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Making Birmingham a Flood Resilient City: Challenges and Opportunities

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Abstract: The city of Birmingham has experienced a number of significant flooding events in the past two decades. The impacts of these flood events include physical damage to critical infrastructure, as well as significant losses caused by business interruption and general disruption to communities. Human losses and impacts can be life changing. This study identifies the current challenges and opportunities of managing flood risk in the city of Birmingham, drawing on a desk-based account of current flood risk management (FRM) practice and diagnostic evidence. This interrogation adopts the use of a ‘flood resilience circle model’ to consider ways to address the challenges in a methodological manner aligned to an integrated approach to flood risk management. Solutions aligned to the key FRM stages of prevention, preparation, response and recovery are provided. The findings will be of interest to policy makers and decision makers on how to address current weaknesses in FRM practices towards the prospect of a sustainable approach that improves the resilience of the city and delivers multiple benefits. Recommendations made include the adoption of a blue-green systems approach, the development of a new communication strategy aligned to motivating behaviour change, and improved flood forecasting especially for surface water flooding.

Keywords: flooding; flood resilience; flood resilience circle; flood risk management; flood impacts; resilience

1. Introduction

Major cities around the world have suffered substantial losses caused by flooding. This includes cities in Europe such as Prague (2002), Bern (2005) and Hull (2007); cities in the US such as New Orleans (2005) and Houston (2017); cities in Africa such as Lagos (2017) and Nairobi (2018); cities in China including Wuhan (2016) and Nanjing (2017); and cities in Australia including Brisbane (2010) and Melbourne (2018). The impacts of these flood events include physical damage to critical infrastructure, buildings and homes; commercial, industrial and residential contents; as well as significant losses caused by business interruption and general disruption to communities [1]. Human losses are also experienced in the form of psychological harm, distress and, in extreme cases, fatalities [2]. These damages caused by floods continue to increase [1]. Over the past three decades more than 100 million people have been affected by floods annually with more than 2.8 billion people affected since 1990 across the globe [3]. Data from the Emergency Events Database (EM-DAT) source shows that flood events are becoming more frequent with a significant increase in the number of reported events over the last decade [3]. Furthermore, forecasts show that these events will increase in both frequency and severity [4]. For example, it has been projected that UK flooding may escalate, by up to 30 times over the next 75 years, with huge financial implications [5,6].

The past two decades have seen a number of flooding events affecting the city of Birmingham, UK from sources including watercourses, surface water, sewers, groundwater and reservoir failure [7]. Flooding continues to constitute a major nuisance to key features of the city, with a growing concern that a combination of rapid urban expansion and extreme weather events will significantly exacerbate these problems [8]. However, for many years, the standard response to mitigate against flooding has been by the use of flood defence systems. In the case of Birmingham city, flood defence walls, storage tanks, balancing ponds, land drainage and highway drainage are some of the structural measures that have been put in place to reduce the likelihood of flooding and its impacts [9].

Due to the interplay of extreme floods, population growth and rapid urbanization, flooding has increased such that these conventional flood risk management (FRM) measures of concrete structures and other defences have now become inadequate and unsustainable across various communities [10]. However, thinking has changed from the single concept of outright resistance of inundation towards the establishment of a softer and more sustainable measure of dealing with flood risk through the concept of resilience [11].

While the concept of resilience is an emergent approach to help cities deal with natural hazards including flooding [10], the concept has enjoyed prominence in both academic research and policy (see for example, [11–14]). However, Hammond et al. [15] believe that for a city to be resilient to flooding, innovative and adaptable strategies are needed to manage flood risk. According to Liao, these strategies must ensure that the city possesses the capacity to endure flooding and regroup itself in order to minimize potential impact while socio-economic identity is maintained [16]. It is acknowledged that no strategy can totally eradicate the impact of flooding, but based on Liao's definition of a resilient city, the adopted FRM strategy must possess three key properties which are essential when it comes to preserving individual safety and urban identity. These properties are: (i) localized flood-response capacity, (ii) timely adjustments after every flood, and (iii) back-up components in the subsystem, these being standby resources that can be activated during or after the flood event. One of these properties is evident in Birmingham city's flood risk management system (the localised flood response). Flood response within the city is a function of the resilience team in local authorities which is governed by the Civil Contingencies Act [9]. The Civil Contingencies Act, alongside non-legislative measures, is designed to provide a single framework for the protection of civilians in the United Kingdom. The Act is made up of two essential parts—provisions for civil protection and emergency powers. However, flood response is just one aspect of the flood risk management approach for which Birmingham City Council possesses the lead responsibility to coordinate, based on the Flood and Water Management Act 2010 [17]. The Lead Local Flood Authority function introduced by the Act is more of an operational one rather than strategic. However, if the city is going to be resilient to flooding, then the authority in charge must adopt an innovative, strategic and adaptive FRM strategy which incorporates the other properties identified in Liao's definition.

Birmingham is the second most populous city and one of the fastest growing cities in the UK, with much progress made in recent years to transform the city's reputation [18]. However, this rapid regeneration and development has impacted the nature of the landscape and the urban nature of the city [7]. Consequently, this has exposed the city's buildings and infrastructure to significant amounts of flooding, particularly from flash flooding. This form of flooding is more challenging to manage and often leaves communities with little or no time to prepare or evacuate [7]. Evidently, the city has the second highest number of properties at risk of surface water flooding within the UK, and this represents a particular cause for concern [19]. Furthermore, the city is widely exposed to other sources of flooding. For example, in recent years (i.e., 1998, 1999, 2000, 2005, 2007, 2008, 2012, 2013, 2016 and 2018), the city has experienced a number of flood events from sources including watercourses, groundwater and sewers [7,20]. Meanwhile in this period over 2000 properties were affected [7,20]. In 2018 alone, about 126 roads and approximately 1600 properties were flooded [20]. These events have had a devastating impact on both homes and businesses in the affected areas. The immediate and the longer-term consequences have been a source of significant stress and reason for concern in

the affected communities [20]. These prevalent conditions have led to the need for the city to develop a positive, proactive and plan-led approach to address the challenges posed by the increasing flood risk. These risks represent the potential for huge losses and also affect future plans of the city if not properly managed.

