on resilience measures

Floor Construction	Flood return period (year) / Flood probability (p)	Flood depths (mm)				
		0-150	151-300	301-500	501-1000	Over 1000
Concrete Solid floor	5 year (0.20)	£69,612	£76,773	£100,088	£136,726	£149,882
	10 year (0.10)	£34,806	£38,386	£50,044	£68,363	£74,941
	20 year (0.05)	£17,403	£19,193	£25,022	£34,181	£37,471
	25 year (0.04)	£13,922	£15,355	£20,018	£27,345	£29,976
	40 year (0.025)	£8,701	£9,597	£12,511	£17,091	£18,735
	50 year (0.02)	£6,961	£7,677	£10,009	£13,673	£14,988
Suspended timber floor	5 year (0.20)	£76,573	£84,450	£110,097	£150,398	£164,870
	10 year (0.10)	£38,287	£42,225	£55,048	£75,199	£82,435
	20 year (0.05)	£19,143	£21,113	£27,524	£37,600	£41,218
	25 year (0.04)	£15,315	£16,890	£22,019	£30,080	£32,974
	40 year (0.025)	£9,572	£10,556	£13,762	£18,800	£20,609
	50 year (0.02)	£7,657	£8,445	£11,010	£15,040	£16,487

Table 8.4 Expected Cumulative Damage (ECD) avoided for semi-detached properties based on resilience measures

Floor Construction	Flood return period (year) / Flood probability (p)	Flood depths (mm)				
		0-150	151-300	301-500	501-1000	Over 1000
Concrete Solid floor	5 year (0.20)	£78,938	£82,269	£92,427	£103,086	£118,573
	10 year (0.10)	£39,469	£41,134	£46,214	£51,543	£59,287
	20 year (0.05)	£19,734	£20,567	£23,107	£25,771	£29,643
	25 year (0.04)	£15,788	£16,454	£18,485	£20,617	£23,715
	40 year (0.025)	£9,867	£10,284	£11,553	£12,886	£14,822
	50 year (0.02)	£7,894	£8,227	£9,243	£10,309	£11,857
Suspended timber floor	5 year (0.20)	£86,832	£90,496	£101,670	£113,394	£130,431
	10 year (0.10)	£43,416	£45,248	£50,835	£56,697	£65,215
	20 year (0.05)	£21,708	£22,624	£25,418	£28,349	£32,608
	25 year (0.04)	£17,366	£18,099	£20,334	£22,679	£26,086
	40 year (0.025)	£10,854	£11,312	£12,709	£14,174	£16,304
	50 year (0.02)	£8,683	£9,050	£10,167	£11,339	£13,043

Table 8.5 Expected Cumulative Damage (ECD) avoided for terraced properties based on resilience measures

Floor Construction	Flood return period (year) / Flood probability (p)	Flood depths (mm)				
		0-150	151-300	301-500	501-1000	Over 1000
Concrete Solid floor	5 year (0.20)	£74,941	£77,106	£76,940	£90,262	£106,583
	10 year (0.10)	£37,471	£38,553	£38,470	£45,131	£53,291
	20 year (0.05)	£18,735	£19,277	£19,235	£22,566	£26,646
	25 year (0.04)	£14,988	£15,421	£15,388	£18,052	£21,317
	40 year (0.025)	£9,368	£9,638	£9,617	£11,283	£13,323
	50 year (0.02)	£7,494	£7,711	£7,694	£9,026	£10,658
Suspended timber floor	5 year (0.20)	£82,435	£84,817	£84,633	£99,289	£117,241
	10 year (0.10)	£41,218	£42,408	£42,317	£49,644	£58,621
	20 year (0.05)	£20,609	£21,204	£21,158	£24,822	£29,310
	25 year (0.04)	£16,487	£16,963	£16,927	£19,858	£23,448
	40 year (0.025)	£10,304	£10,602	£10,579	£12,411	£14,655
	50 year (0.02)	£8,244	£8,482	£8,463	£9,929	£11,724

Across different property types and flood depths, the ECD avoided are considerable if resilience measures are implemented, although the ECD avoided values tend to decline as the flood return period increases. This means that properties located in high flood risk areas are likely to benefit more from the implementation of flood resilience measures.

8.3 BENEFIT COST RATIO OF PLFRA MEASURES WITHOUT INTANGIBLE BENEFITS

Having estimated the costs (in chapter 7) and the gross tangible benefits (section 8.2) of adaptation measures, the next and final stage is the presentation of results in a simple and understandable form for decision making. In doing this, BCR techniques are typically used. The BCR was defined in chapter 3 as the ratio of the present value of the benefits relative to the present value of the costs (Preez, 2004). This represents the ratio of total benefits over total costs, both discounted as appropriate. BCR for resistance and resilience measures are presented in this section.

8.3.1 Analysis of benefit cost ratio (BCR) of resistance measures

Knowledge of the relationship between cost and benefits of the measures has the potential to assist homeowners in making a decision to invest in such measures. The equation used in establishing the benefit cost ratio of resistance measures is presented as:

BCR = ECD_{rs} / CM_{rs} ……………………………………………………………equation 16

Where ECD_{rs}, denotes value of gross tangible benefits of resistance measure (as presented in Table 8.1, and CM_{rs}, denotes cost of resistance measures (as summarised in chapter 7, Table 7.8).

From equation 16 above, it can be inferred that the relationship between the costs and the associated benefits of the resistance measures is such that the costs of the measures must be less than the value of the benefits for it to be cost beneficial.

Table 8.6 presents the BCR of resistance measures across different property types and two deployment methods. Due to the low cost of manually deployed resistance measures, a high benefit cost ratio was yielded when compared with automatic deployed measures. Across different property types, the benefit cost ratio for manually deployed resistance measures ranges from 9.8 to 16.3 within the 20% flood probability (5-years flood return period) which is categorised as high flood risk area. This means that for every £1 spent on manually deployed resistance measure between £9.80 and £16.30 is gained as benefit within the first five years if such properties are inundated again. Conversely, the BCR for automatic deployed resistance measure ranges from 7.7 to 13.5 within the 20% (5-years) flood return period, meaning that for every £1 spent on automatically deployed resistance measure, benefits of £7.70 and £13.50 are gained within the first five years if such properties are flooded again. In contrast, neither manually nor automatic deployed measures are cost effective for properties located in areas designated as 40-years or greater return period. These benefit cost ratios presented here shows an enhanced BCR when compared with other studies, such as Thurston *et al.* (2008); JBA (2012) and Royal Haskoning (2012).

Table 8.6 Benefit cost ratio of resistance measures based on different property types and deployment methods

Flood return period (year) / Flood probability (p)	Bungalow		Detached		Semi-detached		Terraced	
	Manual	Auto	Manual	Auto	Manual	Auto	Manual	Auto
5 year (0.20)	14.5	11.3	9.8	7.7	15.8	11.7	16.3	13.5
10 year (0.10)	7.2	5.7	4.9	3.8	7.9	5.9	8.1	6.7
20 year (0.05)	3.6	2.8	2.5	1.9	3.9	2.9	4.1	3.4
25 year (0.04)	2.9	2.3	2.0	1.5	3.2	2.3	3.3	2.7
40 year (0.025)	1.8	1.4	1.2	1.0	2.0	1.5	2.0	1.7
50 year (0.02)	1.4	1.1	1.0	0.8	1.6	1.2	1.6	1.3

8.3.2 Analysis of benefit cost ratio (BCR) of resilience measure

The equation used in establishing the benefit cost ratio of resilience measures is presented as:

$$BCR = {ECD_{rt}}/{CM_{rt}} \quad \text{……equation 17}$$

Where ECD_{rt}, denotes value of the gross benefits of resilience measure (as presented in Tables 8.2-8.5), and CM_{rt}, denotes cost of resilience measures (as summarised in chapter 7, Table 7.8).

After applying equation 17, BCR were calculated for resilience measures based on different property types and varying flood depths. Table 8.7 presents the BCR for the four property types, across different flood return periods and based on floor construction materials/methods. The decision rule of CBA is such that when B ≥1 the project should be implemented (Snell, 2011).

It can be seen that across different flood depths and property types, it is cost beneficial to invest in resilience measures for concrete floor construction property located in area designated as 25-years flood return period (which is a 4% chances of being flood in 25-years period) or over. Properties located within the 5-years flood return period (20% flood probability) yielded the highest BCR across all properties and flood depth. BCR of 8.3 was recorded for a concrete floor bungalow flooded up to 500mm, whilst its timber counterpart yielded BCR of 5.7. That is, for every £1 spent on resilience measures for a concrete floor bungalow located in high risk flood area of 5-years flood return period with flood depth of up to 500mm, the benefit gained is £8.30 and for suspended timber floor bungalow the benefit gained is £5.70, if such properties are inundated within the first five years of investing in the measures.

The BCR presented in this research are higher when compared to other studies such as Thurston *et al.* (2008) and Royal Haskoning (2012). This is explained by the use of actual event data, which in most cases are higher than the theoretical approach on which these studies were based. For concrete and timber floor properties located in areas designated as having 40-years or greater flood return period, the BCR≤1, meaning that resilience measures may not be cost beneficial for such property, if only the tangible benefits are taken into consideration. The analysis conducted on the costs and benefits of adaptation measures (without intangibles) has shown that, in most circumstances, the use of resilience measures will be less cost beneficial when compared to resistance measures, this reflects the higher upfront installation costs of resilience measures.

The findings for both resistance and resilience measures provide support for the null hypothesis which stated that the benefits of PLFRA measures will outweigh the costs of the measures based on flood risk and flood return periods. Therefore the alternative hypothesis that the costs will outweigh the benefits is rejected. There is sufficient evidence from these results to accept the null hypothesis that the tangible benefits of PLFRA measures outweigh the costs.

Table 8.7 Benefit cost ratio of resilience measures based on different house types, varying flood depths, flood return period and flood probability

Floor construction	**Flood return period (year)**	**Bungalow**				**Detached**					**Semi-detached**					**Terraced**				
		Flood depths (mm)				**Flood depths (mm)**					**Flood depths (mm)**					**Flood depths (mm)**				
		0-150	**151-300**	**301-500**	**501-1000**	**0-150**	**151-300**	**301-500**	**501-1000**	**Over 1000**	**0-150**	**151-300**	**301-500**	**501-1000**	**Over 1000**	**0-150**	**151-300**	**301-500**	**501-1000**	**Over 1000**
Concrete solid floor	5 year (0.20)	6.2	6.0	8.3	7.0	5.7	5.4	5.6	6.0	6.2	6.2	5.7	5.9	5.6	6.1	5.7	5.3	5.0	5.4	5.4
	10 year (0.10)	3.1	3.0	4.2	3.5	2.9	2.7	2.8	3.0	3.1	3.1	2.9	2.9	2.8	3.1	2.9	2.6	2.5	2.7	2.7
	20 year (0.05)	1.5	1.5	2.1	1.8	1.4	1.3	1.4	1.5	1.6	1.5	1.4	1.5	1.4	1.5	1.4	1.3	1.2	1.3	1.3
	25 year (0.04)	1.2	1.2	1.7	1.4	1.1	1.1	1.1	1.2	1.2	1.2	1.1	1.2	1.1	1.2	1.1	1.1	1.0	1.1	1.1
	40 year (0.025)	0.8	0.7	1.0	0.9	0.7	0.7	0.7	0.8	0.8	0.8	0.7	0.7	0.7	0.8	0.7	0.7	0.6	0.7	0.7
	50 year (0.02)	0.6	0.6	0.8	0.7	0.6	0.5	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.5	0.5	0.5	0.5
Suspended timber floor	5 year (0.20)	4.2		5.7		5.8	5.1	5.7	6.0	6.2	6.1	5.3	5.6	5.6	5.7	5.6	5.1	4.4	4.3	4.8
	10 year (0.10)	2.1		2.8		2.9	2.5	2.8	3.0	3.1	3.0	2.7	2.8	2.8	2.8	2.8	2.6	2.2	2.2	2.4
	20 year (0.05)	1.0		1.4		1.4	1.3	1.4	1.5	1.5	1.5	1.3	1.4	1.4	1.4	1.4	1.3	1.1	1.1	1.2
	25 year (0.04)	0.8		1.1		1.2	1.0	1.1	1.2	1.2	1.2	1.1	1.1	1.1	1.1	1.1	1.0	0.9	0.9	1.0
	40 year (0.025)	0.5		0.7		0.7	0.6	0.7	0.7	0.8	0.8	0.7	0.7	0.7	0.7	0.7	0.6	0.5	0.5	0.6
	50 year (0.02)	0.4		0.6		0.6	0.5	0.6	0.6	0.6	0.6	0.5	0.6	0.6	0.6	0.6	0.5	0.4	0.4	0.5

8.4 SUMMARY

The flood damage profile for resilience measures in the form of expected annual damage (EAD) avoided was established, the result shows that bungalow exhibit higher EAD avoided value due to the higher costs of reinstating bungalow following flood damage. The values of expected cumulative damage (ECD) avoided for each of the measures over 20-years for different property types were subsequently established. Following which the BCR analyses of the data on costs and benefits of PLFRA measures were presented. An overview of the trends of gross tangible benefits and benefit cost ratio across different property types, flood depths and varying flood return periods were also presented. The evidence from the analysis clearly indicates that the tangible benefits of adaptation measures vary on the basis of different property types and varying flood depths.

It is shown from the findings that for every £1 spent on manually deployed resistance measures insurers benefit between £9.80 and £16.30 and for automatically deployed resistance measures the benefits are between £7.70 and £13.50, depending on property type and flood depth. However, this is based on the assumption that such properties are located in an area with 20% flood probability (5-years flood return period). Further, the findings with regards to the resilience measures showed lower benefit cost ratios when compared to the resistance measures. Investment in resilience measures yielded average of £5.90 for every £1 for property located within the 20% (5-years) flood return period, whilst the combined manual and automatic resistance measures yielded average of £12.60 for every £1 invested. It can be concluded that the relationship between benefit cost ratio and flood return period is inverse in nature, that is, as the return period increases, then the benefit cost ratio decreases.

Having established the benefits of PLFRA in the form of expected cumulative damage (ECD) avoided and its benefit cost ratio in this chapter, comprehensive CBA models of adaptation measures are developed in the next chapter by incorporating the value of intangible benefits in the analysis.

CHAPTER NINE: DEVELOPMENT OF CBA MODEL OF PLFRA MEASURES

9.1 INTRODUCTION

Willingness to pay (WTP) values to avoid intangible impacts of flooding were established in chapter six, whilst in chapter seven the additional costs of PLFRA measures were established, in chapter eight, the tangible benefits in the form of expected cumulative damage (ECD) avoided of different PLFRA measures based on different property types, flood depths and floor construction methods were established. These analyses have provided some insight into the benefit cost ratio of adaptation measures but without incorporation of the intangible benefits.

This chapter addresses the eighth objective of the research, which is to develop a CBA model of PLFRA measures which incorporates all relevant cost and benefit components. This will enable the additional costs of adaptation measures to be related to the benefits of the measures and thus assist in decision making process for adaptation measures. By so doing, this chapter attempts to answer the final research question of whether or not investing in PLFRA measures can improve the general well being of households and yield greater benefits to households, this is explored by presenting the benefit cost ratio, which includes the intangible benefits of PLFRA measures.

9.2 COMBINED TANGIBLE AND INTANGIBLE COST BENEFIT ANALYSIS MODEL

The main research aim was to develop a CBA model of PLFRA measures ensuring that all associated costs and benefits are incorporated in the developed model. Overall, it was established that the sum of £653 per household per year be taken as the value of the intangible impacts of flooding on households. The value of tangible and intangible benefits were combined and incorporated in the CBA model.

9.2.1 Empirical benefits of PLFRA measures to homeowners

In order to develop the CBA model of PLFRA measures, the combined benefits of the measures from the empirical analysis in chapter six were aggregated so that the value could be incorporated in the model. For the purpose of this research the following equation was used to derive the combined benefits of the measures:

$$TB_{home} = B_{In\tan} + B_{\tan} \quad \text{……………………………………..........................equation 18}$$

Where, TB_{home} is the total benefit, which is the summation of the intangible and tangible benefits to homeowners, these benefits exclude repair and temporary alternative accommodation costs, which are normally paid for by individual insurance providers. B_{intan} is the mean annual WTP values established in section 6.10.1, and B_{tan} is the potential benefit, which is the summation of extra expenses incurred while in temporary alternative accommodation as presented in section 6.4.5. The expected tangible benefits figure (B_{tan}) for a household is related to the flood return period; therefore, the value within the cost benefit model is based on flood probability. By applying the flood probability to the value of extra expenses incurred by respondents while in alternative accommodation (as presented in section 6.4.5), the total avoided loss based on expenses on food, travel, telephone and unpaid leave were estimated, this is presented in Table 9.1.

Table 9.1 Total annual extra expenses incurred, while in alternative accommodation based on flood probability *(B_{tan})*

Activities on which extra expenses were incurred	*Mean extra expenses	Flood Probability (Return Period)					
		20% (5yrs)	10% (10yrs)	5% (20yrs)	4% (25yrs)	2.5% (40yrs)	2% (50yrs)
Food	£231.65	£46.33	£23.17	£11.58	£9.27	£5.79	£4.63
Travelling	£185.00	£37.00	£18.50	£9.25	£7.40	£4.63	£3.70
Telephone	£150.35	£30.07	£15.04	£7.52	£6.01	£3.76	£3.01
Unpaid leave	£302.70	£60.54	£30.27	£15.14	£12.11	£7.57	£6.05
Total	**£869.70**	**£173.94**	**£86.97**	**£43.49**	**£34.79**	**£21.74**	**£17.39**

***Mean extra expenses obtained from the raw survey data**

The total annual benefits to homeowners were computed by combining the value of B_{intan} and the value of B_{tan} for each flood probability; the resulting figures were entered into the database. In order to establish the cumulative benefit to homeowners (TB_{home}), which is the avoided loss over 20-years, the annual benefits to homeowners based on flood probability were discounted by 8% over 20-years. These discounted values were included in the benefit data set to account for the total benefits of PLFRA measures in readiness for the development of CBA model of PLFRA measures.

9.3 CBA MODEL OF PROPERTY LEVEL FLOOD RISK ADAPTATION (PLFRA) MEASURES

Motulsky (1995) defined a model as a mathematical abstraction that is an analogy of events in the real world. Ford (2009) asserted that a model can come in many shapes, sizes, and styles. However, Ford (2009) emphasised that a model is not the real world but merely a human construct to help in understanding the real world systems. In general, all models have an information input, an information processor, and an output of expected results. In this research, the main aim was to develop a CBA model of PLFRA measures to assist in the decision making process on investing in adaptation measures. Having established the additional cost of PLFRA measures and benefits of the measures, this section presents the CBA model of PLFRA measures based on property types, floor construction methods (suspended timber and concrete) and flood depths.

9.3.1 Cost benefit model of resistance measures

In developing the CBA model for resistance measures, the value of intangibles were discounted and entered into the database, this generates the discounted benefit of resistance measures (Table 9.2) and subsequently the benefit cost ratios were generated (Table 9.3).

In Table 9.2 with the inclusion of the value of intangible benefits, there is a significant increase in the total value of benefits from investing in either manual or automatic resistance measures. For instance, in chapter 8 section 8.2.1, the gross benefit of investing in manually deployed resistance measure for a bungalow property located in an area designated as 5-years return period was £98,356; however, when the value of intangible benefit is accounted (Table 9.2), the benefit increases to £106,475 representing an 8% increase.

Table 9.2 Median discounted benefit of resistance measures incorporating value of intangible benefits

Flood return period (Flood probability FP)	Bungalow		Detached		Semi-detached		Terraced	
	Manual	Automatic	Manual	Automatic	Manual	Automatic	Manual	Automatic
5 year (0.20)	£106,475	£130,572	£71,121	£86,557	£70,954	£86,348	£64,622	£78,466
10 year (0.10)	£56,443	£68,492	£38,766	£46,484	£38,682	£46,380	£35,517	£42,438
20 year (0.05)	£31,427	£37,451	£22,589	£26,448	£22,547	£26,395	£20,964	£24,425
25 year (0.04)	£26,424	£31,243	£19,353	£22,440	£19,320	£22,399	£18,053	£20,822
40 year (0.025)	£18,919	£21,931	£14,500	£16,429	£14,479	£16,403	£13,688	£15,418
50 year (0.02)	£16,418	£18,827	£12,882	£14,426	£12,865	£14,405	£12,232	£13,617

The relationship between the overall benefit cost ratio and flood return period for different property types and deployment methods when intangible benefits are accounted for is presented in Table 9.3. With the inclusion of intangible benefits, the

BCR increase by approximately 8.3% when compared with BCR without intangible benefits, as discussed in section 8.3.1 (Table 8.6). Manually deployed resistance measures yielded higher benefit when compared with automatically deployed measures. This is due to the low upfront cost of manually deployed measures. The result shows that for every £1 invested in manually deployed measures on a bungalow located in an area designated as 5-years flood return period, a return of £15.70 can be achieved, this representing the value of avoided loss. The automatically deployed measures yielded a return of £12.10. It can be inferred that if manually deployed resistance measures are deployed correctly and function effectively, they can avoid flood losses effectively as the automatic deployed measures. The main reason for the significant difference in the benefit cost ratio for both manual and automatic resistance measures is due to the higher initial cost of installing automatic measures.

