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On framing flood risk communications through maps: Effects on the real estate market

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ABSTRACT

Flood maps are commonly used for flood risk communication. Misinterpretation of these maps can lead to over-heightened flood risk perception, with adverse risks for real estate markets. We, therefore, aim to identify an appropriate approach for framing these maps to mitigate such risks. To do this, we carry out five randomised control trials (RCT) in the UK and Pakistan, with each RCT asking a different group of 40 residents in each country to specify their willingness-to-pay (WTP) for coastal residential properties. In the first RCT, we provide no flood risk map. In each subsequent RCT, we provide a flood risk map framed differently. Our flood risk map frames include those with technical language, colour variations, and more accessible risk information. Our findings indicate that real estate demand uncertainty increases in response to flood risk maps, regardless of the framing approach used. We find that there is less WTP for properties in any zones with flood risk information, regardless of whether the risk is very low. This finding indicates that risk aversion takes precedence in real estate decisions under flood risk maps, leading to property devaluation in all flood risk zone categories. We discuss the wider implications of these findings.

1. Introduction

Flooding is becoming a common occurrence globally, with significant socioeconomic impacts. For example, from 2000 to 2019, flooding affected 1.6 billion people and caused USD 651 billion in economic damage (Devitt et al., 2023) and 130,608 fatalities (CRED, 2024). The number of people affected by floods are estimated to be equivalent to the number of people affected by all other natural hazards (Birkholz et al., 2014). Flood impacts are increasing (Fig. 1), and this increase is projected to continue in response to climate change and ongoing socio-economic developments (Rentschler et al., 2022). Anticipated global flood exposure damages are estimated to be USD 6 billion yearly, which are expected to rise to USD 52 billion by 2050 (Déguénon et al., 2023).

With specific focus on coastal flooding, the latest Intergovernmental Panel on Climate Change report asserts with high confidence that coastal flooding will increase in most low-lying coastal areas due to the very likely to virtually certain continued rises in relative sea-levels (Ranasinghe et al., 2021). Moreover, the World Resources Institute (WRI) anticipates that about 15 million people will be affected by coastal flooding by 2030. The financial consequence of this projection is USD 177 billion in damages to urban coastal properties (WRI, 2020). Rapid urbanisation and population growth in coastal zones will inevitably increase the number of people and assets exposed to coastal flooding. This is further complicated by inadequate coastal flood risk management systems in many developing regions, escalating the vulnerability of these regions to the adverse socioeconomic impacts of flooding (Jongman et al., 2012; WRI, 2020). In the last decade, flood risk management has shifted primary focus from structural approaches (levees, dams, barriers) to incorporating non-structural approaches (risk communication strategies), for improving community resilience, with flood risk communication forming a key part of ongoing flood resilience building initiatives (Rasool et al., 2022; Rollason et al., 2018; Van Alphen et al., 2009).

Flood risk communication, if done right, can play a vital role in flood preparedness by improving public understanding and reducing flood risk (Ali et al., 2022). Bangladesh, for instance, provides a good case study example of effective flood risk communications, as these communications significantly reduced the number of fatalities from cyclone flooding in 2007 (Paul, 2009). For context, the 2007 Sidr cyclone caused 3406 deaths in Bangladesh, whereas Gorky – a similar magnitude cyclone that made landfall in Bangladesh in 1991 – caused 140,000 deaths. The high death toll from the 1991 cyclone flooding was

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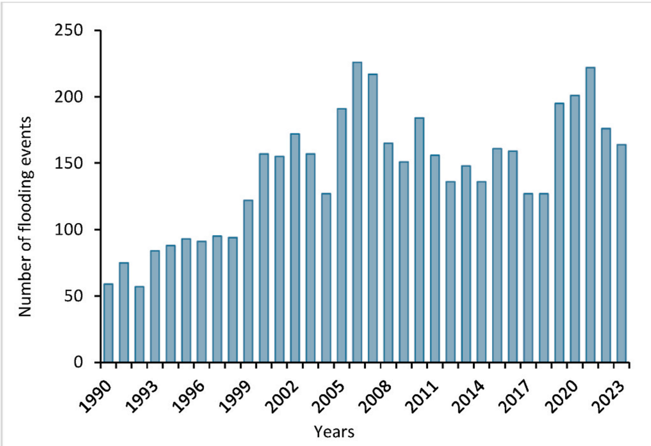


Fig. 1. Global flood events (1990–2023). Adapted from CRED (2024); Salas (2024).

primarily attributed to inadequate flood warnings and flood risk communications. With increasing flood risks globally, flood risk communication is becoming an integral aspect of flood risk reduction and flood hazard preparedness (Rollason et al., 2018; Seenath et al., 2025). These communications often take the form of community-based programmes, early warning systems, and flood risk maps – the latter being the most common approach used by government agencies globally (Henstra et al., 2019; Shr & Zipp, 2019; Seenath et al., 2025). For example, the USGS provides detailed flood risk maps for states in the USA (USGS, 2018). Similarly, the Environment Agency in England disseminates flood risk information through a national Risk of Flooding from Rivers and Sea map, providing flood risk information at the postcode level (EA, 2023).

There are four common types of maps used for flood communication: (a) flood danger map, (b) flood hazard map, (c) flood vulnerability map, and (d) flood damage risk maps (Table 1) (Merz et al., 2007). Combining these elements with information on the likelihood of flooding occurring provides a way to visualise flood risk. The effectiveness of flood risk maps in building community flood resilience hinges on public trust in the data presented and the institutions that produce them. When people perceive these maps as accurate and reliable, they are more likely to invest in flood risk mitigation and adaptation strategies at the household level. Conversely, if the maps are poorly perceived due to limited trust in the information and institutions responsible for these maps, people may disregard them. This, in turn, can lead to higher vulnerability and economic losses as a consequence of failing to take necessary protective actions. Additionally, misunderstanding flood risk maps can lead to one of two concerning scenarios: (a) over-heightened flood risk perception, with the risk of causing undue alarm and anxiety to homeowners (De Marchi et al., 2007); (b) downplayed flood risk perception, with the risk of poor flood hazard preparedness (Ridolfi et al., 2020). Flood risk maps are undoubtedly a useful instrument for physical flood risk management, helping to identify and manage areas exposed to and at risk of flooding. However, if these maps are poorly communicated or misinterpreted by the general public, they can lead to inadequate flood resilience measures at the local and household levels and/or amplified (unwarranted) levels of anxiety (Percival et al., 2020), with wider socioeconomic implications. For example, residential properties in areas erroneously perceived to be at risk of flood hazards, perhaps due to inaccessible (difficult to interpret) conveyance of flood risk information through highly technical maps, can result in these properties being at risk of property devaluation, with risks for the real estate market and wider macroeconomy (Seenath et al., 2025).

Framing flood risk maps to avoid misinterpretation, over-heightened risk perception and downplayed risk perception is challenging. To a large extent, the effectiveness of flood risk maps hinges on its presentation and visualisation. Simplicity and clarity should always be prioritised to ensure they are accessible to both experts and lay members of society and public (i.e., local stakeholders) (Fuchs et al., 2009; Stephens et al., 2024). Clear, distinguishable symbols, colours, and straightforward visual elements are crucial for enhancing comprehension and reducing cognitive load especially, as lay members of society generally prefer simple and intuitive maps (Henstra et al., 2019). This allows end users to focus on the essential information without distraction (MacEachren, 1994; Fuchs et al., 2009; Monmonier, 2018). Poor design choices, such as overly complex legends, small text, or confusing symbols, can lead to misinterpretation and hinder effective flood risk communication (Henstra et al., 2019). Additionally, the use of technical language and inconsistent colour schemes can cause confusion, with implications for either downplaying or over-heightening flood risk perceptions (Chesneau, 2011; Van Alphen et al., 2009). Therefore, carefully framing flood risk maps is pivotal in conveying essential flood risk information in a way that is easily understood by all users in order to maximise flood hazard response and preparedness at the community and household levels.

The failure to effectively communicate flood risk information can lead to residential real estate market uncertainties/risks where properties are devalued not because of actual flood risk but because of over-heightened flood risk perception in response to overly technical and/or inaccessible information (Seenath et al., 2025). Residential real estate risks are particularly important to consider, as real estate markets are explicitly linked to the health of the macroeconomy (Bouchouicha & Ftiti, 2012). The real estate market does not always fully price in flood risks especially when flood risk information is not clearly communicated to potential buyers. This mispricing can have broader implications for the stability of the real estate market, which, in turn, can affect the overall economy (Hino & Burke, 2020).

Properties located in flood risk predicted zones often see a depreciation in value due to high perceived risk and potential for future flood damage (Hino and Burke, 2020, 2021). Consumers in the real estate market looking to buy a property often go through a conveyancing process (Seenath et al., 2025). Through this process, home buyers get access to a property's flood risk information. If a property is located in an area that is erroneously classified as being at flood risk, home buyers will either not be willing to purchase such property or may be willing to pay a significantly lower cost than the asking price. For instance, values for properties classified into flood zones within FEMA flood maps for

Table 1
Types of flood maps based on Merz et al. (2007, pp. 231–251).