Flood events in recent years have identified gaps in the local flood risk management strategy relating to inadequate planning and design of flood risk reduction [20]. Consequently, it has become imperative to dive deeper into the current FRM strategy and also to consider further research into identifying FRM approaches and structures adopted elsewhere. The essence of this is to examine the current approach in light of researches on FRM and flood resilience in order to have a sound and legitimate basis for effective planning and development of the city's FRM policies and strategies.

The aim of this study is to identify the current challenges and opportunities of managing flood risk in the city of Birmingham. The study draws on a desk-based account of current flood risk management (FRM) practice in the city, diagnostic evidence drawn from reports and a review of the latest research on resilience. The investigation will adopt a critical lens to the current flood risk strategy and approaches towards identifying opportunities for improvement at the city, community and property scale. The study also examines the most recent flood event within the city, with a focus on the measures taken in order to discover the gaps in the current planning and implementation process.

The following section provides an overview of the concept and meaning of the term, resilience. This is followed by an account of the current management of flood risk in the city of Birmingham. Section 4 goes on to introduce and describe the flood resilience circle model and its further adaptation for the purposes of this study. This provides a robust framework for the evaluation of the existing FRM strategy and approaches. Following this, Section 5 attempts to evaluate the challenges and the opportunities in the current strategy adopted by the city. The final section highlights the solutions aligned to the key FRM stages of prevention, preparation, response and recovery and outlines the implications.

2. The Concept of Resilience

In order to apply the concept of resilience to flood risk management, the terms resilience and flood risk management have to be clearly defined. Afterwards, the understanding of both terms is combined into a definition of resilience in the context of flood risk management [21]. Resilience from a general viewpoint, represents the capacity of an urban system, exposed to a hazard, to adapt by resisting or adjusting in order to remain functional both structurally and in terms of organisation [22]. The term, resilience, has been adopted to cover many different facets of resisting disturbances and adapting to one's environment [23].

In the context of urban flooding, flood resilience is defined as the acceptable level of flooding that an urban system can tolerate, and this entails the system's ability to function during and after a flood event [24]. Implicit in this definition is the ability to state the level of flood characteristics the system is able to withstand. Meanwhile, the exposure rate of urban fabrics to flood hazard continues to grow which has led to a corresponding increase in the level of damages caused by floods to cities worldwide [25]. The effect of this upsurge is seen in some forms, one of which is the inability of existing structural measures to provide acceptable levels of protection [24]. Therefore, flood risk management in urban areas plays an essential role in preventing or reducing the impacts of flooding and curtailing the increasing level of damage [26].

According to De Bruijn, flood risk management is understood as all the activities that enable a region to cope with flooding [21]. Further, while the use of resilience as a frame for viewing flood risk management is essential, it is critically dependent on a well-specified meaning of resilience [27]. The concept of resilience adopted has to capture all the various activities necessary for a region to stay safe. The concept of resilience as used in water (and flood risk) management was first derived from ecology [21]. Meanwhile, in the ecological literature, resilience has been viewed mainly in two different ways—engineering and ecosystem resilience—each focusing on different aspects of

stability [28]. Ecosystem resilience, otherwise referred to as ecological resilience, views resilience as the ability of a disturbed system to absorb change and thereby exist with a different set of equilibrium properties, while engineering resilience sees resilience as the system's ability to return to its stable state after being disturbed, which simply means developing resistance to flooding. Therefore, in ecology, the concept of resilience and the related concept of resistance are used to describe a system's ability to cope with disturbances and to persist without huge irreversible changes in their most important characteristics [21].

This definition tends to deal with flood risk through the application of both hard and soft engineering measures. However, the adoption of resilience in flood risk strategy will often boost system robustness. This type of strategy will not only address the consequence component of risk, but also serve as a key mechanism associated with the reduction of flood impacts. The traditional approach of engineering measures, with the focus on building structures, is widened to consider all possible measures to deal with flood risk, including spatial planning, communication, evacuation, and emergency response. These more resilient (and integrated) strategies rely on the self-organizing capacities of the social subsystems and on stimulating their capability to learn and adapt.

3. The Flood Risk Management System in Birmingham

This section describes the characteristics of the study area including the nature of the flood risk and the sources of flooding.

3.1. Study Area

Birmingham is a major city situated in central England, the largest city of the West Midlands conurbation and one of England's vital industrial and business regions. Often described as the second city of the UK, Birmingham provides a major managerial, recreational and social focus. With an estimated population of over 1 million, it covers a land area of about 270 km². The city comprises of five localities, each of these having two constituencies which are: Central: Hall Green and Selly Oak constituencies; East: Hodge Hill and Yardley constituencies; North: Erdington and Sutton Coldfield constituencies; South: Edgbaston and Northfield constituencies; and West: Ladywood and Perry Barr constituencies. Figure 1 shows the boundaries of the constituencies. Birmingham is the largest local authority in both the United Kingdom and Europe [7]. The study area falls mainly into the Humber River Basin District, however 0.5% of the study area to the south-west of the conurbation drains to the Severn River Basin District [7]. The area is served by the Environment Agency West Midlands Area and Severn Trent Water.