Table 9.3 Benefit cost ratio for resistance measures incorporating intangible benefits

Flood return period (Flood probability FP)	Bungalow		Detached		Semi-detached		Terraced	
	Manual	Automatic	Manual	Automatic	Manual	Automatic	Manual	Automatic
5 year (0.20)	15.7	12.1	11.1	8.5	17.8	12.9	18.6	15.0
10 year (0.10)	8.3	6.3	6.0	4.5	9.7	6.9	10.2	8.1
20 year (0.05)	4.6	3.5	3.5	2.6	5.7	4.0	6.0	4.7
25 year (0.04)	3.9	2.9	3.0	2.2	4.8	3.4	5.2	4.0
40 year (0.025)	2.8	2.0	2.3	1.6	3.6	2.5	3.9	3.0
50 year (0.02)	2.4	1.7	2.0	1.4	3.2	2.2	3.5	2.6

9.3.2 Impacts of incorporating intangible benefits in the CBA model of resistance measures

When intangible benefits are incorporated in the benefit analysis of resistance measures, the results show that the benefit cost ratio incorporating the intangible value of benefit, yielded approximately 8% more than the BCR without intangible value. The majority of the resistance measures based on different property types are cost beneficial up to 50-

years flood return period showing BCR ≥ 1. This result is a significant uplift over the BCR without the inclusion of intangibles (Table 8.8). The least cost beneficial within the 50-years flood return period is automatic resistance measures deployed in a detached property, this shows a BCR of 1.4. (i.e. for every £1 spend on resistance measure for a detached property a benefit of £1.40 is yielded). When this is compared to the benefit cost ratio without the value of intangible benefits (Table 8.8, row 5 column 8) it shows that at 50-years flood return period, it is not cost beneficial to invest in automatic resistance measures. It can, therefore, be inferred that the incorporation of intangible benefits in the CBA model of resistance measures generates an improved financial benefits. Thereby, making it cost beneficial for properties located in low flood risk areas.

9.3.3 Cost benefit analysis (CBA) model of resilience measures

Research has shown that the property type, floor construction and flood depth are the major factors that have the potential to influence the costs and benefits of flood protection measures, such as resilience measures (Penning-Rowsell *et al*. 2005; Thurston *et al.* 2008; Joseph *et al.* 2011a; Royal Haskoning, 2012). Therefore, in developing the CBA model of resilience measures, these three variables were included in the model. First the median cost of resilience measures presented in chapter 7, section 7.5 (Table 7.8) was used, and then the discounted benefit of resilience measures were generated incorporating the value of intangible benefits obtained from empirical analysis; thereafter, the benefit cost ratios were calculated based on the three variables. The results of the analyses based on different property types are presented in the next section.

The discounted median benefits of investing in resilience measures for the four property types (bungalow, detached, semi-detached and terraced) based on two different floor construction methods and different flood depths are presented in Appendices C-1 to C-4. Resilience measures yielded higher financial benefits across all flood depths relative to benefits without the inclusion of intangible benefits. With the incorporation of intangible benefits the result shows significant improvement of approximately 9% when compared with tangible benefits of resilience measures as discussed in section 8.2.2. Further, the impact of incorporating the value of intangible impacts in the model shows that for all flood return periods, the benefit outweighs the cost, meaning that investing in resilience measures for a property located in area defined as low flood risk is cost beneficial when value of intangible benefits is included in the model.

The median value of benefit of resilience measures presented in Appendices C-1 to C-4 were used together with the cost presented in Table 7.7 to generate the BCR to assist in decision making on investing in resilience measures for all the property types used in this research with varying flood depth and floor construction methods. The combined results are illustrated in Table 9.4. The discussion on the benefit cost ratio for each of the property type is presented below.

Benefit cost ratio of a bungalow property

Across four different flood depths for a bungalow with a solid concrete floor, investing in resilience measures is cost beneficial up to 40-years flood return period, apart from flood depth over 500mm where the benefit cost ratio was less than 1 (BCR = 0.9). Although for a suspended timber floor, the result shows that investing in resilience measure is cost beneficial for property located in area designated up to 25-years flood return period, over this return period it is no longer cost beneficial to invest in the measures. The incorporation of intangible benefits shows improvement in benefits for only concrete floor bungalow while for suspended timber floor bungalow the threshold at which it is cost beneficial to invest in the resilience measures remains the same when compared to BCR without intangibles (section 8.3.2), although there is a marginal improvement in the value of BCR with and without intangible benefits (e.g. BCR without intangible benefits = 4.2, while BCR with intangible benefits = 4.6). This is due to the higher cost of adapting a suspended timber floor property to flood risk by replacing the timber floor with concrete as discussed in chapter 2.

Benefit cost ratio of a detached property

The BCR of investing in resilience measure incorporating intangible benefit for a detached property is illustrated in Table 9.4. Similar to a bungalow, for a detached property with a solid concrete floor construction, the results show that it is cost beneficial to invest in resilience measure if such property is located in an area designated as 40-years flood return period or shorter, with the exception of property with flood depths over 500mm, where at flood return period 40-years, the result shows a BCR of 1:1, meaning that for every £1 invested in the measure, a benefit of £1 is gained as value of avoided loss. However, for a suspended floor detached property, investing in resilience measures is cost beneficial at flood return period of 25-year or less. Although, flood depth up to 150mm shows a BCR of 1.1 for a flood return period of up to 50-years, meaning that for every £1 invested in resilience measure a benefit of £1.10 will be gained as the value of avoided loss.

Benefit cost ratio of a semi-detached property

The analysis of the benefit cost ratio for a semi-detached property as presented in Table 9.4 shows a similar result to the one obtained for detached property. It is generally cost beneficial to invest in resilience measures if such properties are located in flood areas designated as 40-years flood return period. Equally, for a semi-detached property with suspended timber floor, investing in resilience measures is cost beneficial if such property is located in a 40-year flood return period area, apart from flood depths over 500mm, which show BCR of 1:1.

Benefit cost ratio of a terraced property

The BCR for terraced property presented in Table 9.4 are similar to other property types. For a terraced property with concrete floor, it is generally cost beneficial to invest in resilience measures if such property is located in flood area designated as 40-years flood return period, with the exception of flood depth up to 500mm and over 1000mm which show BCR of 1:1. For a terraced property with suspended timber floor across flood depths, investing in resilience measure is cost beneficial if such property is located in an area designated as 25-years flood return period. However, properties which normally experience shallow floods (up to 100mm) are seen to be cost beneficial up to 40-years flood return periods (BCR 1:1.2).

The CBA models of resilience measures presented in this section show the flood threshold at which investing in resilience measures becomes cost beneficial when intangible benefits are accounted for, is significantly higher when compared with BCR with no intangible benefits.

EA/DEFRA (2004) suggested that where results are sensitive to any weighting adjustment, a sensitivity analysis should be provided. In line with this suggestion, a sensitivity analysis was carried out to determine the effect of using lower discount rates on the developed CBA model as discussed in section 4.3.3.

Table 9.4 Benefit cost ratio (BCR) for resilience measures incorporating the value of intangible benefits

Floor construction	Flood return period (Flood probability (p)	Bungalow				Detached					Semi-detached					Terraced				
		Flood depths (mm)				Flood depths (mm)					Flood depths (mm)					Flood depths (mm)				
		0-150	151-300	301-500	501-1000	0-150	151-300	301-500	501-1000	Over 1000	0-150	151-300	301-500	501-1000	Over 1000	0-150	151-300	301-500	501-1000	Over 1000
Concrete solid floor	5 year (0.20)	6.8	6.5	8.8	7.3	6.4	5.9	6.1	6.4	6.6	6.8	7.0	7.8	8.7	9.9	6.4	6.5	6.5	7.5	8.8
	10 year (0.10)	3.6	3.4	4.6	3.8	3.4	3.2	3.2	3.3	3.4	3.6	3.4	3.4	3.2	3.5	3.4	3.1	3.0	3.1	3.1
	20 year (0.05)	2.0	1.9	2.5	2.0	2.0	1.8	1.8	1.8	1.8	2.1	1.9	1.9	1.8	1.9	2.0	1.8	1.7	1.8	1.7
	25 year (0.04)	1.7	1.6	2.0	1.6	1.7	1.5	1.5	1.5	1.5	1.8	1.6	1.6	1.5	1.6	1.7	1.5	1.4	1.5	1.4
	40 year (0.025)	1.2	1.2	1.4	1.1	1.3	1.1	1.1	1.0	1.1	1.3	1.2	1.2	1.1	1.1	1.2	1.1	1.0	1.1	1.0
	50 year (0.02)	1.1	1.0	1.2	0.9	1.1	1.0	0.9	0.9	0.9	1.1	1.0	1.0	0.9	1.0	1.1	1.0	0.9	0.9	0.9
Suspended Timber floor	5 year (0.20)	4.6		6.4		6.4	5.6	6.1	6.3	6.5	6.7	5.8	6.0	6.0	6.0	6.2	5.6	4.8	4.7	5.1
	10 year (0.10)	2.5		3.3		3.4	3.0	3.2	3.3	3.4	3.6	3.1	3.2	3.1	3.2	3.3	3.0	2.6	2.5	2.7
	20 year (0.05)	1.4		1.8		2.0	1.7	1.8	1.8	1.8	2.0	1.7	1.8	1.7	1.7	1.9	1.7	1.4	1.4	1.5
	25 year (0.04)	1.2		1.5		1.7	1.4	1.5	1.5	1.5	1.7	1.5	1.5	1.4	1.4	1.6	1.4	1.2	1.2	1.2
	40 year (0.025)	0.9		1.0		1.2	1.0	1.0	1.0	1.0	1.2	1.1	1.1	1.0	1.0	1.2	1.0	0.9	0.8	0.9
	50 year (0.02)	0.7		0.8		1.1	0.9	0.9	0.9	0.9	1.1	0.9	0.9	0.9	0.9	1.0	0.9	0.8	0.7	0.7

9.4 SENSITIVITY ANALYSIS

Sensitivity analysis is used to determine how *"sensitive"* a model is to changes in the value of the variables of the model and to changes in the structure of the model (Breierova and Choudhari, 1996). Sensitivity analysis helps build confidence in the model by studying the uncertainties that are often associated with variables in models. Breierova and Choudhari (1996) asserted that sensitivity analysis can also indicate which variables are reasonable to use in the model. If the model behaves as expected from real world observations, it gives some indication that the parameter values reflect, at least in part, the "real world". In order to ascertain the effect of a flexible discount rate on the developed CBA models of PLFRA measures a sensitivity analysis was, thus, carried out.

The discount rate used in the calculation of the present value of costs and benefits for the model was 8%. The sensitivity of the model to changing this has been assessed for all the property types used in this research (see appendix C-5 for complete results). Table 9.5 illustrates the results for bungalow and terraced properties installing resilience measures with discount rates of 3.5% (HM, Treasury 2003) and 8%, which was used in the CBA models. As can be seen reducing the discount rate from 8% to 3.5% increases the flood threshold at which it is cost beneficial to invest in resilience measures for these properties. For instance, investing in resilience measures for a concrete floor bungalow with varying flood depth is seen to be cost beneficial up to 50-years flood return period, the least BCR is 1.4 for flood depth up to 1000mm. Equally, for a suspended timber floor bungalow the effect of lower discount rates (3.5%) makes it cost beneficial up to 50-years flood return period. With a higher discount rate of 8% for a concrete floor bungalow, the flood threshold at which investing in the measure is cost beneficial was at 40-years flood return period, and 25-years flood return period for suspended timber floor bungalow. Generally, a reduction in the discount rate from 8% to 3.5% shows that for all the properties with either concrete or timber floor, it is cost beneficial to invest in resilience measures even when a lower discount rate is used in the models.

Table 9.5 Impact of flexible discount rate on the developed CBA model of resilience measures (3.5%)

Floor construction	**Flood return period (Flood probability (p)**	**Bungalow (3.5% discount rate)**				**Bungalow (8% discount rate)**				**Terraced (3.5% discount rate)**					**Terraced (8% discount rate)**				
		Flood depths (mm)				**Flood depths (mm)**				**Flood depths (mm)**					**Flood depths (mm)**				
		0-150	**151-300**	**301-500**	**501-1000**	**0-150**	**151-300**	**301-500**	**501-1000**	**0-150**	**151-300**	**301-500**	**501-1000**	**Over 1000**	**0-150**	**151-300**	**301-500**	**501-1000**	**Over 1000**
Concrete solid floor	5 year (0.20)	10.1	9.7	13.2	11.0	6.8	6.5	8.8	7.3	9.5	9.8	9.7	11.3	13.1	6.4	6.5	6.5	7.5	8.8
	10 year (0.10)	5.4	5.1	6.9	5.7	3.6	3.4	4.6	3.8	5.1	4.7	4.4	4.7	4.6	3.4	3.1	3.0	3.1	3.1
	20 year (0.05)	3.0	2.9	3.7	3.0	2.0	1.9	2.5	2.0	2.9	2.7	2.5	2.6	2.5	2.0	1.8	1.7	1.8	1.7
	25 year (0.04)	2.6	2.4	3.1	2.5	1.7	1.6	2.0	1.6	2.5	2.3	2.1	2.2	2.1	1.7	1.5	1.4	1.5	1.4
	40 year (0.025)	1.8	1.7	2.1	1.7	1.2	1.2	1.4	1.1	1.8	1.7	1.6	1.6	1.5	1.2	1.1	1.0	1.1	1.0
	50 year (0.02)	1.6	1.5	1.8	1.4	1.1	1.0	1.2	0.9	1.6	1.4	1.4	1.4	1.3	1.1	1.0	0.9	0.9	0.9
Suspended Timber floor	5 year (0.20)	6.9		9.2		4.6		6.4		9.3	8.4	7.2	7.0	7.7	6.2	5.6	4.8	4.7	5.1
	10 year (0.10)	3.6		4.8		2.5		3.3		4.9	4.5	3.8	3.7	4.0	3.3	3.0	2.6	2.5	2.7
	20 year (0.05)	2.0		2.5		1.4		1.8		2.8	2.5	2.2	2.0	2.2	1.9	1.7	1.4	1.4	1.5
	25 year (0.04)	1.7		2.1		1.2		1.5		2.4	2.1	1.8	1.7	1.8	1.6	1.4	1.2	1.2	1.2
	40 year (0.025)	1.2		1.4		0.9		1.0		1.7	1.5	1.3	1.2	1.3	1.2	1.0	0.9	0.8	0.9
	50 year (0.02)	1.0		1.2		0.7		0.8		1.5	1.3	1.1	1.1	1.1	1.0	0.9	0.8	0.7	0.7

9.5 SUMMARY

This chapter has presented the CBA model of PLFRA measures. In doing this, the relationship between cost and benefit of adaptation measures were established. The developed CBA model was based on three most important variables, which have influence on the costs and benefits of the PLFRA measures, these variables are property type, floor construction methods and flood depth.

From the results presented in this chapter, it can be concluded that there is a relationship between costs and benefits of adaptation measure, which is supported by the empirical evidence. The developed CBA models show the flood threshold at which each of the adaptation measures are cost beneficial. Due to the low initial cost of resistance measures, it yielded more benefits when compared with resilience measures. However, the developed models assume that the measures were implemented and functioned effectively, if this assumption is violated the benefit to cost ratio presented in this chapter may not be achieved.

The effect of varying the discount rate on the model was tested by carrying out a sensitivity analysis using a lower discount rate of 3.5%. It was found that the flood threshold at which resilience measures is cost beneficial with low discount rate increases significantly for properties with either concrete or timber floor. Having developed the CBA model of PLFRA measures, the next chapter describes the validation process, which includes both external and internal validation.

CHAPTER TEN: VALIDATION OF THE DEVELOPED CBA MODEL OF PLFRA MEASURES

10.1 INTRODUCTION

This chapter presents the results of the validation of the CBA model of PLFRA measures developed for managing flood risk at household levels in England. The aim of the validation process is to test the validity of the developed model and to ascertain if the concepts and methodologies adopted for the research are robust enough and to ascertain the reliability of the findings. Validation also provides a firm background against which the findings can be generalised. Thus, validation is important because it reflects the potential objectivity and reliability of the model. This chapter, therefore, addresses the seventh research objective.

10.2 THE PRINCIPLE OF VALIDATION

The concept of validation means different things to different people in different disciplines and contexts. Nanda *et al*. (2000) concluded that it is difficult to define validation with quantitative formulas. The concept of validation can be viewed in three stages of the research process; these are the conceptual, methodological and empirical stages (Brinberg and McGrath, 1992). At the conceptual stage of the research, validation can be established by assessing the effectiveness, internal consistency, testability and adaptability of the concepts used. At the methodological stage of the research, it would be expected that efficiency power, absence of bias, and explicitness would prevail; and at the empirical stage of the research, it would be expected that the research should be beneficial or relevant in terms of any potential practical applications and should also be subject to replication and convergence towards identifying its boundaries (Ikpe, 2009).

Brinberg and McGrath (1992) suggested that any attempt at validating a research process should reasonably aim at integrating the three domains, while a plausible methodology for assessment is for the researcher to strive towards value, correspondence and robustness. The issue of value deals with the merit of the research, while correspondence is the degree at which the features of the relations in various stages of the research match or fit together. Robustness deals with testing the consistency of the empirical findings through replication, convergence and differentials (Adcock and Collier, 2001; Beach *et al.* 2006).

10.3 VALIDATION OF MODEL

The purpose of carrying out model validation is to confirm that the developed model is appropriate in the light of the purpose of the research investigation. Egbu (2007) asserted that validation of a model is the process of assessing the ability of the model to do what it sets out to achieve. Thus, the process of model validation is to ascertain that the model represents the characteristics of the general population and not peculiar to the samples used in its estimation (Hair *et al.* 2010). In social sciences, validation has two essential components: internal and external validity. Internal validity encompasses whether the results of the study are legitimate because of the way the groups were selected, data were recorded or analysis performed. External validity, often referred to as "generalisability", involves whether the findings obtained from the study are transferable to other groups of interest (Last, 2001). However, through proper study design and strict procedural execution, a high level of validity, both internal and external, can be achieved. Last (2001) concluded that without internal validity, it is not possible to have external validity.

10.4 INTERNAL VALIDATION

Internal validation relates to how cause-effect relationships (i.e. X causes Y) are free from sources of bias arising from research design (Garson, 2008). Lack of internal validity may, therefore, imply that the independent variable is not responsible for the effect detected in the dependent variable. Quantitative survey research tends to exhibit low internal validity as a result of their inability to conclusively establish causal relationships (Michell and Jolley, 2001). However, in order to reduce the possible bias in the design and implementation of this research, best practices were adhered to as far as possible throughout the research process.

According to Ankrah (2007) appropriate procedures for checking internal validity are rare. Some researchers have, however, attempted to show evidence of internal validity by implementing several strategies. Notable among these attempts are the works of Proverbs (1998) and Xiao (2002) in which they attempt to demonstrate internal validity through search of convergence among research findings, published research and academic validation. The premise is that if convergence is demonstrated among these three aspects, arguments about X and Y relationships made in the research can be considered as valid. This strategy has been used by other researchers such as Ankrah, (2007), Tuuli (2009) and Manu (2012) as a means to weigh the findings of their studies against published studies, as well as to subject the studies to expert scrutiny. Using the examples of these works, the following sections attempt to show how the research findings converge with published research and pass academic scrutiny.

10.4.1 Convergence of Research Findings with Published Research

In the words of Maxwell (1992) the convergence of research findings with published research is referred to as theoretical validity, which is the presence or absence of agreement within the community of inquirers about the descriptive or interpretive terms used. Convergence of the findings of this research and published research has been shown in several sections in the previous chapters by continually referring to the extant literature. In this section, references are only made to the relevant sections in the thesis. Convergence of the findings as to the cost of different adaptation measures with published research is shown in chapters 7, 8 and 9. However, with regards to the quantitative findings, especially on the WTP to avoid intangible impacts and psychological effect of flooding on households, convergence with past research is also evident from the continual reference to the extant literature in the analysis section of chapter 6. By making reference to literature in discussion of the results of the analysis, the findings are found to be broadly consistent with this body of knowledge. Taken together, there is adequate convergence between the research findings and previous studies.

