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Research article

Co-RISK: a tool to co-create impactful university–industry projects for natural hazard risk mitigation

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Abstract. Translation of geoscience research into tangible changes, such as modified decisions, processes, or policy, in the wider world is an important yet notably difficult process. Illustratively, university-based scientists and professionals work on different timescales, seek different insights, and may have a substantial cognitive distance between them. The work on Co-RISK reported in this paper is motivated by an ongoing need for mechanisms to aid this translation process. Co-RISK is an accessible (i.e. open access, paper based, zero cost) toolkit for use by stakeholder groups within workshops. Co-RISK has been developed to aid the co-creation of collaborative inter-organisational projects to translate risk-related science into modified actions. It is shaped to avoid adding to a proliferation in increasingly complex frameworks for assessing natural hazard risk and is given a robust basis by incorporating paradox theory from organisation studies, which deal with navigating the genuine tensions between industry and research organisations that stem from their differing roles. Specifically designed to ameliorate the organisational paradox, a Co-RISK workshop draws up "maps" including key stakeholders (e.g. regulator, insurer, university) and their positionality (e.g. barriers, concerns, motivations) and identifies *exactly* the points where science might modify actions. Ultimately a Co-RISK workshop drafts simple and tailored project-specific frameworks that span from climate to hazard, to risk, to implications of that risk (e.g. solvency). The action research approach used to design Co-RISK, its implementation in a trial session for the insurance sector, and its intellectual contribution are described and evaluated. The initial Co-RISK workshop was well received so it is envisaged to be applicable to other sectors (i.e. transport infrastructure, utilities, government). Joint endeavours enabled by Co-RISK could fulfil the genuine need to quickly convert the latest insights from environmental research into real-world climate change adaptation strategies.

1 Introduction

There is interest in converting university-based research into commercial success (Mowrey and Nelson, 2004; Dowling, 2015; Evans, 2016) and societal impact (Reed, 2018). Effective, trustworthy translation of environmental science so that it can be used in policy and decision-making practice is a well-recognised and ongoing challenge (Evans, 2006; Dowling, 2015; Cordner, 2015; Margalida et al., 2015; Scott et al., 2018). This is true even when there is broad agreement that working together would be mutually beneficial. Examples of such endeavours include coping with a changing climate (Ostrom, 2010) and transitioning to low-CO_2 sources of energy (Gregg et al., 2020). Various modes of university–business interaction exist, such as spin-out companies or patenting (D'Este and Perkmann, 2011). Of these modes, collaboration is the most frequent channel, which includes joint pre-competitive research, directed contract research, and consultancy (D'Este and Patel, 2007; Perkmann and Walsh, 2007). Thus, a spectrum of collaborative options exists for the use of risk-related university science in the wider world, yet all of these must engage a variety of interested parties and need a plausible and tractable project plan to overcome a variety of difficulties inherent to cooperation across organisational boundaries. By designing an accessible toolkit (Co-RISK) to co-create joint collaborative projects, the work reported in this paper aims to assist the translation of science related

to natural hazard risk into modified actions. Ultimately, application to a variety of sectors is envisaged, including infrastructure (e.g. rail, road, telecommunications, power), but Co-RISK originates from the consideration of financial risk (e.g. insurance, mortgages, catastrophe bonds).

Insurance is a key financial mechanism to mitigate the impacts of natural hazards (Mitchell-Wallace et al., 2017). Taking averages for 2000–2022, it absorbed USD 84 billion of the estimated USD 301 billion annual global losses for these risks (Lörinc et al., 2023). It is one of the largest global financial services industries and is very concerned with accurately assessing risk in a changing world – e.g. "insuring the climate transition" (UNEP, 2021). Indeed, recently, an executive at Lloyds of London insurance market called for "urgent" action from firms to invest in risk modelling, using a "well-considered" investment targeted at those threats posing the bigger threats (FT, 2023). This knowledge-driven approach will rely on input from environmental science, and, illustratively, Innovate UK will provide ∼ GBP 1 billion (by 2024–2025) of government funding annually to facilitate this (UKRI, 2022). Co-RISK's intention is to be a pragmatic tool for day-to-day use to help ensure the efficient use of such knowledge exchange resources by streamlining stakeholder engagement processes.

