A SITUATIONAL PARADIGM ON FLOODING AND BUILT ENVIRONMENT INTERVENTIONS IN THE UK

T. Wigglesworth, O. Adeniyi, K. Ginige* and J. Pearson

Department of Architecture and Built Environment, Northumbria University, United Kingdom

ABSTRACT

Flooding in the United Kingdom (UK) is increasing in both frequency and severity, leading to huge social and economic cost consequences, despite which there seems to be limited data or research on built environment related interventions such as effectiveness of flood defence schemes across the UK. As the UK remains at the pinnacle of urban development, this study seeks to underline the inherent relationship between flooding occurrences and the construction industry related interventions. The study examined the effectiveness of flood defences in the UK, regarding their economic suitability, their physical effectiveness and how they are managed and funded by the UK Government. Case study research strategy was employed and interview was used as the data collection method in the case study. This study revealed that the underlying cause of increased flooding in the UK is due to several factors including; climate change and urbanisation. In terms of the physical defences built to protect the built environment, the study has shed light on the level of protection they offer, their cost effectiveness and how such schemes are financed. This study targeted the creation of a situational paradigm that could be transposed and generalised to enhance the understanding of flooding intervention in the UK and other urban environments.

Keywords: *Built Environment; Defences; Disaster; Flood; Leeds; Paradigm.*

1. INTRODUCTION

Natural disasters can cause far reaching damage with the effects from one single event reverberating around the globe through loss of life and property and with economic side effects such as reduced trade and manufacturing, causing even wider disruptions (Ofori, 2004). The IME (2013) states that with 55% of the world's GDP and 44% of trade, and Asia and Pacific forms the powerhouse of the global economy today. It is therefore evident that natural disasters could have a detrimental effect on the global economy and world trade. Leinster (2009) submitted that flooding is a common hazard in the United Kingdom (UK) and has caused significant economic losses. Climate change has been projected to lead to an increase in riverine flooding across the whole of Europe (Kundzewicz *et al.*, 2010) and therefore, an increase in damage and losses is likely in the future. A 40% increase in the number of weather related natural disasters since 1980 can be attributed to climate change (Global Humanitarian Forum, 2009). This view is supported by Neumayer and Barthel (2011) and Pielke *et al.* (2008) as the studies submitted that climate change, the rise in living standard, a general increase in population, growth in asset and people concentration in urban areas, industrialisation of risk-prone areas (e.g. coastlines and fluvial plains) are leading to an increase in disaster frequency and cost. Similarly, vulnerability to disasters is increasing due to reasons such as growing population, climate change and other underlying development issues (Wuthisuthimethawee, 2016). Theory on the current global situation has been proposed by several sources such as the Intergovernmental Panel on Climate Change (IPCC) that the impact of global climate change is increasing the frequency of natural disasters both now and in the future (Solomon *et al.*, 2007; Munich Re, 2003).

Flooding in the UK is increasing in both frequency and severity, leading to a huge social and economic cost consequences. Since much of the physical damage brought about by disasters is to structures and infrastructure (Ofori, 2004), the construction industry and the built environment professionals have a vital role to play

*Corresponding Author: E-mail – kanchana.ginige@northumbria.ac.uk

(Malalgoda *et al.*, 2010; Ofori, 2004). As a result, there have been built environment-related interventions. Despite, there seems to be very little data or research surrounding the effectiveness of this interventions and especially flood defence schemes across the UK from the perspective of a built environment professional. Based on the aforementioned, the aim of this study is to analyse the effectiveness of flood defences in the UK, with regards to their economic suitability, their physical effectiveness and how they are managed and funded by the UK Government. This study presents the formation of a pattern consisting of the attributing factors of intra-urban flooding, this will culminate in the creation of 'Leeds paradigm model'. The Leeds model is a situational paradigm which will take the knowledge gained from data collected from stakeholders and literature to explain the interrelationship of factors and other situations. This will form the basis of a generalizable model of factors influencing intra-urban flooding, solutions to intra urban flooding, and an outline of the critical success factors of urban flood schemes.