10.4.2 Academic Validation of Research Findings

The process of disseminating the findings of this research to practitioners and the wider academic community through the publication of conference papers, journal papers 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, Runeson and Loosemore, (1999) asserted that it is a process of critical inquiry, which is meant to provide an informed, fair, reasonable and professional opinion about the merits of research work. 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 outlining the basis of a decision, often raises issues that range from minor to essential, 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. This form of peer review also provides useful feedback, which can be incorporated in the research to improve its validity.

To date, five papers related to this research have been published and presented at international conferences. These are:

Joseph, R., Proverbs, D., Lamond, J. and Wassell, P. (2012) *Use of CVM Valuation Method to Quantify Social Benefits of Property-Level Flood Risk Adaptation Measures: Theoretical Approach.* 21st International conference on Construction and Real Estate Management. Kansas City USA (October 1st - 2nd 2012)

Joseph, R., Proverbs, D., Lamond, J. and Wassell, P. (2012) *Towards the development of a comprehensive systematic quantification of the costs and benefits of property level flood risk adaptation.* 3rd International Conference on Flood Recovery, Innovation and Response (FRIAR). Dubrovnik, Croatia. (30 May – 1 June 2012).

Joseph, R., Proverbs, D., Lamond, J. and Wassell, P. (2011a) *A critical synthesis of the intangible impacts of flooding on households.* International conference in building resilience: Interdisciplinary approaches to disaster risk reduction and the development of sustainable communities. Sri Lanka (July 2011).

Joseph, R., Proverbs, D., Lamond, J. and Wassell, P. (2011b). *A critical synthesis of the tangible impacts of flooding on households*, 27th ARCOM annual conference, University of the West of England, Bristol, United Kingdom.

Joseph, R., Proverbs, D., Lamond, J. and Wassell, P. (2011c). *The potential of CBA towards increasing the uptake of property-level flood risk adaptation.* 5th International Conference on Flood Management (ICFM5) Tokyo –Japan (27-29 September 2011) – Abstract only submission.

Three additional journal papers have been submitted in highly rated journals; two of them have been published, while the third has been accepted with amendment. These are:

Joseph, R., Proverbs, D., Lamond, J. and Wassell, P. (2013a). *Application of the concept of cost benefits analysis (CBA) to property level flood risk adaptation measures: A conceptual framework for residential property*. Structural Survey (In print)

Joseph, R., Proverbs, D., Lamond, J. and Wassell, P. (2013b). H*omeowners' perception of the benefits of property level flood risk adaptation (PLFRA) measures: the case of the summer 2007 flood event in England*. Safety and Security Engineering journal (under review).

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), pp.279-293.

In the course of this research programme, two book chapters have been submitted for publication. These are:

Joseph, R., Proverbs, D., Lamond, J. and Wassell, P. (2014). The cost of flooding on households. *In* Booth, C. and Charlesworth, S. (eds.) *Water Resources in the Built Environment – Management Issues and Solutions.* London: Blackwell Publishing Limited. (*In print*).

Joseph, R., Proverbs, D. and Lamond, J. (2014). Flood risk mitigation: Design considerations and cost implications for new and existing buildings. *In* Robinson, H; Symonds, B; Gilbertson, B and Ilozor, B (eds). *Design Economics for the Built Environment.* John Wiley & Sons *(in print).*

The acceptance of these papers and book chapters for publication in these forums after going through a rigorous peer review process provides confirmation that the research has met the high scholarly and academic standards required by these forums and is, therefore, scholarly and academically valid. (list of publications and abstracts are in appendices E-1 and E-2).

10.4.3 Convergence of published research and academic validation

The acceptance of papers for publication (which by extension implies an acceptance of the published research cited in the papers) is a demonstration of convergence between published research and academic validation (Proverbs, 1998; Ankrah, 2007; Tuuli, 2009 and Manu, 2012). This is built on the basis that the papers make arguments, interpretations and evaluate findings against published research and, as such, once the papers are accepted both the content of the papers and the published research cited in them are validated.

Table 10.1 shows that a total number of 355 of published works were cited in the 10 (with the exclusion of abstract only paper) papers which have been published. Although there is duplication of references in some of the papers as they address a similar subject, there are also many distinct and paper-specific references, which support the findings reported in each paper. Based on the gross number of references, there is an average of 35.5 citations per paper. Following the precedence of Proverbs (1998), Ankrah (2007), Tuuli (2009) and Manu (2012) it is argued that the acceptance of these papers for publication demonstrates that there is convergence between published research and academic validation.

Table 10.1 Citations in journal, conference, report and doctoral workshop papers

No	Authorship	Year	No. of Citations
1	Joseph *et al.*	2013	54
2	Joseph *et al.*	2013	55
3	Joseph *et al.*	2013	30
4	Joseph *et al.*	2013	36
5	Joseph *et al.*	2012	23
6	Joseph *et al.*	2012	30
7	Joseph *et al.*	2011	46
8	Joseph *et al.*	2011	30
9	Joseph *et al.*	2011	34
10	Joseph *et al.*	2011	Abstract only
11	Joseph *et al.*	2009**	17
		Total	**355**
		Mean	**35.5**

***Publication that led to the birth of this research project*

10.5 EXTERNAL VALIDATION

External validity is the extent to which relationships and findings hold or generalise over variations in persons, settings, treatments and outcomes (Shadish *et al.* 2002). It is, therefore, a process of ascertaining the level of confidence that can be placed on the findings of any study. External validity can be demonstrated in three interrelated ways; replication, convergence analysis and boundary search (Brinberg and McGrath, 1985; Ahadzie, 2007). In the following sections, these three aspects of external validation with regards to this research are discussed and where evidence exists, these are presented.

10.5.1 Replication

Replication is a question of whether repeating a study the same pathway, elements, relations and embedding systems will result in the reproduction of the original findings (Brinberg and McGrath, 1985). Replication is often necessary to confirm the findings of studies because it is often difficult to rule out all possible alternative explanation to the results. However, replication is rarely used to demonstrate external validity within the same study for reasons such as; access to the same set of participants and the logistical constraints in carrying out the same research again. Besides the constraints in carrying out the same research again, an exact replication of any study is actually not practical since no two occasions are the same. Therefore, in this research like many before (e.g. Phua, 2004; Anvuur, 2008), demonstrating external validity through replication of the entire study was not a feasible option for reasons of time, cost and logistical constraints.

10.5.2 Convergent analysis

Convergent analysis encompasses the use of different methodologies or research strategies to study the same phenomenon (Denzin, 2009). The principle of validity in convergence is that confidence is gained where there is agreement of substantive outcomes derived from the use of different and independent models, methods and occasions (Brinberg and McGrath, 1985). Convergence in the findings of research can be investigated across three main domains (Brinberg and McGrath, 1985); the substantive domain (i.e. different respondents or context); methodological domain (i.e. different measurement techniques/methods or research strategies) and conceptual domain (i.e. different conceptualisations or models).

A further step in search for convergence, which was also applied, is referred to as *respondent validation* (Silverman, 2006). According to Creswell (2009), this refers to as 'member checking'. In respondent validation, the research participants are invited to provide feedback on the validity and the usefulness of the research findings (Silverman, 2006; Creswell, 2009). Reason and Rowan (1981) asserted that the process of validating research findings through participant's feedbacks has been described as a characteristic of good research.

The process of participant validation is a familiar phenomenon in construction management research and takes several forms (Phua, 2004; Hari *et al.* 2005; Ankrah, 2007; Anvuur, 2008; Tuuli, 2009; Manu, 2012) including follow up interviews with selected respondents (Phua, 2004); the use of focus groups (Anvuur, 2008); and the use of a follow-up questionnaire sent to research participant complimented by a summary findings from the research (Ahadzie, 2007; Ankrah, 2007; Tuuli, 2009; Manu, 2012). In this research the latter approach involving a summary of findings report and feedback form was adopted. Consideration was given to using focus groups or interviews to validate the research finding, however, this option was rejected because of time and financial constraints, coupled with the fact that recruitment process will have to go through the ABI for approval of the process. However, other researchers have shown that the use of feedback form in lieu of focus group or interviews always yield similar results (Tuuli, 2009; Manu, 2012). Therefore, the use of feedback form to validate the research findings will not cast doubt on the validity of the research findings.

A feedback form was designed to achieve three objectives: (1) verification of the validity of the research findings; (2) verification of the industrial relevance of the research findings (as summarised by the Decision Support Lookup Tables DSLT) to household level flood risk management; and (3) verification of the professional's understanding of the developed DSLT. Two sets of participants were engaged in the validation process, these are homeowners (n=13) who were part of the main survey and loss adjusters/surveyors (n=21). The decision to include loss adjuster/surveyors in the validation process hinged on the assumption that, these are the professionals who are in the best position to advise homeowners of the costs and potential benefits of PLFRA measures, thus, the developed model is expected to be of great importance and use to these professionals.

A five page summary of key research findings and a feedback form (Appendices D-1 and D-2) were sent to all the homeowners who participated in the main survey and indicated to participate in a further part of the study. Further, a summary of key research findings and a feedback form (Appendix D-3) were sent to loss adjuster/surveyors. In selecting loss adjuster/surveyor who provided feedback on the research findings, the list of loss adjuster/surveyors who have previous experience of working on reinstating flood damage properties was obtained from the researcher's employer. The list contained a total of 21 loss adjuster/surveyors; it was decided to email the summary of findings and feedback form to all of them.

In all a total of 34 participants were sent the report and feedback form, comprising of 13 homeowners and 21 loss adjuster/surveyors. The summary of findings and feedback form (in fillable Acrobat PDF) were mainly sent by email.

10.5.2.1 Results of the Participant Validation

In total twenty two (22) participants returned the feedback form, these comprise of 10 homeowners and 12 loss adjuster/surveyors, representing a combined 64.7% response rate. As previously discussed, the loss adjuster/surveyors respondents included mainly those who have worked in flood reinstatement projects in the past. The results of the completed feedback forms are summarised below.

Analysis of homeowners feedback

Homeowners' responses in relation to whether the value of WTP was a realistic reflection and the simplicity of the developed DSLT are illustrated in Table 10.2. In response to whether the value of £653, which represents the intangible benefit of investing in PLFRA measures is realistic or not, six respondents, representing 60%

responded in confirmation that this value is realistic. 30% were uncertain whether the value is realistic or not, whilst, 10% (1) disagree. In response to whether the developed decision support lookup tables (DSLT) are simple to use, seven respondents, representing 70% responded in confirmation, whilst 30% of respondents were uncertain as to the simplicity of the DSLT.

Table 10.2 Homeowner's feedback on realistic of WTP value and simplicity of the DSLT (n=10)

Question	Responses					
	No response	Strongly Agree	Agree	Uncertain	Disagree	Strongly Disagree
(1) The research found that the average financial benefit in relation to avoiding psychological effects of flooding by investing in flood protection measures was £653 per household per year. To what extent do you agree that this amount is realistic?	0% (0)	0% (0)	60% (6)	30% (3)	10% (1)	0% (0)
(7) Please indicate your level of agreement with this statement 'The Decision Support Lookup Tables are easy to understand'	0% (0)	0% (0)	70% (7)	30% (3)	0% (0)	0% (0)

Homeowners were asked if the knowledge of the financial benefit of investing in resistance and resilience measures can assist them in making a decision to invest in the measures. Table 10.3 illustrates that eight respondents, representing 80%, agreed that the knowledge of the financial benefit can help them. Respondents were asked to state why the knowledge of the financial benefits of investing in resistance and resilience measures will assist them in making a decision to invest in the measures, some of the reasons provided by the respondents are given below:

> *'There must be evidence of a clear return on investment to be made and these stats help to prove that fact. Too often claims are not supported by evidence'. (Respondent 1).*
>
> *'Knowing the real financial benefit of spending money on protecting property is a good and vital piece of information' (Respondent 9).*

Table 10.3 Homeowner's feedback on usefulness of the research findings in decision making on resistance and resilience measures (n=10)

Question	Responses			
	No response	**Yes**	**No**	**I don't know**
(2) The research has estimated the cost and benefit of manually deployed resistance measure for properties in similar circumstances to your own. For example, for every £1 invested in manual resistance flood protection measures, a £8.50 benefit is gained as a value of avoided loss if the property is located in an area with 10 percent chances of being flooded in 10 years. Investing in automatic resistance flood protection measures will yield a benefit of £6.35 as a value of avoided loss. Will your knowledge of these potential benefits assist you in making decision on investing in resistance flood protection measures?	0% (0)	80% (8)	10% (1)	10% (1)
(4) The research has estimated the cost and benefit of manually deployed resistance measure for properties in similar circumstances to your own. For example, a bungalow with concrete floor construction located in an area with 10 percent chances of being flooded in 10 years, and with anticipated flood depth up to 500mm. For every £1 invested in resilience flood protection measures with the inclusion of the value of intangible benefits, a £4.60 is gained as the value of avoided loss. Will your knowledge of these potential benefits assist you in making decision on investing in resilience flood protection measures?	0% (0)	80% (8)	10% (1)	10% (1)

Respondents were asked to rate the extent to which the entire research findings can assist them in making decision on investing in flood protection measures, Table 10.4 shows that some 60% of respondents stated that the research findings will assist them in decision making on investing in flood protection measures to a moderate extent, whilst 30% stated that it will assist them to some extent.

Table 10.4 Homeowner's feedback on general usefulness of the research findings in decision making on flood protection measures (n=10)

Question	Responses					
	No response	**To a large extent**	**To a moderate extent**	**To some extent**	**To little extent**	**Not at all**
(6) From your flood experience, to what extent can the findings from this research assist you in making a decision on investing in flood protection measures?	0% (0)	0% (0)	60% (6)	30% (3)	0% (0)	10% (1)

Respondents were asked to provide any other general comments they may have in connection with the findings. Generally, it was agreed by respondents that the research findings are useful. Some of the comments indicating this are given below:

> *'Brilliant piece of research. All the best!'* (Respondent 2)
>
> *'Your research has provided a new WTP value of £653 this will be used widely as it can replace the Environment Agency value of £200, which is almost 10 years old' (Respondent 3)*
>
> *'The research is timely with the ever increasing frequent occurrence of flood event. Well done!' (Respondent 10).*

Some respondents, however, commented that they are not sure of how to use the DSLT and highlighted the need to develop the DSLT in a form of expert system. These comments are:

> *'I am not particularly sure of how to use the decision support lookup tables' (Respondent 8)*
>
> *'I think it would be a good idea if DSLT can be developed into a system with some drop down buttons to select variable' (Respondent 9).*

These comments highlight the need for developing a tool that is tailored to individual property needs taking into consideration all different variables, which can be encountered in individual properties. Although the fact that the research findings have not been developed into an expert system does not invalidate the findings. However, the comments highlighted the potential usefulness of the research findings.

Analysis of Loss adjuster/Surveyor's feedback

As previously mentioned the validation also sought to verify the relevance of the research findings and the ease of using the DSLT by professionals who are in a position to advise homeowners on the potential benefit of investing in PLFRA measures. Loss adjuster/Surveyors responded to a number of questions in relation to the research findings based on their individual experience of the flood recovery process. The responses in connection with the Loss adjuster/Surveyors opinions of the research findings are summarised (Table 10.5 and 10.6).

In terms of the research findings that show the benefit of adaptation measures outweighs the cost, based on respondents experiences, the responses ranged from uncertain to strongly agree with majority of the respondents (i.e. 10 representing 83.3%) indicating at least 'agree' (Table 10.5). This means that the research findings are accord the professional expectations.

With regards to the simplicity of the DSLT, 10 respondents, representing 83.3% agreed that the DSLT is easy to use and understand. Some of the comments in this regard are:

> *'It helps in advising on cost measures to mitigate upon flood and to protect homes owners if these costs are know earlier' (Respondent 1)*
>
> *'This is a very rare research work. As most of the time Surveyors are only interested in the tangible benefits due to the fact that most insurance policies are based on policy of indemnity. So any estimating tool which includes intangibles has actually gone extra mile.' (Respondent 12)*

This further reinforces the validity of the research findings and is an indication that the information given by the DSLT has industrial relevance.

Table 10.5 Loss adjuster/surveyor's feedback on the benefit of PLFRA and the simplify of the DSLT (n=12)

Question	Responses					
	No response	Strongly Agree	Agree	Uncertain	Disagree	Strongly Disagree
(1) Based on the package of adaptation measures used in the research, we found that the benefits of adaptation measures outweigh the costs of the measures. From your experience, to what extent do you agree with this finding?	0% (0)	25% (3)	58.3% (7)	16.7% (2)	0% (0)	0% (0)
(9) Please indicate your level of agreement with this statement 'The Decision Support Lookup Tables is easy to understand'	0% (0)	41.7% (5)	41.7% (5)	16.6% (2)	0% (0)	0% (0)

In Table 10.6, as part of verifying the industrial relevance of the research findings as summarised by the DSLT, the respondents were asked to respond to four additional questions. These questions asked if the DSLT addresses important estimation problem when establishing the cost and benefits of PLFRA measures, 83.8% of respondents confirmed that the DSLT addresses these problems. Further, respondents were asked if the knowledge of the potential financial benefits of resistance and resilience measures as summarised in the DSLT can assist them in advising their client whether or not to invest in the measures; a majority of the respondents confirmed that the information is useful for them in their professional roles (n=11, representing 91.7%). Some of the comments in this regard are:

> *'Having this information is very crucial in giving to homeowners particularly in areas of flood return. it will minimise the cost and the intangible benefits in the long run.' (Respondent 1)*
>
> *'Knowledge of these financial benefits can go a long way in advising homeowners on investing in flood protection measures' (Respondent 2)*
>
> *'Good avenue to evidence benefit to clients' (Respondent 4)*

'Because it assists in calculating the potential financial benefits of spending money in protecting properties' (Respondent 6)

'Great return on investment' (Respondent 12).

Respondents were asked if there are any important factors left out the DSLT, 11 respondents, representing 91.7% of respondents were of the opinion that the DSLT has included all necessary factors. However, one respondent, representing 8.3% was of the opinion that the DSLT did not include all factors. This respondent's comment is:

'The DSLT should be developed into a system similar to the BCIS reinstatement calculator. How you are going to do that, I don't know. (Respondent 7).

As discussed previously, it has been identified that the research findings can be developed into an expert system or similar for general use; however, due to time and financial constraint this cannot be done in this research.

Table 10.6 Loss adjuster/surveyor's feedback on the usefulness of the research findings in advising homeowner on investing in PLFRA measures (n=12)

Question		Responses		
	No response	Yes	No	I don't know
(2) With the inclusion of the value of intangible benefits in the Decision Support Lookup Tables (DSLT), in your opinion, would you say that the DSLT addresses an important problem on the estimation of cost and benefit of flood protection measures?	0% (0)	83.3% (10)	0% (0)	16.7% (2)
(4) The research found that for every £1 invested in manual resistance flood protection measures with the inclusion of the value of intangible benefits, the value of avoided loss was £8.50 for a property located in an area designated as 10 years flood return period and for automatic measures £6.35 is gained. Will your knowledge of these potential benefits assist you in advising your clients (homeowners) whether or not to invest in resistance measures?	0% (0)	91.7% (11)	8.3% (1)	0% (0)
(6) The research found that for every £1 invested in resilience flood protection measures with the inclusion of the value of intangible benefits, the value of avoided loss was £4.60 for a bungalow with concrete floor construction, with a flood depth of up to 500mm and located in an area designated as 10 years flood return period. Will your knowledge of these potential benefits assist you in advising your clients (homeowners) whether to invest in resilience measures?	0% (0)	91.7% (11)	8.3% (1)	0% (0)
(10) From your experience, are there any important factors which ought to be included in the DSLT?	0% (0)	8.3% (1)	91.7% (11)	0% (0)

Overall, it can be concluded from the responses that there is convergence between the views of the respondents and the findings of the quantitative inquiries. The findings of the research are thus a sound reflection of the comprehensive assessment of the costs and benefits of PLFRA measures. There is a reasonable indication that the information given by the DSLT is relevant to flood risk management at household levels. There is, however, scope for improving the user-friendliness of the DSLT by using the information illustrated in the DSLT to develop an expert system.

10.5.3 Boundary Search

Boundary search addresses the issue of the conditions under which the findings of a study will not hold (Brinberg and McGrath, 1985). This aspect of external validity is often established over time through replications and triangulation techniques to define the scope and boundaries of the findings of a particular study. Researchers, therefore, rarely deliberately go beyond either replication or convergence analysis to search for the boundaries associated with their findings in the same study (Brinberg and McGrath, 1985). The constraints to replication discussed earlier for example, time, cost and logistical constraints are also applicable here, for which reasons boundary search cannot be performed in this study. Future studies replicating aspects of this research outside the domain of flood risk management may contribute to defining the boundaries for the findings of this research.