Map type	Description	Source
Flood danger	Illustrates the geographic distribution of flood danger through the extent of flooding, flow velocity, and water depth.	Beden and Keskin (2021)
Flood hazard	Illustrates the geographic distribution of flood hazards containing information about the magnitude of flooding for events with a given exceedance probability.	De Moel et al. (2009)
Flood vulnerability	Illustrates the geographic distribution of flood vulnerability on the areas that are most likely to experience severe consequences from a flood based on socioeconomic factors (population density, poverty rate, and infrastructure density) and susceptibility of the built environment.	Merz et al. (2007); Ha et al. (2023)
Flood damage risk	Illustrates the geographic distribution of flood damage risk integrating factors like hazard exposure and socioeconomic vulnerability for events with a given exceedance probability.	Merz et al. (2007); Ha et al. (2023)

Table 2
Recent flood statistics for the UK and Pakistan.

Event	Impact	Economic damage	Sources
Storm Desmond, Eva, Frank (Winter Floods 2015–2016)	Flooding across Northern England, Scotland, and Wales.	£1.6 billion	Barker et al. (2016); GOV.UK (2021); Black (2022)
Storms Ciara, Dennis (Winter Floods 2019–2020)	Flooding across UK, especially in Northern England.	£333 million (estimated £2.1 billion without defences)	GOV.UK (2021); Jardine et al. (2023)
Pakistan floods 2010	1985 deaths, 18 million people affected, 12 million homes damaged.	$9.7 billion	DEC (2015); Waseem and Rana (2023)
Pakistan floods 2022	1739 deaths, 33 million people affected, 2.2 million homes damaged or destroyed.	$15.2 billion	CDP (2023); Havstrup and Pauw (2023)

Georgia (USA) depreciated by up to 10% after these maps were released (Atreya et al., 2013). In this regard, poor flood risk communication presents a clear risk for the real estate market through property devaluation and associated negative wealth, with risks for the macroeconomy. Real estate markets directly affect the health of the macroeconomy. This link acts as a channel through which monetary policy impacts economic conditions. For example, changes in interest rates directly impacts housing affordability. This influences consumer spending and economic growth. Variability in real estate prices also affects household wealth, which, in turn impacts consumer spending. For example, decreased property value can reduce household wealth which leads to lower levels of consumption, in turn, slowing economic growth. Hence, real estate markets and the macroeconomy have a bidirectional relationship where macroeconomic conditions influence real estate prices.

Flood risk information also affects the cost and availability of insurance, which, in turn, influences property values (Duží et al., 2017). Properties in predicted/classified flood risk areas have higher insurance premiums. This can lead to a decrease in demand and, consequently, lower property values. Properties in areas newly designated as high-risk within FEMA flood maps often depreciate in value due to associated increases in insurance costs (Kousky, 2010). Additionally, investors use flood risk information to make informed decisions about resource allocation. This information, therefore, explicitly determines areas for investment and non-investment, potentially resulting in lost economic opportunities for areas with an overestimated (erroneous) flood risk classification. Flood risk maps containing underestimated flood risk levels also present challenges (Seenath et al., 2016), potentially causing investments in high flood risk areas that are erroneously classified/predicted as being at low flood risk, with implications for financial losses.

With the above context in mind, we need to ensure that flood risk maps are effectively framed, particularly given the socioeconomic risks associated with their perception and use. Well-framed flood risk maps are crucial for mitigating against over-heightened and downplayed risk perception. Mitigating these will likely minimise the socioeconomic risks associated with flood risk maps. We, therefore, aim to *identify an appropriate approach for framing flood risk maps, to mitigate poor risk and hazard perception and associated socioeconomic risks*. We do this through evaluating real estate decision-making under various flood risk maps, each framed differently, with focus on the UK and Pakistan. We see these as important first steps before focusing on how to ensure accurate flood risk information within these maps. Our focus on the UK and Pakistan – two contrasting worldview countries – enables key insights on improving flood risk communications to facilitate more robust flood resilience strategies with low socioeconomic risks globally.

2. Test sites

For our study, we focus on the UK and Pakistan, two countries with contrasting economies. Although flooding is common on a global scale, some countries are more disproportionately affected than others, as is the case between the UK (a developed world country) and Pakistan (a developing world country). According to the United Nations, the International Energy Agency, and the World Resources Institute, the UK, being a small country in terms of landmass, accounts for 1% of global emissions as of 2022 (GOV.UK, 2024) – a significant contribution relative to the country's population of ~68 million people (WBG, 2024b), which is equivalent to 0.8% of the world's population. Conversely, Pakistan, which is home to ~240 million people or 2.99% of the world's population (WBG, 2024a), contributes only 0.3% to global emissions, yet is more adversely affected by climate-related hazards, such as flooding, relative to the UK (Havstrup & Pauw, 2023).

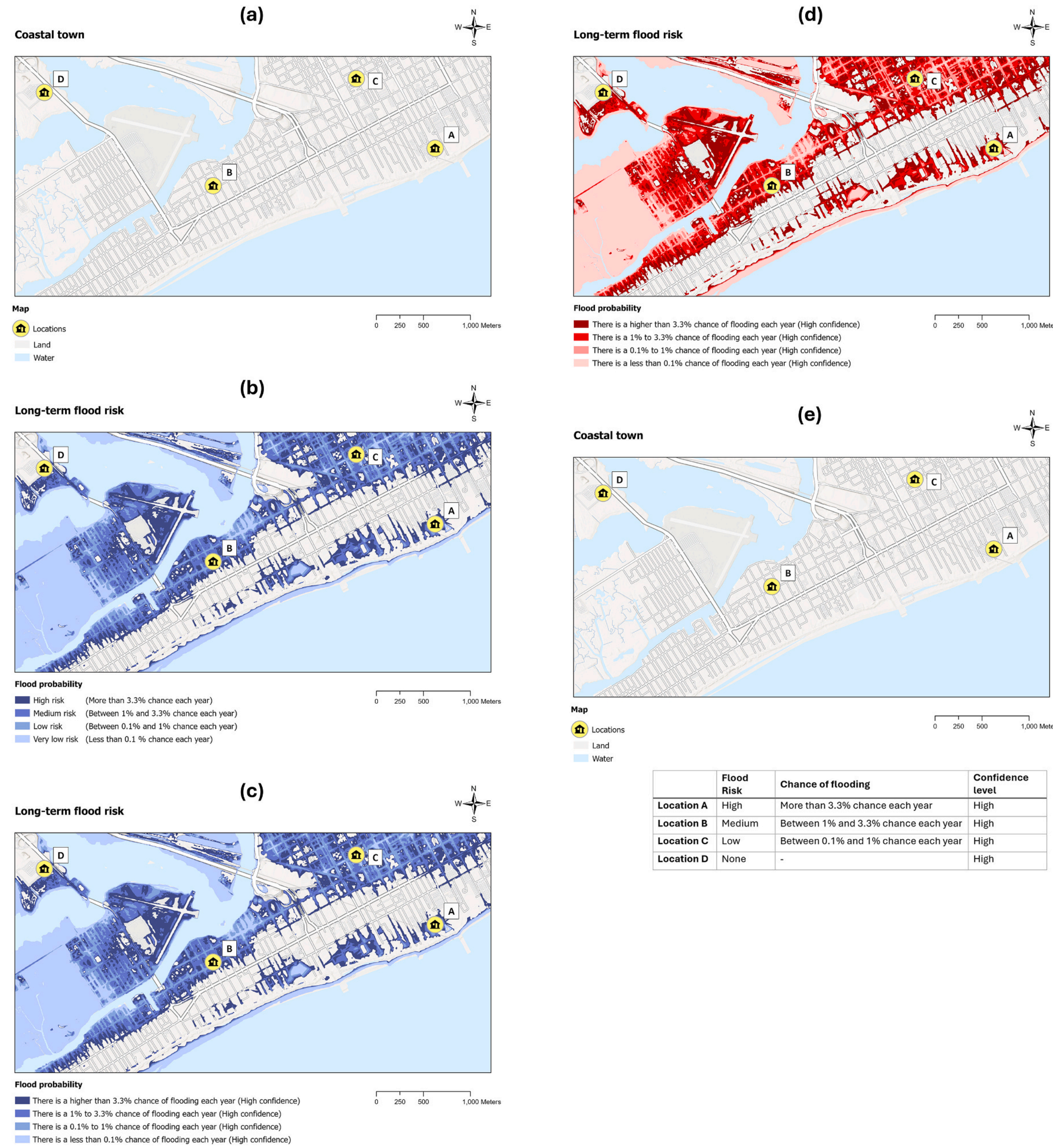
Regardless of their emissions, the UK and Pakistan are both commonly affected by flooding (see Table 2). Pakistan's diverse topography, from the world's second-highest peak, K2, in the north to the coastal areas along the Arabian Sea, makes it particularly susceptible to flooding. The 2021 annual Pakistan Federal Flood Commission (FFC) report notes that Pakistan has been consistently affected by flooding since its independence, with the first significant flood occurring in 1950, followed by 26 more incidents up to the 2020s (FFC, 2021). Similarly, in recent years, the UK has been hit by significant flood events, with considerable socioeconomic damages (Table 2).