2. LITERATURE REVIEW

2.1. FLOODING IN THE UNITED KINGDOM

The frequency and severity of flooding is predicted to increase in the UK (ABI, 2007; Soetanto *et al.*, 2008). Foresight Report (2003) commissioned by the Office of Science and Technology, United Kingdom concluded that an increasing flood risk was evident because of climate change affecting the seasonal rainfall patterns. In the same vein, Lamond *et al.*, (2012) concluded that between now and 2080 annual rainfall could increase by as much as 40%.The increased prevalence of natural disasters cannot be solely attributed to climate change or natural factors, a human element of the increase concerns how the built environment manages the whole project life cycle, across all sectors including residential, commercial and infrastructure (Soentanto *et al.*, 2008). For example, high up the River Thames, along non-tidal stretches there are an estimated 12,000 residential properties with an estimated value upward of £1Billion (McGlade, 2002). Flooding in these areas would be labelled as a 'natural disaster' whereas more evidently it is the combined increase of urban development in flood susceptible locations (Bosher, 2008).

In the UK, the continued prevalence of flooding occurrences has been attributed to the decrease in river dredging during the last decade. Stewart Agnew MEP (2014) placed the responsibility for this reduction on the decision to dissolve/integrate the National Rivers Authority into the remit of the Environment Agency (EA), who subsequently placed a large proportion of UK Rivers under the EU Habitat Directive, protecting them from dredging among other processes. The Royal Society for the Protection of Birds (RSPB) have highlighted their opposition to these methods due to the negative affect it has on the natural environment, particularly in the case of the 2013 flooding seen on the Somerset levels they opposed the notion that dredging alone would mitigate the flood risk in this area (Harper and Bowern 2014). Wheater and Evans (2009) provided a summary of driver groups for fluvial and intra-urban flooding, this includes climate change, catchment run-off, groundwater system and processes, fluvial system and processes, urban system processes, coastal processes, human behaviour and socio-economics. The specific drivers in the driver groups include precipitation, temperature, sea-level rise, rural land management, environmental regulation, river morphology, vegetation and conveyance, blockage, external flooding, asset deterioration, coastal morphology, stakeholder behaviour among others.

2.2. FLOODING AND BUILT ENVIRONMENT INTERVENTIONS

Ofori (2003) submitted that "the built environment bears the brunt of damage from disasters of all kinds". Subsequently, Bosher (2008) called for the construction sector to take greater responsibility for the planning, design, construction and maintenance of the built environment. In the same vein, Ingirige *et al.* (2008) identified the construction industry and built environment disciplines as having a primary role in reducing the risk of flooding. The built environment professionals need to be engaged further as a resource for delivering built environment interventions (Bosher *et al.*, 2007). Currently in the UK, more than 5 million homes and over 300,000 businesses are currently at risk of flooding (RICS, 2015). Recent widespread flooding across the UK has once again exposed the vulnerability of the built environment towards flooding. About £1.1 billion is estimated as the current annual cost of flood damages in the UK, with around 1 in 6 properties exposed to some level of flood risk (Blackmore, 2015). The figures published by the Association of British Insurers show a 200% increase in the cost of flood damages since the 1990s (Shrubsole, 2008).

The Stern (2007) was undertaken to investigate the economic impact of climate change. The review concluded that the financial effects of flooding in the United Kingdom was severely underestimated; the current estimate of£1 billion increasing to around £27 billion by 2100. In conclusion, they reiterated that this could only be avoided by extensive financial investment. Several human and anthropogenic factors in the UK have led to several flood events over the past decades. Carlisle is situated on a flood plain, which coupled with ineffective efforts of restricting development in this vulnerable area contributed to the widespread damage caused by the 2005 floods (Bosher, 2008). Towards mitigating the impact of disasters, the Department for Environment, Food and Rural Affairs (DEFRA), United Kingdom expended sums ranging from £500 - £670m annually on flood defences in cash terms from 2007/08 to 2014/15 (Bennet *et al.*, 2014). Apart from expenses on flood defences, the government also spend on the repair of affected communities (Shrubsole, 2015). In 2014, the UK government announced a drop in flood defence funding from £2.37Billion (2005-2010) to £2.34Billion (2010-2015) (Shrubsole, 2015).