10.6 SUMMARY

This chapter has presented efforts to validate the research findings within the context of internal and external validation processes. The internal validation sought convergence of the research findings, published research and academic validation. Five (5) conference papers, three (3) journal papers and two (2) book chapters have been developed and published. In all these papers, a significant number of references have been cited to support the arguments advanced in these papers. It is, thus, concluded that this research is convergent with the established knowledge in the domain of flood risk management at household levels and in the applicability of the concept of CBA to PLFRA measures.

In the external validation, respondent validation was employed in convergence analysis. This involved 10 homeowners and 12 loss adjusters/surveyors who commented on the validity, usefulness as well as the industrial relevance of the research findings as summarised by the (DSLT). Generally the responses from homeowners concur with the research findings indicating that the findings are valid and accurately represent the information which has the potential to assist homeowners in making decision whether to invest in the measures or not. The responses from the Loss adjusters/Surveyors also generally indicate that the findings of the research as summarised by the DSLT are of relevance to flood risk management at household levels. The respondents were of the opinion that the DSLT is a very useful tool, which can assist them in offering advice on PLFRA measures. However, both the homeowner and Loss adjusters/Surveyors expressed views that point to the need to use the research findings to develop a more user friendly system, such as an expert system.

On the basis of the validated research findings, it is appropriate to finally draw conclusions on the entire research and make relevant recommendations. This is addressed in the next chapter.

CHAPTER ELEVEN: CONCLUSIONS AND RECOMMENDATIONS

11.1 INTRODUCTION

The comprehensive analysis of the costs and benefits of PLFRA measures has been explored in this research, with a particular emphasis on monetising the intangible benefits of adaptation measures, which has received less attention in the past. This has led to a number of research findings which have been consolidated by the development of a CBA model of PLFRA measures. The incorporation of the intangible benefits of PLFRA measures in the developed CBA model has provided improved and robust decision making information on the adoption of PLFRA measures. 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.

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 take into consideration the value of intangible benefits of PLFRA measures. As a result, detailed values of the intangible benefits of PLFRA measures remain elusive in the extant literature. Thus, the existing CBA models of PLFRA measures appear to lack essential information and this raising doubt about the accuracy and validity of these existing models. This led to the development of four research questions:

- How can the intangible impacts of flooding on households be quantified and monetised?
- What is the value of intangible impacts of flooding on households?

- What is the relationship between costs and benefits of adopting PLFRA measures?
- Do the benefits of PLFRA measures outweigh the associated costs?

In order to answer these questions, the research aimed to empirically investigate the cost and benefit of PLFRA measures, with a particular emphasis on establishing and incorporating the value of intangible benefits of the measures in the CBA model. To achieve this aim, eight research objectives were developed.

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 events worldwide and specifically in the UK, 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. A review of extant literature on flood events in the UK and other parts of the world revealed that the frequency and occurrence of flooding are on the increase worldwide. This being partly due to the effects of climate change and development pressure arising from urbanisation. Two major impacts of flooding were identified in the extant literature, these were categorised as, tangible and intangible impacts, with further classification into direct and indirect impacts. It was found that the intangible impacts affect flood victims more than the tangible impacts especially for fully insured homeowners, and in some cases these intangible impacts last longer (i.e. for months or years).

The literature review revealed there are PLFRA measures that can be implemented at household levels, which have the potential to reduce the tangible and intangible impacts of flooding on households; these are categorised into resistance and resilience measures. However, the effectiveness and suitability of each of the measures depends on several factors amongst which are the anticipated depth of flooding, the nature of flooding (pluvial, fluvial or ground water), frequency of flooding, property type, and wall/floor construction methods. The review revealed that some attempts have been made towards the development of cost and benefit of these measures; however, the focus of most of these studies have centred on the tangible benefits due to the inherent difficulty in quantifying and monetising intangible impact of flooding on households. This review was, therefore, helpful in underpinning the view that there was indeed a dearth of research towards developing a full understanding of costs and benefits of PLFRA measures.

Objective 2*: To critically review the concept of CBA and its applicability to the study of PLFRA measures, with particular emphasis on available methods of valuation of less monetised impacts (intangible) of flooding on households, with the aim of incorporating it in the CBA model.*

This objective is addressed in chapter 3. An in-depth review of CBA literature was undertaken towards developing a suitable approach for its application in the domain of PLFRA measures. The review revealed two main methods of quantifying intangible benefits of PLFRA measures. These are revealed preference methods (RPM) and stated preference methods (SPM). Given the context of the research, the SPM was adopted. The review revealed that the contingent valuation method (CVM) of SPM is more appropriate to elicit the value of willingness to pay (WTP) to avoid the intangible impacts of flooding on households from homeowners. The RPM was rejected because it requires prior knowledge of a related or substitute market in which the environmental goods to be valued is implicitly traded. Information derived from observed behaviour in the substitute markets is then used to estimate WTP, which represents individual's valuation of, or the benefits derived from, the investment in flood adaptation measures. The lack of any related or substitute market for the intangible impact of flooding on households made the use of RPM inappropriate for this research. The identification of a suitable method of quantifying intangible impact of flooding on households for the purpose of incorporating it in the CBA model of PLFRA measures represented an achievement of the second research objective.

Objective 3: *To develop a conceptual framework, specific to domestic property in the UK, of the costs and benefits of property level flood risk adaptation measures based on a synthesis of the extant literature.*

This objective is addressed in chapter 4. CBA model framework is often used to explain the link between different costs and benefits parameter of PLFRA measures. A review of existing CBA model of flood adaptation measures was undertaken with the intent of obtaining insight into how these costs and benefits parameters are incorporated in the CBA decision making framework. It was revealed from the literature review that the existing CBA models of flood adaptation measures acknowledged the importance of intangible benefits, but due to difficulties in monetising these intangible impacts were largely ignored. This suggests that the full benefits were not being accurately reflected in these earlier studies. By identifying this major gap in the existing CBA model, a conceptual framework of CBA model of PLFRA measures was thus developed. The framework also detailed factors which have been suggested to influence the costs and benefits of PLFRA measures. Three hypotheses were put forward to verify the influence of these factors. The development of the conceptual framework, thus, represented an achievement of the third research objective.

Objective 4: *To elicit domestic homeowners' willingness to pay (WTP) values in order to reduce the intangible impacts of flooding on their households and subsequently employ appropriate statistical analysis techniques with a view to exploring factors which has the potential to influence the WTP values and the adoption of PLFRA measures.*

This is addressed in chapters 5 and 6, building on the achievement of the third objective. The need to empirically verify the developed conceptual model and also to implement the measurement framework dictated the adoption of the quantitative inquiry. Drawing on the findings from the extant literature, a questionnaire was designed to elicit the views of homeowners on flood risks, flood impacts, measures to reduce the impacts and the WTP values to avoid the identified impacts.

Through the questionnaire, homeowners provided information on five main issues: (1) the flood experience prior to and after 2007; (2) the severity of the 2007 flood impact on the households and the maximum amount homeowners are willing to pay to avoid flood impact on their households; (3) the awareness and implementation of flood adaptation measures; (4) the perceived benefits of installing adaptation measures; and (5) value of other expenses incurred by homeowner while in temporary alternative accommodation, which were not reimbursed by their individual insurers. Following a successful pilot of the questionnaire, a main survey was undertaken on a sample of regions affected by

2007 flood event. Any area with less than 50 affected properties was not included in the sample. All together, the survey yielded 280 responses representing a 12.1% response rate.

The statistical analysis conducted on the data included descriptive statistics, inter-rater agreement tests, and correlation and regression analysis. The descriptive statistics provided a thorough understanding of the respondents' experience and how the 2007 flood event affected their households, thus, the findings drawn from their responses will be a credible reflection of the WTP to avoid impact of flooding on households. The descriptive statistics, in particular arithmetic mean, was used to aggregate the individual responses of the respondents to have single representative measures in relation to the questions on level of respondents' agreement with the potential benefits of PLFRA measures and the factor which has potential to influence the adoption of PLFRA measures. In order for the mean measures to be interpreted with confidence, an inter-rater agreement test was then 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 on the severity of the impact of flooding and the psychological effect of flooding on households by using the relative important index (RII).

Prior to establishing the value of intangible benefits from the questionnaire responses, correlation and regression analysis were undertaken for the test of hypotheses. Building on the result of correlation and regression analysis, the mean value of intangible benefits to avoid intangible impact and psychological effect of flooding on households was established as £653 per household per year. The value was, therefore, incorporated in the CBA model of PLFRA measures developed in chapter 9 of this thesis. The test of hypotheses confirmed that the benefit of PLFRA measures outweighs the cost of the measures, therefore the null hypotheses was accepted. The empirical verification of the conceptual framework and subsequent establishment of the value of intangible benefits of PLFRA measures represented an achievement of the fourth research objective.

Objective 5: *To collect data on the actual reinstatement costs of flood damaged properties affected during the 2007 summer flood event and establish the additional cost of adopting PLFRA measures based on different property types, flood depth and floor construction methods.*

This objective is addressed in chapter 5 and 7. The identification of an appropriate conceptual framework paved the way towards fulfilling the first part of objective 5. Subsequently and in particular, in order to help establish the necessary convergence with similar studies on PLFRA measures, positivism was adopted as the underlying research paradigm that influenced the design of the research instrument. Therefore, using the construct from the framework and also drawing extensively on recent flood risk management literature, a broad range of costs of PLFRA measures were identified based on the two main adaptation measures, resistance and resilience measures. These represent the additional cost of adopting adaptation measures. These costs represent the independent variable of the model. Conversely, the benefits of PLFRA measures were identified, these benefits represent the dependent variable. The development of various cost components of the CBA model from actual event data set a platform for the development of the questionnaire, which was used to obtain cost of resistance measures from damage management contractors. This helped to achieve the fifth objective.

Objective 6: *To establish the expected cumulative damage (ECD) avoided of PLFRA measures and to subsequently use appropriate statistical analysis techniques to explore the relationship between costs and benefits of the measures.*

This is addressed in chapter 8. The results of the analyses of the actual reinstatement costs and additional cost of the measures presented in chapter 7 were used to estimate the expected cumulative damage (ECD) avoided over 20-years period. The BCR of the data on costs and benefits of PLFRA measures without the inclusion of intangible benefits showed that for every £1 spent on manually deployed resistance measures insurers benefit between £9.80 and £16.30 and for automatically deployed resistance measures the benefits are between £7.70 and £13.50, depending on property type and flood depth.

Subsequently in chapter 9, the results presented in chapter 7 and 8 were used to develop the CBA model of PLFRA measures by incorporating the value of intangible benefits. The benefit cost ratio (BCR) analysis was carried out to establish the CBA model of each of the PLFRA measures based on various flood depth, property types and floor construction methods thus represented the achievements of the main research aim.

Objective 7: *To test, refine and validate the CBA model towards its potential relevance for practical application in flood risk management at household levels.*

This is addressed in chapter 10. The validation of the research findings was carried out based on two main validation processes, that is internal and external validation. In the internal validation, convergence between research findings, published research, and academic validation was sought. Among these three aspects, convergence was demonstrated indicating agreement between the research findings and the established knowledge.

In the external validation, respondent validation was employed in convergence analysis. Twenty two respondents comprising of ten homeowners and twelve Loss adjuster/Surveyors commented on the validity and industrial usefulness in the domain of flood risk management at household levels of the research findings as illustrated in the decision support lookup tables (DSLT). The responses from the homeowners indicated a strong level of agreement with the research findings indicating that the findings are useful and have the potential to assist in decision making on investing in PLFRA measures. Responses from Loss adjuster/Surveyors also indicated that the findings of the research are of relevance to the management of flood risk at household level especially during flood recovery periods. However, both homeowners and loss adjuster/surveyors expressed views that the DSLT should be developed into more user friendly software application. The successful validation of the research findings represents an achievement of the seventh research objective.

Objective 8: *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 CONCLUSIONS OF THE RESEARCH

This research, through detail review of extant literature, analysis of actual flood event data relating to the 2007 flood event in England and analysis of survey questionnaires, has established evidences to support the following main conclusions:

- The intangible impacts of flooding can often assume more significance to people than financial losses. It was revealed in this research that these intangible impacts are often not included in the CBA of PLFRA measures due to the inherent difficulty in their quantification. PLFRA measures, such as installation of resistance or resilience measures and registering for flood warning direct services, have the potential to reduce these intangible impacts of flooding on households. Therefore, the inclusion of the value of intangible benefits in the CBA model of PLFRA measures has the potential to provide more robust information to support reliable decision making when investing in PLFRA measures.
- Several economic methods of quantifying intangible impacts of flooding on households were considered; however, the CVM was employed. This was used to elicit WTP values from homeowners to avoid intangible impacts of flooding on their households. The advantage of using CVM is that respondents were provided the opportunity to state the maximum amount they were willing and able to pay to avoid the intangible impacts.
- It was concluded in this research that the value of WTP to avoid impacts of flooding on households is £390 per household per year. Conversely, the value of WTP to avoid psychological effects of flooding on households is £263 per household per year. Thus, producing combined mean WTP values of £653 per household per year. Factors which determine the WTP values were identified as

stress of flood, anxiety, worrying about loss of house values, future flooding, income and age of respondents.

- The additional cost of resistance measures was established and found to range between £3,800 to £10,800 depending on property types and deployment methods. Equally, the additional cost of resilience measure ranges from £12,200 to £28,300 and £13,300 to £28,800 for concrete and suspended floor properties, respectively, also largely dependent on property types and flood depths.
- With the inclusion of intangible benefits, the benefit cost ratios of resistance measures increase by approximately 8.3%, when compared with benefit cost ratio without intangible benefits. For every £1 invested in manually deployed measures on a bungalow located in an area designated as 5-years flood return period, a return of £15.70 can be achieved; the automatically deployed measures also yielded a return of £12.10.
- The benefit cost ratios for resilience measures with the inclusion of the value of intangible benefits across four different flood depths for a bungalow with a solid concrete floor, performed fairly consistent up to 25-years flood return period. Although for suspended timber floor, the result shows that investing in resilience measure is only beneficial for property located in area designated as 5 to 10 years. For instance, it was found that for every £1 invested in resilience measures on a bungalow located in an area designated as 5 years flood return period, a return on investment of £6.80 can be achieved.
- The ratio analysis revealed that when total cost of PLFRA measures are compared to the total benefits, which include the intangible benefits of the measures, the benefits far outweigh the costs of the measures especially for properties located in high flood return areas. Thus, supporting the null hypothesis.

These conclusions provide answers to the research questions posed to develop the CBA model of PLFRA measures. In summary, the benefit of PLFRA measures outweighs the cost and the inclusions of intangible benefits increase the flood thresholds at which investing in PLFRA measures are cost beneficial.

11.4 CONTRIBUTION TO KNOWLEDGE

This research has provided new insight into the study of CBA model of PLFRA measures from the homeowners' perspective. The contribution of this research to knowledge are discussed under three sub headings; CBA model of PLFRA measures, which was 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 understanding to the value of intangible benefits of investing in PLFRA measures which could be used in related studies in the UK; and dissemination of the research findings.

11.4.1 Contribution of the CBA model of PLFRA measures

A unique feature of the developed models is the inclusion of intangible variables, which have been overlooked in most previous studies. These were measured by using an innovative means of eliciting WTP values from homeowners. This has helped to develop robust benefit cost ratios (BCR), similar to BCR developed by the government when considering major flood defences. The model developed in this research provides the much-needed conceptual clarity by showing the interconnectivity among various variables, thus, making its applicability to real life events possible. The model draws on the various approaches used in estimating costs and benefits of PLFRA measures which will assist end users such as homeowners in deciding how best to reduce the impacts of flooding. The model has a wide range of potential beneficiaries such as homeowners, loss adjusters and government departments and agencies responsible for flood risk management. The model can be used to assess the cost effectiveness of adaptation measures thereby addressing one of the known barriers to the uptake of the measures.

11.4.2 The value of intangible benefits of PLFRA measures

The value of intangible impacts of flooding on households has been measured through a questionnaire survey to elicit the WTP values of homeowners. A distinctive insight has been gained and the intangible benefit of adopting PLFRA measures has been established as £653 per household per year. This is seen as a major contribution of the research as it supplement the EA/DEFRA (2004) value of intangible of £200 per household per year which is almost 10-years old and it still stands as the only value currently being used in flood defence appraisal process despite the fact that it is almost 10-years old. The establishment of a new value of intangible impact of flooding on household can now be used in the domain of flood risk management.

11.4.3 Dissemination

Findings from this research have been presented as the research progressed at international conferences, and published in peer reviewed journal, conference proceedings and in book chapters. Further, the findings have been discussed at meetings and workshops of the insurance brokers. Further publications are in preparation and in review. 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 remove the barrier of information in the decision making process on investing in PLFRA measures.

Therefore, it supplements Government policy in encouraging the take-up of PLFRA measures in the UK.

11.5 IMPLICATIONS OF THE RESEARCH FINDINGS.

The findings of this research have several important implications for flood risk management 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:

The PLFRA measures decision support lookup tables (DSLT) is a unification of the entire research findings. This can be developed based on excel spreadsheet whereby the user will be able to select the property types, floor construction methods and the anticipated flood depths. For the DSLT to be effective and update, it may have to be index-linked so that at any particular time it is meant to be used, the result will not need to be updated by consumer price index (CSI).

The developed CBA model for both resistance and resilience measures can be used by flood risk management practitioners to advise homeowners of the cost and potential benefits associated with their investment in adaptation measures, most especially during reinstatement period, since research has shown that implementing adaptation measures during flood recovery period or plan maintenance is more cost beneficial when compared to retrofit.

With regards to how the findings from this research can be used by insurance companies, or brokers can use the findings to advise their potential customers, most especially those in high flood risk areas, on the cost effectiveness of PLFRA measures. The introduction of the Flood Re signifies that affordable insurance provision will be made available for those homeowners in high flood risk areas, but this will only cover the tangible cost of reinstatement; therefore, homeowners can still be advised based on the findings presented in this research whether or not investing in PLFRA measures are cost beneficial. Further, the findings from this research could inform the debate around Flood Re. There will be a significant financial benefit to the insurer if the homeowner is able to invest in the measures; however, to encourage homeowners in investing in the measures, insurance companies can incentivise homeowners by way of premium reduction. The financial benefit of such decision can be calculated by using the findings presented in this research, especially the cost benefit ratios.

The developed CBA model of PLFRA measures can be used by homeowners to make informed decision on adaptation measures to be adopted or it can be used by flood risk assessors employed by homeowners to carry out flood risk assessment on their properties, and then implement its recommendations. The report from risk assessor can be used to advise insurance companies of the steps already taken by homeowners to reduce potential flood risk. This may make such property to be insurable at affordable price.

During flood recovery period, loss adjusters are in most cases appointed to discuss the extent of the insurers' liability with the homeowners, during this discussion about policy cover and repair, the findings from this research can be used to advise homeowners of the opportunity to invest in PLFRA measures at additional cost, however, showing the indicative financial benefit of investing in the measures to the homeowners can encourage them in adopting adaptation measures.

The findings from the research could be used for budgetary purposes on government grants on adaptation measures, most especially the fact that the findings include value of intangible benefits. The UK government, under the umbrella of Flood Re, is currently in discussion with the ABI to contribute financially towards reinstatement cost, if there is large scale flood event such as the one experienced in the summer 2007, thus findings from this research can provide a cost and benefit indication during the reinstatement period which may encourage government from assisting homeowners to take-up the resilience measures.

11.6 RECOMMENDATIONS FOR FURTHER RESEARCH

This research, having focused on developing CBA model of PLFRA measures, cannot claim to have addressed in full all issues related to the costs and benefits of PLFRA measures. Therefore, further research is recommended in the following areas:

- Findings from this study require a replica study in commercial property owners for comparison and validation of the universality of these findings. In carrying out research on commercial properties, there is a need to devise a means to tackle the challenges on data accessibility, which is a peculiar issue on commercial properties.
- The second area is in regards to the method of elicitation of WTP values from homeowners as used in this research. There are other SPM elicitation methods which can be used. Research could be carried out to use other elicitation methods such as choice modeling method and then be compared and contrasted with the findings of this research to see if the values of WTP would similar to the findings in this research.

- This research was limited by the current economic conditions. If these conditions change as indicated in recent economic reports, the mean WTP to avoid impact of flooding on households may change. Therefore, it is recommended that further research should be carried out, say in the next 3-years, to establish whether an improvement in the economy has any impact on WTP values.
- The CBA model developed in the course of this research was aimed at simplifying decision making on investment in PLFRA measures. The use of appropriate software to simplify the simulation process and make it easier for the users would enhance the accessibility of the findings. A semi-automated template which is interactive, user friendly, and with more simulation options could be useful, this is in line with the suggestions by homeowners and loss adjusters/surveyor at the external validation stage of the research.