Figure 1. Birmingham ward and constituency boundaries map [29].

3.2. The FRM Nature of Birmingham City

As defined by Schanze, flood risk management is the continuous and holistic societal analysis, assessment and mitigation of flood risk [30]. Flood risk management in a narrow sense embodies the practice of managing an existing flood risk situation while, in a broader sense, it encompasses the planning of a system with the sole aim of reducing the flood risk [31]. Under the Flood and Water Management Act 2010, Birmingham City Council has a responsibility for developing and maintaining a strategy for managing flood risk [17]. However, the initial guidance provided by the Department for Environment, Food and Rural Affairs (DEFRA) to help the Lead Local Flood Authorities in coordinating flood risk management was somewhat limited and more operational than strategic [32].

The City Council however, has an emerging Local Flood Risk Management Strategy (LFRMS) developed with the principal aim of ensuring that flood risk within the region is clearly understood and aptly managed. Therefore, the strategy intends to inform the public about all the stakeholders involved in managing risk, improve their understanding of the level of flood risk and acquaint them with the measures that can be taken to manage risk. The LFRMS sets out to achieve its aim through seven objectives which are: defining stakeholders' role; establishing the type and level of flood risk; who manages flood defences; how flood events are managed and investigated; how flood risk schemes are prioritised; reducing the impact of development; and considering the environment [7].

3.3. The Flood Type and Level of Flood Risk

Key objectives of the LFRMS are to present the predominant types of flooding and develop a clearer understanding of the flood risk within the region. The city has experienced a number of flood events in recent years with many of these arising from watercourses, surface water, sewers and groundwater. The vulnerability of the city is due to its location, as well as its topographical

and geological characteristics [7]. However, flash flood events have become the most commonly experienced as a result of the features of the landscape and the urban nature of the city. These features aggravate the risk of this type of flood and often leave communities with little or no time to prepare or evacuate [7].

The next sub-sections describe the various flood types commonly experienced within the city, highlighting the stakeholder responsible for managing risk at each level.

3.3.1. River Flooding

While Birmingham does not have large rivers that could result in the kind of flooding that draws national attention and intervention of the Environment Agency [7], it does however have 12 main rivers with several ordinary watercourses and reservoirs (see Figure 2). Most of these water-bodies possess natural floodplains which are areas intended for overbank flow or as buffers for the impacts of flooding. Nonetheless, parts of rivers have been heavily modified in places by human activity—some parts of these rivers have been redirected and constricted which now flow within engineered walls [7].