There are approximately 80,000 homes across the UK at risk of 'intra urban' flooding; the annual flood management costs associated with these areas is over £320 million (Government Office for Science, 2011). 'Intra urban' flooding is a growing global problem due to the rapid increase of urbanisation in the 21st century. In 2010 the global average of the urbanised population passed the 50% mark (IME, 2013). 'Intra urban' flooding is a symptom of an inadequate water system that is failing to accommodate ever increasing flood levels, the urban water system comprises of a combination of the above ground surfaces and the water service infrastructure (Thorne *et al*., 2007). Urban creep is another product of increased urbanisation; this is the process of increasing the impervious area, through small and large scale urban developments (Thorne *et al*., 2007) this factor exacerbates pluvial flood risk. Right now, fluvial and pluvial flooding is a growing problem in the urban environment.

One of the methods for combatting the effects of intra urban flooding is to introduce a sustainable urban drainage system (SUDS). This technique is an integrated alleviation system that encompasses all facets of the urban environment; it seeks to treat water in a different way to conventional drainage (Thorne *et al*., 2007). Lamond *et al.* (2012) state that the benefits of using this technique for flood attenuation are both clear and "unequivocal". There are several individual drainage devices that can be used in a SUDS system. The four main classifications are as follows: filter strips, permeable surfaces, infiltration devices and detention services (Lamond *et al.*, 2012). Lamond *et al.* (2012) also listed some vegetative devices (rain gardens, wetlands, swales, household rain gardens, filter strips) and hard devices (porous paving, concrete rain garden, rainwater harvesting, front gardens and school playing fields). The implementation and construction of a SUDS scheme can change in both scope and definition depending on whether retrofitting the system into the existing built environment or integrating it into a new build scheme (Lamond *et al.*, 2012). Currently in the UK hard drainage infrastructure is designed to deal with a 1:30 year storm (Thorne *et al*., 2007). Considering the evidence pointing towards an increase in intense rainfall events, peak river flows and rising sea levels, most would consider this inadequate.

3. RESEARCH METHOD

Qualitative research allows for a greater understanding of participants' experiences, determining the significance of variables through their discovery and discussion (Corbin and Strauss, 2008). In this study, case study research strategy was employed because it is effective in research to support claims being made and draw conclusions. Case studies can be undertaken with regards to individuals, organisations and groups, and for this research the case study focused predominantly on a flood defence construction project, the Leeds Flood Alleviation Scheme (LFAS). This case study is one of the most significant built environment-related flood interventions in the UK, it was purposively selected based on its potential revelatory attribute. This study specifically focused on LFAS project costs, cost benefits, the financing of the project and the effectiveness of the flood protection the scheme offers to establish a situational pattern of flood defences. Primary data was collected using four in-depth semi-structured interviews with management and construction professionals involved in LFAS. Table 1 outlines the profiles of the interviewees. The data facilitated creating a situational paradigm outlining the cause and effect of 'intra urban' flooding - The case of Leeds with the expectation of enhancing the understanding of the growing problem across major UK urban areas. The interviews were further used to corroborate both the secondary and primary data acting as a method of triangulation to create the situational paradigm.

Table 1: Profile of Interviewees

Interviewee	Position	Experience (Years)
A	Project Manager	17
B	Civil Engineer	11
C	Quantity Surveyor	7
D	Project Manager	4

4. LEEDS FLOOD ALLEVIATION SCHEME (LFAS)

Before the turn of the century, Leeds was not regarded as an area that presented a high risk of flooding. However, flooding over recent years has highlighted a growing problem in the area. The city of Leeds is situated on the River Aire which contributes to pluvial flooding; compounding this is the risk of fluvial flooding due to the unsuitable drainage and increased urbanisation. Over the past decade, upon the need for defences was highlighted, various schemes have been proposed and rejected due to several factors including financial constraints and community intervention. Finally, in 2012, the business case was passed for the development of the LFAS. A £45million investment was funded by a new model of public funding. The system encompasses several existing defence technologies and innovative system.