Having these two contrasting countries – the UK and Pakistan – as test sites offers the opportunity to examine the nuances of flood risk perceptions while providing a broader perspective to compare how decision-making in response to flood risk maps vary between developed and developing countries. Past studies highlight that risk perception is heavily influenced by socioeconomic, cultural, and political contexts (Slovic, 1987; Renn, 2017). In developed countries, risk perceptions are often shaped by a combination of technological advancements, regulatory frameworks, and high levels of public awareness. This leads to a more systematic and institutionalised approach to risk management (Beck, 1993; Giddens, 1999). Conversely, in developing countries, risk perceptions may be more influenced by immediate socioeconomic challenges, limited access to information, and lower levels of trust in institutions (Douglas & Wildavsky, 1983; Shah et al., 2022). These differences can lead to varying priorities and strategies in risk management which reflects broader global inequalities in resources, governance, and resilience (Tierney, 2014). By comparing these two countries, our study contributes to a deeper understanding of how local contexts influence risk perceptions and inform the development of more culturally sensitive flood risk communication.

3. Methods and data

3.1. Flood risk mapping and communications

Towards refining how we frame flood risk communications to minimise socioeconomic risks, with specific focus on real estate risks, we first develop five maps of an undisclosed coastal town in New Jersey (USA), marking four locations – A, B, C, and D – in these maps to form the basis for our Randomised Control Trials (RCT) on real estate decision-making under flood risk information. Location A = seafront location, B = residential area with close proximity to the sea, C = a further inland location than B, and D = furthest away from the sea. Map 1 (Fig. 2a) is our baseline map, containing no flood risk information. Maps 2–5 are flood risk maps, each presenting the same flood risk



	Flood Risk	Chance of flooding	Confidence level
Location A	High	More than 3.3% chance each year	High
Location B	Medium	Between 1% and 3.3% chance each year	High
Location C	Low	Between 0.1% and 1% chance each year	High
Location D	None	-	High

Fig. 2. Baseline (a) and flood risk maps (b–e) generated for our undisclosed coastal town. Maps (b) to (e) display the same flood risk information in different frames.

information in different mapping frames. Specifically.

- Map 2 (Fig. 2b) presents long-term flood risk information for our undisclosed coastal town following the design and framing of the UK National Flood Risk Map (EA, 2023). It categorises areas at risk of flooding in one of four colours depending on their flood risk probability: (a) dark blue = high risk (more than 3.3% chance of flooding each year), (b) mid blue = medium risk (between 1% and 3.3% chance of flooding each year), (c) light blue = low risk (between 0.1% and 1% chance of flooding each year), and (d) very light blue = very low risk (less than 0.1% chance of flooding each year).
- Map 3 (Fig. 2c) presents the same long-term flood risk information as Map 2 for our undisclosed coastal town, except it contains the confidence level for all risk information provided. This allows us to understand the nuanced effects of language and framing on risk perception and decision-making.
- Map 4 (Fig. 2d) presents the same long-term flood risk information as Map 3 for our undisclosed coastal town, but with a red colour grading scheme to illustrate varying flood risk probability levels. Here, we use a red colour grading palette to frame the flood risk information, as colours are inherently linked to emotions and can elicit strong feelings that affect the understanding and perception of risk information, with implications for decision-making. For example, red is often associated with danger, which may lead to over-heightened risk perception.
- Map 5 (Fig. 2e) presents the same long-term flood risk information as Map 2 for our undisclosed coastal town, but in a tabular form. This approach takes into account cartographic literacy and allows us to examine whether people are more influenced by visual or textual information in their decision-making. Essentially, this framing approach focuses on simplicity and clarity, allowing us to gauge whether people respond differently to information presented in a more straightforward way.

We reemphasise here that all flood risk information is kept constant in all maps. The key difference in each map is the framing approach used to convey this information. We do not reveal the specific location of the coastal town here and elsewhere in order to avoid panic and bias, especially as our study does not undertake any physically realistic assessment of flood risk.

We use *ArcGIS Pro* to develop all our flood risk maps, following the bathtub flood modelling approach applied by Seenath et al. (2016). As per the principles of this model, we apply a simple raster-based calculation in *ArcGIS Pro* to identify areas in our undisclosed coastal town that are lower than 1.25, 1.5, 1.75, and 2 m in order to categorise areas into very low, low, medium, and high flood risk probability, respectively. This raster calculation is based on a 3 m resolution post Hurricane Sandy Digital Elevation Model of New Jersey, vertically referenced to the North American Vertical Datum of 1988, developed by the National Oceanic and Atmospheric Administration, National Centres for Environmental Information (Eakins et al., 2015; NCEI, 2017). To address the well-known issues of hydraulic connectivity associated with the bathtub modelling approach (see Seenath et al., 2016), we remove all flood risk predicted areas that are not hydraulically connected to the coast or any other water body. We emphasise here that these predictions of flood risk probabilities are all *hypothetical*, as realistic flood risk estimations and projections are not required for the purposes of our study, which is simply designed to gauge residential real estate decision-making under alternative flood risk mapping frames. In this regard, any coastal town globally with adequate data for flood mapping would have been appropriate for our study's design.

3.2. Primary data collection

We use the maps above to set up five Randomised Control Trial (RCT) surveys, targeted at adults living and working in the UK and Pakistan, to examine the influence of alternative flood risk mapping frames on residential real estate decision-making in these countries, as below.

- *RCT 1:* In this trial, we present our baseline map (Fig. 2a) to a group of 40 UK residents and 40 Pakistani residents. We ask them to: (a) assume that they are interested in buying a property in the undisclosed coastal town in the map; (b) specify how much they would be willing-to-pay (WTP) to live in locations A, B, C, and D in the map, and; (c) specify their most and least preferred living location of the four location options (A, B, C, or D) presented in the map.
- *RCT 2:* In this trial, we present Map 2 (Fig. 2b) to a second group of 40 UK residents and 40 Pakistani residents and ask them to consider this map and complete the same tasks as those in RCT 1.
- *RCT 3:* In this trial, we present Map 3 (Fig. 2c) to a third group of 40 UK residents and 40 Pakistani residents and ask them to consider this map and complete the same tasks as those in RCT 1.
- *RCT 4:* In this trial, we present Map 4 (Fig. 2d) to a fourth group of 40 UK residents and 40 Pakistani residents and ask them to consider this map and complete the same tasks as those in RCT 1.
- *RCT 5*: In this trial, we present Map 5 (Fig. 2e), which contains flood risk information in a table as a legend item only, to a fifth group of 40 UK residents and 40 Pakistani residents. Here again, we ask all participants to consider this map and complete the same tasks as those in RCT 1.

In each RCT, we provide participants with the following information about the undisclosed coastal town.

For UK residents

> A two-bedroom house in this coastal town has an **average selling price of £200000**.
> The area has more than **2 miles of sand beaches**, with wide paved boardwalks.
> You can expect to find **all local amenities**, including shopping centres, health care services (e.g., pharmacies, GP), emergency services (e.g., fire), protective services, childcare services, schools, personal and self-care services (e.g., salons), hospitality services (e.g., food outlets), etc.
> The area is also located **well-serviced** by public transportation (e.g., buses and trains), with easy access to public and private Universities and major international airports.

For Pakistan residents

> A two-bedroom house in this coastal town has an **average selling price of Rs. 50,000,000**.
> The area has more than **2 miles of sand beaches**, with wide paved boardwalks.
> You can expect to find **all local amenities**, including shopping centres, health care services (e.g. pharmacies, GP), emergency services (e.g. fire), protective services, childcare services, schools, personal and self-care services (e.g. salons), hospitality services (e.g. food outlets), etc.
> The area is also located **well-serviced** by public transportation (e.g., buses and trains), with easy access to public and private Universities and major international airports.

The overarching aim of these RCT surveys is to identify an approach for framing flood risk maps that minimises socioeconomic risks, such as those linked to residential real estate demand uncertainty. At the start of each RCT survey (before WTP questions), we ask all participants to declare their age and to specify whether they are living and/or working in the UK or Pakistan. These two questions serve as eligibility control questions.

In RCTs 2–5, after the WTP questions, we ask participants to declare whether "*the flood risk information was easy to interpret*" by selecting Yes or No and then to explain their response. Following this, we ask all participants to specify "*What information should be included to make flood maps easier to understand?*" We next ask them to declare whether they "*trust the flood risk information presented in the map?*" by selecting Yes or No and, finally, to explain their response. Collectively, responses from these questions enable us to understand how best to frame flood risk maps in order to minimise misinterpretation of flood risk information and over-heightened flood risk perception.

A key control in the design of our RCTs is that we do not allow participants to modify answers previously submitted. Doing so ensures that we capture their immediate unbiased response to any flood risk information presented. Also, we do not to reveal any information about floods, risks or maps in our participant information sheet, again to avoid bias. Instead, we inform participants that the survey focuses on coastal real estate property pricing and preferences to capture their unbiased perspective. Our RCTs received ethics clearance from the University of Oxford Central University Research Ethics Committee (reference number: SOGE C1B 24 44).

