Participatory Agent-Based Modelling for Flood Risk Insurance

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Abstract. In the context of climate change adaptation, there has been a recent research focus on the impact of flood insurance on flood risk reduction behaviour. ABM has been recently used in such researches to model the interaction of stakeholders. We build on this foundation and propose the integration of participatory methods as a mean for capturing the socio-cognitive and behavioral aspects of flood risk insurance, which have been missed in such models. The results of our suggested line of research on *Participatory ABM for Flood Risk Insurance* can support public and private sector stakeholders, considering their preferences and contextual requirements.

Keywords: Flood risk reduction, Insurance, Human behaviour, Participatory methods, Agent-based modeling

1 Introduction

In the wake of massive economic losses from flooding in recent decades, policy makers and governments have showed growing interest in using insurance as an economic flood risk management tool [1, 2]. However, the direct and indirect impacts of insurance policies on overall flood risk reduction and prevention of communities are not clear yet [2]. Beyond financial recovery impacts, insurance can influence the behaviour of those at flood risk [3]. While it can encourage more risky behavior (e.g., property development in high risk locations with reliance on the insurance support)[4] but can also trigger desirable risk reduction behaviors, through incentive mechanisms like risk-base pricing, deductibles, and no-claims bonuses [5, 6]. Such desirable behaviours are either in individual level (e.g., flood proofing of properties, retrofitting of houses, and building/buying properties out of the high risk zones), community level (e.g. local flood protection measures), or government level (prohibiting property development in high risk zones) [7].

Recent studies have shown that actors' responses to flood insurance policies are not merely cost-benefit oriented [8, 9]. Rather, actors strongly rely on socio-cognitive and behavioural aspects of decision making such as risk perception, dynamic preferences, and social values. This is, actors with similar economic situations (in the same flood zone area) may end up with different decisions and actions. Dismissing these aspects of decision making, traditional flood risk management methods focus on merely quantitative factors by estimating (1) frequency and magnitude of flood hazards, (2) properties' exposure to the flood, and (3) the vulnerability level of properties to the flood hazards [9].

To incorporate human decision processes, Agent-Based Modeling (ABM) has been used in a few number of flood risk analysis studies[10–13]. Building on such an agent-based perspective, we see the need for integrating stakeholders' knowledge and perceptions using participatory techniques. In this study, we suggest the combination of *participatory modelling methods* and ABM as an approach to capture and present the realistic and contextualized human behavior in simulating impacts of flood insurance policies. Then, we explain applicability of three participatory methods i.e. narrative data analysis, fuzzy cognitive mapping and role-playing game in this approach.

2 Flood Risk Insurance and Human Behavior

Flood insurance policies and their implementation differ widely across countries with respect to their reach, ownership, and mechanisms. It can be provided by the private insurance market alone (e.g., flood insurance in Ireland), with government intervention (e.g., the National Flood Insurance Program in the United States), or a combination of both (e.g., Flood Re in the United Kingdom). It can be mandatory (e.g., in France and Spain) or voluntary (in most of countries). Flood insurance can also be subsidized (reinsurance under Flood Re in the United Kingdom), indemnity-based (e.g. in Ireland and Australia), or index-based (e.g. mostly in developing countries) [3] [6]. People's acceptability and reactions to such insurance policies might be complicated. For example, [14] show that Hungarian government subsidy in insurance rates causes high concentration of properties in high-risk areas in upper Tisza River. On the other hand, it was also realized that government subsidy remained ineffective to attract insurance buyers in this area [15]. To simulate the impact of different insurance policies on flood risk reduction behavior we need an understanding of who the actors are and what risk reductive actions they can possibly take. The main actors influencing or influenced by flood insurance policies are: *homeowners*, *insurers*, *government*, and *developers*[4]. Following [16, 7], the general actions, processes, and interactions among these actors are listed below:

- **Homeowners** periodically (1) decide to renew their flood insurance, (2) may want to sell/buy a property in flood zone, (3) invest in *property-level protection measures* to make their houses more flood resistant and resilient (e.g. using a variety of barriers for doors, windows, and pipes, installing external walls, changing the floor cover, and raising electrics and services above likely flood level).
- **Insurers** estimate the property-level flood risk and inform homeowners the calculated insurance premiums per property. This calculation varies among different insurance companies and may take the homeowners' property-level protection measures into account. This will be a basis for providing compensations to properties following a flood.
- **Local governments** can support the risk reduction process by legislating or funding (1) local flood protection measures, e.g. building flood defence and sustainable drainage system, and (2) property-level protection measures. In terms of legislation, they may accept/reject property development plans with respect to not only financial benefits but also flood risk and socio-environmental concerns.
- **Developers** mostly identify optimal lands (based on potential benefits), submit development proposal to the local government, build new houses, and sell them on the market.

Studies have shown that many of such decisions and actions (specifically those from homeowners and local governments) are not made purely based on the actors' economic gains and losses (maximizing benefits and minimizing costs of flood and insurance premiums). Instead,

[3] While *indemnity-based* insurance compensate for the quantity of loss and charge risk-based pricing, *index-based insurance* pays out by reference to an index and regardless of the quantity of loss.

[4] Other involved actors might be NGOs and private sectors such as banks, water companies, architects and urban planners.

the socio-cognitive and behavioural factors such as past flood experience and risk awareness, social network, people-centre risk communication, culture, trust and norms—forming actors' *perceptions, preferences and values*—play more important roles in determining the decisions and actions toward reducing flood risk [12, 17–20].

To capture these aspects into risk assessment, ABM has previously been used to apply scientific theories of human behavior in flood risk management [21]. Such theories in the core of ABM were traditionally based on the established view in (non-behavioural) economises, e.g., by assuming merely self-interested utility-maximizer agents. Recently, this perspective shifted towards social-psychological theories such as protection motivation theory [22, 12] and prospect theory [23, 9, 24, 25]. In this more realistic perspective, human risk adaptation behavior is described boundedly rational resulting from individual's (1) threat appraisal and (2) coping appraisal, both of which highly depend on human perceptions in terms of *perceived* vulnerability, *perceived* flood severity, and *perceived* effectiveness/feasibility of interventions. But, how to capture such perceptions is still an open question. For example, how individuals make decision about purchasing insurance or implementing other flood risk reduction measures, what may impact their risk perceptions, and how their perceptions, values and preferences may change their decisions and coping actions? We argue that a combination of *participatory methods* and ABM would be a robust modelling approach, answering such questions and providing support to stakeholders in flood risk insurance analysis.

3 A Methodological Toolbox

Participatory methods are in general used to actively engage actors in co-design, co-analyze and co-implementation of policy option simulation [26] and involve their heterogeneous perceptions, preferences, and values in the process of behavior-aware modelling [27]. In this section, we introduce three methods that can be used in integrating real-world human behaviour in the ABM of flood risk insurance.

Narrative Data Analysis (NDA) techniques provide formal structures for the process of using narrative data (collected in structured, semi-structured or unstructured interviews) to develop decision making processes in ABM [28, 29]. NDA generally consists of four stages: (1) conducting interviews, (2) transcribing them into text, (3) analyzing text, and (4) coding decision rules for an ABM [29–32]. Using narrative data to develop ABM of flood risk insurance may offer the possibility to gather additional valuable information—not achievable by questionnaires—and result in more empirically grounded and contextualized simulations of human flood adaptation behavior. However, developing a systematic process for translating flood-relevant narrative data into ABM program codes requires further investigations.