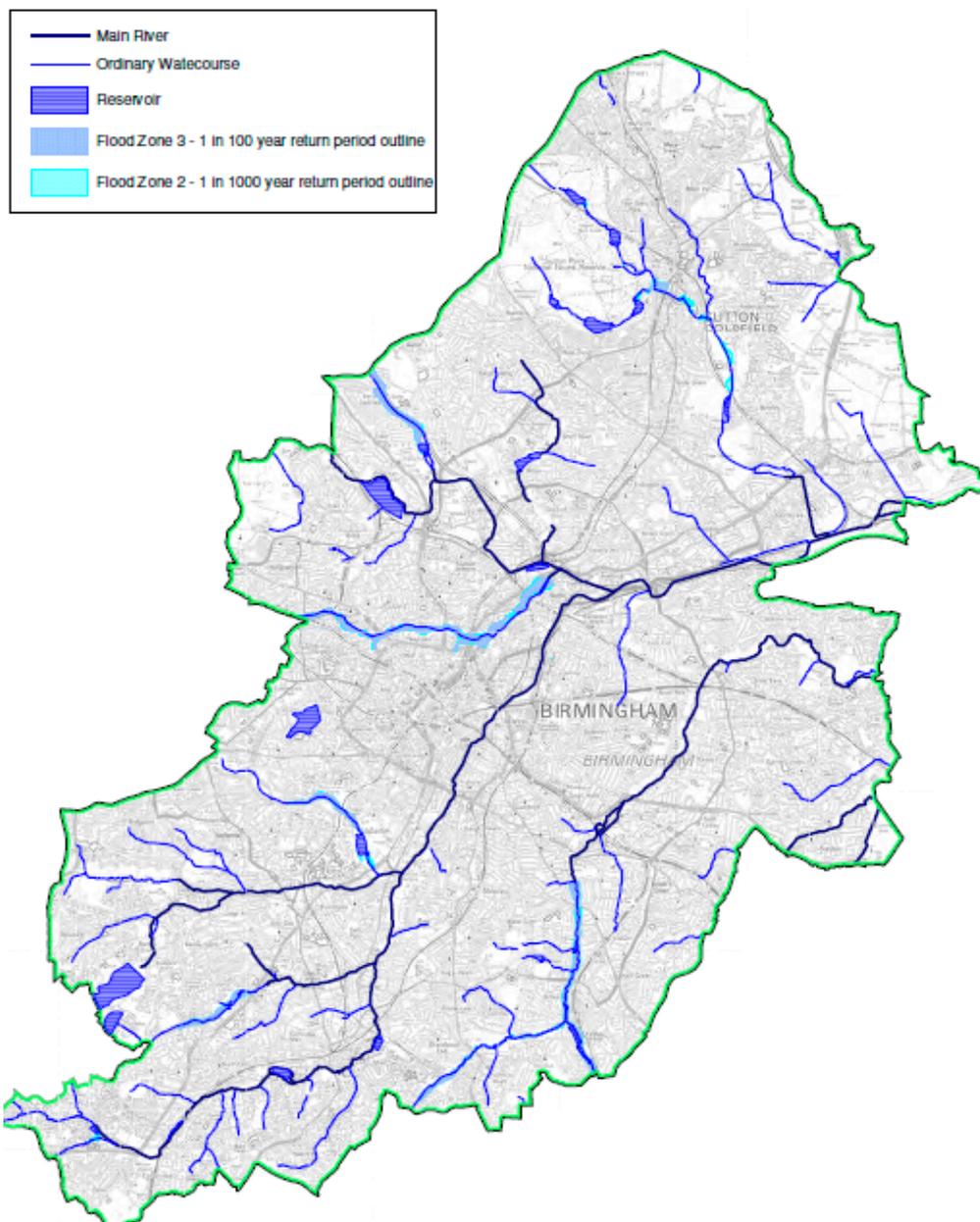


Figure 2. Flood map for ordinary water courses in Birmingham city [33].

The Environment Agency holds responsibility for the management of flood risk on main rivers, while the flood risk management of other water-bodies not specified as main river remains the responsibility of the City Council. However, in both cases the riparian owner is responsible for maintenance of a watercourse through their land.

3.3.2. Surface Water Flooding

Surface water is rainwater which is on the surface of the ground and has not moved into a watercourse, drainage system or sewer. Surface water flooding occurs in cases where high rainfall exceeds the drainage capacity in an area. Most surface water flood incidents contain sewage, which indicates the interaction of rainwater with sewerage and drainage systems. The urban nature of Birmingham, with significant impermeable areas across the city, generates significant surface water runoff which places extreme pressure on the existing drainage systems [34]. Birmingham has a history of surface water flooding, where heavy rainfall overwhelms drainage systems and watercourses [34]. In 2009, it was estimated that 22,900 properties were at risk of surface water flooding in Birmingham, making the city the highest ranked settlement of properties at risk from surface water flooding after London [35].

The easiest indication of this kind of flooding is the presence of surface water runoff on the highway. In the case of Birmingham City Council, maintenance of highway drainage is undertaken by Amey, the Council's Maintenance and Management Partner.

3.3.3. Groundwater Flooding

Groundwater flooding tends to occur after long periods of continuous rainfall. Continuous rainfall results in more water permeating into the ground and causing a rise in the water table above normal levels. For Birmingham, the presence of a geological fault that travels from the north-east to the south-west, passing just to the south of the city centre [7], means that there is variation in groundwater depths across the city. Therefore, the flood risk presented by groundwater is concentrated in the area immediately surrounding major and minor watercourses [34]. While there are localised areas of groundwater flood risk, there is predominantly low groundwater flood risk in the area to the north-west of the fault, with wide variation from low to very high risk to the south-east of the fault. Flooded basements are the primary indication of groundwater flooding. As the water level rises the water may emerge above ground level causing flooding of buildings and roads and can also affect infrastructure and services such as underground trains and sewers. When water gets to the surface the damaging potential also rises. However, the City Council is the statutory management authority responsible for managing the groundwater flood risk at local level (Flood and Water Management Act 2010) [17].

3.3.4. Sewer Flooding

Sewer flooding occurs when sewers are overwhelmed by heavy rainfall or when they become blocked. Currently, according to the Sewers for Adoption guidance, foul water sewers are designed so that they possess the capacity to deal with all runoff from a storm with a 3.33% chance of occurring in any given year without causing above the ground flooding [7,36]. Individual property and land owners have responsibility for their own piped drainage infrastructure. Where piped drainage becomes part of the general shared infrastructure it is generally adopted as public and becomes the responsibility of Severn Trent Water.

3.3.5. Reservoir Flooding

Birmingham has 22 reservoirs and failure of these reservoirs can present a catastrophic flood risk. Large raised reservoirs, described by the Reservoir Act 1975 as those that hold over 25,000 cubic meters of water, present a specific risk during times of heavy rainfall [37]. Any overtopping can cause a threat to the stability of dams [7]. Reservoir flood maps are available from the Environment Agency website but for large reservoirs only. These maps only serve as a guide and not for forecasting what will happen. Half of these reservoirs are the responsibility of Birmingham City Council [7], while the remaining half are the responsibility of several other organisations including the Environment Agency, Severn Trent Water, British Waterways and private companies. However, the reservoirs owned by the City Council are designed to protect against a rainfall event that statistically should only occur once in 10,000 years or greater.

4. Method

A systematic literature review was conducted in three stages with the focus on what resilience and flood risk management scholars are addressing as represented in published articles and the link between these concepts. Electronic database searches were performed through the use of the Scopus database to search for appropriate research works via the following keywords: flood, resilience and flood risk management. Scopus was selected because it has the largest database of peer-reviewed literature [38,39]; it also has the capacity for searching, discovery and analysis [40].

In the first stage of the search, the keyword flood was restricted to be found in the title and abstract. Also, the search was allowed for papers published up to March 2019, with no lower date limit set. Consequently, a total of 135,851 papers addressing some aspect of flooding were displayed. However, when resilience and flood risk management were added to refine the search, only 4974 papers were identified.

The second stage involved more exclusions to further refine the results. The exclusions included refinement in subject areas, document type, publication stage, source title and language which were not directly related to the topics. Subject areas like earth and planetary sciences, agricultural and biological science, business, management and accounting, and the likes were removed, while the publication stage was limited to final and the not in press documents were excluded from the search. This refinement reduced the number of publications displayed to 66.