In the academic literature, the difficulties around the process of science–society interactions in the environmental science are captured in the literature around stakeholder engagement (Phillipson et al., 2012; Kujala et al., 2022; Bamzai-Dodson et al., 2021) and knowledge exchange and co-production (Norström et al., 2020). Although the literature does a good job of identifying the knowledge and process challenges that come with these interactions, it tends overlook what Kujala et al. (2022) have termed a "dark side" of stakeholder engagement, namely that there may be genuine tensions around conflicts of interest and trust between partners involved. In order to mitigate these tensions, Co-RISK builds on the insights of paradox theory. Paradox theory is a body of study in organisational studies that seeks to understand ways to overcome tensions in inter-organisational partnerships (Carmine and Marchi, 2023) where cooperation between competing organisations is mutually beneficial (Smith et al., 2017).

Co-RISK is a tool developed to assist the co-creation of collaborative impactful projects for natural hazard risk mitigation. It originates from a recent, successfully completed collaborative project, dubbed TOGETHER, which aimed to mitigate jointly occurring flooding and extreme wind risks in the insurance sector (Hadzilicos et al., 2021; Appendix A). TOGETHER's participants spanned the spectrum of relevant organisations, from university to regulator (Fig. 1), giving them a holistic view of the project's necessary scope. Yet, even with a highly experienced team, ongoing ad hoc discussion was needed to refine a valuable and tractable project and to determine the detail of necessary tasks. No resource tailored to guide the planning and execution of project-based tasks like TOGETHER, to translate risk-related science, was known to the team. Thus, it was clear that there was a need to create a toolkit or other training material that might assist many others in doing similar projects, ideally being a participatory activity in line with best practice (Reed, 2008). The challenge was to make this toolkit simple and usable whilst spanning the spectrum from hazard to impact (Fig. 1) and also being adaptable and applicable to a variety of tasks. In this endeavour, it was important to avoid over-complexity or creating just another task-specific natural hazard risk framework. Hindsight reflections on TOGETHER offered the opportunity to learn and to build and design a first version of Co-RISK, whilst being based in a particular project lent a bottom-up and task-based philosophy to the enterprise.

Co-RISK is a tool developed for the purpose of knowledge exchange, as described above. It builds on natural hazard risk frameworks, includes stakeholder mapping, and uses ideas from paradox theory. These components are illustrated in Fig. 2 and are further introduced below.

To assist with understanding and assessing physical risk (e.g. for insurers), natural hazard risk frameworks (e.g. Cremen et al., 2022) have become plentiful. These frameworks are graphical simplifications outlining blocks of knowledge, often from different specialisms (e.g. hazard, value of asset at risk), within a conceptual model to be applied to quantify a selected natural hazard risk or risks. The challenge when translating geoscience research in practice is to span the full spectrum from the research on climate and extreme weather to hazard, to risk, to the implications of impacts (Fig. 1) in a single framework that is clear yet detailed enough to be useful for the task. Simple, clear frameworks can be created by sacrificing detail (e.g. Cremen et al., 2022). Holistic frameworks for complex, multi-faceted, interacting natural hazard risks also exist (e.g. Simpson et al., 2021), yet they are themselves complex abstractions and cannot be fleshed out with detail until applied to a specific risk or scenario (WSP, 2020; Simpson et al., 2021). In this vein, it is common to create and disseminate a framework geared towards a specific audience and task, leading to a proliferation of frameworks. A regulator-led, industry-targeted framework for assessing the financial impacts of physical climate change (PRA, 2019), for instance, has identifying business decision(s) as its first step. The premise is that a physical climate change study would typically be done with the aim of informing a business decision or activity, which is not the case for a university-based researcher (Hillier et al., 2019b). Frameworks in a (re)insurer-led assessment of climate change implications, including hazard, omit explicit studies of climate or weather but give weight to risk and impact (UNEP, 2021). In general, in a business-led framework, only dimensions of interest tend to be included, those with potential material impact upon the financial bottom-line (Carmine and Marchi, 2023). In contrast, scientific frameworks on co-occurring hazards (Hillier and Dixon, 2020; Bevacqua et al., 2021) typically include detail on hydro-meteorological processes (i.e. climate, weather)

