Manuscript

Title

"The best flood I ever had": contingent resilience and the (relative) success of adaptive technologies

Abstract

The practical operationalisation of resilience within cities is strongly linked to technology, such as better construction materials or redesigning urban form. Institutional and private sector actors often focus on issues relating to the technological innovation journey, such as 'pathways' to implementation or 'barriers' to market uptake, rather than whether adaptive technologies are the most appropriate resilience solution. These discourses frame urban resilience from the perspective of an innovation journey where technologies are perceived to succeed if there is high uptake. However, given the multi-perspective and multi-scale nature of urban resilience, the idea of 'success' inevitably has complex spatial, temporal and scalar dimensions. The paper uses the case of property level flood resilience (PFR) technologies in the United Kingdom to introduce the notion of 'contingent resilience' as a means to understand the trade-offs that are part of assessing and evaluating climate resilient technologies. We reveal that there are fundamental contradictions in what is deemed as a 'success' depending on *who* is framing the problem, *when* the judgement is made, or *where* the scale of analysis lies. Above all, the paper highlights the importance of illuminating the struggles that do not just define success, but that spatially and temporally redistribute climate resilience in a hidden manner.

Keywords

Flood risk management, innovation, adaptive technologies, climate resilience, climate change adaptation.

Highlights

- Climate resilience in urban areas is increasingly turning to adaptive technologies in practice.
- Governments define success via innovation journeys and market uptake.

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- Success in adaptive technologies varies between actors, across scales, and over time.
- We should recognise the continency of resilience when appraising the success of adaptive technologies.

Introduction

'The elimination of the word "success" is important'
Cedric Price (quoted in Mathews, 2005: 78 – 9)

The current zeitgeist around smart, sustainable and resilient cities emphasises innovation and creativity as a means to address the challenges of environmental change (Viitanen and Kingston 2014; Hodson and Marvin 2014; Hodson et al. 2017). For many, the challenge is to understand how technologies are adopted within societies; that is, how technologies achieve successful market uptake and salience (e.g. Jaffe et al., 2005; Geels and Smit, 2000; Geels 2004). While innovative technologies and the sharing of learning between cities around resilience issues can be a positive experience, technological implementation can lead to a 'moral hazard', directing attention away from the need to change risky behaviours (Corner and Pidgeon 2014). Many also fail to question the extent to which technological innovation is preferred due to its synergies with economic growth, or notions of 'progress' (Gray, 2004). Such approaches may privilege 'human exceptionalism' (Catton and Dunlap, 1978), with 'nature' cast as something to be mastered through human ingenuity (White, 2015; Swyngedouw, 2015).

Similar critical observations have permeated resilience theory and practice, particularly with regard to analysing the power and politics around who shapes agendas and outcomes, noting that the resilience rhetoric '[imposes] a rationality that is incongruent with the complex reality of how socio-economic issues combine with ecological systems' (Bahadur and Tanner, 2014: 203). For example, scholars acknowledge how resilience is complex, contingent and contested amongst different actors, which emphasises the importance of developing governance perspectives that are able to bring these political issues to light (e.g. Bahadur and Tanner, 2014, O'Hare and White, 2013; Vale, 2014; Chelleri et al., 2015; Meerow and Newell, 2016, Davoudi et al., 2018). Although technology will undoubtedly be part of the mix of urban resilience strategies, there is a

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need to recognise the extent to which its implementation may also bring hidden redistributive risk effects. Yes, the application of technology within cities may be deemed a 'success', but critical questions remain with regard to for whom, when, and where (Meerow and Newell, 2016).

With the Intergovernmental Panel on Climate Change proclaiming that we have very little time in order to keep global warming to below 1.5°C (IPCC, 2018), climate resilience has taken a distinctively adaptive turn. Despite the risk that climate change presents, there is a realpolitik at play where many organisations and policy-makers try to emphasise the economic positives that can be gained through enabling resilience, particularly where it relates to innovation and investment in new technology. For instance, the European Commission (2013: 5) promotes the realisation of 'climate-proof cities' where 'adaptation action will bring new market opportunities and jobs'. The UK Government (2011: 2) has similarly merged risk and opportunity, identifying resilience as a key feature of a 'green economy' which 'can help UK businesses to manage risks…increase resilience…and seize the opportunities from new and emerging markets, both nationally and internationally'. Likewise, the 100 Resilient Cities initiative drew from the language of investment, frequently discussing the value of a 'resilience dividend' or emphasising that cities struggle to undertake projects often due to the difficulty in proving the 'bankability' of potential solutions (Rowling, 2018). In urban areas, resilience has thus been increasingly re-framed as a technological, political and administrative strategy that provides economic benefits for those who either design responses or reap the benefits of their implementation.