We develop our RCT surveys using JISC surveys (https://www.onlinesurveys.ac.uk/) and administer these trials online via the Prolific Surveying Platform (https://www.prolific.com/) to UK participants and through snowball sampling to Pakistani participants from 14-JUN-2024 to 19-JUL-2024. To ensure that participants do not complete more than one survey in the UK, we exclude their Prolific IDs in the subsequent surveys. We initially set a target of 40 participants for each RCT survey in the UK and Pakistan based on our internal funding constraints and operational feasibility. By monitoring the RCT surveys as they progressed, we noted a convergence in survey responses and outcomes in each RCT, suggesting that this sample size was optimal for capturing reliable and stable results to meet our study's objective. The observed stability in our findings suggests that there would likely be diminishing returns from increasing the sample size further, as additional participants would likely contribute minimally to enhancing the precision or altering the conclusions. While larger sample RCTs may still be necessary to validate our results in broader contexts, the convergence seen in our RCT responses provide sufficient evidence that 40 participants per RCT was an efficient and adequate sample size for our study. Our overall sample size following all RCT surveys is 400, with 200 responses each from the UK and Pakistan. We provide a copy of our RCT surveys and dataset as supplementary material.

As all RCTs were carried out online, all surveys were completed digitally, either via mobile phones, laptops, desktops or tablets. This means that participants had access to the static digital map developed for their respective RCT (all of which were of very high resolution), so that they can zoom in on the map as required, for example, to get a better sense of distance from sea for a particular location using the scale bar. Having interactive maps that enable participants to pan around an area are beyond the scope of our study, as we are primarily interested in how people respond to flood risk information about a potential property location that they are likely to be interested in. This is consistent with similar exploratory studies on real estate demand uncertainty in response to flood maps (see, e.g., Seenath et al., 2025).

The maps created, which underpin our RCT surveys, fall within the category of flood hazard maps (Table 1), as they illustrate the geographic distribution of flood hazards with information on the probability of flooding at postcode level. It does not contain information on flood depths for a particular location or property. There are three reasons why we base our RCT surveys on flood hazards maps. *First*, flood hazard maps are the most widely available and accessible type of flood information that are commonly used by the general public, insurers, and policymakers to assess flood risk (Seenath et al., 2025). Notable examples of these include England's national flood risk map, FEMA flood maps in the USA (https://www.fema.gov/flood-maps), and the Flood Risk Areas Viewer map, which provides flood risk information for the European Union member states (https://discomap.eea.europa.eu/floodsviewer/). The widespread (and growing) availability of flood hazard maps, therefore, makes such types of maps ideal for our study, to understand how individuals perceive and respond to flood risk in real-world decision-making scenarios. *Second*, flood hazard maps are easier to interpret and more appropriate for our study, as they align with the information typically accessed by homebuyers and property owners during conveyancing searchers (for buying homes) and property valuation and purchasing decisions. Past studies have shown that more technical flood maps – characteristic of flood danger maps – often cause confusion among lay members of the public, who generally fail to understand the technical language that accompany such maps (Burningham et al., 2008; Henstra et al., 2019). In turn, this has implications for over-heightening flood risk perceptions, with inherent socioeconomic risks. As our aim is to identify an approach that minimises such risks, flood hazard maps are more appropriate for our RCT surveys. *Third*, unlike fluvial (riverine) flooding, for example, it is much more complex to predict theoretically realistic flood depths associated with coastal flooding, as: (a) this requires significant computational and data resources, and (b) coastal flood depths are mostly contingent on the extremities of sea-level fluctuations during storms, which is difficult to predict (see Vogt et al., 2024, for the challenges in such predictions) – there is far more uncertainty in coastal flood predictions than any other types of flood predictions. For this reason too, flood hazard maps are optimal for our study's aim.

Additionally, we recognise that, apart from flood maps, there would be other information that people have access to regarding a property's flood risk. For example, coastal communities typically have building codes that account for flood hazards. In the UK, for instance, all doors and windows in seafront homes are required to be classified in accordance with BS 6375 - Performance of windows and doors. However, information on building codes is not typically communicated in flood hazard maps (see examples of flood risk maps provided above), although these maps do inform such codes. Hence, for this reason, we do not provide such information on our RCT maps, as we are primarily interested in understanding real estate decision-making under flood hazard maps. We argue that understanding how people perceive and respond to such maps, which are increasingly becoming available in the public domain, is a critical first step in refining how flood risk information is conveyed to avoid over-heightened risk perceptions.

The language used in our RCT surveys is English, as this is the official language of the UK and the primary language used by the Government of Pakistan. However, as our RCTs are administered online, and people are required to use a mobile, tablet, laptop or desktop to complete these, all our RCT surveys can automatically be translated to other languages using the language translation features in these devices.

Furthermore, in line with similar studies (see, for example, Seenath et al., 2025), the RCT surveys presented here do not consider participant socioeconomic characteristics (e.g., gender, education, income) and personal traits, as understanding the data generating process behind our RCT experiments are beyond the scope of this study. In this study, our primary focus is on examining causal relationships between exposure to flood maps and real estate decision-making behaviour, rather than on how these behaviours vary by demographic or personal characteristics. We argue that this approach is a crucial first step in refining flood risk communications to minimise uncertainty in such decisions and, in turn, the associated socioeconomic risks (e.g., those related to property devaluation). Delving into individual traits of our participants, such as their socioeconomic conditions, can be a useful subsequent step, but this is beyond the scope of our study. Moreover, national level flood risk maps are designed as mass communication tools, not tailored to specific demographic groups. Hence, our study's design reflects the general nature of these maps, aiming to evaluate their overall efficacy in influencing decision-making without bias from individual characteristics.

3.3. Statistical analysis

To examine the impact of flood risk maps on real estate decision-making, we apply both descriptive and inferential (independent $t-$*tests*) statistical methods. We analyse the differences in WTP, how people change their location preferences, and how framing of flood risk maps influence these decisions in locations A, B, C, and D (Fig. 2) across RCT surveys with (RCT 2–5) and without (RCT 1) flood risk maps. Moreover, we explore whether increases in real estate demand uncertainty is contingent on the accessibility of flood risk information presented. We do this by using market volatility to represent real estate risk, following Seenath et al. (2025). Specifically, we compute the changes in standard deviation, which is a common and standard metric of volatility, between our baseline RCT scenario (RCT 1), which has no flood risk information, and our RCT scenarios with flood risk maps (RCT 2–5). Additionally, to gauge property gains and losses, we calculate the mean differences in WTP values for all property locations (A, B, C, D), again following Seenath et al. (2025). This allows us to control for participants who may be inclined to offer very high or very low WTP values based on their personal socioeconomic conditions or individual characteristics traits. We then run independent $t-$*tests* to examine whether the mean differences in WTP between our baseline RCT scenario (RCT1) are statistically significantly different from those with flood risk maps (i.e., RCT 2–5). We also examine whether there are any specific flood risk mapping frames that significantly increase or decrease real estate demand uncertainty, measured through significant fluctuations in WTP decisions across RCTs.

3.4. Thematic analysis

To support our statistics, we carry out thematic analysis to identify the common themes behind our participants' preferences for *most* and *least* preferred living locations, which we illustrate through word clouds. We analyse participants' justifications and identify common themes across all RCTs. This qualitative analysis complements our quantitative analysis by highlighting participants' thought processes, concerns, and reasons behind their WTP real estate decisions. Additionally, we also carry out thematic analysis to understand the common themes that emerge in our participants qualitative responses to the open-ended questions on easiness of map interpretation and trust in flood risk information (Section 3.2). For these specific analyses, we consider the responses from RCTs 2–5 only, as RCT 1 does not contain any flood risk mapping and, therefore, no flood risk related questions.

4. Results and analysis

Tables 3–5 indicate the most preferred housing location decisions and their associated thematic analysis results for the UK and Pakistan. In both the UK and Pakistan, we find that the provision of flood maps considerably influences housing preferences. In the UK, for example, location A is the most preferred location in the baseline RCT survey (RCT 1 = no flood information). However, in RCTs 2–5 with flood maps, locations C and D are the most preferred housing location. The primary reasons for these differences in location preferences between RCT1 and RCT 2–5 include "Low Flood Risk" and "Cheaper Insurance", indicating a strong risk-averse behaviour among UK respondents under flood maps. In Pakistan, location A remains relatively popular even in RCT 2–5 with flood risk maps. This may be due to the appeal of the "Waterfront" aspect. However, there is still a noticeable difference in location preference among Pakistani participants, with locations C and D recording a slight increase in popularity as we move from RCT 1 (no flood risk map) to RCT 2–5 (flood risk maps), with "Low Flood Risk" being a driving factor behind this trend. This suggests that while flood risk information does influence housing decisions in Pakistan, aesthetic and locational preferences, such as proximity to water, still play a role in their preferences. Overall, these findings indicate that flood risk maps prompt more risk-averse residential real estate demand decisions in both the UK and Pakistan. However, the degree to which these maps influences residential real estate preferences varies. In particular, we see more pronounced changes in location preferences between RCT 1 (no flood information) and RCT 2–5 (flood maps) among UK residents than Pakistani residents.