Fuzzy Cognitive Mapping (FCM) is a knowledge co-production method in which stakeholders collaboratively develop a cognitive map (a weighted and directed graph). In an FCM, components of a system and their casual relationships are identified and semi-quantified via stakeholders' perception [33, 34]. FCM can be useful in enabling stakeholders to represent their decision making process. Moreover, FCM can capture the uncertainty of human perceptions by translating verbal causal weights like very low, low, medium, etc. into numerical values. To collect flood-related decision making process, for instance, actors can be asked to identify (1) the actions they take to reduce flood risk, (2) the conditions, drivers, barriers and timing of those actions, and (3) the impact of each action on the flood risk of properties. There have been limited number of studies on using this method to inform actors' decision rules in the ABM (e.g. see [27, 35, 36]) which can be used as a basis for FCM-based ABM for flood insurance analysis.

Role-Playing Game (RPG) is a participatory method in which players are asked to behave as particular actors in a roughly defined setting [37]. Observing the decisions and actions made by game-players can reveal implicit social rules, norms, and values. Such social concepts are not easy to grasp during survey questioners and interviews [26, 38]. To develop an RPG-based ABM for flood risk insurance, the players can be asked to participate in a game, specified by flood-related barriers/incentives and under different flood insurance policies. Gathering data on various rounds of game play can provide justifications for formulating ABM decision rules. In a two-sided relation, one can also use the output of ABM for updating insurance policies in RPG. There are some games developed to present, model, or train the flood risk reduction activities. For instance games that focus on adopting flood-reducing building codes (e.g., *Extreme Event Game*, *FloodSim*, *Stop Disaster*) and those that focus on retrofitting vulnerable houses and public buildings (e.g., *Cultural Memory Game*, *Flood Resilience Game*, and *Hazagora*) [39]. Such games can be integrate with the ABM of flood risk insurance.

4 Challenges and Opportunities

Selecting the most appropriate method to develop a participatory ABM for each flood insurance study is a challenging task. Basically, each participatory method has its own challenges and potentials. For example, FCM-based ABM provides an accessible and easy-to-use software for non-modelers who want to capture and represent the perception of a large group of stakeholders. However, it is weakly expressive for representing spatial and temporal aspects of the problem. On the other hand, RPG-based ABM is effective for creating synergy and interaction among stakeholders and observing actors' behaviour in response to each other's actions and environmental changes. However, developing and playing games can be costly in terms of time and resources. Moreover, verifying whether game plays correspond to actions in real life is challenging (in principle, players may act differently in real-life circumstances). Knowing potentials/challenges of these methods, to identify the appropriate participatory ABM for flood risk insurance, we need to consider context-related specifications. This includes (1) the spatial and social heterogeneity of decision makers, (2) the scope and specificity of decisions, and (3) inherent complexity and uncertainty of the human decisions and actions. Moreover, the technical issues of each methodology relating to translating qualitative data into quantitative data and formal rules need to be further studied [40].

5 Concluding Remarks

This position paper is the first attempt in proposing the application of participatory ABM for flood risk insurance. We analyzed the behavioural and socio-cognitive dimensions of flood risk insurance, elaborated on applicable methodologies to capture them, and explained further methodological potentials/challenges. The results of the proposed line of research can be used by different types of stakeholders: homeowners, insurers/developers, and local governments. Homeowners can explore which flood risk reduction measures might be useful for them, insurers/developers can learn about the effectiveness of insurance policies, and local governments can get insights on how to support different flood risk reduction measures in terms of subsidy and legislation.

Applicability and Practical Links: We plan to apply our participatory approach by collecting and formalizing human decision making processes of surface flood risk in Camden borough, London, and integrating them into an existing ABM [16]. This model can be used to test the impact of the UK insurance policies on the uptake of flood risk reduction measures. Moreover, we aim to link our work to practical tools, specifically to FRMC (Flood Resilience Measurement for Communities). This tool—developed by Zurich Flood Resilience Alliance (ZFRA)—is implemented in 9 countries and validated by 110 communities as a decision support tool for flood risk reduction [41, 42].

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