5. DATA ANALYSIS AND RESULTS

Since qualitative analysis builds on natural ways of thinking, interviews were conducted and the responses were coded using the thematical method. Thereafter, the themes were used to build a common understanding of the response; thus, allowing the formation of concepts. Specifically, the interviews provided the theoretical 'themes' that outlined the relationship between the research variables. This analysis provided a detailed set of situational concepts which were used to form the situational paradigm. The creation of the situational paradigm consists of 'case' specific patterns obtained from the triangulation of both secondary data/literature and case study interviews.

Presented below are the findings from the interviews. The themes were aligned with associated discussions in the literature towards the creation of a situational paradigm.

5.1. DRIVING FACTORS FOR INCREASED FLOODING FREQUENCY AND SEVERITY

Three of the four interviewees highlighted climate change as a driver of increasing flooding frequency and severity in the UK, with interviewee stating *"climate change is a primary driver"*. Primarily interviewees A and D mentioned the changing climate is resulting in more *"frequent heavy storms"* and *"severe, warmer and wetter weather"*. These views are shared by Soentanto *et al.* (2008) and by the Foresight Report (2003) who link climate change to increasing severe weather patterns. Another factor that ranked just as highly as climate change was unsustainable development. This theme consists of many individual points from interviewee A stating that *"a period of increased building in the environment"* to interviewees B and C highlighting the *"property development low within a flood plain"* and *"development of greenfield sites"*. The views of unsustainable development as an attributing factor are advocated by Mc Glade (2002). Urbanisation has been identified throughout the secondary research as a driving factor in flooding severity (Bosher, 2008; Thorne *et al.*, 2007; Wheater and Evans, 2009). Interviewee A highlights *"more roads, more houses and more hard surfaces"*. These increases can be regarded as 'urban creep'. Upon reflection interviewee C, simply states *"urban expansion"*. Lastly, socioeconomic issues are highlighted by only two interviewees A and B, who state *"Government and European farming policies impacting vegetation removal upstream"* plus *"planning and development control"*. The response of interviewee A may point to an inherent problem within Government for dealing with flood hazards. Although these two individual socioeconomic issues are not covered in chapter two this emphasizes the need for more probing into the cause and effect such issues. The factors identified include climate change, urbanisation, unsustainable development, and socioeconomic issues.

5.2. ADEQUACY AND INFLUENCES ON BUILT ENVIRONMENT PROTECTIONS PROVIDED

The common consensus across all interviewees was that currently enough is being done when considering all the protection of the built environment although all agreed that more could still be done. This question has supplied an initial closed response, but then also opened discussions probing deeper into the factors that may influence protection. The most mentioned of the three highest factors highlighted was the financial aspect, this theme could again be transferred into sub themes to explore the issue in greater detail but the exploration of this aspect was limited in this study. Interviewees A, B and C all identified financial factors as influencing protection. Interviewees A and B highlighted the financial constraints on Governments *"with the limited resources of governments and organisations"* and *"funding constraints from the Government"*. The opinions of the interviewees are also views shared by Shrubsole (2015) who points out the lack of government budget allowance to combat the issue.

All but one of the interviewees identified future developments as having an impact on the levels of protection across the UK, with interviewees A, D and C all mentioning that the impact of future developments will have on protection, these views can be encapsulated by interviewee A; *"New developments that don't do enough to protect themselves, often ignoring advice from the environment agency or other organisations or other organisations as they still carry on with developments that aren't appropriate for the location"*. The research of Ingirige *et al.* (2008) correlates these views in respect to the future increase of flooding in the UK and how the built environment will play a primary role in flooding protection both now and in the future. Another primary factor identified by interviewees A, C and D was education, this was discussed by A, who a pointed out the lack of education is an attributing factor adversely affecting protection. Whereas, Interviewee C highlights *"researching the extent of current flood protection development"*, this could aid improvement of protection. Finally, interviewee D reflects on the factor by noting an increase in education *"people are more aware of the issue"*. Finally, interviewee A and B mentioned the existing environment and the practicality of protection respectively, although these factors arenot as prominent, the need to provide practical solutions to protecting existing infrastructure is of paramount importance. Thorne *et al.* (2007) agrees with these views as they point out existing hard drainage is not adequate. The factor identified are finance, buildability, education, existing environment, future development.