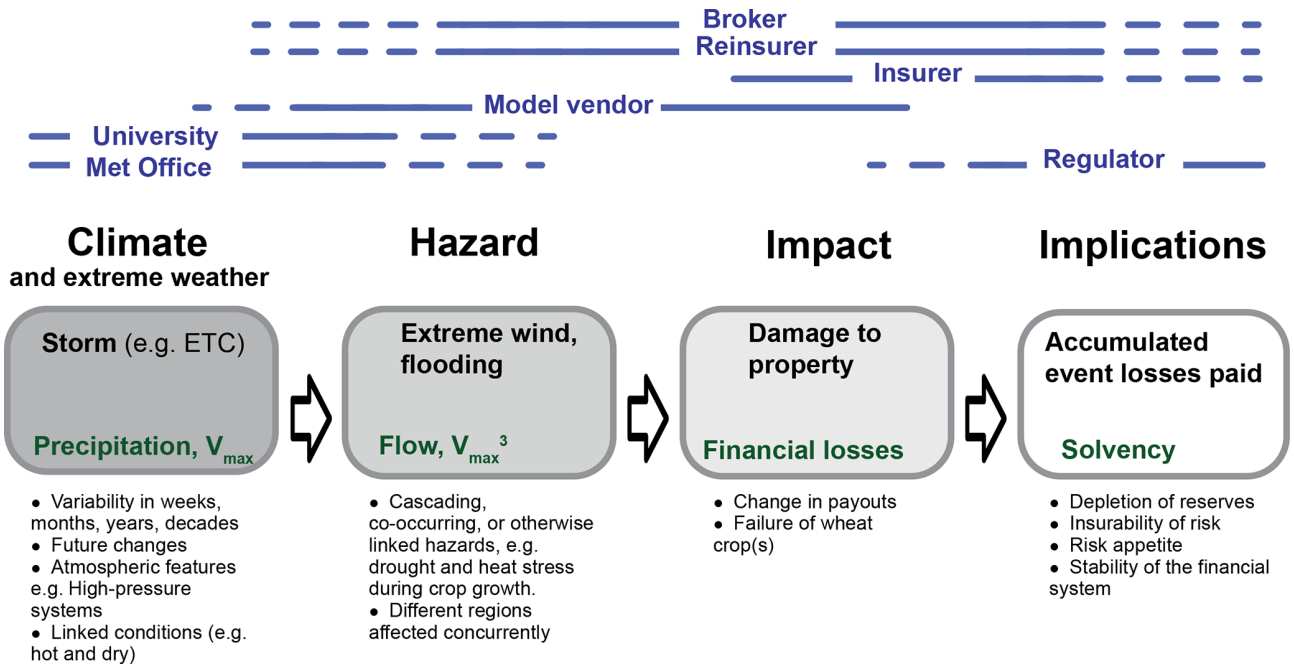

Figure 1. Schematic framework of the progression from scientific study of climate and extreme weather (left) to the implications if the risks that these represent are realised (right), synthesised from Fig. 1 of Hillier and Dixon (2020), Fig. 8 of Bevacqua et al. (2021), and impact pathway in Fig. 5 of UNEP (2021). Grey boxes illustrate processes of interest (black) and measures related to this (green) for extra-tropical cyclones (ETCs), a type of storm. At the top (blue) are the typical positions of organisations relevant to the insurance sector on this spectrum, which naturally positions and distinguishes them. At the bottom, in small type, are arbitrarily selected examples of considerations at each stage. To translate a selected piece of risk-related science into (re)insurance, this spectrum must be traversed, and as relevant organisations occupy distinct positions this diagram is a useful conceptualisation for project-planning exercises, such as Co-RISK. Of course, feedbacks exist, such as in the selection of the scientific task to pursue, but this is not the focus here.

and reach to losses but omit a quantification of the implications (e.g. firms' solvency). The alternative proposed in Co-RISK is to equip participants, potential project colleagues, with knowledge and guidance to prepare their own tailored and detailed framework spanning from climate knowledge through to its implications (Fig. 1), which is simple and useable because it is task specific, thereby creating an impactful change in scientific research.