To develop the analysis, we examine a particular kind of adaptive technology—Property-level Flood Resilience (PFR)—to open up a conceptual discussion around the divergent success claims inherent within adaptive technologies. PFR technologies are applied at building scale in order to reduce the direct risk of flooding to a property. The importance of PFR has steadily grown since 2007 as part of flood risk management strategy in the UK and elsewhere to provide resilience at local scales. Such measures may be temporary or permanent and include door guards, window guards, air brick covers, and flood doors (Fig 1). PFR technologies can be broadly divided into two types: resistance measures that aim to keep flood waters out of a property (or to slow the rate of entry)

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and resilience measures that assume that property will enter a property and seek to minimise damage (e.g. easy-to-replace internal materials).

Fig. 1: Example of a PFR resistance measure: a temporary guard in operation with air brick cover. Source: Authors, January 2018. [In colour]

By interrogating the complex and interconnected nature of the system within which these technologies are designed and integrated, we reveal and question the processes of interpretation and negotiation that are core to urban resilience and identify current gaps between theory and practice. There are two main parts to the argument. First, that although ‘success’ is predominately framed by institutional and private sector actors and agencies in line with long-held norms of technological innovation journeys and market uptake, the broader success of resilience is inherently dependent: it is contextual, relative, and contingent across space, time and scale. In particular, property owners viewed success as more about absolute performance than implementation or relative

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improvement. The ‘best flood ever’ referred to in the title was still a disruptive flood even though it was less destructive because of the implementation of mitigating measures. . Second, by drawing on the intellectual resources of Science and Technology Studies (STS) this research contributes to ongoing critiques relating the translation of resilience theory to practice by highlighting how the growing trend for adopting technical, designed urban ‘solutions’ should be subject to parallel critical attention concerning claims of resilience ‘success’. To merge these two themes, we introduce the term ‘contingent resilience’ as a means to better communicate that ideas of success will only hold for certain people, at certain times and in certain places. By highlighting how adaptive technologies can only ever bring ‘contingent resilience’ we help bring to light and deepen the multi-perspective and multi-scale dimensions of urban resilience and contribute to discourses relating to translating resilience theory into practice in cities.

Unsettling the success-failure binary in complex systems

Given how the practical implementation of resilience has gained momentum, particularly through the introduction of new technologies, we commence by examining conceptualisations of technology and its relationship to society. There is also a need to understand the complexity of risk and resilience, how this is governed, and perceptions of these concepts. Doing so reveals the importance of asking questions concerning the actors involved in a technology’s becoming (who?), the scale at which it is applied (where?), and the timescale that technology operates in (when?). To underpin the conceptual framing this section links two main strands of literature: STS and critiques of resilience regarding its contingent nature.

STS examines the way in which technology and society co-evolve through the mutual shaping of technology and practice (e.g. Jasanoff 2004; 2012). In the context of urban development, technologies are refracted through policies, institutions, intermediaries, and social practices—all of which can be understood as a set of relations that help govern and mediate (Jasanoff, 2005). From this perspective, technologies are socially contested and negotiated, a view that seeks to unsettle the uncritical linearity that is so closely associated with the ‘becoming’ of technology (Hughes, 1987; Bijker et al., 1987). The existence of a ‘black box’ effect common to technical objects (e.g. Jacobs et al., 2007) does, however, mean that those with technical competencies, such as elite actors or agencies, hold significant power during these processes to frame desirable outcomes

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(e.g. White, 2019). Therefore, when promoting technologies within complex and dynamic social-ecological systems, claims of success are hidden displays of power. For instance, literature on urban risks recognises how the introduction of technologies may create cascading or new risks to complex systems, or even serve to normalise or redistribute threats and responsibilities rather than 'solve' risks (Beck, 1992, 1999; Giddens, 1991). Research also argues that technology is fetishised and privileged in notions of progress and emancipation (Kaika, 2005) with threats and crises paradoxically recast as opportunities for (neo-liberal) economic growth (Klein, 2007).

In acknowledging the uncertainty of urban resilience, the technical professions have responded with a shift away from precise 'fail-safe' approaches to develop technologies that are 'safe-to-fail': where 'failures and design systems [are anticipated] strategically so that failure is contained and minimized' (Ahern, 2011: 342). This shift towards contingency highlights the importance of interrogating success claims, particularly those that maintain the central position of technological innovation, despite acknowledging failure at different scales within highly networked urban systems. It also links to the governance of urban resilience: who or what, for example, holds liability should there be a failure? Claims of success, therefore, also make claims of liability and responsibility. Allied to this, the presence of 'residual risks' - those which remain even where adaptive technologies have been put in place - raise further questions over the temporality of 'success'.