The final stage entailed the title, abstract and full text screening of the 66 papers selected in stage 2 in order to cut off studies whose scopes were too broad. The abstract and the text of each of the papers were manually scanned with emphasis on removing the less relevant papers. For example, those broadly focused on climate change rather than flooding (e.g., [41]), papers discussing drought (e.g., [42]), and papers focused on the ecological effects of flooding on flora and fauna but with no social or policy focus (e.g., [43,44]). Also, at this stage, other reports were included from the Birmingham City Council database on flood risk management strategies in order to understand the structure of FRM in the city of Birmingham and how it relates to what has been published by scholars. Figure 3 presents an overview of this process.

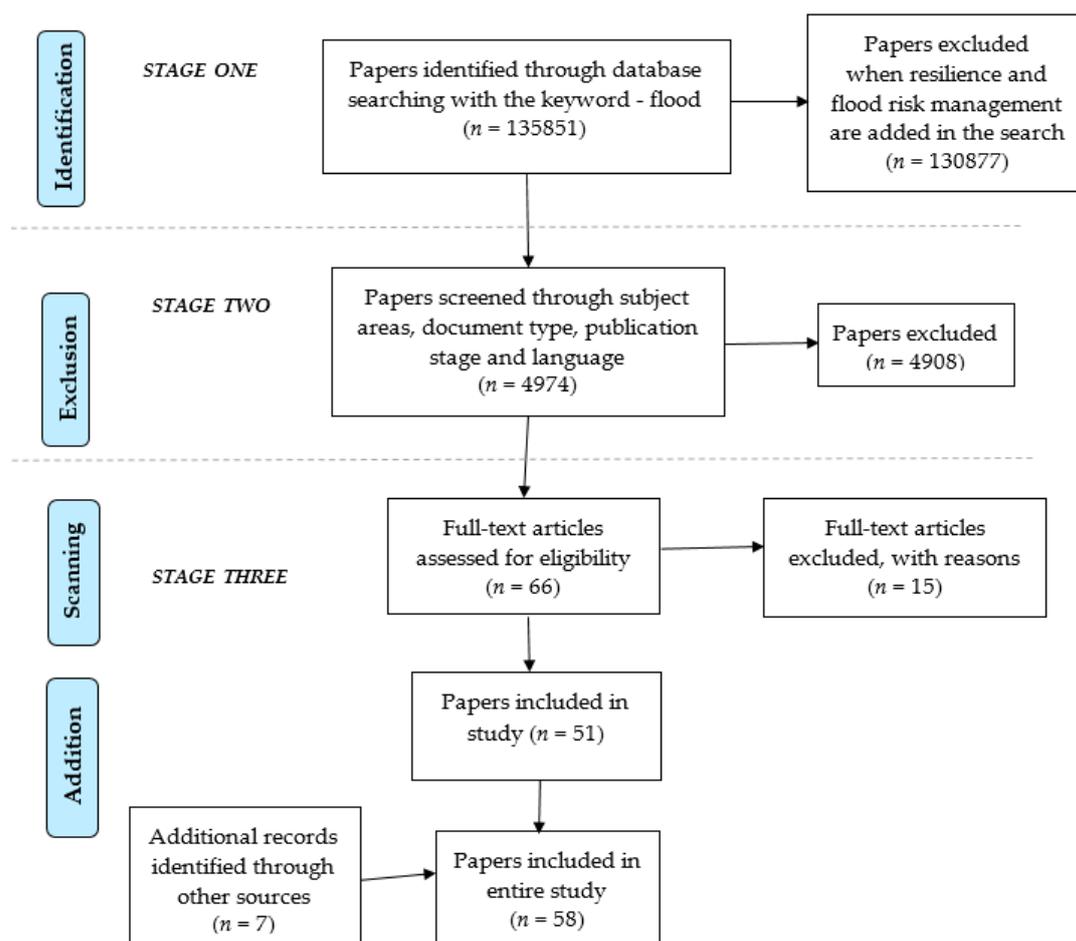


Figure 3. The flow diagram of the Systematic Literature Review (SLR) for the paper selection.

5. The Flood Resilience Circle

Figure 4 shows an approach based on an adapted version of the flood resilience circle developed by Royal Haskoning [45], and which can be applied to help make cities resilient to flooding. This approach considers a four-phase intervention to flood resilience which comprises of prevention, preparation, response and recovery phases. The model depicts a three-step activity necessary to carry out each phase. The inner circle represents how cities are being affected by flooding and how they can move to becoming a resilient city.

Cities are being exposed to the reality of changing climate whose damaging effects are already evident in every corner of the world [46]. While extreme weather events are a natural feature of the climate system [47], these events are becoming more frequent and more intense as a result of climate change (see Figure 4). According to Steffen et al. [47], this increase in frequency of occurrence is due to the fact that these events are now occurring in a more energetic climate system, in an atmosphere that is warmer and wetter than it was in the 1950s. In the UK, the occurrence of extreme weather events has increased in recent years, with four of the five wettest years on record for the UK occurring since the turn of the millennium (2000, 2002, 2008 and 2012) [19].

These events expose weaknesses within cities' flood risk management approaches and create opportunities for learning about building for the future to make cities more resilient. For any city with a risk of flooding there is always the choice of redesigning the city so that it is more resilient to floods. As depicted in Figure 4, for the affected city to become resilient, it has to learn from these extreme events and invest in resilient rebuilding to help protect residents in an efficient and cost-effective manner and also encourage business continuity. Planning for resilience makes investments in people, assets and the value created in cities more secure.