Stakeholder management and mapping are key skills in projects with multiple participants (i.e. individuals) and partners (i.e. organisations) (e.g. Bourne and Weaver, 2009). At its most basic, stakeholder mapping is simply identifying who needs to be involved in a project. However, such mapping also includes characteristics such as what influence stakeholders have, their views on a subject, and what their success criteria might be (Walker et al., 2008; Phillipson et al., 2012). For Co-RISK, mapping is restricted to stakeholders' viewpoints on the project (e.g. concerns, motivations) and is designed to identify and allay the tensions that may arise within a collaborative project across the industry–science divide where organisational interests do not fully align. These tensions, arising from organisational paradoxes (Carmine and Marchi, 2023), are typically felt by both organisations and individual agents representing these organisations and have to be handled and managed (Bengtsson and Raza-Ullah, 2017).

Co-RISK is differentiated in a number of ways from existing work. First, it draws on natural hazard risk frameworks, stakeholder mapping, and paradox theory (Fig. 2); however, as far as the authors are aware, the toolkit is unique in its combination of these elements for the purpose of enhancing the translation of risk-related science into modified actions via the co-creation of collaborative projects. Second, it is unusual, although not unique, in being intrinsically participatory. For instance, it does not involve the mapping *of* stakeholders by an outsider or other (e.g. Walker et al., 2008); rather, the mapping is by stakeholders (including university-based researchers) for stakeholders (e.g. Bou Nassar et al., 2021). Third, Co-RISK sits on a higher level of abstraction than a framework, so a diversity of stakeholders and research problems can be accommodated depending on the context and risk quantification required. It is a toolkit (i.e. training material) to create task-specific frameworks, allowing for the creation of project plans of usable complexity that are holistic – spanning the whole spectrum from weather and climate to their implications (i.e. Fig. 1) – yet detailed.

This paper describes the action research approach used to design Co-RISK and evaluates its implementation in a

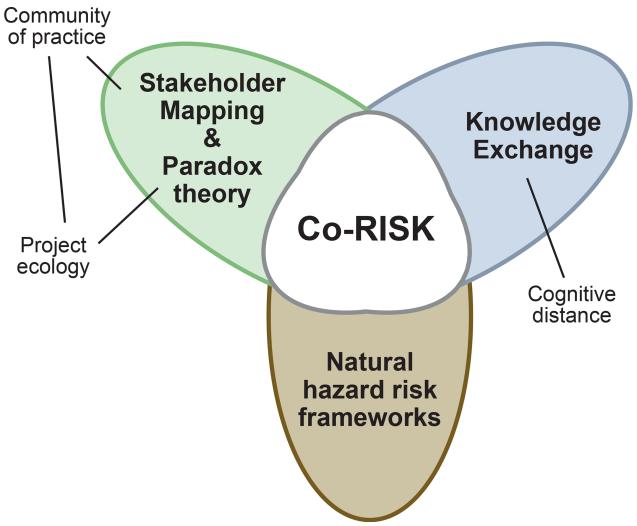

Figure 2. Simplified illustration, highlighting in shaded areas the main knowledge domains that are combined to formalise the creation of the Co-RISK toolkit. Co-RISK's purpose is knowledge exchange and the translation of risk-related science into modified decisions, processes, or policy in the wider world. Stakeholder mapping and paradox theory provide a means to analyse participants and envisage potential project teams, whilst a natural hazard risk framework is used to simplify and organise the environmental and associated business (e.g. insurance) environment. Some selected, related literature is shown, but no attempt to show all inter-connections is made.