To add further nuance to the governance of urban resilience, individuals perceive safety, risk, and danger differently which is partly institutionalised through organisational structures (Pidgeon, 2010). However, the acknowledgement of varying conceptions of risk lie outside of many academic and policy discourses on technical innovations (see Hodson et al., 2007). While there is a preferred truth in policy narratives concerning the promotion of technology and the provision of information to overcome barriers, more theoretical research questions this simplistic stance. For instance, Pidgeon (2010: 213) argues that: '(…) the problem may become so complex, vague or dynamic…that different individuals and organisations can only ever hold partial, and often very different and changing, interpretations of the situation'. Such a changeable view can be seen in relation to the variable individual perception over time dependent upon where 'people's relationships to particular risky technologies are more open and transitory than references to “fear”, “dread”, “anxiety” or “concern” would imply’ and where everyday attitudes towards a potentially risky technology can ‘move in/out of proximity’ to the individual (Bickerstaff and Simmons, 2009: 867). Moreover, while risk information is provided by various agencies, data can be inconsistent and there is ambiguity over how citizens understand this (Wachinger et al., 2013). Essentially this literature emphasises the tension between theoretical work that positions risk as mutable, multi-dimensional, and multi-scalar, and more simplistic claims of urban resilience success relating to, say, barriers, technological uptake or adoption, or market penetration. Furthermore, it highlights how a focus on implementation may mask ‘the extent to which there are often bitter disputes over the technology itself’ (Latour, 2003: 37).

Scalar tensions are also evident when considering urban resilience (Davoudi et al., 2018). Flood defences in high value neighbourhoods may increase exposure to others less able to benefit from such measures (Bahadur and Tanner, 2014). Further, local innovation activities may conflict with national level priorities (Taylor Buck and While, 2015) or flood defences may legitimise building on flood plains even though approaches at catchment scales caution against this; a phenomenon known as the ‘safe development paradox’ (Burby, 2006). Given this, clear-cut understandings of what constitutes as ‘success’ in terms of resilience building will vary at different spatial scales. Successful implementation can lead to contradictory outcomes and potential ‘failure’ at other spatial scales.

Research also highlights that claims of temporal success should not be uncritically accepted. Technologies may appear to be fixed and stable entities, but they have fluid dimensions where ‘there are many grades and shades of ‘working’, or adaptations and variants’ (de Laet and Mol, 2000: 225). Technological fixes also deteriorate over time, with an associated decline in their efficacy. The temporal question can be seen in more mundane discussions around repair and maintenance which are often overlooked in favour of the innovative and creative moments of production (Graham and Thrift, 2007). This focus reveals further tensions *within* designations of success; the need to repair and maintain may be regarded as a ‘failure’ of some component. Moreover, ‘successful’ material artefacts such as buildings, may in fact have ‘failed’ in the past, have been repaired, and may fail again in the future (Edensor, 2016). In a more general sense, technologies to address urban resilience can lead to maladaptation in the long term and

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potentially impede intergenerational justice where the economic needs of the present trade off against the future (Beck 1992, Barnett and O'Neill, 2010; O'Hare et al., 2016; White and Haughton, 2017). Thus, whether a technology is functionally efficient in itself cannot solely explain whether it becomes 'successful' or 'fails' over an extended period of time.

Lastly, particular policy framings will influence claims of success and inevitably privilege the adoption of particular 'solutions' or 'fixes' (Füngfeld and MacEvoy, 2014). They may even over-state the benefits of technologies, given that proving their efficacy relies on a series of selective trial and error experiments (Taylor Buck and While, 2015). There is a hidden politics to the selection, design, and application of technology, which may serve to support preferred ideological, professional or institutional outcomes. As such: 'it is thus important to reveal how science and technology can serve to internalize and reproduce certain values without seeming to' (Castree et al., 2014). This is political since harnessing the promise of technologies requires: 'an engaged political project that asks evaluative questions about how urban technologies are socially appropriated, why and in whose favour?' (Coutard and Guy, 2007: 730).

This section has emphasised how technologies may be understood as relational *components* nested within intricate socio-technological (and socio-ecological) systems (Hughes, 1987; Bijker et al., 1987). It also highlights how technological success may be contingent and that this is shaped by governance and power arrangements. In particular the extent to which problems are framed, the acknowledgement of issues connected to scale or time, or the involvement of views and values of differing social actors. Consequently, it is crucial to analyse the relations at play; how the wider systems, technologies and users are co-dependent and co-evolve, how they behave when in use, or the competing claims and evaluative frameworks attached to how technologies succeed and fail. Drawing from this literature, our empirical analysis of PFR centres on three related lines of enquiry: success for whom, success when and success where.

Materials and Methods

Our research examines how PFR became an accepted method of flood risk management within the UK. The work is based on several research grants that have looked at the PFR market in the UK between 2009 and 2018, providing an in-depth view of the emergence,

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negotiation, and acceptance of an urban resilience technology in practice. In addition to the interviews and workshops described in an earlier paper (*reference removed for peer review*), we reviewed around 60 policy documents from 2004 onwards relating to flood risk management and climate change adaptation that made reference to flood resilience at both local, regional and national levels.