Tables 6–8 indicate the least preferred housing location decisions and their associated thematic analysis results for the UK and Pakistan. In both the UK and Pakistan, flood risk maps, regardless of the framing approach used, have a considerable influence on our respondents' least preferred housing locations. In the UK, for example, location A becomes more frequently selected as the least preferred housing location as we move from RCT 1 (no flood risk map) to RCT 2–5 (flood risk maps); increasing from 10% of least preferred housing location selections in RCT 1–70% in RCT 5. A similar trend occurs for locations B and C, mainly due to perceptions of these locations having a higher flood risk. Conversely, location D moves from recording the most selections for least preferred housing location in RCT 1 (72.5%) to becoming one of the more preferred living locations under flood maps in RCT 2–5, mainly due to perceptions of this location having a lower flood frisk. All of these trends reported here are seen among our Pakistani respondents. Overall, we find that both UK and Pakistani residents exhibit a clear tendency to avoid locations perceived to be at risk of (actual) flooding, which indicates that flood risk maps have a direct impact on residential real estate preferences, very consistent with Seenath et al. (2025) findings.

Table 9 presents the thematic analysis results of our UK and Pakistani participants' responses on the easiness of map interpretation and trust in flood risk information. Most participants – 78.75% in the UK and 81.48% in Pakistan – find our flood maps easy to interpret, with clarity and colour coding being the key factors behind these maps being easy to interpret. A minority of our survey participants find the interpretation of our flood maps somewhat difficult, primarily for reasons relating to difficulty in differentiating between the colour gradations used for representing very low to high flood risk. Participants that struggled with map interpretation have recommended using a multicolour palette to differentiate between different levels of flood risk. Additionally, 79.38% (76.5%) of participants in the UK (Pakistan) declare that they trust the information in our flood maps, with confidence in the source of the flood risk predictions being the primary reason for this trust. Among our UK sample, participants' trust our maps, mainly because they do not have a reason to not trust them – this is plausibly linked to UK residents (more broadly) being more aware of the credibility of flood risk information from official sources. However, among our Pakistani sample, their trust in our flood risk information is largely linked to this information appearing legitimate.

Table 10 compares our respondents' willingness-to-pay (WTP) for properties in the four locations (A – D) across the five RCT surveys. From this table, we see that RCT 1 (no flood information) generally records the highest mean WTP values for properties in all locations (A – D) in both

Table 3
Most preferred living location under alternative RCT scenarios. Red = decline; Green = increase.

United Kingdom										
Location	Baseline (non-flood)		Flood maps							
	RCT 1		RCT 2		RCT 3		RCT 4		RCT 5	
	Freq.	*Percent*	*Freq.*	*Percent*	*Freq.*	*Percent*	*Freq.*	*Percent*	*Freq.*	*Percent*
A	23	57.5	16	40	14	35	22	55	4	10
B	11	27.5	2	5	2	5	0	0	5	12.5
C	5	12.5	8	20	9	22.5	9	22.5	12	30
D	1	2.5	14	35	15	37.5	9	22.5	19	47.5
	40	100	40	100	40	100	40	100	40	100
Pakistan										
Location	Baseline (non-flood)		Flood maps							
	RCT 1		RCT 2		RCT 3		RCT 4		RCT 5	
	Freq.	*Percent*	*Freq.*	*Percent*	*Freq.*	*Percent*	*Freq.*	*Percent*	*Freq.*	*Percent*
A	18	45	20	50	10	25	12	28.57	5	12.5
B	10	25	3	7.5	4	10	7	16.67	3	7.5
C	11	27.5	9	22.5	13	32.5	12	28.57	20	50
D	1	2.5	8	20	13	32.5	11	26.19	12	30
	40	100	40	100	40	100	42	100	40	100

Table 4
Underlying reasons for most preferred housing location among UK participants under alternative RCT scenarios.

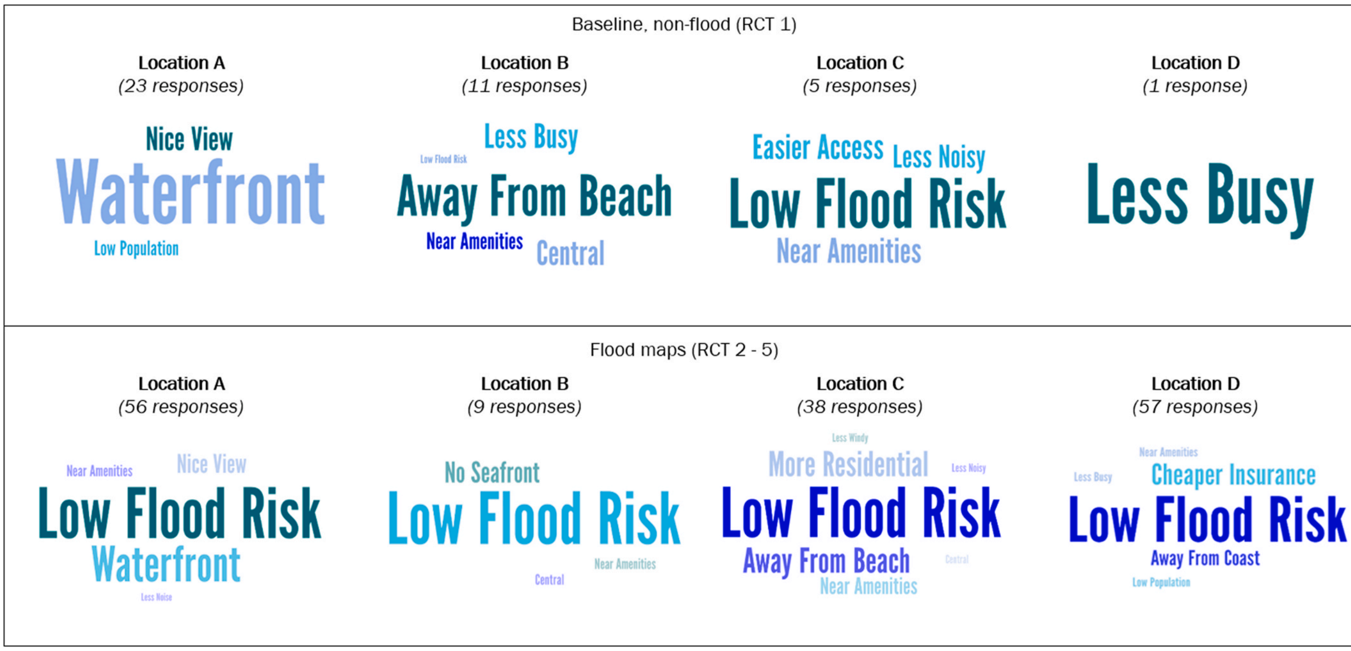
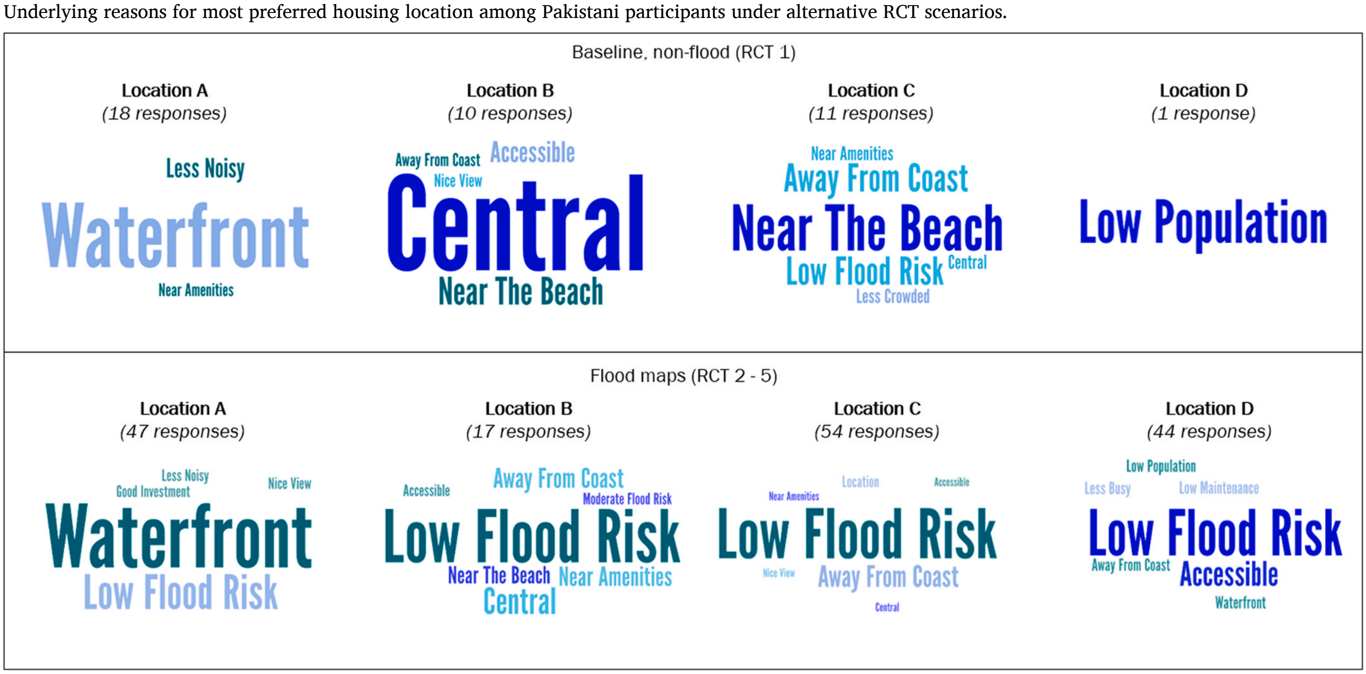


Table 5
Underlying reasons for most preferred housing location among Pakistani participants under alternative RCT scenarios.