trial session, and it is structured as follows. First, organisations and their roles in the insurance sector are described, and a theoretical perspective building on organisation studies and economic geography is presented to understand the paradoxes and tensions inherent in collaborative university–industry projects (Sect. 2). Secondly, the action research methodology used to create and evaluate Co-RISK is described (Sect. 3) (e.g. Bou Nassar et al., 2021). After this, the research results used to create Co-RISK are outlined (Sect. 4), and then the Co-RISK toolkit is described and evaluated (Sect. 5). Finally, in Sect. 6, Co-RISK's performance in practice on the day in its trial is evaluated, and Co-RISK's ability to ameliorate the organisational paradox is discussed alongside its broader contribution to the endeavour of enhancing the translation of risk-related science into modified actions.

2 The science–business interface for natural hazard risks

Whilst having the potential to be applied more widely, Co-RISK originates from work in the insurance sector. Here, translation of science into modified insurance projects is rife with organisational paradoxes, where trust between participants in the face of organisational tension is essential to prevent the parties involved from taking advantage of information asymmetries that may arise. The insurance sector, its organisations, and their roles and a conceptualisation of how they work together in projects at an individual and institutions level are outlined below.

2.1 Project ecologies and insurance

Advanced financial products contain an amalgam of highly specialised expert knowledge, bridging topical specialisms, regulatory and legal insights, historical transactions data, and knowledge of the socio-technical infrastructure in which these products get positioned (Bassens and Van Meeteren, 2015). At its core, any financial product consists of an imagined future (Beckert, 2016) with an associated risk profile commenting on whether or not that future is likely to come to pass. In the case of an investment, this is a future that needs to be made believable to investors taking on the risk. In the case of insurance, the emphasis shifts to a more accurate understanding of future risk so that these can be more sharply underwritten on the insurance market. Creating these imagined futures requires bringing together the expertise of many different financial, legal or regulatory, and environmental science experts (Weinkle, 2020). As these different forms of knowledge do not commonly reside within a single firm, they often require project work. Key is that the projects are temporary, but the networks that sustain these projects become more solidified with each successful project, something that Grabher (2004) termed a "project ecology". Participants gain reputations as reliable collaborators among project participants. Project ecologies tend to be comprised of participants from overlapping communities of practice. These communities of practice originate from a shared identity and mutual understanding lubricated by being part of the same industry or indeed being part of the same localised industry cluster (Nooteboom, 2004; Wenger, 1998). Financial centres, or world cities, have been identified as important clusters of highly specialised knowledge pertaining to financial products where inter-organisational project work is rife (Bassens and Van Meeteren, 2015; Bassens et al., 2021). Think, for instance, about the insurance cluster in the city of London (Cook et al., 2007).

The insurance sector (see Chap. 2.3 of Mitchell-Wallace et al., 2017) consists of entities that hold risk themselves (i.e. primary insurers, reinsurers, and other financial institutions) and companies who provide tools or advice to help them do so effectively (i.e. brokers, consultants, catastrophe vendor model companies). In the UK, risk holders are regulated by the Prudential Regulation Authority (PRA) within the Bank of England. Risk holders provide the service of aggregating and spreading risk, and this diversification allows them to profit, with accurate pricing of risk providing the basis to earn the most (Timms et al., 2022). For primary insurers, who sell directly to individuals and companies, overpricing loses customers, whilst under-pricing leads to finan-

cial loss. A similar concept applies to reinsurance (insurance for insurers). The companies providing advice and support (e.g. brokers) profit by arguing that they do this better than their competitors, who work similarly. The PRA has dual aims, namely to ensure a stable yet competitive financial system as financial stability requires "an efficient flow of funds in the economy and confidence in financial institutions" and, thus, to neither over- nor under-regulate. Inter-organisational tension is easily illustrated, with primary insurers wishing to pass risk to reinsurers as cheaply as possible, who in turn would like to be paid as much as possible to take the risk, with negotiations revolving around estimates of what the true risk is. In short, a variety of insurance organisations each have their own differing abilities, requirements, drivers, and restrictions, which express themselves differently in different aspects of commercial activity (Timms et al., 2022; Hillier et al., 2019a). Yet, advantage exists in collaborating to better understand emerging (e.g. markets in new countries, co-occurring hazards) or changing (e.g. with climate) risk.