Selected documents that referenced PFR were examined in closer detail. We used frame analysis to understand how certain epistemic communities (Haas, 1992) coalesced around the policy discourse on PFR, sought to define success, and how this is shaped and reshaped through interaction over different scales and across different actors and outlets (Foucault, 1971; Goffman, 1974). Entman (1993: 52) noted that framing helps to understand four fundamental characteristics of an issue: they define problems; diagnose causes; make moral judgments; and suggest remedies. Frames therefore provide interpretive storylines to shape information and ways of thinking, in this case around PFR technologies, consciously or unconsciously. The discursive analysis of frames relating to PFR helped to uncover the way in which meaning is attached to policy issues by different actors (Dryzek, 2012; Flyvbjerg, 1998; Hajer, 2002; Hajer and Versteeg, 2005; White and Nandedkar, 2019). By making the framing processes explicit, we could query who has the power to frame policy and technological success, and the resultant implications of this framing. Each document was examined to judge the notion of resilience implicit in the promotion of technologies, the extent to which the thinking supported short- and/or long-term goals, and the extent to which the focus shifted from solely being concerned with market uptake. Additionally, the analysis was supported by the researchers close involvement with policymakers and practitioners through attendance at steering groups and industry-led workshops that attempted to mainstream PFR through standardisation and guidance for PFR technologies (Flyvbjerg, 2002). Throughout the data collection period it became increasingly clear that there was a tension between different actors in terms of whether and how PFR products could be considered successful or not; an issue to which we now turn.

Contesting Technological Success

For almost two decades, there has been an increasing acceptance that large-scale flood defences cannot be the sole response to flooding. The European Floods Directive (Council Directive, 2007/60/EC) recognised the complexity of flooding and shifted to a systems-based approach by enshrining, for example, catchment-based management and non-structural measures, such as early warning systems, urban planning, and the provision of measures to enable citizens to make their own judgements through flood risk maps. The changing language of the UK's Department for Environment, Food and Rural Affairs (Defra), whose remit includes flood defence spending, helps frame and contextualise this change, shifting from narratives of flood defence to flood risk management (Johnson and Priest, 2008) and, more recently, towards flood resilience and the use of PFR. Table 1 summarises the key policy and strategy developments underpinning the emergence of PFR and provides insights into the framing discussion or urban resilience.

Year	**Author**	**Policy/Strategy**	**Main urban resilience aim**
2007	UK Government	The Pitt Review	Identified the need for PFR as part of a wider flood resilience strategy.
2009	DCLG	Planning Policy Statement 25 – Development and Flood Risk Practice Guide	Where properties are built in flood risk areas, construction should be resilient to mitigate flood risk
2014	Defra/DCLG	Repair and Renew Grant	To help people with flooded homes buy and install measures to reduce the risk of flooding
2016	Defra/DCLG	Flood Resilience Grant	To help people with flooded homes to make their properties better prepared to cope with flooding
2016	UK Government/Building Research Establishment (BRE)	Property Flood Resilience Action Plan (The Bonfield Review)	To bring business interests together to facilitate the uptake of PFR and enhance 'recoverability'.
2017	Adaptation Sub-Committee of the Committee on Climate Change	Progress report on adaptation to climate change	Identified that the uptake of PFR needs to rapidly increase in order to address the increasing amount of properties at risk of flooding under climate change
2019	CIRIA	Code of practice and guidance for property level resilience	To provide a standardised approach and guidance to support the uptake of PFR

Table 1: Main policy/strategies that support the mainstreaming of PFR.

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Table 1 demonstrates both the emergence and framing of property level technology as an urban resilience solution and how the dominant language of technology brings with it its own norms and logics, such as connected to business, uptake or standardisation that will inevitably influence discourses of success. The starting point was the high profile flooding event of 2007 that led to the recommendation of retrofitting property-level resistant and resilient measures as part of a portfolio of approaches at different scales (Pitt, 2008). This initial strategy subsequently received further support and alignment within other related documents. For example, government support to increase the uptake of PFR was bolstered following responses to the widespread flooding in England over 2013/14 and 2014/15. As part of the recovery, the Government made one-off grants of up to £5000 available to encourage property owners to use the window of opportunity afforded by repairs to make their properties more resilient.

We begin to see framing discourses typically associated with technology emerge with calls to address 'barriers to uptake'. This is due, in part, to the make-up of the stakeholders involved, as industry and government combined to develop *The Property Flood Resilience Action Plan* (Bonfield, 2017). Here, we see urban resilience strongly re-framed in line with market logics and industry preferences with the aim to '…make the installation of flood resilient measures part of 'normal' business practice for those involved in the repair of buildings post flooding' (Bonfield, 2017: 4). The document goes further in defining success in terms of the number of properties in receipt of PFR and the amount of public funds spent upon it, a claim that was echoed in wider climate change documents. For instance, PFR was identified in the Adaptation Sub-Committee (ASC) of the Committee on Climate Change (CCC) as essential to meeting the needs of the increasing number of properties at risk of flooding due to climate change, but there was a concern that uptake was not fast enough to meet this demand based upon current trends (ASC 2019: 130).

While the literature review emphasised that there are a number of different ways of framing the success or failure of PFR, we can see how this contextual perspective does not influence the policy arena. The example has synergies with the 'process and outcome' oriented framing that is prevalent with other technology innovations, where the focus is on a process that can swiftly get a product to market and the outcome is enabling

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uptake, even though this may not meet the needs of stakeholders who have not been involved in discussions. In short, success is framed as a product that is deemed fit for purpose and fitted. Failure is connected to problems regarding the innovation journey or market uptake. The policy documents and strategies also cascade these simple and selective success frames to other urban actors and agencies. We now bring the implications of this situation to light by examining three central lines of inquiry regarding contingent resilience in practice: success for whom, when and where.