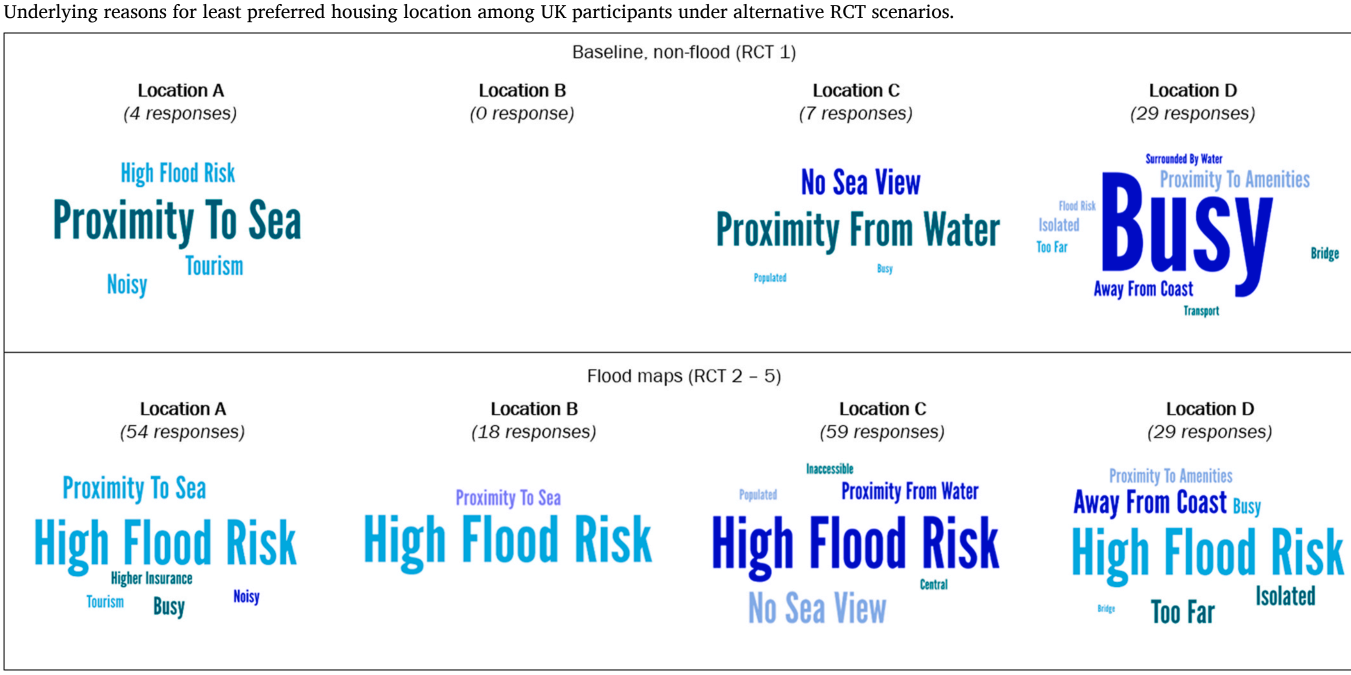
our UK and Pakistani samples. Property values for all four locations (A – D), however, see a general depreciation in RCT 2–5, under alternative flood maps. More specifically, in the UK, properties in locations A – C record considerable declines in WTP across RCT 2–5 relative to in RCT 1, with the lowest WTP values under RCT 2. Location D in the UK also records a decline in WTP under RCT 2–4 relative to RCT 1, but records a mean increase in WTP under RCT 5 relative to RCT 1 for reasons attributed to low flood risk perceptions (Table 4). Relatively similar trends are observed in Pakistan. In Pakistan, locations A and D see declines in WTP under RCT 2–4 relative to RCT 1. However, locations B and D record an increase in mean WTP under RCT 5 relative to RCT 1, mainly for reasons attributed to low flood risk perceptions (Table 5).

Our independent $t-test$ results show that most of the above changes in WTP between RCT 1 (baseline) and RCT 2–5 (flood risk maps) are statistically significant at the 1% significance level, particularly in the UK (Table 11). This finding provides strong empirical evidence that flood maps present a considerable risk to residential real estate markets in terms of property devaluation, consistent with the findings of Seenath

Table 6
Least preferred living location under alternative RCT scenarios. Red = decline; Green = increase.

United Kingdom										
Location	Baseline (non-flood)		Flood maps							
	RCT 1		RCT 2		RCT 3		RCT 4		RCT 5	
	Freq.	*Percent*	*Freq.*	*Percent*	*Freq.*	*Percent*	*Freq.*	*Percent*	*Freq.*	*Percent*
A	4	10	10	25	10	25	6	15	28	70
B	0	0	4	10	6	15	5	12.5	3	7.5
C	7	17.5	17	42.5	19	47.5	20	50	3	7.5
D	29	72.5	9	22.5	5	12.5	9	22.5	6	15
	40	100	40	100	40	100	40	100	40	100
Pakistan										
Location	Baseline (non-flood)		Flood maps							
	RCT 1		RCT 2		RCT 3		RCT 4		RCT 5	
	Freq.	*Percent*	*Freq.*	*Percent*	*Freq.*	*Percent*	*Freq.*	*Percent*	*Freq.*	*Percent*
A	5	12.5	18	45	20	50	11	26.19	28	70
B	0	0	3	7.5	2	5	6	14.29	2	5
C	14	35	9	22.5	9	22.5	16	38.10	1	2.5
D	21	52.5	10	25	9	22.5	9	21.43	9	22.5
	40	100	40	100	40	100	42	100.1	40	100

Table 7
Underlying reasons for least preferred housing location among UK participants under alternative RCT scenarios.



et al. (2025). The less statistical significance in mean WTP differences between RCT 1 (baseline) and RCT 2–5 in Pakistan, seen in Table 11, may be linked to socioeconomic and cultural differences in risk perception (Botzen et al., 2009; Lo & Chan, 2017; Rana et al., 2020; Rasool et al., 2022), an angle which we do not explore in this study. One theory may be that people in Pakistan prioritise economic stability over risk aversion, which may lead them to settle for flood risk properties despite being aware of the risks (Shah et al., 2022). Additionally, people in Pakistan may be more accustomed to living with risks due to their socioeconomic limitations. Poorer areas are more likely to be affected by floods in Pakistan (Knippenberg et al., 2024), which can translate into limited financial flexibility to make more risk averse decisions.

5. Discussion

Our study highlights a direct link between residential real estate demand decisions and flood maps. Similar to Seenath et al. (2025), we find that seafront properties are the most preferred living locations in the absence of such maps, attracting higher willingness-to-pay estimates, primarily because of their waterfront appeal. However, these

Table 8
Underlying reasons for least preferred housing location among Pakistani participants under alternative RCT scenarios.