5.3. HOW THE LEEDS FLOOD ALLEVIATION SCHEME IS FINANCED

From the data supplied by the thematical analysis has provided us with the information required to start the formation of the situational paradigm. From asking this question it opens discussion on the effectiveness of the funding model and provides an insight into the Interviewees knowledge of where the funding comes from. We can see that interviewees A, B and D identified all the contributing parties, this was in stark contrast to interviewee C's response who only identified *"Leeds City Council"* as contributing, because of the responses the three most knowledgeable Interviewees were probed as to their opinions of the effectiveness of the finance model. Interviewee A highlighted that there was a *"number of strands of funding for the scheme that contributes to greater project security"*. From this response, it is clear the interviewee was in favour of the funding model. Upon discussion Interviewee projected the theory that greater involvement from a wide range of stakeholders would ultimately increase both protection and overall benefits for the wider community *"there's a mix of funding that comes forward and this was a pretty good model"*. When questioned upon the funding's effectiveness interviewee D simply put *"yes the model is effective"* the views of these interviewees may point to a future model of urban flood defence funding, Specifically considering the future flooding report (2004) who outline a need to increase in flood spending over the coming years. This question firstly aided progression of the situational paradigm by identifying the specific funding avenues utilised for the LFAS scheme. In addition, the responses highlight the levels of funding received from different public departments. The funding sources identified are Leeds City Council, Environment Agency, Regional funding, Department of Environment, Food and Rural Affairs.

5.4. PERCEIVED ADEQUACY AND ISSUES WITH CURRENT GOVERNMENT SPENDING

Upon responding to the initial question all interviewees responded with a yes to the inadequacy of funding apart from interviewee D who poses the question *"A difficult one, because is spending ever going to be adequate?"* This response outlines the general theme for the preceding discussions; although respondents answered with a *"yes"* they all went on to discuss the varying factors attributing to the adequacy of funding.

Interviewees A, B and C all noted that in some way future developments affect the adequacy of government spend, Interviewee A suggests that *"looking at how future developments are put together, you know, thinking outside the box there as well, there is certainly more that I am sure can be done"*. Interviewee B has a similar outlook on the issue, supporting that greater emphasis is required on planning for flood protection on future developments. These views tie in directly to the responses of interviewees C and D who both reflect on the current approach to flood funding. Interviewee D identifies a *"more reactive than proactive with spending"*. These views are shared by interviewee C who states, *"Unfortunately though funding for these schemes tend to be more of a 'reaction' to seasonal conditions rather than proactively developing high risk areas that are yet to be affected"*. The above issues portray a situation that where funding is used reactively in responding to current issues. Considering the limited budgets of government this leads to an increased need for a pro-active approach to funding, by involving future developments plans in currents funding schemes greater value for money could be attained. The issues of concern identified from the interviews are reactive over proactive approach, availability of budgets, future developments, and effectiveness of spending. Despite the interviewees' concern about the adequacy of spending on defending Leeds from flood, they all agreed that Leeds have been made less vulnerable. Interviewees suggested the use of sustainable urban drainage. Both interviewees B and D identified this method as being key to reducing the risk of urban flooding in the Leeds catchment. Interviewee B proceeds to elaborate on the specific elements that such a system would consist of *"introducing water gardens and you know going down to the level of individual properties where, you know, using water butts as a means of storage"*. The use of such methods was advocated by Thorne *et al*., (2007) who describes the benefits of using sustainable Urban Drainage (SUDS) as *"unequivocal"*. Interviewee has identified the need for *"investment in new infrastructure and new build environment"* to increase flooding protection in the future. This view supports the conclusions of Stern (2007). Finally, interviewee C specifies a method of construction previously unknown to the researcher *"future-proofing"*. This method has not been explored previous to this discussion.

There was a resounding agreement upon responses that the Leeds Flood Alleviation Scheme will be cost effective, with interviewee A replying with a resounding *"absolutely yeah"* that captured the general tone for all interviewees' thoughts. Upon discussion interviewees A and B highlight the process used in the project to ensure the cost benefits for the scheme were achieved with each highlighting a *"business case"* and a *"cost benefit analysis"*. From these responses, extensive research was undertaken through the schemes conception. Interviewee C provided the greatest insight into the cost effectiveness of the scheme by simply comparing the cost of the defences to the potential cost of damages; he concluded that the cost of repairs over a 50-year period *"would be 2.5 times higher than the total cost of the LFAS"*. Interestingly, the interviewees displayed a convincing general knowledge of the construction technology the scheme utilises, with each providing exploration of certain elements.