Success for whom?

The previous section revealed how the success of flood resilient technologies at the property level scale has been framed by elite policy actors around traditional notions of markets and uptake. The data helps reveal the effects of this framing, as for some local authority flood risk managers PFR is identified as a less expensive 'stop-gap' measure where communities are awaiting a hard flood defence scheme (White et al., 2016) or is seen as 'the only game in town' for many local authorities who are legally obliged to help constituents to become more resilient. Cuts to funding mean that local authorities tend to perceive PFR to be more affordable than large-scale flood defence programmes (Interview, Flood Risk Manager). To further underscore this, a central government representative noted that PFR schemes 'were developed to shut people up' who were complaining about fewer capital flood defence schemes (Interview, civil servant). Therefore, norms of cost-benefit analysis have underpinned PFR as a preferred technical 'solution', particularly within the context of financial austerity and high uncertainty. Conveniently, PFR technologies also fit within a wider narrative that expands (or fragments) the responsibility for flood risk management to a greater range of parties, including property owners (Johnson and Priest, 2008). PFR can be 'sold' to property owners as part of a resilience rhetoric in line with the techno-managerial policy logic (White and O'Hare, 2014). For these actors, technological integration is typically discussed as an outcome to be achieved or a process to be delivered, with the success of a technology assessed in terms of the extent to which either is realised.

Similarly, the entrepreneurial narratives of PFR manufacturers and industry provides insights into their definition of success. With regard to the development of products, many agreed with the tried-and-tested metaphor of what some called 'back of the fag pack' approaches that reflect both the emergent nature of the industry and success being about fewer barriers to design and uptake (Interview, PFR manufacturer A). Here, they attempted to address the gap in the market for property-level flood products through ad hoc measures and prototypes which were, in some instances, assembled by a self-funded sole business operator. The interviewees from the industry sector revealed a strong consensus that success is a process that supports small businesses to be innovative and flexible, with less 'red tape' that may affect their ability to develop and test prototypes and sell these to property owners. Examining PFR product development reveals that standards were introduced to provide assurance, but this was a 'Publicly Available Specification' (PAS) rather than a fully-fledged British Standard. PASs are best practice agreed by a group of interested stakeholders who self-regulate and codify performance levels (BSI, 2014). A full standard requires consensus amongst a wide range of stakeholders whereas a PAS may be developed through consultation, but does not necessarily require consensus. This situation indicates that industry has not settled on a set of best practices or, more simply, has only agreed that success is implementation rather than performance. However, although individual products are tested and successfully achieve a 'Kitemark', the ways that flood water enters a building is complex and the dynamic nature of floods meant that few products had been tested in a 'real' environment (JBA, 2014). Thus, there is no real knowledge of the extent to which they successfully prevent flood waters entering a building. In practice, it often takes more than one type of PFR technology to increase the resilience of a property; as one stakeholder pointed out: 'ultimately you want a resilient property rather than a resilient product' (Workshop 2, local authority officer 2).

The perspective of property owners provides more nuance, particularly as selling more products may not be beneficial to many. Logically, PFR businesses advertise within and target an urban area when property owners may be most receptive—that is, immediately after a flood event. Concern was expressed over 'cowboy' companies, who capitalised on flood events by focussing on affected areas in the immediate aftermath: 'we've seen the market almost take the route of the proverbial double-glazing salesman…and when someone on the end building is anxious, they will buy the product anyway even if it is not the most appropriate for them' (Interview 2, PFR Manufacturer). This means that property owners may be in receipt of technologies that are a 'success' from a technical or market-based logic, but which may not be appropriate for particular building types or vulnerable people. The result may be that the property is still prone to flooding and would be

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perceived as a failure by citizens. It was clear that the logic of property owners was very different. They did not care about market uptake. Their sole consideration was seeking to protect their own lives, properties, and possessions. While success from their perspective was unambiguous, some property owners were willing to be sanguine about the products. Despite being flooded, the PFR technologies lessened the damage and led one property owner to describe her third flood experience, and the first one with PFR, as 'the best flood I ever had' (Gupta 2014). Other stakeholders made different claims of success. Insurers, for example, were cautious. They deemed success as a fully working sector for the delivery of PFR with due certification and standards: 'how do we go from those one or two pieces of tech to something that works more widely? That's about systems and protocols across the (PFR) sector, making sure they are ok and that we can rely on them for pricing risk' (Interview, Insurer).

It is clear that simplistic technical narratives of success and failure do not mesh well with the dispersed governance of floods in the UK nor the design limitations of PFR technologies. It was also apparent that the initial framing between government and industry shaped the logics of flood risk managers working in practice, but was not shared by all, particularly property owners. We can now better appreciate that success for *whom* will have implications for success for *where* and *when*. There is little doubt that technology can play a role in urban resilience, but currently the framing of success has less to do with increasing resilience and more to do with private sector profit and technological norms. Consequently, narratives of success are imposed, focused on fixes, and privilege an elite view of success that is highly contingent.