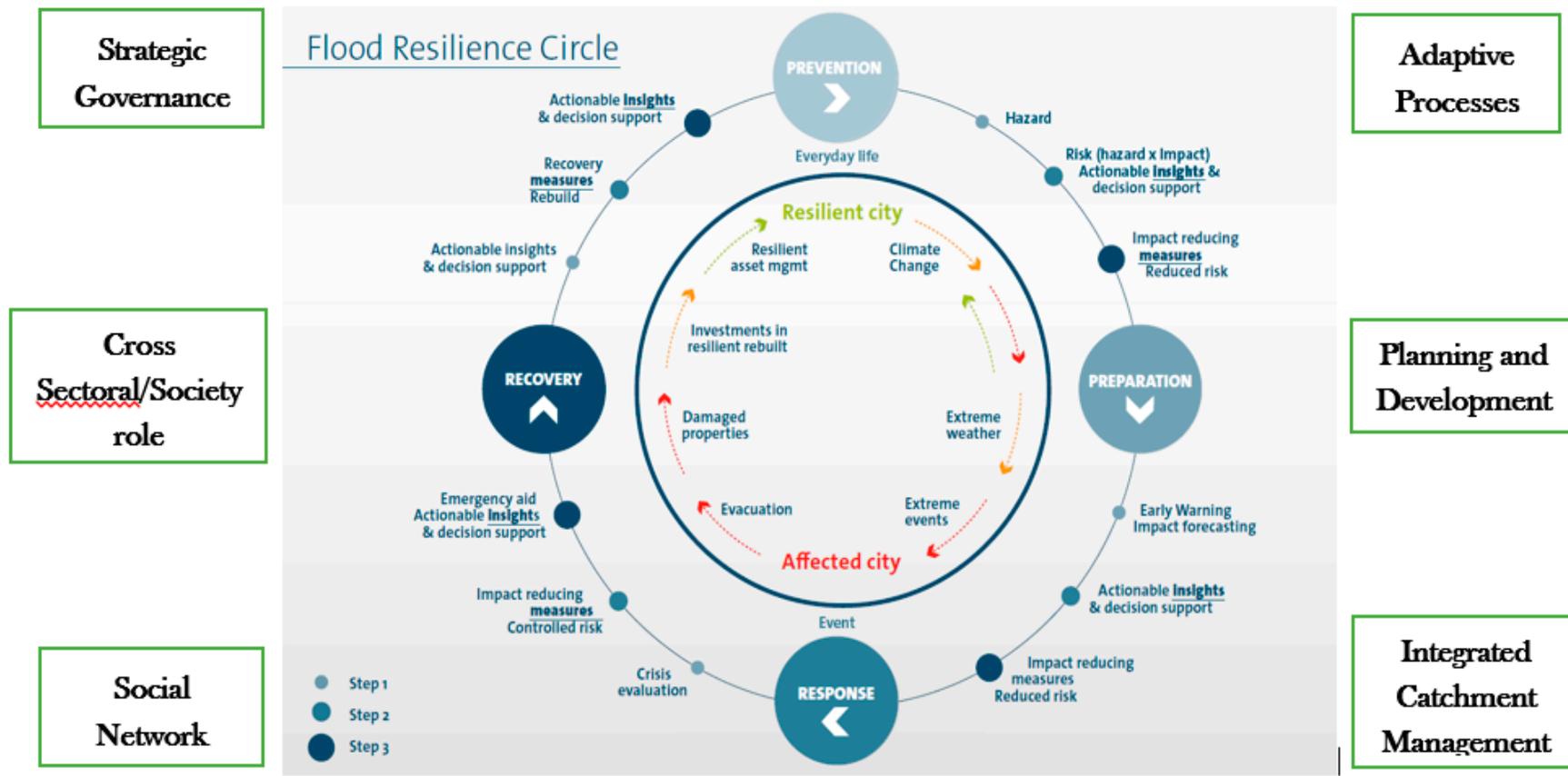


Figure 4. The flood resilience circle. (Adapted from Royal HaskoningDHV [45]).

Meanwhile, the outer circle indicates the four-phase approach to developing resilience within the city, comprising: prevention, preparation, response and recovery. This represents the FRM strategy required to adapt the key features of the city against flood impacts. These four stages are described and summarised in Table 1. However, to become an effective FRM strategy, the approach needs to incorporate the following key features deemed necessary in light of current thinking:

1. Adaptive in nature to changes in climate and also to processes that focus on achieving the FRM goals [48].
2. Integrated catchment management (ICM) is the process of bringing various parties and interests in a catchment together through regional land and water management plans to achieve whole catchment improvements [49].
3. Strategic governance involves trust, transparency, accountability and scrutiny [50].
4. Cross sectoral/society role entails integration of institutions and organisations within the city in the FRM process [51].
5. Planning and development, including the development of blue-green infrastructure, Sustainable Drainage Systems (SuDS) on a catchment, local and household scale, catchment-based approaches, drainage and sewerage [52].
6. Social network, also linked to social contracts, social capital, community leadership and networks [53].

Table 1. Four types of flood risk management strategies.