The most frequently mentioned element was the moveable weirs with interviewee D stating *"This will be the first time this innovative technology has been used in the UK"*. Essentially, this new technology has been a key factor in increasing overall protection. Interviewee A proceeds to briefly explain the technology of the moveable weirs *"So there's two major weirs through the River Aire corridor through Leeds and they're being rebuilt to accommodate essentially an air bag system whereby during periods of high river flow the air bags are deflated, the level of the weir drops and that effectively allows water to pass through the system quicker"*. All respondents highlighted the use of the linear defences as a technology used, although only half of the Interviewees mentioned the removal of the Knostrop cut island. This could in retrospect indicate lack knowledge among the project team. The responses provided an insight into the technologies used, these technologies are possible solutions that could be used in other urban areas across the UK, progressing the creation of the situational paradigm. The technologies identified to have been engaged in Leeds are moveable Weirs, linear defences and Island removal.

Interviewees A and B highlighted other different methods of attenuation systems with A mentioning the use of *"upstream storage"* who then goes on to specify an instance where he had worked on a scheme involving such methods *"I have recently been involved in the construction of a new reservoir in Morpeth"*. This shows that alternative measurers are in use across the UK. The second attenuation method highlighted by Interviewee B consisted of *"surplus water drainage"*. The uptake of innovative flood technologies has been slow in the UK according to Lamond *et al*. (2012). Interviewee proceeded to discuss the possibilities of natural drainage as an alternative method specifically Interviewee A states *"there options are construction of sort of more kind of wetland areas"*. These methods can be utilised as part of future development schemes to offset the risk

increase caused from urbanisation, the use of environmentally advantageous methods would be welcomed by organisations such as the Royal Society for the Protection of Birds (RSPB).

The final two alternative methods advocated by Interviewees A and D respectively include hard surface measures particularly the use of *"by-pass channels"* which would be appropriate for use in the urban environment. Lastly Interviewee D mentions the *"wider use of silt control"* which could include dredging; Stuart Agnew MEP is a strong supporter of this method. The other possible methods identified are water storage system, natural drainage system, urban drainage system and river management.

5.5. FURTHER COMMENTS ON THE LFAS

The most common theme arising upon reflection was that the 2015/2016 floods had a negative impact on the LFAS project but upon closer inspection the views of interviewee D provide a more positive outlook *"scheme got off quite lightly"* and proceeding to state that on *"a more oddly positive note I think the floods have actually helped us"*. These views were shared by interviewee A who reiterates that the flooding had *"really focussed the mind to make things happen"*. Reflecting on the positive attitude of interviewees A and D, Interviewee B also noted that the *"scheme held up pretty well"*. Portraying a situation where things could have been a lot worse. It is important to note that although there may have been a silver lining all Interviewees opened by listing the negative impacts of the project. With interviewee C stating that *"Knostrop Weir was severely affected by the winter flooding"*. In addition, the remaining interviewees went on to highlight the time and cost implications of the flooding. Specifically, interviewee C mentioned the commercial impacts and interviewee B the impacts on project programme.

5.6. THE SITUATIONAL PARADIGM

The situational paradigm in the case of Leeds, UK is a model suggesting a solution to intra-urban flooding with a particular focus on structural flood defences. The creation of the model is a result of the triangulation of both the primary and secondary data obtained from this study. The data has been used to identify the key components of the 'Leeds Paradigm'. The key components in the case of LFAS were identified as a situational pattern. The next stage of the process is the creation of the situational paradigm, which will take the knowledge gained from the Leeds model, transposing onto this the patterns and interrelationship of factors of other situations, leading to the generalisation of the 'Leeds Model', thereby creating the 'situational paradigm' for the factors of and solutions to intra urban flooding generally and an outline of the critical success factors of urban flood schemes. This paradigm can then be applied to other major UK urban environments, furthering the appreciation of possible risks and potential solutions. Ultimately, the 'situational paradigm' can be used for the selection and justification of future urban flood defence schemes, in summary; the emerging patterns identified in this research and required for the creation of the paradigm is presented in Figure 1.