11.7 SUMMARY

The research was conducted by applying the well-known concept of CBA to PLFRA measures with the incorporation of intangible benefits of the measures in the CBA model. This chapter has, thus, provided a review of the original research objectives and the extent to which they were achieved. The main conclusions addressing the research aim and, hence, the research questions have been presented; and the main contributions to knowledge have been summarised. The practical implications of the research findings and recommendations for further studies have also been presented.

In summary, the research has developed the CBA model of PLFRA measures, representing a robust mechanism for decision making on investing in PLFRA measures by homeowners. The model could be used by flood risk management professionals to advise homeowners of the potential benefits of investing in PLFRA measures. It is, therefore, contended that the developed CBA models have the potential for improving the up-take of PLFRA measures among the floodplain residents. This research, thus, provides the much-needed comprehensive cost and benefit information in the domain of flood risk management at household levels.

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APPENDIX A-1: LETTER OF PERMISSION TO USE DATA FOR THE RESEARCH

Association of British Insurers
51 Gresham Street
London
EC2V 7HQ

20th June 2012

Dear Mr Joseph,

Re: Request for permission to use data

Thank you for your request regarding the use of policyholder contact details within your PhD research degree at the University of the West of England. We are happy to inform you that we have no problem with you approaching the participants from the ABI Research Paper (2009) on Resilient Reinstatement, as part of your research into the intangible effects of flooding. We note that your research will be undertaken in strict accordance with the University's standards and procedures for ethics and will be fully compliant with all data protection requirements.

We would, however, kindly ask that you keep us in the loop regarding the findings from the research. We would envisage this as coming through an executive summary at the point of completion of the thesis. We would also wish to be informed should the results of the research be published more widely.

Please let us know if you have any questions on any of this. Also, we apologise for not having provided a definite answer sooner.

Yours Sincerely,

Rod Logan
Statistical Analyst
Association of British Insurers
Tel: 020 7216 7385
Email: rod.logan@abi.org.uk

APPENDIX A-2: TYPICAL COVER LETTER FOR MAIN SURVEY

Dear Homeowner,

LETTER OF INVITATION TO PARTICIPATE

My name is Rotimi Joseph, and I am a PhD student studying at the University of the West of England, Bristol working under the supervision of Professor David Proverbs, Dr Jessica Lamond and Mr Peter Wassell. As part of my doctoral programme I am carrying out a study into the costs and benefits of adapting homes to flood risk in order to reduce future flood damage. The main purpose of the research is to develop a deeper understanding of the costs and benefits involved in adapting homes to flooding. It is hoped this will lead to the development of a decision support tool to assist homeowners in determining what flood risk adaptation measures would be beneficial to their own property.

The study is concentrating on the 2007 flooding event and on those properties that were flooded. We understand through the Association of British Insurance (ABI) domestic insurance claim data base, (which is a confidential database used solely for research purposes) that your property was flooded during this event and I would like to invite you to participate by completing the enclosed questionnaire. Other homeowners that experienced flood damage to their properties in 2007 have also been invited to participate in the study. Your participation in the research is invaluable and I estimate completion of the questionnaire will take no more than 20 minutes of your time.

Some of the questions in the questionnaire concern your feelings about the 2007 flood event and we recognise that you may not want to be reminded of the event. Rest assured that the study has received approval from the University and complies with the University's strict ethical procedures and standards. The questionnaire is enclosed within the envelope marked 'Main Questionnaire' and should only be opened having read this letter of invitation and the enclosed participant information sheet.

Should you choose to participate in the research, please open the envelope, complete the questionnaire, and return it in the enclosed stamped self-addressed envelope. Please note that returning the completed questionnaire will be considered as your consent to participate in this survey. You are allowed to withdraw your consent on or before 4th September 2013. (Our contact details are at the bottom of this letter). Further details on the research project, what you are expected to do, some important contact details and in particular how the information you provided will be used are detailed in the enclosed participant information sheet.

If you wish to receive a copy of the results of the research, please indicate as such in the questionnaire 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

Rotimi Joseph
Doctoral Student
Tel: 0117 32 83667
Email: Rotimi.joseph@uwe.ac.uk

Professor David Proverbs
0117 3283562
David.proverbs@uwe.ac.uk

APPENDIX A-3: QUESTIONNAIRE

INVESTIGATING THE COSTS AND BENEFITS OF ADAPTING HOMES TO REDUCE FUTURE FLOOD DAMAGE – YOUR VIEWS

This is an independent doctoral study carried out by the University of the West of England (UWE), Bristol and is for academic and research purposes only. It is a follow up of the exercise in 2009 that was carried out in partnership with the Association of British Insurers (ABI).

The questionnaire seeks to find out how homeowners feel about the effects of flood damage to their property and how willing people would be to pay for adaptations to be carried out to their homes to prevent similar damage in the future. Ultimately, the object of the research is to help homeowners make informed decisions about adapting their home to future flooding.

The information you give will be held confidentially by the UWE Bristol 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 no longer than 20 minutes. We hope that you will find the questionnaire interesting.

Section A: General Information about you and your household

A1. Are you a		☐ Homeowner		☐ Tenant	
A2. Are you a		☐ Male		☐ Female	
A3. How old are you?		☐18-38	☐ 39-64	☐ 65-74	☐ Over 75
A4. How long have you lived here?	☐ 1-2 years	☐ 3-4 years	☐ 5-6 years	☐ 7-8 years	☐ Over 8 years
A5. How many people are there in your household (including infants)?		☐ 1	☐ 2-3	☐ 4-6	☐ Over 6

Section B: Your flood experience

B1. How many times did you experience flooding to your property before **2007?**	☐ None	☐ One	☐ Two	☐ other, please specify		
B2. How many times have you experienced flooding to your property after the summer **2007** flood event**?**	☐ None	☐ One	☐ Two	☐ other, please specify		
B3. Were you and your household relocated to an alternative accommodation while your property was repaired in 2007?	☐ Yes	☐ No				
B4. For how long?	☐ 1-3 months	☐ 4-6 months	☐ 7-9 months	☐ 10-12 months	☐ Over 12 months	☐ Not applicable
B5. Did you receive flood warning before your property was flooded in 2007? Please tick one box	☐ Yes	☐ No	☐ Don't know			
B6. How long before the flood waters entered your home did you receive the warning? Please tick one box	☐ Less than 1hour	☐ 1-3 hours	☐ 4-7 hours	☐ 8-12 hours	☐ over 13 hours	☐ Not applicable
B7. Were you able to do anything to prevent damage to your property as a result of the warning?	☐ Yes	☐ No	☐ Don't know	☐ Not applicable		

Section C: Impacts of 2007 flood on your household

C1. Please rate the severity of the impacts of the 2007 flood event on the members of your household. Please tick all that apply.

Flood Impacts	No Impact	Marginal Impact	Moderate Impact	High Impact	Extreme Impact
	1	2	3	4	5
Stress of flood					
Having to leave home for longer period					
Dealing with insurers					
Dealing with builders					
Time to return to normal household activity					
Worry about future flooding					
Strains between family					
Deterioration to physical health					
Deterioration to mental health					
Loss of irreplaceable/sentimental items					
Disruption of livelihood and income					
Destruction of property					
Worry about loss of house value					
Increase in insurance premium					
Inability to obtain insurance cover					
Other – Please specify					

C2. What is the total amount you would be willing to pay each year for your household to avoid the flood impacts listed in section C1 above?	Please enter amount. £

C3. Please indicate to what extent the following psychological effects have affected members of your household.

	Never	Rarely	Sometimes	Very often	Always
	1	2	3	4	5
Anxiety when it rains or when river levels rise					
Increased stress levels					
Depression					
Sleeplessness					
Nightmares					
Flashbacks to the flood event					
Increased use of alcohol					
Increased visits to the GP					
Increased anger					
Increased tensions in relationships For example, more arguing					
Difficulty concentrating on everyday tasks					

C4. What is the total amount you would be willing to pay each year for your household to avoid the psychological effect listed in section C3 above?	Please enter value £

Section D: Awareness of flood adaptation measures

D1. There are many flood adaptation measures which can be used to reduce flood impacts on your properties and households, these includes resistance and resilience measures. Please indicate the adaptation measures you were aware of and implemented in 2007 when your property was repaired. Please tick all that apply to your household.

	Aware	Not Aware	Implemented	Not Implemented
	1	2	1	2
Registering for flood warning				
Use of Sandbags to prevent water entering				
Moving vulnerable items to first floor				
Relocating kitchen to first floor				

D2. Please indicate which of the resistance measures you were aware of and which of these you implemented in your property. Please tick all that apply to your household.

	Aware	Not Aware	Implemented	Not Implemented
	1	2	1	2
Covers that you can use for Airbricks and Vents				
Waterproofing of external walls				
Installation of non return value to prevent water coming through drains				
Smart airbricks and vents that close automatically				
Guards you can use to cover doors and windows				
Door and window guards that close automatically				
Silicone gel around openings for cables				

D3. What was the total approximate cost of the resistance measures you implemented after the summer 2007 flood event?	Please enter the value £

D4. Please indicate which of the resilience measures you were aware of and which of these you implemented when your property was repaired in 2007. Please tick all that apply to your household.

	Aware	Not Aware	Implemented	Not Implemented
	1	2	1	2
Installing concrete floor instead of timber floor				
Replace carpet floor finishing with floor tiles				
Replacing normal plaster with water resistant plaster				
Raising electrical sockets above likely flood level				
Moving gas and electric meters above likely flood level				
Tanking of ground floor and basements				
Replacing kitchen units with plastic units				
Replacing kitchen units with stainless steel units				

D5. What was the total approximate cost of the resilience measures you implement after the summer 2007 flood event?	Please enter the value £

Section E: Benefit of installing adaptation measures in your property

E1. To what extent do you agree or disagree with the following statements about adapting your property to flood risk and their potential to reduce the effect of future flooding on your property. Please tick one box for each statement.

	Strongly disagree	Disagree	Uncertain	Agree	Strongly agree

	1	2	3	4	5
Adapting property to flood risk can reduce/eliminate health effect					
Adapting property to flood risk can reduce worrying					
Adapting property to flood risk can increase community cohesion					
Adapting property to flood risk can reduce strain between family					
Adapting property to flood risk can reduce/eliminate stress of dealing with builders in future					
House value can be maintained by adapting property to flood risk					
Insurance costs can be reduced by adapting property					
Knowledge of the expected flood damage would encourage taking action to adapt property to flood risk					
Knowledge of flood frequency can encourage taking action to adapt property to flood risk					
I am in favour of adapting my property to flood risk in order to reduce flood impacts on my households					
I can afford to spend money on adaptation measures					
It is not my responsibility to adapt my property to flood risk					
It is the responsibility of my insurer to adapt my property to flood risk since I am fully insured					
It is not possible to prevent flood damage to property					
Adapting property to reduce flood impacts is a waste of money					

Section F: Financial impact of 2007 on your household

F1. Please indicate whether you incurred any costs for the following which were not reimbursed by your insurance company. Please tick all that apply to you.

	£0.00	£1 - £200	£201 - £400	£401 - £600	£601 - £800	Above £800 please state amount if known (£)
Extra expenses on food						
Extra travel cost: For example, due to increase in distance from alternative accommodation location to children's or work compare to from your home						
Extra phone expenses: For example, using mobile phone often due to non availability of landline						
Un paid leave: For example, time to wait for builder or loss adjuster						

Other expenses (Please specify)						

Section G: Your Household income

G1. What is your household income per year?	☐ < £5000	☐ 5,000- £14,999	☐ £15,000- £24,999	☐ £25,000- £34,999	☐ £35,000- £44,999	☐ £45,000- £54,999	☐ Over £55,000
G2. How would you describe the occupation of the main income earner?	☐ Professional /managerial	☐ Clerical and other white collar	☐ Skilled manual	☐ Semi-skilled / unskilled manual	☐ Unemployed	☐ Retired	

Section H: Other comments about your experience

H1. Please use this space to add any comments upon your experience of 2007 flood event and the ways in which your household was affected.

H2. Please indicate if you want to be sent a summary of findings	☐ Yes	☐ No

Thank you for completing the questionnaire. Your answers will assist us in developing a comprehensive method of quantifying costs and benefits of adopting property level flood risk adaptation measures.
If you require additional information or any clarification, please feel free to call me (Rotimi Joseph) on 0117 32 83667, alternatively you can send me an email: Rotimi.joseph@uwe.ac.uk

APPENDIX A-4: SAMPLE REMINDER POSTCARD

UWE BRISTOL

University of the West of England

Investigating the Costs and Benefits of Adapting Homes to Reduce Future Flood Damage

POSTCARD

Reminder to Participate

Investigating the Costs and Benefits of Adapting Homes to Reduce Future Flood Damage – Your Views

Dear Homeowner,

You should have received a copy of our questionnaire survey in the on 8th February 2013. The main purpose of the research is to develop a deeper understanding of the costs and benefits involved in adapting homes to flooding. It is hoped this will lead to the development of a decision support tool to assist homeowners in determining what flood risk adaptation measures would be beneficial to their own property.

If you have already returned your questionnaire, thank you for your reply. If not, please do so as soon as possible. However, if you have decided not to participate in the survey, please accept my sincere apologies for contacting you again.

Your participation is highly valuable and appreciated.

Rotimi Joseph
Doctoral Student
Tel: 0117 32 83667
Email: Rotimi.joseph@uwe.ac.uk

APPENDIX B-1: RESEARCH SAMPLE BUILDING TYPOLOGY

Property Type	No in the sample	Age of property	Flood depth (mm)	Flood Duration (hrs)	Floor construction methods	Wall construction methods
Bungalow	2	1956-1979	0-150	<24	Suspended timber	Cavity
Bungalow	1	1921-1955	301-500	<24	Solid concrete	Solid
Bungalow	1	1921-1955	0-150	<24	Suspended timber	Cavity
Bungalow	1	1956-1979	0-150	25-48	Suspended timber	Cavity
Bungalow	4	1956-1979	0-150	73>	Solid concrete	Solid
Bungalow	2	1956-1979	0-150	<24	Solid concrete	Cavity
Bungalow	2	1956-1979	151-300	<24	Solid concrete	Cavity
Bungalow	2	1921-1955	301-500	25-48	Suspended timber	Solid
Bungalow	2	1921-1955	301-500	73>	Solid concrete	Cavity
Bungalow	1	1956-1979	301-500	25-48	Solid concrete	Cavity
Bungalow	2	Post 1995	501-1000	25-48	Solid concrete	Solid
Bungalow	2	1956-1979	501-1000	25-48	Solid concrete	Cavity

Property Type	No in the sample	Age of property	Flood depth	Flood Duration	Floor construction method	Wall construction method
Detached	2	1980-1995	301-500	<24	Solid concrete	Cavity
Detached	1	1956-1979	0-150	<24	Suspended timber	Cavity
Detached	1	1980-1995	151-300	<24	Solid concrete	Cavity
Detached	2	Post 1995	151-300	<24	Solid concrete	Cavity
Detached	1	Post 1995	0-150	<24	Solid concrete	Cavity
Detached	2	1956-1979	151-300	<24	Suspended timber	Cavity
Detached	1	1921-1955	0-150	<24	Suspended timber	Cavity
Detached	2	1956-1979	501-1000	<24	Solid concrete	Cavity
Detached	1	1980-1995	Over 1000	<24	Solid concrete	Cavity
Detached	3	1980-1995	301-500	25-48	Suspended timber	Cavity
Detached	3	1956-1979	0-150	<24	Solid concrete	Cavity
Detached	3	1956-1979	151-300	<24	Solid concrete	Cavity
Detached	1	1980-1995	501-1000	73>	Solid concrete	Cavity
Detached	1	1980-1995	151-300	<24	Suspended timber	Cavity
Detached	1	Post 1995	151-300	<24	Suspended timber	Cavity
Detached	2	Post 1995	0-150	<24	Suspended	Cavity

					timber	
Detached	3	1980-1995	Over 1000	<24	Suspended timber	Solid
Detached	1	Post 1995	501-1000	49-72	Suspended timber	Cavity
Detached	4	1956-1979	301-500	<24	Suspended timber	Cavity
Detached	1	Post 1995	301-500	25-48	Solid concrete	Cavity
Property Type	**No in the sample**	**Age of property**	**Flood depth**	**Flood Duration**	**Floor construction method**	**Wall construction method**
Semi-Detached	1	1956-1979	0-150	<24	Suspended timber	Cavity
Semi-Detached	9	1956-1979	151-300	<24	Solid concrete	Cavity
Semi-Detached	1	1921-1955	151-300	<24	Solid concrete	Solid
Semi-Detached	5	1921-1955	0-150	<24	Solid concrete	Solid
Semi-Detached	1	1956-1979	151-300	<24	Suspended timber	Solid
Semi-Detached	14	1921-1955	501-1000	25-48	Solid concrete	Solid
Semi-Detached	4	Pre 1920	301-500	49-72	Solid concrete	Solid
Semi-Detached	1	1956-1979	301-500	25-48	Suspended timber	Cavity
Semi-Detached	3	1921-1955	301-500	25-48	Solid concrete	Solid
Semi-Detached	2	Post 1995	151-300	<24	Solid concrete	Cavity
Semi-Detached	2	Post 1995	0-150	<24	Solid concrete	Cavity
Semi-Detached	4	Pre 1920	151-300	<24	Solid concrete	Solid
Semi-Detached	2	1956-1979	501-1000	<24	Suspended timber	Cavity
Semi-Detached	9	1956-1979	0-150	<24	Solid concrete	Cavity
Semi-Detached	4	1956-1979	301-500	<24	Solid concrete	Cavity
Semi-Detached	3	1921-1955	501-1000	<24	Suspended timber	Cavity
Semi-Detached	2	1921-1955	0-150	<24	Suspended timber	Cavity
Semi-Detached	1	1921-1955	151-300	<24	Suspended timber	Cavity
Semi-Detached	3	Pre 1920	0-150	<24	Suspended timber	Solid

Semi-Detached	1	1921-1955	301-500	<24	Suspended timber	Cavity
Semi-Detached	1	1956-1979	151-300	25-48	Solid concrete	Cavity
Semi-Detached	1	1956-1979	151-300	<24	Suspended timber	Cavity
Semi-Detached	1	Pre 1920	151-300	25-48	Suspended timber	Solid
Semi-Detached	1	Pre 1920	0-150	25-48	Suspended timber	Solid
Semi-Detached	1	1956-1979	501-1000	<24	Suspended timber	Cavity with installation
Semi-Detached	1	1921-1955	0-150	<24	Suspended timber	Solid
Semi-Detached	1	1921-1955	Over 1000	<24	Solid concrete	Cavity
Semi-Detached	1	1956-1979	301-500	73>	Solid concrete	Cavity
Semi-Detached	1	1956-1979	0-150	73>	Solid concrete	Cavity
Semi-Detached	4	1921-1955	301-500	25-48	Suspended timber	Cavity
Semi-Detached	1	1956-1979	301-500	25-48	Solid concrete	Cavity
Semi-Detached	2	1956-1979	301-500	49-72	Solid concrete	Cavity
Semi-Detached	9	1956-1979	501-1000	25-48	Solid concrete	Cavity
Semi-Detached	1	1956-1979	501-1000	<24	Solid concrete	Cavity
Semi-Detached	2	1921-1955	0-150	25-48	Solid concrete	Cavity
Semi-Detached	5	1980-1995	501-1000	25-48	Solid concrete	Cavity
Semi-Detached	1	1980-1995	301-500	25-48	Solid concrete	Cavity
Semi-Detached	4	Post 1995	301-500	25-48	Solid concrete	Cavity
Semi-Detached	1	1980-1995	0-150	25-48	Solid concrete	Cavity
Semi-Detached	1	1921-1955	501-1000	<24	Solid concrete	Cavity
Semi-Detached	1	1921-1955	Over 1000	<24	Suspended timber	Cavity
Semi-Detached	2	1921-1955	Over 1000	25-48	Suspended timber	Cavity
Property Type	**No in the sample**	**Age of property**	**Flood depth**	**Flood Duration**	**Floor construction method**	**Wall construction method**