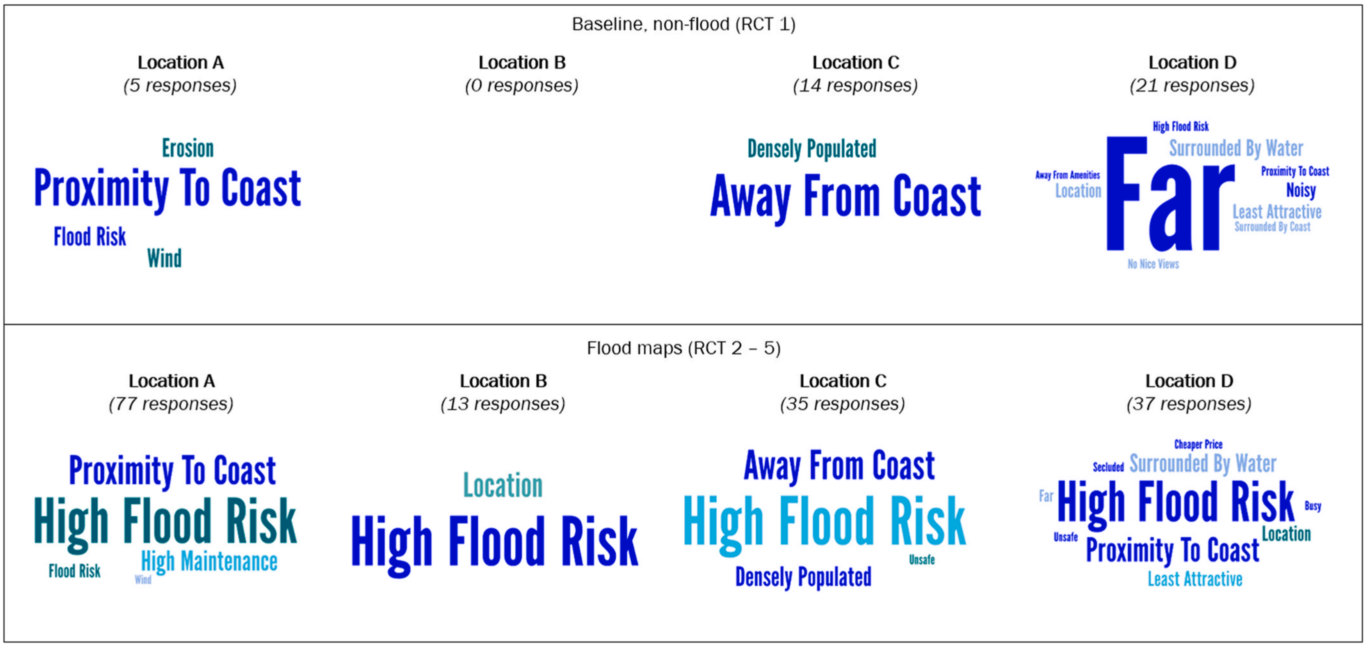


Table 9
Underlying themes in UK and Pakistani residents' perceptions of map interpretation and trust in flood risk information under RCT 2–5.

trends reverse under flood maps, regardless of the framing approach used to design such maps, reflecting a shift in public demand for housing preferences based on risk aversion as opposed to personal preferences. These findings align with those of Bourdeau-Brien and Kryzanowski (2020). Along with heightened risk perception and increased risk averse behaviour reflected through the marked differences in housing preferences recorded under flood maps in RCT 2–5 relative to RCT 1 (no flood information), flood risk information considerably induces real estate demand uncertainty, observed through WTP fluctuations in RCT 2–5 relative to RCT 1 across our UK and Pakistani samples. These findings

Table 10
Willingness-to-pay (WTP) estimates for properties in locations A – D under alternative RCT scenarios. Red = decline; Green = increase.

United Kingdom

Location	Baseline (non-flood) RCT 1 WTP (£) Mean	SD	Flood maps RCT 2 WTP (£) Mean	SD	RCT 3 WTP (£) Mean	SD	RCT 4 WTP (£) Mean	SD	RCT 5 WTP (£) Mean	SD
A	240,500.00	58,109.10	172,005.25	81,856.31	172,501.62	69,812.49	187,125.00	43,865.87	162,800.01	46,528.30
B	193,760.00	49,871.28	156,505.25	65,082.65	164,026.50	44,597.14	160,200.00	50,827.11	175,150.00	30,198.11
C	183,232.50	55,260.95	145,380.02	63,712.28	153,550.47	51,484.08	155,375.00	45,942.93	182,500.00	34,436.86
D	175,450.00	42,491.60	153,379.50	61,240.21	165,827.25	54,538.14	165,875.23	34,229.28	193,050.00	30,991.27

Pakistan

Location	Baseline (non-flood) RCT 1 WTP (Rs.) Mean	SD	Flood maps RCT 2 WTP (Rs.) Mean	SD	RCT 3 WTP (Rs.) Mean	SD	RCT 4 WTP (Rs.) Mean	SD	RCT 5 WTP (Rs.) Mean	SD
A	42,065,789.47	10,865,374.62	37,445,945.95	17,085,481.08	31,628,571.43	16,896,024.10	32,315,789.47	15,327,250.54	27,212,903.23	16,170,399.75
B	39,592,105.26	15,243,897.89	35,891,891.89	12,415,903.30	30,218,571.43	15,589,485.93	28,419,736.83	14,976,980.26	41,677,419.35	58,731,386.89
C	40,934,210.53	15,789,224.45	35,783,783.78	12,136,687.12	33,762,857.14	15,702,399.32	26,406,315.79	14,776,717.52	37,064,516.13	13,769,375.40
D	33,565,789.47	16,483,477.01	32,351,351.35	16,335,401.60	29,785,714.29	16,137,408.91	29,368,421.05	15,781,311.31	58,161,290.32	91,071,069.97

Table 11
Independent $t-test$ for mean differences in WTP between RCT 1 (baseline) and RCT 2–5 (flood maps). *** denotes statistical significance of the $t-test$ statistic at the 1% level. ** denotes statistical significance of the $t-test$ statistic at the 5% level. Red = loss in property value. Green = gains in property value.

United Kingdom

Independent $t-test$ between RCT 1 (baseline) and RCT 2 – 5 (flood maps)

Location	RCT 1 – RCT 2 Diff. (£) [% change]	t-stat.	RCT 1 – RCT 3 Diff. (£) [% change]	t-stat.	RCT 1 – RCT 4 Diff. (£) [% change]	t-stat.	RCT 1 – RCT 5 Diff. (£) [% change]	t-stat.
A	68,494.75 [-28.48%]	4.315***	67,998.38 [-28.27%]	4.735***	53,375 [-22.19%]	4.637***	77,699.99 [-32.31%]	6.601***
B	37,254.75 [-16.65%]	2.874***	29,733.50 [-15.36%]	2.811***	33,560 [-17.32%]	2.981***	18,610 [-9.6%]	2.019**
C	37,851.98 [-20.66%]	2.839***	29,682.03 [-16.2%]	2.486***	27,857.50 [-15.2%]	2.452***	732.50 [-0.4%]	.071
D	22,070.50 [-12.58%]	1.873**	9,622.75 [-5.48%]	0.880	9,574.77 [-5.46%]	1.110	-17,600 [+10.03%]	-2.116**

Pakistan

Independent $t-test$ between RCT 1 (baseline) and RCT 2 – 5 (flood maps)

Location	RCT 1 – RCT 2 Diff. (Rs.) [% change]	t-stat.	RCT 1 – RCT 3 Diff. (Rs.) [% change]	t-stat.	RCT 1 – RCT 4 Diff. (Rs.) [% change]	t-stat.	RCT 1 – RCT 5 Diff. (Rs.) [% change]	t-stat.
A	4,619,843.52 [-10.98%]	1.393	10,437,218.04 [-24.8%]	3.110***	9,750,000 [-23.18%]	3.199***	14,852,886.24 [-35.31%]	4.372***
B	3,700,213.37 [-9.35%]	1.151	9,373,533.83 [-23.68%]	2.596***	11,172,368.43 [-28.22%]	3.223***	-2,085,314.09 [+5.27%]	-0.211
C	5,150,426.75 [-12.58%]	1.581	7,171,353.39 [-17.52%]	1.944**	14,527,894.74 [-35.49%]	4.141***	3,869,694.4 [-9.45%]	1.072
D	1,214,438.12 [-3.62%]	0.320	3,780,075.18 [-11.26%]	0.989	4,197,368.42 [-12.5%]	1.134	-24,595,500.85 [+73.28%]	-1.484

align with those of Bin and Polasky (2004); Zhang (2016); Belanger and Bourdeau-Brien (2017); Seenath et al. (2025), affirming that flood risk information leads to residential real estate property devaluation. Such fluctuations in property values have considerable risks for real estate markets, which involves many stakeholders (e.g., estate agents, local communities, banks, insurance firms), and the wider macroeconomy (see, e.g., Rajapaksa et al., 2016; Seenath et al., 2025). More work is needed towards improving communication of flood risk information in flood maps in such a way that it prevents an over-heightening of risk perception, to reduce residential real estate market uncertainty that is disproportionate to the flood risk. This is particularly important as flood maps contain considerable degrees of uncertainty, meaning that some areas may be erroneously classified as being at risk of flooding (Seenath et al., 2016, 2025; Hino & Burke, 2021; Gourevitch et al., 2023). There is also a need to ensure that the uncertainty inherent in these maps does not translate into wider socioeconomic risks. However, we cannot fail to recognise the undeniable importance of these maps in guiding flood risk management. Ultimately, we need to communicate flood risk information as clearly as possible with due acknowledgement of the uncertainty to minimise socioeconomic risks while still using these maps to inform flood risk management decisions – achieving this will require a tricky balancing act in how we communicate and use such information. This is where future research efforts should be directed.