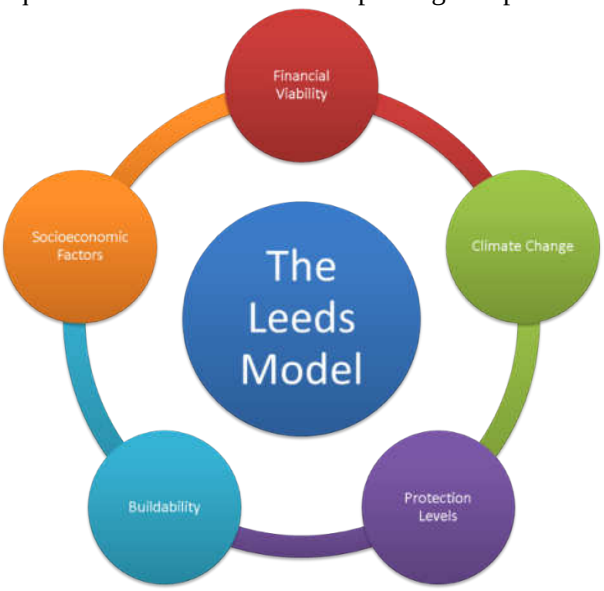

Figure 1: The 'Leeds Model'

6. CONCLUSIONS

The discussions presented general themes that are not too dissimilar to the points identified in the literature, with climate change being identified along with increased urbanisation as major attributing factors to the increase of flooding frequency and severity. Following from this there was a common consensus that considering current economic climate and the varying constraints upon government that currently enough was being done to adequately protect the built environment. Through the various discussions surrounding the situation in Leeds it was apparent that the current scheme was considered cost effective, offering an adequate level of protection while being funded effectively by an innovative method of public funding, involving various key stakeholders; thus, justifying the schemes outlay. The latter discussions of the interviews were centred on the construction technologies involved with flood defences and the current knowledge among construction professionals. Through exploration, many alternative methods of flood defence were identified, with relative gaps in interviewees' knowledge occasionally. Towards the creation of a situational paradigm, additional case studies are necessary to achieve a wider sample of results, thus, improving correlation and reducing the risk of biased results by increasing the variable saturation. This will be considered in further works.

7. REFERENCES

ABI, 2007. *Adapting to our changing climate: a manifesto for business, government and the public* [online]. Available from:http://static1.1.sqspcdn.com/static/f/270724/1875476/1220367254470/climate_change_final.pdf?token=3393C2G8amE7WS6uDMNDVLfB75c%3D [Accessed 24 Mar. 2016].

Blackmore, R. 2015. *The Economic Impact of the NRFA Peak Flow Database. Research Impact Consulting*.[online]. Available from: https://www.ceh.ac.uk/sites/default/files/The%20Economic%20Impact%20of%20the% 20NERC% 20 Peak%20Flows%20Database_0.pdf [Accessed 24 Mar. 2016].

Bosher, L.S., 2007. *Social and Institutional Elements of Disaster Vulnerability: The case of south India*. Bethesda: Academia Press.

Bosher, L.S., 2008. *Hazards and the built environment: attaining built-in resilience*. New York: Taylor and Francis.

Corbin, J., and Strauss, A., 2008. *Basics of qualitative research: Techniques and procedures for developing grounded theory*. London: Sage.

Foresight Report, 2003. *Foresight Future Flooding*. [online]. Available from: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/300332/04-947-flooding-summary.pdf [Accessed 24 Mar. 2016].

Global Humanitarian Forum. 200. *The Anatomy of a silent crisis Global Humanitarian Forum*. [online] Available from: http://www.ghf-ge.org/human-impact-report.pdf [Accessed 24 Mar. 2016].

Harper, M. and Bowern, M. 2016. *RSPB position on dredging in the Somerset Levels and Moors - Martin Harper's blog - Our work - The RSPB Community* [online]. Available from: http://www.rspb.org.uk/community/ourwork/b/martinharper/archive/2014/02/01/rspb-position-on-dredging-in-the-somerset-levels-and-moors.aspx [Accessed 24 Mar. 2016].