STRATEGY	DESCRIPTION
Prevention	This is also referred to as flood avoidance and entails activities that are carried out prior to a flood event. It involves identifying flood related hazards and having a proper understanding of flood risk and also working with people who are exposed on how to limit exposure and collectively minimise risk. Prevention measures focus on reducing the chances of flooding and the impacts of flooding, in case it floods, by trying to discourage development in flood prone areas thereby limiting flood risk exposure of both people and properties. Measures comprise of both structural (such as construction of dams, levees, dykes, diversion channels) and non-structural approaches (such as having a good understanding of flood hazard).
Preparation	This approach acknowledges that it is not possible to completely eradicate the risk of flooding and therefore it builds on developing preparedness to minimise the consequences of floods. With more effort put into preparation, the easier it will be for cities to cope with severe and unpredicted events and to help reduce shock. These measures include the development of flood warning and forecasting systems. The purpose of flood warning is to offer advice about future flooding so that people can act to minimize the impacts.
Response	Even with the application of non-structural flood mitigation measures such as flood avoidance and preparation strategies, it is key to recognize that residual flood risk will remain. These are plans targeted towards dealing with this residual flood risks and their aftermath. The response involves several activities which form the flood emergency plan. An appropriate and implementable emergency plan will facilitate emergency response through the efficient allocation of rescue resources and evacuation plans in order to minimise flood impact. These plans need to be nested so that the top-down Local Resilience Forum-led approaches intersect with bottom-up community-led approaches seamlessly. A frequent failure is to impose top-down approaches on community level plans.
Recovery	This entails the recovery of different features of the city from flood impacts, such as human (individual basic recovery can take up to two years while emotional recovery may take longer time), physical (residential and commercial properties, critical infrastructure), social (community) and financial (businesses). This approach enables cities to bounce back, in good time and probably better than they used to be, after a flood event. Measures include reconstruction or rebuilding plans which may also provide opportunity for making the features of the city more resilient to similar events. In the process of recovery, two things are vital: first, is to ensure that the city gets back to its normal life even while reconstruction work is on-going; and second, is to reduce the reconstruction time as much as possible.

These features have been added to the flood resilience circle as shown in Figure 4.

6. Challenges in Current FRM Practise

This section describes the current flood risk management practise in the city of Birmingham in line with the four-phase intervention to flood resilience in the flood resilience circle. It also identifies the challenges present in each of these stages, drawing on some of the most recent reports and evidence including the May 2018 flooding in the city.

6.1. Prevention

The main means of protection is by flood defence embankments which are positioned along the rivers to protect against fluvial flooding such as flood defence structures and raised defences. These flood defences serve as a measure for reducing the probability of flooding (hazard) within the city. Some of these embankments offer protection from flooding up to an annual probability of 1 in 100 years (1% AEP, annual exceedance probability), while a majority of the flood defences offer a standard of protection of 1 in 50 years (2% AEP) or less.

Apart from these formal defences with known standards of protection, there are numerous informal defences with the standard of protection and maintenance regimes not known. However, some of the areas designated as flood zone 3 by the Environment Agency (with both land and properties under high probability of flooding) are deficient of any flood defences and those that are present are poorly maintained. Evidence from the report issued on flood incidence within the city in May 2018 outlines these challenges and that people who lived in these areas suffered substantial losses [20].

In terms of the non-structural measures, one of the very current issues is about the language being used to talk about community resilience and communicate issues and concerns [54,55]. The approach used in educating and acquainting the community can be regarded as somewhat patronising and has failed to recognise the cultural and behavioural change issues that underpin this. The proportion of people who believe that they are not at risk remains high [56].

6.2. Preparation

In the preparation stage, the city adopts a flood alert and warning system as a means to manage residual risk, albeit this is not the sole measure to offer protection against flooding. There are three flood alert areas and 23 community-based flood warning areas which cover parts of the main rivers. However, the Environment Agency who are in charge of delivering these alerts and warning systems within the city recognised the challenges encountered with conveying flood warnings in such a way that communities are informed early enough to have time to respond and act upon it. The evidence presented by the report on the issues arising in the May 2018 major flooding event show that residents who registered with *Floodline* only received flood warning after properties were already flooded. One of the key issues for Birmingham is that flood warnings typically do not come in time and are targeted at only a very small proportion of those at risk.

6.3. Response

In order to respond to a range of emergencies (including flood events) within Birmingham, a central multi-agency team referred to as the Birmingham Resilience Team (BRT) was established. The team is responsible for ensuring appropriate emergency management procedures are in place and also for maintaining business continuity arrangements, which is a component of the recovery stage [9]. However, the team is divided into two elements: (i) the Birmingham City Council Emergency Planning with the primary objective of developing, implementing and ensuring that the City Council emergency planning and the business continuity plans and arrangements are in place; and (ii) partnership emergency planning with the aim of enhancing and accelerating the development of Birmingham multi-agency emergency plans and arrangements through a co-located multi-agency team [9]. The team consists of full-time officers from the police, fire services and National Health Service (NHS). However,

an aspect that requires attention is the command and control structure in place. Mostly, this does not permit the response team to enhance triggers or lower thresholds which could enable the partners to intervene in order to support response. This seems to be a major concern of the multi-agency emergency responses [57]. There is also a need for some further clarification between the role and responsibilities of the statutory Local Resilience Forum coordinated by the City Council and the City Council Resilience Team. There is evidence to suggest that there is some dispute between the different organisations, particularly around the triggers.

6.4. Recovery

This stage of the FRM approach, entails providing support to those affected in flood events to help them get back to normal life. The city appears to have several organisations alongside the resilience team who are committed to providing help in the recovery stage. However, there seems to be no clear roadmap on the level of commitment provided by these organisations and this impacts the adequate provision of support to victims. The needs of those affected changes as the event progresses from the initial response to recovery, which normally demands longer-term solutions. There is a wide range of issues that people have to deal with at this stage which changes over time. The National Flood Forum (NFF) estimates that it takes between 6 to 18 months for people and businesses to get back on track. Most recovery processes only focus on the short-term recovery. Therefore, there has to be a clear plan on how to manage the different stages in the recovery process. This challenge was encountered in the May 2018 flood incident where it was reported that there was no proper coordination of the level of support provided to victims by the various organisations involved [20].