Our study attempted to find an approach for framing flood risk maps to minimise socioeconomic risks and achieving the balancing act aforementioned. We did this by experimenting with alternative mapping frames – ranging from technical maps to more accessible framing of technical information – for communicating flood risk information through RCT surveys, to gauge which mapping frame is best for reducing socioeconomic risks. However, our results failed to reveal an appropriate mapping frame for doing so. Instead, we find that risk-averse behaviours generally dominated real estate decisions regardless of the map framing approach used (Tables 10–11), indicating that people were more responding to the visuals of flood extent predictions, rather than the written text on flood risk probability. This implies that our respondents generally failed to perceive the information in our flood maps as flood 'risk' and instead interpreted such information as 'actual' flood information, again consistent with Seenath et al. (2025) findings. We did, however, notice an increase in WTP values for location D across both UK and Pakistani samples (Table 11) under RCT 5 relative to RCT 1. RCT 5 had a map indicating the four locations (A – D) accompanied with a table containing flood information for each location (in other words, it had no flood extents layered onto the map) (Fig. 2e). The WTP increase for location D under RCT 5 across both samples imply that tabulating flood risk information as opposed to visualising this information on a map *may* reduce real estate demand uncertainty attributed to such information. This finding adds weight to our theory that people respond more to visuals on a map in decision-making, with colours used for illustrating flood extents likely leading to over-heightened risk perceptions. However, our study does not provide ample evidence to support this conclusion. More research is, thus, required to examine the impact of different flood risk information framing (e.g., visual information versus tabulated information) on real estate decision-making.

Furthermore, we find that both our UK and Pakistani samples show similar risk-averse behaviours, evident though declining WTP values in RCT 2–5 (flood maps) relative to RCT 1 (baseline, no flood map), though these behaviours are more consistent and pronounced among UK participants. Among Pakistani participants, there are some fluctuations and inconsistency in WTP trends when comparing RCT 5 results to those from RCT 1–4 (Tables 10–11), with locations B and D gaining value in RCT 5. This finding indicates that UK residents have higher perceptions of flood risk or have higher trust in flood risk information, which may be linked to the European Floods Directive (Directive 2007/60/EC) that require all flood risk management plans (including risk maps) in the UK to be published and made available to the public. Conversely, Pakistan does not have a specific legal mandate that requires the publication and public availability of flood risk maps. The presence of such legal mandates in the UK likely enhances public trust in risk management authorities which may influence risk-averse behaviours. This feeds into the facets of public awareness, transparency and accessibility of critical information; and potentially explains why our UK respondents appear to be more consistent with their risk aversion behaviours in real estate decision-making than our Pakistani respondents. The slight inconsistency in WTP trends observed in RCT 5 among our Pakistani respondents suggests that, while they recognise the risk of flooding, other influential housing demand factors, such as aesthetics, cultural appeal of waterfront properties, and access to amenities (e.g., Costas et al., 2015; Naeem & Rana, 2023), had a more tangible impact on their residential real estate decision-making. These findings suggest that an understanding of cultural and regional influences on real estate decisions may help to improve overall flood risk communication through maps. What might be effective in one localised context may not necessarily yield the same results in another. Implicit in this theory is the likely need for tailored communication approaches that consider local perceptions and values. However, the extent to which this can be feasibly accommodated is debatable as flood risk maps are a form of mass communication tools at national levels, rather than tools for targeted audiences. Though, flood risk maps for local communities and specific societies may require such considerations.

Our findings indicate that no one particular type of flood risk mapping frame influences real estate decision-making relative to another type. Rather, our findings demonstrate that the framing of flood risk maps – whether more detailed or simplified – is less influential than people's inherent risk-averse nature. Also, our results from both UK and Pakistani samples show that access to flood maps significantly devalues property, causing housing demand uncertainty, regardless of contrasting worldviews between the two countries. This underscores the need for carefully balanced flood risk communication strategies at national levels that provide clear information without inflicting real estate market risks and compromising flood risk management efforts. Lastly, though there are similar trends among both our samples, we observe more consistency among UK residents and relatively more variability among Pakistani residents' residential real estate decision-making under flood maps. This suggests that localised contexts may have some marginal influence in influencing flood risk perception, hence there may be a need for tailored approaches in flood risk mapping to effectively accommodate diverse audiences, at least in cases where such maps are for specific communities or regions in a country.

We are mindful that our WTP results are contingent on our RCT surveys design. Our surveys, although robust in their design and conform to established standards for this line of work (see, e.g., Seenath et al., 2025), only evaluate the influence of flood hazard maps on real estate decisions, which may be a potential limitation in helping us comprehensively understand the actual impact of flood risk information on such decisions. We, hence, identify four future research pathways towards addressing this. ***First***, future work could explore how the provision of flood depth information and building codes within flood maps influences decision-making and property valuation, potentially by integrating hazard maps with depth-specific, velocity/danger information, and wider community level GIS datasets to provide a more nuanced analysis. ***Second***, future work should also consider participants' profiles, to better understand the personality traits and underlying socioeconomic conditions that inform real estate decision-making in response to flood risk maps. Such work can identify the causal factors behind risk aversion and over heightened risk perceptions, with implications for refining how we present and communicate flood risk information via maps. ***Third***, there are many stakeholders invested in flood risk maps – e.g., insurance firms, real estate consumers, banks, real estate agents. Future work should, therefore, perhaps consider a participatory systems mapping approach (e.g., Penn et al., 2022; Sanò et al., 2014; Suno Wu et al., 2021) for improving such maps. A systems mapping approach will likely be able to capture the interdependencies among stakeholders, ensuring flood risk maps meet diverse needs effectively. Our RCT surveys tried to mimic the level of information that people generally have access to when going through the property purchase/conveyancing search process. This process typically gives information at postcode level only; hence we opted for this approach (using a static digital map) rather than providing participants with an interactive map where they can pan around an area. This aligns with our aim in gauging how people respond to risk information they have access to when making real estate decisions. However, while property-specific flood risk will often be the primary concern for buyers, we recognise that broader flood hazard patterns across the community could also influence real estate demand decisions, particularly in terms of perceived neighbourhood resilience and accessibility. Hence, a ***fourth*** research pathway can examine real estate decisions in response to interactive flood maps (or alternative forms of property level flood risk communications) of a wider area (beyond just property/postcode level).

6. Conclusions

Our study investigates the impact of flood risk communication through differently framed flood risk maps on real estate decision-making in the UK and Pakistan. Using Randomised Controlled Trial (RCT) surveys, we examine how varying flood risk mapping frames – such as technical language, colour gradations, and tabulated information – influence willingness-to-pay (WTP) decisions for properties in hypothetical flood-prone areas within an undisclosed coastal town. Our findings demonstrate that WTP values for properties depreciates under flood maps – regardless of the framing approach used – largely because of over-heightened risk perception and risk-averse behaviour in response to visual flood risk information within these maps. This suggests that access to flood maps disrupt market behaviour leading to more cautious decision-making across diverse participant profiles. We also observe marginal differences in WTP trends between our UK and Pakistan samples, with UK participants displaying more consistent risk-averse responses and Pakistani participants demonstrating some variability in their real estate decision-making, plausibly influenced by socioeconomic and institutional contexts. This trend indicates a higher level of uncertainty and risk aversion in real estate decision-making in the UK where there is a legal mandate to make flood risk information openly accessible, in turn, increasing public trust in this information, even though such information may be inherently uncertain. Conversely, the variability seen in WTP decisions among Pakistani participants suggests that flood risk information may be met with scepticism or influenced by cultural factors, plausibly due to a lack of mandate for the public provision of such maps there. This suggests that localised contexts may have some influence (albeit marginal in the grand scheme) in influencing flood risk perception, hence there may be a need for tailored approaches in flood risk mapping to effectively accommodate diverse audiences, at least in cases where such maps are targeted at specific communities or regions in a country.

Our study makes several contributions to science, research, practice, and policy. For science, it advances the understanding of how flood risk map framing influences economic behaviour, in terms of real estate decisions, filling a critical gap in the flood risk communication literature. Methodologically, we introduce RCTs as a tool for evaluating the socioeconomic risks of flood risk communication. For practice, our findings emphasise the need for designing flood maps that balance accuracy and accessibility, so that these maps can continue to be used for informing physical flood risk management while informing local stakeholders in a way that it improves their individual levels of flood resilience without causing over-heightened risk perceptions. For policy, our study underscores the importance of legal frameworks mandating the publication of credible and detailed flood risk maps, especially in developing countries such as Pakistan, in order to enhance public trust and promote informed decision-making with careful consideration of risk information.

While our study has clear theoretical and practical implications for improving flood risk communications, we recognise that there are some limitations that offer opportunities for future research. Our findings are shaped by the design of our RCT surveys, which focus on flood risk maps at the postcode level and may not fully capture broader community-level flood dynamics or the influence of more interactive flood mapping tools. Additionally, the lack of detailed flood risk maps and legal mandates in Pakistan limits the direct applicability of our findings to real-world contexts there. Future research should explore how integrating additional factors, such as flood depth information and community-level datasets, or adopting participatory approaches with diverse stakeholders, could enhance the utility of flood risk maps. Further work is also needed to investigate the role of socioeconomic and psychological factors in shaping flood risk perceptions and real estate decisions, particularly in regions with limited institutional support for flood risk communication.

CRediT authorship contribution statement

Nimra Yousaf: Writing – review & editing, Writing – original draft, Visualization, Formal analysis, Conceptualization. **Avidesh Seenath:** Writing – review & editing, Visualization, Formal analysis. **Linda Speight:** Writing – review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

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