Success where?

Scalar complexity adds a further dimension to claims of success. Any definition of resilience success (and conversely 'failure') relies upon the context in which it is used. Theoretically and conceptually, we are increasingly encouraged to see resilience from a systems perspective, however, technologies such as PFR are spatially blind. This can be seen through the lens of 'residual risks'. UK planning guidance (CLG, 2015: section 14) legitimates the notion of residual risk with regard to development in flood risk areas where: 'residual risks are those remaining after applying the sequential approach to the location of development and taking mitigating actions.' By residual, there is an explicit

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recognition that mitigation efforts will not eliminate risk, it is rather redistributed spatially and temporally.

More pointedly, the entire concept of defending against flooding at a building or community scale was an anathema for some citizens. In workshops, several users who had the measures fitted to their homes viewed their installation as an admission of failure rather than success. They framed success as new or strengthened traditional flood defences or a modification of the drainage system. The problem was not that houses, or flood receptors in technical language, were flooding and therefore needed a fix, it was a general problem of a lack of investment as they believed flooding should be managed at the source or pathway, rather than the receptor. As one local councillor in an area suffering from pluvial flooding stated: ‘The technologies deal with the symptom. But that’s not the cause and we know what the cause is… [one brook] has a Victorian six inch drain – it can’t take it.’ (Workshop 1, local councillor).

A further issue of contingent resilience is related to how technical fixes of this nature displace water, rather than manage flooding across a system. So, from a catchment perspective, success for one stakeholder may bring failure for another as water is pushed elsewhere. The nature of the built form was also a consideration. In many parts of England, for example, there are many terraced properties. If all but one of the properties in the terrace purchase PFR, they are all still exposed, which leaves the technologies largely redundant: ‘My parents had installed technologies in their home, but the neighbours had not’, said one informant, ‘so when the area flooded, my parent’s defences were overwhelmed and their house flooded anyway’ (Workshop 2, utilities company). Therefore, while the fitting of a product to a household may be considered to be a success, at a community level resilience is contingent on the behaviour of others. The reductionist nature of the technologies and properties in the UK stands in contrast to the system perspective advocated in theory. One flood risk management professional commented: ‘everyone will protect their own first (“their castle”). Even within communities, this might make the problems worse elsewhere’ (Workshop 2, local authority officer 4). Such insights show that, in certain cases, the use of new technologies should be accompanied by community-level support and implementation, perhaps through a government body, rather than being put onto the open market for purchase by individuals. Success relating to products and markets is accompanied by individualistic

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narratives of the consumer, but this does not recognise how resilience for others is contingent on more solidaristic approaches.

Success when?

The timing of success claims is the last empirical theme. Some of the newer PFR products are designed to replicate 'ordinary' property components: flood doors that look like normal doors, or that can be automatically deployed (colloquially known as 'fit-and-forget' measures) removing the need for the property owner to initiative or install in the immediate threat of a flood. Here, success is partly measured by their ability to be non-invasive, particularly for property owners who fear that obvious products will publicly acknowledge flood risk and blight property values. However, several interviewees raised the issue of 'fit-and-forget' measures being interpreted too literally: if people fit protection to their properties, and 'forget', they may become complacent, they may not maintain the products or they might be reluctant to form community-level groups and help one another should, given the limitations of technologies, a major flood take place. From an urban resilience perspective, you can see how risk will re-emerge in the future despite being claimed as a success at one point in time.

There was also a challenge to the view of success as being when a product is fitted, rather whether it works or not. Early adopters expressed concern over the design quality of some measures. One resident with PFR claimed that: 'to me it's a bit amateurish, I can tell with my moderate building knowledge that if it was tested, it would seep through…' (Workshop 1, property owner 7). There were significant concerns regarding their suitability. For example in one family home, the products could only be operated by the tallest member of the household, and even then with difficulty: 'I have flood boards, but the handles are on the other side. so I climb a ladder to get over them to get the door open to take them out!' (Workshop 1, property owner 6). Heavy flood boards requiring manual deployment could be sold to an older person with limited mobility. The products may have been tested under laboratory conditions, but they are being marketed to citizens who are largely assumed to be of the same risk profile and share similar capabilities.

The same concerns were seen to occur in the maintenance of products. Workshop participants testified that few products had been inspected since they were installed,

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which revealed this to be a contentious issue. Further, maintenance instructions were inconsistently passed on to the new resident and often only verbally. Many property owners admitted that they rarely checked their products, which increases the risk of them being inadequately deployed in a flood situation. The lack of maintenance can be considered to be a temporal issue insofar as the lack of attention beyond the initial moment of success poses ethical issues that transfer 'failure' into the future for others.