IME, 2013. *Natural disasters saving lives today, building resilience for tomorrow* [online]. Available from: http://www.indiaenvironmentportal.org.in/files/file/natural-disasters-saving-lives-today-building-resilience-for-tomorrow.pdf [Accessed 10 Mar. 2016].

Ingirige, M. J. B., Haigh, R., Malalgoda, C. I., and Palliyaguru, R. S., 2008. Exploring good practice knowledge transfer related to post tsunami housing re-construction in Sri Lanka. *Journal of Construction in Developing Countries*, 13(2), 21-42.

Lamond, J., Booth, C., Hammond, F., and Proverbs, D., 2011. *Flood hazards: Impacts and responses for the built environment*. CRC Press: Florida.

Leinster, P. 2009. *Flooding in England: a national assessment of flood risk*. Almondsbury: Environment Agency.

Malalgoda, C. I., Amaratunga, R. D. G., and Pathirage, C. P., 2010. Exploring disaster risk reduction in the built environment. In: Barret, P., Amaratunga, D., Haigh, R., Keraminiyage, K., Pathirage, C., ed. *CIB 2010 World Congress*, Salford 10 – 13 May 2010. Salford: University of Salford.

McGlade J., 2002. Thames navigation and its role in the development of London. In: *2002 London's Environment and Future (LEAF) Conference*, 9-11 September, University College London, United Kingdom.

Munich, R., 2003. *Press Dossiers: Climate Summit in Cancún Munich Re* [online]. Available from: https://www.munichre.com/en/media-relations/publications/press-dossiers/cancun-2010/index.html?QUERYSTRING=global climate change [Accessed 24 Mar. 2016].

Neumayer, E., and Barthel, F., 2011. Normalizing economic loss from natural disasters: A global analysis. *Global Environmental Change*, 21(1), 13-24.

Ofori, G., 2002. Construction industry development for disaster prevention and response. In: *i-Rec International Conference on Post-Disaster reconstruction: Planning for reconstruction*, 23-25 May, Université de Montreal, Canada.

Pielke, R., Gratz, J., Landsea, C., Collins, D., Saunders, M., and Musulin, R., 2008. Normalized Hurricane Damage in the United States: 19000-2005. *Natural Hazards Review*, 9 (1), 29-42.

RICS, 2015. *Flooding: issues of concern to RICS surveyors and valuers (Residential property)*. London: RICS.

Shrubsole, G., 2016. *Flood risk and climate change – protecting our homes communities and livelihoods* [online] Friends of the earth. Available from: https://www.foe.co.uk/sites/default/files/downloads/flood-briefing-september-2014-47494.pdf [Accessed 24 Mar. 2016].

Soetanto, R., Proverbs, D., Lamond, J. and Samwinga, V. 2008) Residential properties in England and Wales: an evaluation of repair strategies towards attaining flood resilience. In: Hazards and the built environment: attaining built-in resilience. London: Taylor and Francis, pp. 124-149.

Solomon, S., Qin, D., Manning, M., Chen, Z., Marquis, M., Averyt, K. B., and Miller, H. L. ed., 2007. Climate change 2007-the physical science basis [online]. Available from: http://www.irpi.to.cnr.it/documenti/IPCC_2007/AR4WG1_FrontMatter-v2.pdf [Accessed 24 March 2016].

Stern, N., H., 2007. *The economics of climate change: The Stern review*. Cambridge: Cambridge University Press.

Thorne, R. C., Edward, P. E., and Penning-Roswell, E. C., 2007. *Future flooding and coastal erosion risks*. London: Thomas Telford.

Wheater, H., and Evans, E., 2009. Land use, water management and future flood risk. *Land Use Policy*, 26, S251-S264.

Wuthisuthimethawee, P., 2016. Disaster and Climate Change. In: *Ciottone's Disaster Medicine*. Ciottone, G.R., Biddinger, P.D., Darling, R.G., Fares, S., Keim, M.E., Molloy, M. S. and Suner, S. (eds), 2nd edn, Philadelphia: Elsevier, pp. 47-52.