7. Recommendations for Improving the FRM Approach

As flood risk is becoming of increasing concern within the city, coupled with the uncertain weather patterns, it is essential for the city to take up a more sustainable approach to adapt to these features and uncertainties. The following proposed solutions are highlighted to address the challenges in the FRM stages. These recommendations are aimed at the key decision makers responsible for managing flood risk in the city and include the city council, the Local Resilience Forum and the City Council Resilience Team.

1. The city seems to rely on the hard engineering structures to provide protection in the prevention stage. These measures provide solutions for fluvial flooding only, whereas the majority of flooding in 2018 was from a combination of flooding sources, particularly surface water. The investment in blue-green systems across catchments, by managing water from where it falls through the city would represent a more sustainable way of protecting features that are exposed to flooding. The blue-green FRM approach revolves around the concept of 'living with water' and making space for water [58].
2. A communication strategy which creates awareness in organisations and communities and conveys messages in a way that motivates people is needed. This should adopt positive narratives around managing water, flooding and flood risk rather than approaches which attempt to prompt action based on scaremongering or frightening communities about the impacts. This should also recognise that all areas of the city are at some risk of flooding (i.e., anyone can be flooded, but that some areas are more at risk than others). The strategy should identify points where people and businesses have contact with the state, such as conveyancing, council tax and business rates, health, education and ward surgeries, and work with these to increase engagement. The communication strategy could be an element of a social contract between the state and society for better management of water.
3. The development of more precise forecasting, especially for surface water flooding, in order to ensure that flood warnings are conveyed to communities in good time and allow better time to respond. Orographic rainfall is difficult to forecast precisely, but even a few minutes of extra

warning can help at least some people to take action to prevent water ingress or reduce the impact of flooding. There is a need for new residents (whether tenants or owners) to be provided with a clear understanding of what their flood risk is and their riparian responsibilities, as well as where to go for information and guidance on how to better protect themselves and contribute to managing water in the city.

4. In the response phase, there is a need to have a more robust command and control structure that supports the groups involved in flood emergency in their response to flood incidents, particularly to flash flooding events that happen with short notice and surface water flooding that is difficult to forecast. Effort should be directed towards developing actionable information and relationships through empowering the Birmingham City Council emergency planning team with the permission and skills required to collaborate with the Partnership Emergency Planning team (such as the NHS, police, fire service, etc.) and communities as a core part of their work not only during the flood, but also before flood events. Also, there should be greater recognition and acknowledgement of the value and contribution of others (including volunteer groups such as the resilience group, the National Flood Forum, etc.) in terms of developing processes which enable the resilience team to support and benefit from their work.
5. There is also a need to focus on better protecting other features of the city, such as commercial properties, public buildings and critical infrastructure that is located in high flood risk areas. That is, the overall resilience of the city does not only depend on the protection of the residential homes and its residents, but also on the wider built environment and critical features of the city. This approach needs to include consideration of the cascade effect of impacts on critical infrastructure.
6. There is a need to develop a framework for assessing and quantifying the overall level of resilience within the city. This should be based on a series of layers containing property resilience, the 12 catchments and the administrative areas. This should also acknowledge that a majority of the properties which flooded in 2018 were located nowhere near a river. Rather, water flowed through the catchments towards rivers using the highways as well as drainage systems, and in the process, flooding small groups of houses along the way, all over the city. This framework would help to monitor progress of the FRM strategy and also help to inform steps and decision making in improving future levels of resilience. Ongoing research by the authors towards developing a means to quantify resilience at the level of the individual property could provide a useful element of this framework (see [14]).

8. Conclusions

Like many major cities around the world, Birmingham is exposed to a range of flood risks and has endured a spate of recent events which have caused significant damage and disruption to households, businesses and the wider community. Surface water flooding has become the most commonly experienced and is known to be particularly problematic in that it often leaves communities with little or no time to prepare. UK climate change forecasts indicate an increased frequency and intensity of flood events in the future. Coupled with rapid and intense re-development and regeneration of the city, the concerns are that future flooding could be even more disruptive and damaging.

Historically, the standard response to managing flood risk in the city has been through a reliance on engineered flood defences in the form of walls, storage tanks and drainage systems. However, current flood risk strategy in the UK has moved towards more sustainable approaches that adopt the concept of resilience and living with water, to build back better. This study sought to critically examine the current approaches of managing flood risk towards identifying opportunities for improving the resilience of the city. A modified version of the flood resilience circle model was developed to provide a coherent basis for the systematic evaluation of the current approaches. This approach followed the key stages of integrated flood risk management, and incorporated key contemporary features including integrated catchment management and strategic governance.

A number of limitations and weaknesses are found across all stages of the flood risk management framework. For example, in the prevention stage, many high-risk areas in the city are deficient of flood defences and those that are in place are poorly maintained. Communication of risk to communities is found to be wanting, leaving many people believing that they are not at risk of flooding. In terms of the preparation stage, while there exists a reasonable network of flood warnings and alerts, these are found to be ineffective in the event of surface water flooding.

Six key recommendations are put forward towards addressing these weaknesses and helping to improve future resilience, namely: (i) through the implementation of blue-green approaches that can help address the surface water flood risks; (ii) the development of a communication strategy that motivates positive engagement; (iii) improved flood warnings and alerts especially for surface water floods; (iv) the development of more robust command and control structures in the response phase; (v) a need to focus on protection of other features of the city including critical infrastructure; and finally (vi) the development of a clear approach to assessing levels of resilience across the different layers of the individual property, catchment and administration.

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