There is also the risk of complacency and misunderstanding regarding the level of protection that is afforded by defined design parameters: 'You can't think that because you have the technology, and are protected to a certain depth, that you can just sit in your house, not thinking about if the flood overtops your defences.' (Workshop 2, Consultant 1) The way that technological and governmental elites frame successful urban resilience in terms of products can also limit opportunities for adaptive learning or embedding transformational change within a system, either by individual stakeholders or with regard to the urban form. For example, there was a strong perception amongst residents that the existence of PFR would undermine efforts to get investment in hard defences in future. This type of contingent resilience, can therefore foreclose discussions of resilience in other areas.

Discussion

Whilst scholars have repeatedly shown the complexity of resilience theory, in practice this is reduced to a technical exercise with evidence of paradoxes in application whereby attempts to decrease risk in one place may increase risk at other temporal and spatial scales (Chelleri et al., 2015). Our analysis of PFR technologies also demonstrates these paradoxes, but highlights that the power to frame urban resilience 'success' is crucial. Elite governmental and technical actors have defined success and, with PFR, the focus on a swift process and market uptake is at odds with the operation of the technologies in practice and the reluctance of actors, such as insurers, to trust them.

Table 2 reveals the variable framing of success for different actors and the contingent 'resiliences' that are visible behind the simplistic and partial success claims. While there may be overlaps between groups, and that no one group can be treated as a cohesive whole, understanding the different frames is important given the high profile technology enjoys in urban resilience discourse and the power of those typically charged with

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framing and implementing success. Central and local government, often constrained by fiscal spending, are promoting ‘defences’ at property scale to offset reduced flood defence spending at larger scales. As their priority is market uptake it has privileged one set of actors–the manufacturers–who are equally intent on reducing barriers to market. Insurers, on the other hand, prefer for floods to be managed away from properties, but focus on the near-term timescale and look for a reduction in insurance payouts to property owners as a measure of success. Engineers and flood risk managers tend to accept the need for holistic flood risk management and use forecasting techniques. However, this group of actors may ignore how, once a property is fitted with kit, a property appears resilient even though this may change further down the line. The property owners often displayed much more nuanced, long-term perspectives on the extent to which PFR succeeds possibly as a result of repeated flooding episodes. That said, property owners cannot be treated as a cohesive group and the frame will not hold for all. However, the potential is there to promote community-based initiatives rather than privileging a market-based, individualistic narrative that may detract from resilience at different scales and different times.

Overwhelmingly, dominant narratives of successful resilience technologies, and by extension achieving resilient cities, focus on market uptake based on technological norms rather than a more nuanced risk management or resilience norms. The upshot is that appreciation of complexity, uncertainty and systemic perspectives associated with resilience theory are disconnected from practice. Moreover, technological success becomes fixed to a small place at a single point in time, which runs counter to our analysis concerning the contingency of technological success depending on who one asks, where they are located, and whether they take a short-term or long-term view.

Stakeholder	**Aims**	**Contingent resilience**
Central and local government	Increased uptake and removal of barriers	- *Who?* Success as market uptake - *Where?* Property level scale provides market opportunities and diverts attention from changing priorities in flood defence spending - *When?* Short-term thinking due to political cycles

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Engineers/ flood risk managers	Societal risk reduction, spending within constrained budgets	- *Who?* Success as a resilient property with properly installed and maintained equipment - *Where?* Multi-scale: PFR as defences behind the defences - *When?* Mixed. Tend to focus on implementation but do look at forecasting.
Manufacturers	Flexible innovation environment and Increased uptake	- *Who?* Success as market uptake - *Where?* Managing floods at property level provides market opportunities - *When?* Short-term thinking based on market uptake
Insurers	Reduction in exposure, ability to price performance	- *Who?* Success as a reduction in pay-outs - *Where?* Manage floods away from properties - *When?* Short-term thinking based on immediate reduction in risk.
Property owners	Protecting their property and possessions, leaving property price unaffected	- *Who?* Success as a resilient property with minimised damage costs - *Where?* Manage floods away from properties - *When?* Long-term thinking to promote their property.

Table 2: Contested framings of success amongst different stakeholders

Science and technology are political. As Jasanoff (2012: 275) points out, how we choose to live with innovation is also political 'entail[ing] normative judgments about the kinds of people we want to be and the kind of societies we wish to live in'. This is of concern for flood risk management since there is an increasing political belief that citizens should take more responsibility for their safety and that the creation of new markets can fill managerial gaps (Johnson and Priest, 2008). Such perspectives run counter to long-held beliefs and practices whereby citizens may not be willing or have the capacity to manage those risks, particularly those relating to so-called 'natural' disasters (Kaika, 2017). From our analysis, we can see that technological framings of success as market uptake from government and manufacturers run counter to the much more contingent resilience of

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reality. Success varies; yet the policy discourse is myopic regarding the introduction of further risks or the redistribution of existing ones. The fact that failure and success can co-exist together and that the entry of flood waters into a property may mean failure for some, but could be a partial success for others if it is lower than last time.