Terraced	7	Pre 1920	301-500	<24	Suspended timber	Solid
Terraced	2	Pre 1920	Over 1000	73>	Solid concrete	Solid
Terraced	11	Pre 1920	151-300	<24	Suspended timber	Solid
Terraced	1	Pre 1920	0-150	73>	Solid concrete	Solid
Terraced	4	Pre 1920	Over 1000	25-48	Suspended timber	Solid
Terraced	2	Post 1995	151-300	25-48	Suspended timber	Cavity
Terraced	1	1956-1979	151-300	<24	Suspended timber	Solid
Terraced	26	1956-1979	0-150	<24	Solid concrete	Cavity
Terraced	2	1956-1979	151-300	<24	Solid concrete	Solid
Terraced	1	Pre 1920	0-150	25-48	Solid concrete	Solid
Terraced	2	Pre 1920	301-500	25-48	Solid concrete	Solid
Terraced	2	Post 1995	501-1000	25-48	Suspended timber	Cavity
Terraced	5	Pre 1920	501-1000	25-48	Solid concrete	Cavity
Terraced	1	Pre 1920	501-1000	<24	Solid concrete	Solid
Terraced	1	1921-1955	501-1000	73>	Solid concrete	Solid
Terraced	1	Pre 1920	501-1000	25-48	Solid concrete	Solid
Terraced	1	Pre 1920	501-1000	49-72	Solid concrete	Solid
Terraced	1	Pre 1920	151-300	49-72	Solid concrete	Solid
Terraced	1	1980-1995	501-1000	73>	Solid concrete	Cavity
Terraced	2	Pre 1920	0-150	<24	Solid concrete	Solid
Terraced	1	1921-1955	501-1000	49-72	Suspended timber	Cavity
Terraced	1	1980-1995	Over 1000	25-48	Solid concrete	Cavity
Terraced	14	Pre 1920	Over 1000	<24	Suspended timber	Solid
Terraced	3	Pre 1920	0-150	<24	Suspended timber	Solid
Terraced	1	1980-1995	0-150	<24	Suspended timber	Solid
Terraced	2	1956-1979	501-1000	<24	Suspended timber	Cavity
Terraced	2	1980-1995	151-300	<24	Solid concrete	Cavity
Terraced	3	1956-1979	301-500	<24	Solid concrete	Cavity
Terraced	1	Pre 1920	301-500	49-72	Suspended timber	Solid
Terraced	3	1921-1955	151-300	<24	Solid concrete	Cavity
Terraced	2	Pre 1920	501-1000	<24	Suspended timber	Solid

APPENDIX B-2: NORMALITY TEST OF THE RAW WTP SURVEY DATA

Tests of Normality

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
WTP to reduce impact of flooding	0.183	251	0.000	0.835	251	0.000
WTP to reduce psychological effects	0.177	251	0.000	0.772	251	0.000

a. Lilliefors Significance Correction

APPENDIX B-3: CORRELATION OF QUESTIONNAIRE RESPONSES

Correlations

			Respondent age	Household income level	Occupation of the main income earner	Time live in the property	Number of people living in the household	No of times being flooded pre 2007	No of times being flooded post 2007
Spearman's rho	Respondent age	Correlation Coefficient	1.000	-.360**	.652**	.244**	-.225**	.035	-.023
		Sig. (2-tailed)	.	.000	.000	.000	.000	.590	.727
		N	243	243	243	243	243	243	243
	Household income level	Correlation Coefficient	-.360**	1.000	-.611**	-.187**	.218**	-.089	.046
		Sig. (2-tailed)	.000	.	.000	.003	.001	.168	.478
		N	243	243	243	243	243	243	243
	Occupation of the main income earner	Correlation Coefficient	.652**	-.611**	1.000	.220**	-.174**	.037	.042
		Sig. (2-tailed)	.000	.000	.	.001	.006	.566	.517
		N	243	243	243	243	243	243	243
	Time live in the property	Correlation Coefficient	.244**	-.187**	.220**	1.000	-.111	.001	-.071
		Sig. (2-tailed)	.000	.003	.001	.	.084	.983	.268
		N	243	243	243	243	243	243	243
	Number of people living in the household	Correlation Coefficient	-.225**	.218**	-.174**	-.111	1.000	-.015	.061
		Sig. (2-tailed)	.000	.001	.006	.084	.	.812	.345
		N	243	243	243	243	243	243	243
	No of times being flooded pre 2007	Correlation Coefficient	.035	-.089	.037	.001	-.015	1.000	.209**
		Sig. (2-tailed)	.590	.168	.566	.983	.812	.	.001
		N	243	243	243	243	243	243	243
	No of times being flooded post 2007	Correlation Coefficient	-.023	.046	.042	-.071	.061	.209**	1.000
		Sig. (2-tailed)	.727	.478	.517	.268	.345	.001	.
		N	243	243	243	243	243	243	243

Correlations

			Respondent age	Household income level	Occupation of the main income earner	Time live in the property	Number of people living in the household	No of times being flooded pre 2007	No of times being flooded post 2007	Willingness to pay to reduce impact of flooding	Willingness to pay to reduce psychological effects
Spearman's rho	Respondent age	Correlation Coefficient	1.000	-.360**	.652**	.244**	-.225**	.035	-.023	.078	.086
		Sig. (2-tailed)	.	.000	.000	.000	.000	.590	.727	.226	.180
		N	243	243	243	243	243	243	243	243	243
	Household income level	Correlation Coefficient	-.360**	1.000	-.611**	-.187**	.218**	-.089	.046	.032	-.078
		Sig. (2-tailed)	.000	.	.000	.003	.001	.168	.478	.624	.228
		N	243	243	243	243	243	243	243	243	243
	Occupation of the main income earner	Correlation Coefficient	.652**	-.611**	1.000	.220**	-.174**	.037	.042	.012	.061
		Sig. (2-tailed)	.000	.000	.	.001	.006	.566	.517	.852	.342
		N	243	243	243	243	243	243	243	243	243
	Time live in the property	Correlation Coefficient	.244**	-.187**	.220**	1.000	-.111	.001	-.071	.140*	.046
		Sig. (2-tailed)	.000	.003	.001	.	.084	.983	.268	.029	.479
		N	243	243	243	243	243	243	243	243	243
	Number of people living in the household	Correlation Coefficient	-.225**	.218**	-.174**	-.111	1.000	-.015	.061	.052	-.047
		Sig. (2-tailed)	.000	.001	.006	.084	.	.812	.345	.422	.464
		N	243	243	243	243	243	243	243	243	243
	No of times being flooded pre 2007	Correlation Coefficient	.035	-.089	.037	.001	-.015	1.000	.209**	.090	.161*
		Sig. (2-tailed)	.590	.168	.566	.983	.812	.	.001	.161	.012
		N	243	243	243	243	243	243	243	243	243
	No of times being flooded	Correlation Coefficient	-.023	.046	.042	-.071	.061	.209**	1.000	.144*	.217**

	post 2007	Sig. (2-tailed)	.727	.478	.517	.268	.345	.001	.	.025	.001
		N	243	243	243	243	243	243	243	243	243
	Willingness to pay to reduce impact of flooding	Correlation Coefficient	.078	.032	.012	.140*	.052	.090	.144*	1.000	.619**
		Sig. (2-tailed)	.226	.624	.852	.029	.422	.161	.025	.	.000
		N	243	243	243	243	243	243	243	243	243
	Willingness to pay to reduce psychological effects	Correlation Coefficient	.086	-.078	.061	.046	-.047	.161*	.217**	.619**	1.000
		Sig. (2-tailed)	.180	.228	.342	.479	.464	.012	.001	.000	.
		N	243	243	243	243	243	243	243	243	243

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).

Correlations

			Severity of stress impact of flooding	Severity of having to leave home	Severity of dealing with insurer	Severity of having to deal with Builders	Severity of time and effort to return to normal	Severity of worry about future flooding	Severity of strains between family	Severity of deterioration of physical health	Severity of deterioration of mental health	Severity of loss of irreplaceable item	Severity of disruption of livelihood and income	Severity of disruption of property	Severity of worry about loss of house value	Severity of increase in insurance premium	Severity of inability to obtain insurance cover	WTP reduce impact of flooding
Spearman's rho	Severity of stress impact of flooding	Correlation Coefficient	1.000	.528**	.412**	.350**	.517**	.452**	.402**	.531**	.452**	.343**	.281**	.479**	.442**	.221**	.083	.158*
		Sig. (2-tailed)	.	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.001	.198	.014
		N	243	243	243	243	243	243	243	243	243	243	243	243	243	243	243	243
	Severity of having to leave home	Correlation Coefficient	.528**	1.000	.476**	.443**	.476**	.286**	.378**	.418**	.421**	.408**	.323**	.468**	.380**	.331**	.253**	.231**
		Sig. (2-tailed)	.000	.	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
		N	243	243	243	243	243	243	243	243	243	243	243	243	243	243	243	243
	Severity of dealing with insurer	Correlation Coefficient	.412**	.476**	1.000	.613**	.451**	.273**	.310**	.322**	.409**	.208**	.158*	.217**	.308**	.223**	.218**	.124
		Sig. (2-tailed)	.000	.000	.	.000	.000	.000	.000	.000	.000	.001	.014	.001	.000	.000	.001	.054
		N	243	243	243	243	243	243	243	243	243	243	243	243	243	243	243	243
	Severity of having to deal with Builders	Correlation Coefficient	.350**	.443**	.613**	1.000	.407**	.097	.315**	.232**	.309**	.153*	.193**	.270**	.272**	.134*	.185**	.173**
		Sig. (2-tailed)	.000	.000	.000	.	.000	.130	.000	.000	.000	.017	.002	.000	.000	.037	.004	.007
		N	243	243	243	243	243	243	243	243	243	243	243	243	243	243	243	243
	Severity of time and effort to return to normal	Correlation Coefficient	.517**	.476**	.451**	.407**	1.000	.486**	.478**	.488**	.460**	.275**	.211**	.479**	.401**	.224**	.135*	.195**
		Sig. (2-tailed)	.000	.000	.000	.000	.	.000	.000	.000	.000	.000	.001	.000	.000	.000	.036	.002
		N	243	243	243	243	243	243	243	243	243	243	243	243	243	243	243	243
	Severity of worry about future flooding	Correlation Coefficient	.452**	.286**	.273**	.097	.486**	1.000	.325**	.385**	.266**	.181**	.153*	.395**	.412**	.333**	.238**	.261**
		Sig. (2-tailed)	.000	.000	.000	.130	.000	.	.000	.000	.000	.005	.017	.000	.000	.000	.000	.000
		N	243	243	243	243	243	243	243	243	243	243	243	243	243	243	243	243
	Severity of strains between family	Correlation Coefficient	.402**	.378**	.310**	.315**	.478**	.325**	1.000	.534**	.536**	.216**	.317**	.316**	.302**	.279**	.191**	.118
		Sig. (2-tailed)	.000	.000	.000	.000	.000	.000	.	.000	.000	.001	.000	.000	.000	.000	.003	.066
		N	243	243	243	243	243	243	243	243	243	243	243	243	243	243	243	243
	Severity of deterioratio	Correlation Coefficient	.531**	.418**	.322**	.232**	.488**	.385**	.534**	1.000	.652**	.309**	.317**	.377**	.323**	.236**	.196**	.127*

n of physical health	Sig. (2-tailed)	.000	.000	.000	.000	.000	.000	.000	.	.000	.000	.000	.000	.000	.000	.002	.049
	N	243	243	243	243	243	243	243	243	243	243	243	243	243	243	243	243
Severity of deterioration of mental health	Correlation Coefficient	.452**	.421**	.409**	.309**	.460**	.266**	.536**	.652**	1.000	.249**	.282**	.291**	.310**	.237**	.227**	.159*
	Sig. (2-tailed)	.000	.000	.000	.000	.000	.000	.000	.000	.	.000	.000	.000	.000	.000	.000	.013
	N	243	243	243	243	243	243	243	243	243	243	243	243	243	243	243	243
Severity of loss of irreplaceable item	Correlation Coefficient	.343**	.408**	.208**	.153*	.275**	.181**	.216**	.309**	.249**	1.000	.216**	.574**	.302**	.105	.204**	.092
	Sig. (2-tailed)	.000	.000	.001	.017	.000	.005	.001	.000	.000	.	.001	.000	.000	.104	.001	.151
	N	243	243	243	243	243	243	243	243	243	243	243	243	243	243	243	243
Severity of disruption of livelihood and income	Correlation Coefficient	.281**	.323**	.158*	.193**	.211**	.153*	.317**	.317**	.282**	.216**	1.000	.273**	.205**	.168**	.154*	.179**
	Sig. (2-tailed)	.000	.000	.014	.002	.001	.017	.000	.000	.000	.001	.	.000	.001	.009	.016	.005
	N	243	243	243	243	243	243	243	243	243	243	243	243	243	243	243	243
Severity of disruption of property	Correlation Coefficient	.479**	.468**	.217**	.270**	.479**	.395**	.316**	.377**	.291**	.574**	.273**	1.000	.416**	.250**	.177**	.181**
	Sig. (2-tailed)	.000	.000	.001	.000	.000	.000	.000	.000	.000	.000	.000	.	.000	.000	.006	.005
	N	243	243	243	243	243	243	243	243	243	243	243	243	243	243	243	243
Severity of worry about loss of house value	Correlation Coefficient	.442**	.380**	.308**	.272**	.401**	.412**	.302**	.323**	.310**	.302**	.205**	.416**	1.000	.399**	.244**	.248**
	Sig. (2-tailed)	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.001	.000	.	.000	.000	.000
	N	243	243	243	243	243	243	243	243	243	243	243	243	243	243	243	243
Severity of increase in insurance premium	Correlation Coefficient	.221**	.331**	.223**	.134*	.224**	.333**	.279**	.236**	.237**	.105	.168**	.250**	.399**	1.000	.551**	.249**
	Sig. (2-tailed)	.001	.000	.000	.037	.000	.000	.000	.000	.000	.104	.009	.000	.000	.	.000	.000
	N	243	243	243	243	243	243	243	243	243	243	243	243	243	243	243	243
Severity of inability to obtain insurance cover	Correlation Coefficient	.083	.253**	.218**	.185**	.135*	.238**	.191**	.196**	.227**	.204**	.154*	.177**	.244**	.551**	1.000	.195**
	Sig. (2-tailed)	.198	.000	.001	.004	.036	.000	.003	.002	.000	.001	.016	.006	.000	.000	.	.002
	N	243	243	243	243	243	243	243	243	243	243	243	243	243	243	243	243
WTP to reduce impact of flooding	Correlation Coefficient	.158*	.231**	.124	.173**	.195**	.261**	.118	.127*	.159*	.092	.179**	.181**	.248**	.249**	.195**	1.000
	Sig. (2-tailed)	.014	.000	.054	.007	.002	.000	.066	.049	.013	.151	.005	.005	.000	.000	.002	.
	N	243	243	243	243	243	243	243	243	243	243	243	243	243	243	243	243

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).

Correlations

			Frequency of anxiety when it rains	Frequency of increase stress level	Frequency of depression	Frequency of sleeplessness	Frequency of nightmares	Frequency of flashbacks to the flood event	Frequency of using alcohol	Frequency of visit to the doctor's surgery	Increase frequency of anger	Frequency of tension in relationships	Frequency of difficulty in concentrating on everyday tasks	WTP to reduce psychological effects
Spearman's rho	Frequency of anxiety when it rains	Correlation Coefficient	1.000	.801**	.522**	.540**	.313**	.484**	.208**	.355**	.403**	.342**	.461**	.254**
		Sig. (2-tailed)	.	.000	.000	.000	.000	.000	.001	.000	.000	.000	.000	.000
		N	243	243	243	243	243	243	243	243	243	243	243	243
	Frequency of increase stress level	Correlation Coefficient	.801**	1.000	.616**	.591**	.414**	.528**	.266**	.397**	.438**	.411**	.554**	.273**
		Sig. (2-tailed)	.000	.	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
		N	243	243	243	243	243	243	243	243	243	243	243	243
	Frequency of depression	Correlation Coefficient	.522**	.616**	1.000	.728**	.536**	.357**	.296**	.446**	.423**	.459**	.487**	.221**
		Sig. (2-tailed)	.000	.000	.	.000	.000	.000	.000	.000	.000	.000	.000	.001
		N	243	243	243	243	243	243	243	243	243	243	243	243
	Frequency of sleeplessness	Correlation Coefficient	.540**	.591**	.728**	1.000	.612**	.429**	.288**	.409**	.429**	.444**	.527**	.166**
		Sig. (2-tailed)	.000	.000	.000	.	.000	.000	.000	.000	.000	.000	.000	.010
		N	243	243	243	243	243	243	243	243	243	243	243	243
	Frequency of nightmares	Correlation Coefficient	.313**	.414**	.536**	.612**	1.000	.496**	.287**	.443**	.450**	.393**	.404**	.152*
		Sig. (2-tailed)	.000	.000	.000	.000	.	.000	.000	.000	.000	.000	.000	.018
		N	243	243	243	243	243	243	243	243	243	243	243	243
	Frequency of flashbacks to the flood event	Correlation Coefficient	.484**	.528**	.357**	.429**	.496**	1.000	.285**	.550**	.507**	.478**	.522**	.190**
		Sig. (2-tailed)	.000	.000	.000	.000	.000	.	.000	.000	.000	.000	.000	.003
		N	243	243	243	243	243	243	243	243	243	243	243	243
	Frequency of using alcohol	Correlation Coefficient	.208**	.266**	.296**	.288**	.287**	.285**	1.000	.552**	.428**	.435**	.396**	-.028
		Sig. (2-tailed)	.001	.000	.000	.000	.000	.000	.	.000	.000	.000	.000	.663
		N	243	243	243	243	243	243	243	243	243	243	243	243
	Frequency of visit to the doctor's surgery	Correlation Coefficient	.355**	.397**	.446**	.409**	.443**	.550**	.552**	1.000	.542**	.566**	.574**	.121
		Sig. (2-tailed)	.000	.000	.000	.000	.000	.000	.000	.	.000	.000	.000	.059
		N	243	243	243	243	243	243	243	243	243	243	243	243
	Increase frequency of anger	Correlation Coefficient	.403**	.438**	.423**	.429**	.450**	.507**	.428**	.542**	1.000	.582**	.556**	.166**
		Sig. (2-tailed)	.000	.000	.000	.000	.000	.000	.000	.000	.	.000	.000	.010
		N	243	243	243	243	243	243	243	243	243	243	243	243

Frequency of tension in relationships	Correlation Coefficient	.342**	.411**	.459**	.444**	.393**	.478**	.435**	.566**	.582**	1.000	.724**	.135*
	Sig. (2-tailed)	.000	.000	.000	.000	.000	.000	.000	.000	.000	.	.000	.035
	N	243	243	243	243	243	243	243	243	243	243	243	243
Frequency of difficulty in concentrating on everyday tasks	Correlation Coefficient	.461**	.554**	.487**	.527**	.404**	.522**	.396**	.574**	.556**	.724**	1.000	.182**
	Sig. (2-tailed)	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.	.004
	N	243	243	243	243	243	243	243	243	243	243	243	243
WTP to reduce psychological effects	Correlation Coefficient	.254**	.273**	.221**	.166**	.152*	.190**	-.028	.121	.166**	.135*	.182**	1.000
	Sig. (2-tailed)	.000	.000	.001	.010	.018	.003	.663	.059	.010	.035	.004	.
	N	243	243	243	243	243	243	243	243	243	243	243	243

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).

APPENDIX B-4: REGRESSION MODEL STATISTICS FOR COMBINED WTP VALUES

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics					Durbin-Watson
					R Square Change	F Change	df1	df2	Sig. F Change	
1	.299[a]	.089	.086	521.91353	.089	23.661	1	241	.000	
2	.358[b]	.128	.121	511.66384	.039	10.752	1	240	.001	
3	.392[c]	.154	.143	505.29138	.025	7.092	1	239	.008	
4	.412[d]	.170	.156	501.36611	.017	4.757	1	238	.030	1.971

a. Predictors: (Constant), Frequency of increase stress level
b. Predictors: (Constant), Frequency of increase stress level, Severity of increase in insurance premium
c. Predictors: (Constant), Frequency of increase stress level, Severity of increase in insurance premium, No of times being flooded post 2007
d. Predictors: (Constant), Frequency of increase stress level, Severity of increase in insurance premium, No of times being flooded post 2007, Severity of having to deal with Builders
e. Dependent Variable: Combined WTP to reduce impact & Psychological effect of flooding

ANOVA[e]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	6445109.214	1	6445109.214	23.661	.000[a]
	Residual	65646889.749	241	272393.733		
	Total	72091998.963	242			
2	Regression	9260027.463	2	4630013.731	17.685	.000[b]
	Residual	62831971.500	240	261799.881		
	Total	72091998.963	242			
3	Regression	11070668.127	3	3690222.709	14.453	.000[c]
	Residual	61021330.836	239	255319.376		
	Total	72091998.963	242			
4	Regression	12266419.915	4	3066604.979	12.200	.000[d]
	Residual	59825579.048	238	251367.979		
	Total	72091998.963	242			

a. Predictors: (Constant), Frequency of increase stress level
b. Predictors: (Constant), Frequency of increase stress level, Severity of increase in insurance premium
c. Predictors: (Constant), Frequency of increase stress level, Severity of increase in insurance premium, No of times being flooded post 2007
d. Predictors: (Constant), Frequency of increase stress level, Severity of increase in insurance premium, No of times being flooded post 2007, Severity of having to deal with Builders
e. Dependent Variable: Combined WTP to reduce impact & Psychological effect of flooding

Coefficients[a]

Model		Unstandardized Coefficients B	Unstandardized Coefficients Std. Error	Standardized Coefficients Beta	t	Sig.
1	(Constant)	211.983	96.716		2.192	.029
	Frequency of increase stress level	135.761	27.910	.299	4.864	.000
2	(Constant)	-52.387	124.460		-.421	.674
	Frequency of increase stress level	118.216	27.880	.260	4.240	.000
	Severity of increase in insurance premium	87.854	26.793	.201	3.279	.001
3	(Constant)	-212.341	136.802		-1.552	.122
	Frequency of increase stress level	103.344	28.094	.228	3.679	.000
	Severity of increase in insurance premium	82.949	26.523	.190	3.127	.002
	No of times being flooded post 2007	203.624	76.464	.163	2.663	.008
4	(Constant)	-364.546	152.627		-2.388	.018
	Frequency of increase stress level	88.043	28.744	.194	3.063	.002
	Severity of increase in insurance premium	77.373	26.441	.177	2.926	.004
	No of times being flooded post 2007	219.647	76.224	.175	2.882	.004
	Severity of having to deal with Builders	58.683	26.906	.134	2.181	.030

a. Dependent Variable: Combined WTP to reduce impact & Psychological effect of flooding

Residuals Statistics[a]

	Minimum	Maximum	Mean	Std. Deviation	N
Predicted Value	79.1999	1,546.4939	653.3457	225.13926	243
Residual	-1,356.20715	2,101.77734	.00000	497.20533	243
Std. Predicted Value	-2.550	3.967	.000	1.000	243
Std. Residual	-2.705	4.192	.000	.992	243

a. Dependent Variable: Combined WTP to reduce impact & Psychological effect of flooding

APPENDIX C-1: MODEL MEDIAN BENEFIT OF RESILIENCE MEASURES FOR A BUNGALOW PROPERTY

Model of discounted median benefit of resilience measures for a bungalow based on floor types and incorporating value of intangible benefit

Floor construction	Flood return period (Flood probability (p)	Flood depths (mm)			
		0-150	151-300	301-500	501-1000
Concrete solid floor	5 year (0.20)	£95,384	£105,043	£157,002	£206,796
	10 year (0.10)	£50,897	£55,727	£81,707	£106,604
	20 year (0.05)	£28,654	£31,069	£44,059	£56,507
	25 year (0.04)	£24,206	£26,138	£36,529	£46,488
	40 year (0.025)	£17,533	£18,740	£25,235	£31,459
	50 year (0.02)	£15,308	£16,274	£21,470	£26,450
Suspended Timber floor	5 year (0.20)	£106,190	N/A*	£183,667	N/A*
	10 year (0.10)	£57,155	N/A*	£95,039	N/A*
	20 year (0.05)	£32,637	N/A*	£50,725	N/A*
	25 year (0.04)	£26,953	N/A*	£41,862	N/A*
	40 year (0.025)	£19,728	N/A*	£28,568	N/A*
	50 year (0.02)	£17,211	N/A*	£24,137	N/A*

N/A* means not available in the sample

APPENDIX C-2 MODEL MEDIAN BENEFIT OF RESILIENCE MEASURES FOR A DETACHED PROPERTY

Model of discounted median Benefit of resilience measures for a detached property based on floor types incorporating value of intangible benefit

Floor construction	Flood return period (Flood probability (p)	Flood depths (mm)				
		0-150	151-300	301-500	501-1000	Over 1000
Concrete solid floor	5 year (0.20)	£77,731	£84,892	£108,207	£144,845	£158,001
	10 year (0.10)	£42,071	£45,652	£57,309	£75,628	£82,206
	20 year (0.05)	£24,241	£26,031	£31,860	£41,020	£44,309
	25 year (0.04)	£20,675	£22,107	£26,770	£34,098	£36,729
	40 year (0.025)	£15,326	£16,221	£19,136	£23,715	£25,360
	50 year (0.02)	£13,543	£14,259	£16,591	£20,255	£21,570
Suspended Timber floor	5 year (0.20)	£84,692	£92,569	£118,216	£158,517	£172,989
	10 year (0.10)	£45,552	£49,490	£62,314	£82,464	£89,700
	20 year (0.05)	£25,981	£27,951	£34,362	£44,438	£48,056
	25 year (0.04)	£22,067	£23,643	£28,772	£36,832	£39,727
	40 year (0.025)	£16,196	£17,181	£20,387	£25,425	£27,234
	50 year (0.02)	£14,239	£15,027	£17,592	£21,622	£23,069

APPENDIX C-3 MODEL MEDIAN BENEFIT OF RESILIENCE MEASURES FOR A SEMI-DETACHED PROPERTY

Model of discounted median benefit of resilience measures for a semi-detached property based on floor types incorporating value of intangible benefit

Floor construction	Flood return period (Flood probability (p)	Flood depths (mm)				
		0-150	151-300	301-500	501-1000	Over 1000
Concrete solid floor	5 year (0.20)	£87,057	£90,388	£100,546	£111,205	£126,692
	10 year (0.10)	£46,734	£48,399	£53,479	£58,808	£66,552
	20 year (0.05)	£26,573	£27,405	£29,945	£32,610	£36,482
	25 year (0.04)	£22,540	£23,207	£25,238	£27,370	£30,467
	40 year (0.025)	£16,492	£16,908	£18,178	£19,510	£21,446
	50 year (0.02)	£14,476	£14,809	£15,825	£16,891	£18,439
Suspended Timber floor	5 year (0.20)	£94,951	£98,615	£109,789	£121,513	£138,550
	10 year (0.10)	£50,681	£52,513	£58,100	£63,962	£72,481
	20 year (0.05)	£28,546	£29,462	£32,256	£35,187	£39,446
	25 year (0.04)	£24,119	£24,852	£27,087	£29,432	£32,839
	40 year (0.025)	£17,479	£17,937	£19,333	£20,799	£22,929
	50 year (0.02)	£15,265	£15,632	£16,749	£17,921	£19,625

APPENDIX C-4 MODEL MEDIAN BENEFIT OF RESILIENCE MEASURES FOR A TERRACED PROPERTY

Model of discounted median benefit of resilience measures for a terraced property based on floor types incorporating value of intangible benefit

Floor construction	Flood return period (Flood probability (p)	Flood depths (mm)				
		0-150	151-300	301-500	501-1000	Over 1000
Concrete solid floor	5 year (0.20)	£83,060	£85,225	£85,059	£98,381	£114,702
	10 year (0.10)	£44,736	£45,818	£45,735	£52,396	£60,557
	20 year (0.05)	£25,573	£26,115	£26,073	£29,404	£33,484
	25 year (0.04)	£21,741	£22,174	£22,141	£24,805	£28,069
	40 year (0.025)	£15,992	£16,263	£16,242	£17,908	£19,948
	50 year (0.02)	£14,076	£14,293	£14,276	£15,608	£17,240
Suspended Timber floor	5 year (0.20)	£90,554	£92,936	£92,752	£107,408	£125,360
	10 year (0.10)	£48,483	£49,673	£49,582	£56,909	£65,886
	20 year (0.05)	£27,447	£28,042	£27,997	£31,660	£36,148
	25 year (0.04)	£23,240	£23,716	£23,679	£26,611	£30,201
	40 year (0.025)	£16,929	£17,227	£17,204	£19,036	£21,280
	50 year (0.02)	£14,826	£15,064	£15,045	£16,511	£18,306

APPENDIX C-5: EFFECT OF LOW DISCOUNT RATE ON THE DEVELOPED CBA MODEL OF RESILIENCE MEASURES (3.5%)

Floor construction	Flood return period (Flood probability (p)	Bungalow				Detached					Semi-detached					Terraced				
		Flood depths (mm)				Flood depths (mm)					Flood depths (mm)					Flood depths (mm)				
		0-150	151-300	301-500	501-1000	0-150	151-300	301-500	501-1000	Over 1000	0-150	151-300	301-500	501-1000	Over 1000	0-150	151-300	301-500	501-1000	Over 1000
Concrete solid floor	5 year (0.20)	10.1	9.7	13.2	11.0	9.5	8.9	9.1	9.6	9.9	10.2	10.6	11.7	13.0	14.8	9.5	9.8	9.7	11.3	13.1
	10 year (0.10)	5.4	5.1	6.9	5.7	5.1	4.8	4.8	5.0	5.1	5.4	5.0	5.1	4.8	5.2	5.1	4.7	4.4	4.7	4.6
	20 year (0.05)	3.0	2.9	3.7	3.0	3.0	2.7	2.7	2.7	2.8	3.1	2.8	2.8	2.6	2.8	2.9	2.7	2.5	2.6	2.5
	25 year (0.04)	2.6	2.4	3.1	2.5	2.5	2.3	2.2	2.2	2.3	2.6	2.4	2.4	2.2	2.4	2.5	2.3	2.1	2.2	2.1
	40 year (0.025)	1.8	1.7	2.1	1.7	1.9	1.7	1.6	1.6	1.6	1.9	1.7	1.7	1.6	1.7	1.8	1.7	1.6	1.6	1.5
	50 year (0.02)	1.6	1.5	1.8	1.4	1.6	1.5	1.4	1.3	1.3	1.7	1.5	1.5	1.4	1.4	1.6	1.4	1.4	1.4	1.3
Suspended Timber floor	5 year (0.20)	6.9		9.2		9.5	8.3	9.1	9.5	9.7	10.0	8.7	9.0	8.9	9.0	9.3	8.4	7.2	7.0	7.7
	10 year (0.10)	3.6		4.8		5.1	4.5	4.8	4.9	5.0	5.3	4.6	4.7	4.7	4.7	4.9	4.5	3.8	3.7	4.0
	20 year (0.05)	2.0		2.5		2.9	2.5	2.6	2.6	2.7	3.0	2.6	2.6	2.6	2.6	2.8	2.5	2.2	2.0	2.2
	25 year (0.04)	1.7		2.1		2.5	2.1	2.2	2.2	2.2	2.5	2.2	2.2	2.2	2.1	2.4	2.1	1.8	1.7	1.8
	40 year (0.025)	1.2		1.4		1.8	1.5	1.6	1.5	1.5	1.8	1.6	1.6	1.5	1.5	1.7	1.5	1.3	1.2	1.3
	50 year (0.02)	1.0		1.2		1.6	1.3	1.3	1.3	1.3	1.6	1.4	1.4	1.3	1.3	1.5	1.3	1.1	1.1	1.1

APPENDIX D-1: SUMMARY OF KEY RESEARCH FINDINGS

Summary of findings of the investigation into the costs and potential financial benefits of adapting homes to prevent future flood damage

Introduction

The need to take action to prevent future flood damage to properties and households cannot be over emphasised bearing in mind the frequent occurrence of flood events. One of the key steps towards taking preventative measures against flood risk is by investing in flood protection measures. This can be resistance measures (see examples in Table 1) which are install to keep flood water out of building or resilience measures (see examples in Table 2) which are install to reduce the damage caused to the internal fabric of buildings. Central to taking action to protect properties to flood risk is the need to have full knowledge of the costs and benefits of the protection measures. Therefore this research was undertaken to develop a deeper understanding of the costs and benefits of investing in flood protection measures. Notably this study has included the value of intangible benefits (such as stress, disruption to daily life and having to leave home) in the overall benefit of protecting properties against flood risk. Following the completion of this research, property level flood risk adaptation (PLFRA) **Decision Support Lookup Tables** (DSLT) have been developed for resistance and resilience measures. The DSLT was based on packages of resistance and resilience measures shown in Tables 1 and 2.

Table1. Package of resistance measures adopted for the research

Installation / deployment method	Individual Resistance measures
Manual	Demountable Door Guards Manual Airbrick and Vent Covers Sewerage bungs/toilet pan seals Waterproof external walls Silicone gel sealant around cables passing through external walls Sump pump
Automatic	Automatic door guards Smart airbricks and vents Non-return valves on main sewer pipe Waterproof external walls Silicone gel sealant around cables passing through external walls Sump pump

Table 2: Package of resilience measures adopted for the research

Resilience package	Individual Resilience measures
Resilience without flooring	Replace gypsum plaster with water resistant material, such as lime Replace doors, windows and frames with water-resistant alternatives Mount boilers on wall Move electrics well above likely flood level Move service meters well above likely flood level Replace chipboard kitchen/bathroom units with plastic units of water resistant panels Replace MDF panel with water resistant panels Decoration to allow re-wiring
Resilience with flooring	All measures above and Replace timber floor with solid concrete

The research was thus undertaken in pursuit of three objectives as follows:

1. To establish the additional cost of reinstating flood damaged property using resistance and resilience measures
2. To evaluate how much homeowners are willing and able to pay to avoid the intangible impacts and psychological effects of flooding on their households
3. To develop simple **Decision Support Lookup Tables** (DSLT) which integrate the findings from objectives 1 and 2 above.

The findings from the research are presented below:

1. In this research we found that the additional cost of resistance measures ranges from £3,500 to £10,800 depending on property types and deployment methods. (see Table 3)
2. We found that the additional cost of resilience measure ranges from £12,000 to £28,833. (see Table 3.

Table 3 Summary of additional costs of PLFRA measures based on different house types, flood depths, floor construction method and deployment methods

Floor construction	Property type	Cost of resilience measures (CM_{rt}) in flood depth (mm) categories					Cost of resistance measures (CM_{rs})	
		0-150	151-300	301-500	501-1000	Over 1000	Manual	Automatic
Concrete solid floor	Bungalow	£14,100	£16,200	£17,800	£28,300	N/A	£6,800	£10,800
	Detached	£12,200	£14,300	£17,900	£22,600	£24,000	£6,400	£10,200
	Semi-detached	£12,80	£14,400	£15,700	£18,400	£19,300	£4,000	£6,700
	Terraced	£13,100	£14,600	£15,500	£16,800	£19,800	£3,500	£5,200
Suspended timber floor	Bungalow	£23,000	N/A	£28,800	N/A	N/A	£6,800	£10,800
	Detached	£13,300	£17,000	£19,500	£25,100	£26,600	£6,400	£10,200
	Semi-detached	£14,200	£17,000	£18,300	£20,400	£23,000	£4,000	£6,700
	Terraced	£14,700	£16,500	£19,400	£23,100	£24,500	£3,500	£5,200

Note: These costs are in 2013 prices

3. The value of intangible benefit of flood protection measure was estimated as £653 per household per year.

4. Tables 4 and 5 present the **DSLT** for resistance and resilience measures.

How to use the Decision Support Lookup Tables (DSLT)

In developing the lookup table presented in Tables 4 and 5, it was assumed that flood protection measures have been fully implemented and functioned effectively. For instance for resistance measures, it is assumed that the neighbouring owners of semi-detached and terraced properties will also implement resistance flood protection measures

In interpreting the result, for a bungalow property located in an area designated as high risk flood area of 5 years flood return period, it means for every £1 invested in manual resistance flood protection measure, this will be expected to yield a financial benefit in terms of avoided loss of £15.70p. For automatic resistance flood protection measures in areas designated as 5 years flood return period, by investing £1 in the measure, will yield £12.10p.

Steps to be followed in using Table 4 (resistance measures) are as follows:

1. Select types of property in row 1
2. Select the anticipated flood return period from list in column 1
3. Select the preferred measure (manual or automatic), row 2 or 3 depending on the type of property

The cost to benefit ratio can then be read off the DSLT and a decision whether to invest in the measure or not can be made.

For example, a bungalow property located in an area designated as 25years flood return period, the benefit to cost ratio of investing in manually deployed resistance measures can be established as follows:

- Cost of measures (see Table 3, column 8) = £6,800
- Benefit cost ratio of investing £6,800 in manually deployed resistance measure over 20 years period (see Table 4, row 6, column 2) is 3.9. This means that for every £1 invested in the

measure based on the resistance measures adopted for this research a benefit of £3.90 can be gained; this represents the value of avoided loss.

Table 4 Decision support lookup table (DSLT) for resistance flood protection measures with the inclusion of intangible benefits

Flood return period (Flood probability FP)	Bungalow		Detached		Semi-detached		Terraced	
	Manual	Automatic	Manual	Automatic	Manual	Automatic	Manual	Automatic
5 year (0.20)	15.7	12.1	11.1	8.5	17.8	12.9	18.6	15.0
10 year (0.10)	8.3	6.3	6.0	4.5	9.7	6.9	10.2	8.1
20 year (0.05)	4.6	3.5	3.5	2.6	5.7	4.0	6.0	4.7
25 year (0.04)	3.9	2.9	3.0	2.2	4.8	3.4	5.2	4.0
40 year (0.025)	2.8	2.0	2.3	1.6	3.6	2.5	3.9	3.0
50 year (0.02)	2.4	1.7	2.0	1.4	3.2	2.2	3.5	2.6

Steps to be followed in using Table 5 (resilience measures) are as follows:

4. Select types of property in row 1
5. Select floor construction method (column 1)
6. Select the anticipated flood return period from list in column 2
7. Select anticipated flood depth (row 3), this can be known from experience or historic data

An example is provided below:

A detached property of concrete floor construction, located in an area designated as 10 years flood return period, with an anticipated flood depth of up to 500mm. The benefit cost ratio of investing in resilience measures for this property can be calculated thus;

- Cost of measures (see Table 3, row 4, column 5) = £17,871
- Benefit cost ratio of investing £17,871 in resilience measure over 20 years period (see Table 5, row 5, column 9) is 3.2. This means that for every £1 invested in the measure based on the resilience measures adopted for this research a benefit of £3.20 can be gained, this represents the value of avoided loss

Research feedback

I hope the information presented in this summary report will be useful to you and your households. I will appreciate it if you can complete the attached feedback form and email it back to me.

Table 5 Decision support lookup table (DSLT) for resilience flood protection measures with the inclusion of intangible benefits

Floor construction	Flood return period (Flood probability (p)	Bungalow				Detached					Semi-detached					Terraced				
		Flood depths (mm)				Flood depths (mm)					Flood depths (mm)					Flood depths (mm)				
		0-150	151-300	301-500	501-1000	0-150	151-300	301-500	501-1000	Over 1000	0-150	151-300	301-500	501-1000	Over 1000	0-150	151-300	301-500	501-1000	Over 1000
Concrete solid floor	5 year (0.20)	6.8	6.5	8.8	7.3	6.4	5.9	6.1	6.4	6.6	6.8	7.0	7.8	8.7	9.9	6.4	6.5	6.5	7.5	8.8
	10 year (0.10)	3.6	3.4	4.6	3.8	3.4	3.2	3.2	3.3	3.4	3.6	3.4	3.4	3.2	3.5	3.4	3.1	3.0	3.1	3.1
	20 year (0.05)	2.0	1.9	2.5	2.0	2.0	1.8	1.8	1.8	1.8	2.1	1.9	1.9	1.8	1.9	2.0	1.8	1.7	1.8	1.7
	25 year (0.04)	1.7	1.6	2.0	1.6	1.7	1.5	1.5	1.5	1.5	1.8	1.6	1.6	1.5	1.6	1.7	1.5	1.4	1.5	1.4
	40 year (0.025)	1.2	1.2	1.4	1.1	1.3	1.1	1.1	1.0	1.1	1.3	1.2	1.2	1.1	1.1	1.2	1.1	1.0	1.1	1.0
	50 year (0.02)	1.1	1.0	1.2	0.9	1.1	1.0	0.9	0.9	0.9	1.1	1.0	1.0	0.9	1.0	1.1	1.0	0.9	0.9	0.9
Suspended Timber floor	5 year (0.20)	4.6		6.4		6.4	5.6	6.1	6.3	6.5	6.7	5.8	6.0	6.0	6.0	6.2	5.6	4.8	4.7	5.1
	10 year (0.10)	2.5		3.3		3.4	3.0	3.2	3.3	3.4	3.6	3.1	3.2	3.1	3.2	3.3	3.0	2.6	2.5	2.7
	20 year (0.05)	1.4		1.8		2.0	1.7	1.8	1.8	1.8	2.0	1.7	1.8	1.7	1.7	1.9	1.7	1.4	1.4	1.5
	25 year (0.04)	1.2		1.5		1.7	1.4	1.5	1.5	1.5	1.7	1.5	1.5	1.4	1.4	1.6	1.4	1.2	1.2	1.2
	40 year (0.025)	0.9		1.0		1.2	1.0	1.0	1.0	1.0	1.2	1.1	1.1	1.0	1.0	1.2	1.0	0.9	0.8	0.9
	50 year (0.02)	0.7		0.8		1.1	0.9	0.9	0.9	0.9	1.1	0.9	0.9	0.9	0.9	1.0	0.9	0.8	0.7	0.7

APPENDIX D-2: RESEARCH FEEDBACK FORM – HOMEOWNER VERSION

Please provide comments on the usefulness of the research findings as presented in the attached summary report. Respond to the questions below by ticking one of the multiple choice options.