Not only are floods, and their management, dynamic but the implementation of technologies into practice is also beset with social and technical connections in order for them to work properly (Barry, 2001: 15). Mimicking similar discussions in relation to building certification standards, where a technologically innovative sustainable building of 1999 may no longer be considered sustainable today, PFR are a set of technologies that are difficult to compartmentalise and, consequently there is a need to open up the 'black-box'. If 'resilience' is recast as a fluid process, rather than an outcome (Pelling, 2010), then it also becomes clear that the success or otherwise of innovations will similarly be fluid and contested over time. Successful PFR technologies may not equate to successful flood risk management. Achieving simple market penetration may help some, particularly the entrepreneurs, and fits with policies around green growth and smart urbanism, but in practice this may be at the expense of neighbouring buildings or provide a false assurance of safety. After all, the main reason whether a property gets wet or not, is the flood characteristics which cannot be controlled.

The temporal issue also reappears in terms of maintenance and operation. The difficulty of communication is often due to the enormous range and forms of tacit knowledge necessary: including property surveying, flood knowledge, and procedures for installation and building work (Rydin, 2012; May et al. 2015). Yet the need to maintain becomes a means by which societies learn. Routine work that ensures that technologies are kept in mind and, in the case of most types of PFR, such routine work and maintenance is crucial in ensuring their relatively successful operation beyond installation. Innovation—in terms of getting the products to market—is often over-valued when it is the more mundane factors of maintenance that actually matter more in terms of longer-term technological success (Graham and Thrift, 2007).

PFR *may* become widely accepted, surveyors may be trained to appraise buildings and standards may be implemented in order to make the market more efficient. Nevertheless, this article lends weight to the argument that we have become so focused on innovation

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journeys that we often overlook what success and failure actually mean, how they are appraised, by whom, and the effect that failure may have on the present and the future. This is particularly crucial when considering urban resilience from a governance perspective. There are multiple beneficiaries and the dominant technical perspectives preclude resilience from being more long-term, multi-scalar and cross-networked (e.g. Ernston et al 2010; Carter et al 2015; Beilin and Wilkinson 2015). Furthermore, the quest for replicability and scalability of technological approaches to address climate change will need to pay more attention to the contingency of resilience and ensure that any potential 'solutions' are context appropriate.

Conclusion

This article accepts that adaptive technological solutions aiming to increase urban resilience can be a success, but emphasises that this success is contingent. The power to frame success has been shaped by long-standing norms of the technical and policy professions in a way that is much more simplistic than reality. The technological turn in urban resilience has a persuasive air of optimism, and a synergy with economic objectives, that obscures both how resilience is contingent, and how these technologies redistribute resilience spatially and temporally. Technologies are *social* and they are *contested,* but here they are presented as a 'black box' that is difficult for non-technical actors to open up. Stakeholders, particularly end-users, find it hard to counterclaim technical discourses of success once they have been negotiated and framed. Instead, these stakeholders are subject to a future where resilience is much more contingent, and is something for which they may not be prepared.

By focussing solely on the route to market for climate resilient technologies, there is a danger that they become another 'techno-fix' that maintains the gap between resilience theory and practice and is blind to redistributive effects. Moreover, in the context of a dynamic climate and the changing parameters of what are deemed 'acceptable' risk thresholds for climate change, technologies may become less resilient over time. This underscores the need to raise awareness of resilience issues at community level, and to encourage wider learning, through the process of user interaction with adaptive technology processes, nuanced claims of success, and their contingent nature.

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Trade-offs between resilience approaches are already widely mentioned in the literature but there are few critiques of climate resilient technologies in practice. The framework designed to analyse technological success, around whom, when, and where, is a means to bring to light the governance aspects, power relations, and inevitable contingencies that are a part of urban resilience. There will always be the question of which actors and agencies are being privileged by resilience strategies, but we can also see that questions of when this occurs, how long it lasts, and how contingent this is, are also vital. The idea of bringing contingency to the foreground can be applied to other resilience examples. For instance, urban green infrastructure, such as street trees and sustainable drainage systems, can similarly be promoted as part of city marketing strategies for 'green cities' but may result in future house prices rising beyond the range of existing residents, or be perceived to encourage crime (Angelouvski et al. 2019). Beyond climate resilience, the policy evaluation literature has moved towards more granular understandings of policies and historical events to emphasise the 'shades of grey' between success, on one hand, and purported 'failure', on the other (McConnell, 2010; Newman and Head, 2015). As an extension of the discussion of PFR, we therefore hope that the study may influence other researchers to engage with notions of contingent resilience when seeking to understand the role, contribution, and constraints of innovative technologies.

The words success and failure are a staple of innovation framings. For resilience technologies, however, it is important to recognise 'success' and 'failure' is highly contingent. Adaptive technologies like these should be conceived of as political processes, not technical processes, and success as contextual, contested, and perhaps temporary. The discourse of technological fixes displays an ontological certainty and simplistic causality that is disjointed from either how researchers write about resilience or the practices of deploying resilience technology in complex urban systems. . Perhaps, as the visionary architect Cedric Price suggested, the very notion of success needs to be dispensed with in a changing and uncertain world.

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