1. The research found that the average financial benefit in relation to avoiding psychological effects of flooding by investing in flood protection measures was £653 per household per year. To what extent do you agree that this amount is realistic?

   ☐ Strongly Agree ☐ Agree ☐ Uncertain ☐ Disagree ☐ Strongly Disagree

2. The research has estimated the cost and benefit of manually deployed resistance measure for properties in similar circumstances to your own. For example, for every £1 invested in **manual resistance flood protection measures**, a £8.50 benefit is gained as a value of avoided loss if the property is located in an area with 10 percent chances of being flooded in 10 years. Investing in **automatic resistance flood protection measures** will yield a benefit of £6.35 as a value of avoided loss. Will your knowledge of these potential benefits assist you in making decision on investing in resistance flood protection measures?

   ☐ Yes ☐ No ☐ I don't know

3. Please state reasons for your choice:

4. The research has estimated the cost and benefit of manually deployed resistance measure for properties in similar circumstances to your own. For example, a bungalow with concrete floor construction located in an area with 10 percent chances of being flooded in 10 years, and with anticipated flood depth up to 500mm. For every £1 invested in **resilience flood protection measures** with the inclusion of the value of intangible benefits, a £4.60 is gained as the value of avoided loss. Will your knowledge of these potential benefits assist you in making decision on investing in resilience flood protection measures?

   ☐ Yes ☐ No ☐ I don't know

5. If No, please state reasons:

6. From your flood experience, to what extent can the findings from this research assist you in making a decision on investing in flood protection measures?

   ☐ To a large extent ☐ To a moderate extent ☐ To some extent ☐ To little extent ☐ Not at all

7. Please indicate your level of agreement with this statement '**The Decision Support Lookup Tables is easy to understand'**

   ☐ Strongly Agree ☐ Agree ☐ Uncertain ☐ Disagree ☐ Strongly Disagree

8. Please provide any other general comments that you have on the findings. You can also provide any suggestions you may have for improvement (continue on a separate sheet if necessary)

Please save the completed feedback form and return it by email as an attachment to

Rotimi.joseph@uwe.ac.uk

Thank you very much for your time!

APPENDIX D-3: RESEARCH FEEDBACK FORM – SURVEYOR/LOSS ADJUSTER VERSION

Please provide comments on the research findings with regards to your flood experience as a surveyor / loss adjuster who has been involved in flood reinstatement work in the past. Respond to the questions below by ticking one of the multiple choice options

9. Based on the package of adaptation measures used in the research, we found that the benefits of adaptation measures outweigh the costs of the measures. From your experience, to what extent do you agree with this finding?

☐ Strongly Agree ☐ Agree ☐ Uncertain ☐ Disagree ☐ Strongly Disagree

10. With the inclusion of the value of intangible benefits in the Decision Support Lookup Tables (DSLT), in your opinion, would you say that the DSLT addresses an important problem on the estimation of cost and benefit of flood protection measures?

☐ Yes ☐ No ☐ I don't know

11. Please state reason for your choice:

12. The research found that for every £1 invested in **manual resistance flood protection measures** with the inclusion of the value of intangible benefits, the value of avoided loss was £8.50 for a property located in an area designated as 10 years flood return period and for automatic measures £6.35 is gained. Will your knowledge of these potential benefits assist you in advising your clients (homeowners) whether or not to invest in resistance measures?

☐ Yes ☐ No ☐ I don't know

13. Please state reason for your choice:

14. The research found that for every £1 invested in **resilience flood protection measures** with the inclusion of the value of intangible benefits, the value of avoided loss was £4.60 for a bungalow with concrete floor construction, with a flood depth of up to 500mm and located in an area designated as 10 years flood return period. Will your knowledge of these potential benefits assist you in advising your clients (homeowners) whether to invest in resilience measures?

☐ Yes ☐ No ☐ I don't know

15. Please state reason for your choice:

16. From your flood experience, to what extent can the Decision Support Lookup Tables assist you in your professional work to advise your client on investing in flood protection measures?

☐ To a large extent ☐ To a moderate extent ☐ To some extent ☐ To little extent ☐ Not at all

17. Please indicate your level of agreement with this statement '**The Decision Support Lookup Tables is easy to understand'**

☐ Strongly Agree ☐ Agree ☐ Uncertain ☐ Disagree ☐ Strongly Disagree

18. From your experience, are there any important factors which ought to be included in the DSLT?

☐ Yes ☐ No ☐ I don't know

19. If Yes, please specify:

20. Please provide any other general comments that you have on the findings. You can also provide any suggestions you may have for improvement (continue on a separate sheet if necessary)

Please save the completed feedback form and return it by email as an attachment to

Rotimi.joseph@uwe.ac.uk

Thank you very much for your time!

APPENDIX E-1: LIST OF PUBLICATIONS

Journal Papers and Book Chapter

1. JOSEPH, R., PROVERBS, D., LAMOND, J. AND WASSELL, P. (2013a). *Application of the concept of cost benefits analysis (CBA) to property level flood risk adaptation measures: A conceptual framework for residential property*. Structural Survey (In print)
2. JOSEPH, R., PROVERBS, D., LAMOND, J. AND WASSELL, P. (2013b). H*omeowners' perception of the benefits of property level flood risk adaptation (PLFRA) measures: the case of the summer 2007 flood event in England*. Safety and Security Engineering journal (under review).
3. 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), pp.279-293.
4. JOSEPH, R., PROVERBS, D., LAMOND, J. AND WASSELL, P. (2014). The cost of flooding on households. *In* Booth, C. and Charlesworth, S. (eds.) *Water Resources in the Built Environment – Management Issues and Solutions.* London: Blackwell Publishing Limited. (*In print*).
5. JOSEPH, R., PROVERBS, D. AND LAMOND, J. (2014). Flood risk mitigation: Design considerations and cost implications for new and existing buildings. *In* Robinson, H; Symonds, B; Gilbertson, B and Ilozor, B (eds). *Design Economics for the Built Environment.* John Wiley & Sons *(in print).*

Published, Peer Reviewed Conference Papers

6. JOSEPH, R., PROVERBS, D., LAMOND, J. AND WASSELL, P. (2012) *Use of CVM Valuation Method to Quantify Social Benefits of Property-Level Flood Risk Adaptation Measures: Theoretical Approach.* 21st International conference on Construction and Real Estate Management. Kansas City USA (October 1st - 2nd 2012)
7. JOSEPH, R., PROVERBS, D., LAMOND, J. AND WASSELL, P. (2012) *Towards the development of a comprehensive systematic quantification of the costs and benefits of property level flood risk adaptation.* 3rd International Conference on Flood Recovery, Innovation and Response (FRIAR). Dubrovnik, Croatia. (30 May – 1 June 2012).
8. JOSEPH, R., PROVERBS, D., LAMOND, J. AND WASSELL, P. (2011a) *A critical synthesis of the intangible impacts of flooding on households.* International conference in building resilience: Interdisciplinary approaches to disaster risk reduction and the development of sustainable communities. Sri Lanka (July 2011).
9. JOSEPH, R., PROVERBS, D., LAMOND, J. AND WASSELL, P. (2011b). *A critical synthesis of the tangible impacts of flooding on households*, 27th ARCOM annual conference, University of the West of England, Bristol, United Kingdom.
10. JOSEPH, R., PROVERBS, D., LAMOND, J. AND WASSELL, P. (2011c). *The potential of CBA towards increasing the uptake of property-level flood risk adaptation measures.* 5th International Conference on Flood Management (ICFM5) Tokyo –Japan (27-29 September 2011) – Abstract only submission.

APPENDIX E-2: LIST OF ABSTRACTS OF JOURNAL AND CONFERENCE PAPERS PUBLISHED DURING THE RESEARCH PROGRAMME

Application of the concept of cost benefits analysis (CBA) to property level flood risk adaptation measures: A conceptual framework for residential property
Journal of Structural Survey (2014)

Purpose
There has been a significant increase in flooding in the UK over the past ten years. During this time, Government policy has moved from investment in flood defences towards encouraging property owners to take responsibility for reducing the impact of flooding. One of the ways in which this can be achieved is for homeowners to adapt their properties to flood risk by implementing property level flood risk adaptation (PLFRA) measures. While there has been some attempt to develop an understanding of the benefits of such measures, these previous studies have their limitations in that the intangible benefits have not been fully considered. As such, there remains a need for further development of these studies towards developing a more comprehensive understanding of PLFRA measures. It is against this background that a conceptual cost benefit analysis (CBA) framework for PLFRA measure is presented. This framework brings together the key parameters of the costs and benefits of adapting properties to flood risk including the intangible benefits, which have so far been overlooked in previous studies.

Approach
A critical review of the standard methods and existing CBA models of property level flood risk adaptation measures was undertaken. A synthesis of this literature and the literature on the nature of flooding and measures to reduce and eliminate their impacts provides the basis for the development of a conceptual framework of the costs and benefits of PLFRA measures. Within the developed framework, particular emphasis is placed on the intangible impacts, as these have largely been excluded from previous studies in the domain of PLFRA measures.

Findings
The framework provides a systematic way of assessing the costs and benefits of PLFRA measures. A unique feature of the framework is the inclusion of intangible impacts, such as anxiety and ill health, which are known to be difficult to measure. The study proposes to implement one of the stated preference methods (SPM) of valuation to measure these impacts, known as the willingness to pay method, as part of a survey of homeowners. The inclusion of these intangible impacts provides the potential to develop a more comprehensive understanding of the benefit cost ratio (BCR) for different stakeholders. The newly developed CBA conceptual framework includes four principal components: (1) the tangible benefits to insurers; (2) the tangible benefits to the Government; (3) the tangible benefits to homeowners; and (4) the intangible benefits to homeowners.

Research Implications / Originality / Value
The framework presented here provides the much-needed conceptual clarity of the costs and benefits of PLFRA measures for residential properties. This provides the basis for an improved understanding of the costs and benefits of PLFRA measures leading to an improvement in the information available to homeowners. The framework has the potential to be developed into a tool to enable users to assess the cost effectiveness of PLFRA measures. Potential beneficiaries of this tool include homeowners, loss adjusters, insurers and Government departments and agencies responsible for flood risk management. This tool offers the potential to support Government policy concerned with increasing the uptake of PLFRA measures through increasing the information available to homeowners and thereby supporting the decision making process.

Homeowners' perception of the benefits of property level flood risk adaptation (PLFRA) measures: The case of the summer 2007 flood event in England.

International Journal of Safety and Security Engineering (2014)

The occurrence of flood events has far reaching consequences, not only in economic or financial terms but also social and health related. There is a growing body of research that suggests that property level flood risk adaptation (PLFRA) measures have the potential to benefit homeowners in reducing the impact of flooding on households. Emphasis has been placed on the implementation of PLFRA measures, and yet despite this, the take up among the at-risk residents in England is low. One of the reasons identified in the literature is that the homeowner's perceptions of the benefits of the measures are unclear. This research uses the summer 2007 flood event in England to investigate the perception of homeowners in connection with the theoretical benefits of PLFRA measures, by presenting the results obtained from 280 homeowners in England. The results highlighted that there is consensus among respondents that implementing adaptation measures has the potential to reduce health related flood impacts such as worrying, stress and strain between families. However, there was high level of uncertainty with regards to the financial benefits of investing in adaptation measures by way of premium reduction by insurers. It was evident from the analysis that knowledge of the frequency of flood events and expected flood damage rated high as one of the factors perceived by homeowners to influence the uptake of PLFRA measures. Further, the result shows that there is still high level of uncertainty among at-risk populations as to who is responsible to protect homes against flood risk. It is therefore recommended that at-risk population are made aware of the limit of the responsibilities of other stakeholders in the domain of flood risk management at household levels such as Government.

An analysis of the costs of resilient reinstatement of flood affected properties: A case study of the 2009 flood event in Cockermouth

Journal of Structural Survey, 9(4), pp.279-293. (2011)

Purpose – Recently, the focus of UK and European flood risk management policy has been towards promoting the uptake of property level flood adaptation measures. Despite this focus, the take-up of property level flood adaptation measures (both resilient and resistant) remains very low. One of the apparent barriers to uptake is the cost of installing such measures. This study aims to investigate the cost of adopting resilient reinstatement measures by considering a small number of actual properties that were flooded in Cockermouth during 2009.

Design/methodology/approach – Secondary data obtained from a loss adjusting company provides the basis for analysis. The data take into consideration the cost benefit of resilient repair, assuming the same properties were flooded again. The traditional reinstatement costs were established as the actual cost of putting the properties back in a like-for-like manner while resilient reinstatement costs were established by creating new resilient repair schedules based on recommended good practice.

Findings – The results of the study show that the percentage extra cost for resilient reinstatement over traditional repair cost ranged from23 to 58 per cent with a mean of 34 per cent depending on the house type. However, while resilient repairs were found to be more expensive than traditional (i.e. like-for-like) methods, they were found to significantly reduce the repair costs assuming a subsequent flood were to take place. Resilient flood mitigation measures seem most promising and, given repeat flooding, will help in limiting the cost of repairs up to as much as 73 per cent for properties with a 20 per cent annual chance of flooding, which indicates that the up-front investment would be recovered following a single subsequent flood event.

Originality/value – The uptake of resilient reinstatement among the floodplain property owners in the UK is very low and one of the reasons for the low uptake is lack of understanding of the cost and benefit of adopting such measures. While there have been previous studies towards investigating the costs of resilient reinstatement, it is believed that this is the first to use real claims data and information to analyse the tangible costs/benefits of resilient reinstatement.

Use of CVM Valuation Method to Quantify Social Benefits of Property-Level Flood Risk Adaptation Measures: Theoretical Approach

21st International conference on Construction and Real Estate Management. Kansas City USA (October 1st - 2nd 2012)

The current state-of-the-art in flood damage evaluation mainly focuses on the economic evaluation of direct tangible flood impacts during flood alleviation appraisal stage at governmental level. It is contended in this research that important economic and social impacts of flood related vulnerabilities on households are neglected in such evaluation. However, the UK Government flood risk management policy is currently shifting away from basic flood defence towards ‘living with floods’ and ‘making space for water’, thereby advocating that property owners living within the floodplain areas take some responsibility in managing the flood risk. Despite this shift in policy, the uptake of property-level flood adaptation among the floodplain property owners in the UK is very low and one of the reasons for the low uptake is lack of understanding of the cost and benefit of adopting such measures. The challenge of this research is to develop a wider perspective for flood damage evaluation by incorporating the indirect tangible flood impacts and the intangible flood impacts on households through the application of the concept of cost benefit analysis (CBA). This will assist property owners in weighing the costs against the benefits of adopting property level flood adaptation, thereby leading to more informed decisions and therefore, a possible increase in the uptake of property level flood adaptation measures.

Towards the development of a comprehensive systematic quantification of the costs and benefits of property level flood risk adaptation

3rd International Conference on Flood Recovery, Innovation and Response (FRIAR). Dubrovnik, Croatia. (30 May – 1 June 2012).

Research in the UK, has shown that one of the reasons that people may not take action to guard against potential flood damage to their properties is that they lack first-hand information on the costs and benefits of available mitigation measures. From this perspective, fundamental issue of both universal and constraint uncertainties in property-level flood adaptation cost benefit analysis are discussed. Individuals who have direct knowledge of the potential flood risks that they are exposed to and subsequently have information on the costs and benefits of adapting their properties to flood risks would more likely take action, and thus more inclined to undertake mitigation measures.

The application of the concept of cost benefit analysis to flood mitigation measure at household levels has its inherent uncertainties. A major exclusion in the past from flood mitigation cost benefit analyses has been the intangible impacts of flooding upon households, and this represents a form of systemic uncertainty. Research has shown that intangible impacts are both large and more important to affected households than are the tangible impacts; therefore quantification of the intangible impacts of flooding for the purpose of developing a comprehensive cost benefit analysis model is of a paramount importance in assessing the full impact of flooding on households, and hence currently represent a form of systematic uncertainty.

A critical synthesis of the intangible impacts of flooding on households

International conference in building resilience: Interdisciplinary approaches to disaster risk reduction and the development of sustainable communities. Sri Lanka (July 2011).

The frequency and magnitude of flood events has increased significantly in the last few decades. This can be linked to a number of causes, including changes in climate patterns and urban development. The occurrence of a flood event brings about a range of impacts including tangible or measurable effects and intangible, less quantifiable aspects. The tangible impacts of flooding has generally received greater attention in policy, the media and society, while the intangible impacts have received less attention possibly because they are more difficult to encapsulate and they are generally health related issues. However, there is a growing awareness by flood risk managers that intangible impacts of floods have been underestimated in post-flood appraisals. In an attempt to conceptualise the intangible impacts of flooding on households, a critical synthesis of literature is presented towards developing a deeper understanding of the extent of the effect of flooding on the health of households. The review highlights that the health of households is affected by the stress and disruption caused by having to vacate homes following flood event. This is especially true for the more vulnerable members of the communities and the finding also reveal that the effect could last for months and even years. The implications of these findings are that the health impacts of flooding on households could be greatly reduced by flood mitigation measures such as the take up of property level flood adaptation measures as this will reduce the amount of time households will need to vacate their home for repair works following flood events. There is therefore a need for further research towards improving the quantification of these long term health impacts for the purpose of cost benefit appraisals.

A critical synthesis of the indirect tangible impacts of flooding on households

27th ARCOM annual conference, University of the West of England, Bristol, United Kingdom (September 2011)

The impact of flooding on households has been witnessed by an increasing number of UK residents in the last decade. Previous studies in the UK and internationally have identified a wide variety of economic, social and environmental impacts both tangible and intangible, usually during the flood alleviation appraisal stage at Governmental level. The tangible impacts of flooding on households are both direct and indirect in nature. Direct impacts are the impacts caused to buildings and their contents as a result of physical contact of flood water on properties, whereas the indirect impacts occur as a further consequence of the flood and the disruptions of economic and social activities. Most previous studies have focussed on the direct tangible impact of flooding on households largely due to the fact that there are difficulties in accounting for indirect and non-monetary impacts of flooding on households and because this is usually a low priority in the post-disaster recovery effort. This review seeks to identify in detail the indirect tangible impacts of flooding on households, towards contributing to a wider understanding of the tangible impacts of flooding on householders at the individual property level. The review highlights that the indirect tangible impacts have the potential to affect wider communities rather than the flooded households alone, therefore making these indirect impacts an important consideration when considering the true impact of flooding. The review also revealed that since most of the indirect impacts are not insurable, the bulk of the indirect tangible costs of flooding are borne by householders. These findings indicate that there is a need for further research towards improving the assessment of these indirect tangible impacts for the purpose of developing a comprehensive flood mitigation appraisal tool to be used at property level.

The potential of CBA towards increasing the uptake of property-level flood risk Adaptation measures

5th International Conference on Flood Management (ICFM5) Tokyo –Japan (27-29 September 2011)

The economic and environmental costs of flood disasters have increased rapidly in the UK over the last decade. Due to the increase in economic costs, the flood risk management policy in the UK has now moved away from flood defence towards 'living with floods', 'prepare for flood', live with risk' and 'making space for water'. This means that individual property owners need to take on the responsibility of protecting their properties against future flooding.

Cost benefit analysis (CBA) is a project appraisal method that sums up the equivalent monetary values for all the costs and benefits of a project, thereby allowing one to assess if a project is worthwhile. The CBA approach is used by the UK government in carrying out appraisals of proposed flood defence schemes. The government has recently changed its flood risk management investment criteria to allow consideration of both tangible and intangible impacts of flooding in this process. Intangible impacts (such as PTSD, mental health problems) are now being captured by use of a system of differential social weights, although, there is little evidence that this has so far affected the decisions that are currently been made on flood defence scheme investment.

At an individual property level, the main driver for investment especially on flood mitigation is how much the scheme will cost and can I afford it? The concept of applying the CBA approach to assess the long-term benefit of such investment is rarely given rigorous consideration.

This study reports on the potential application of the cost benefit analysis approach for appraising at an individual property-level, the cost effectiveness of flood mitigating measures, by reviewing relevant literature. The review reveals that the CBA approach could help property owners to clearly quantify in monetary terms both the tangible and intangible benefits of investment in flood mitigation measures. It is therefore recommended that the use of CBA at an individual property level for project appraisals should be developed towards increasing the uptake of property-level flood risk adaptation measures.