Illustratively, as the climate changes, the scope and price of insurable assets may shift (Taylor and Weinkle, 2020), presenting a challenge. Different and more (or less) frequent extreme weather effects across the world need to be reflected in the models used by insurance firms. Hence, the insurance industry was relatively early in starting to assess and incorporate climate change within their long-term business models and planning (Thistlethwaite, 2012). However, maintaining a fluent interface between the latest insights from climate research and insurance structures in a highly competitive industry is not self-evident and requires continuous management of paradoxical tensions.

2.2 The challenge of co-opetition: inter-organisational paradoxes

It is the interest of any risk holder to be as resilient as possible to natural hazard risk, now and as climate changes. Indeed, regulatory frameworks typically require them to be so (e.g. Bank of England, 2022). Thus, given the complexity of assessing natural hazard risk (Sect. 2.1), there is ample reason to organise multi-organisational projects. Analogies of shared effort in complex tasks exist in many global industries (Ritala, 2012). Yet, the collaboration within a project runs into fundamental problems when one considers that the project participants who have to contribute their knowledge represent different firms. Potentially, firms are competitors, and if this is the case, having a knowledge advantage can easily turn into a competitive advantage. In the insurance industry this might be historical claims data, which are key to accurate modelling (see Timms et al., 2022), or access to a model's parameters. Although there might be a shared benefit to a successful project, from a firm's perspective, this may put business at risk if the project fails or if trust relationships between the participants break down. How these organisational contradictions and paradoxes may be handled is studied in the field of paradox studies, a subfield of organisation and management science (Smith et al., 2017).

This tension between cooperation and competition on the firm level has been labelled the co-opetition paradox (Gnyawali and He, 2008; Brandenburger and Nalebuff, 1996). A key characteristic is that the conflicting and competing interests of the participating stakeholders involved will not be resolved in the course of the project, only handled, for instance by use of an intermediary as a coordinator (Stadtler and Van Wassenhove, 2016). Consequently, participants may be vulnerable to proprietary knowledge spilling over in the course of the project, putting an emotional strain on the participants that are representatives of their contributing organisation (Raza-Ullah et al., 2014). The tensions in the paradox can only be kept stable in the project process by maintaining trust and understanding between the participants while also keeping the faith in the eventual positive outcome of the project work (Bengtsson and Raza-Ullah, 2017).

2.3 Handling positional tension within a project

Handling inter-organisational tensions within a project requires cognitive and emotional work from individuals in the project team. They have to monitor their actions while also putting in the social labour to work collaboratively in a project team. This labour is eased by embeddedness (network and institutional), namely participants being part of the same industrial field or cluster (Grabher, 2004; Hess, 2004; Van Meeteren, 2014). A shared sense of dos and do nots makes co-working easier, and the likelihood of continued workplace interaction with other team members over time after the project is completed regulates behaviour because of a personal reputational risk if trust is breached. In addition to a degree of mutual trust and understanding, an appreciation of the viewpoint (e.g. constraints, motivations, influence, skills) or positionality (e.g. Glier et al., 2021; Williams et al., 2022) of others is needed for a co-opetition project to be successfully designed and enacted. Logistical or organisational mechanisms, such as non-disclosure agreements with regard to the sharing of proprietary data, can overcome some challenges, but it also useful to explicitly understand factors influencing the actors. For instance, every project participant needs to have something to gain from the process, both personally and for the organisation they represent (Bengtsson and Raza-Ullah, 2017). These interests and institutions, as well as the expert knowledge needed for a particular project, may differ from project to project. Co-RISK is a toolkit that aims to identify ways of handling the paradoxes and tension in the ecologies of projects to translate risk-related science.

3 Research method and data

Starting with a retrospective reflection upon a collaborative case study project (Hadzilicos et al., 2021), with cycles of collaborative analysis ending with a trial workshop to co-

design potential projects, the development of the Co-RISK toolkit was fundamentally action research (e.g. Denscombe, 2010; Kemmis et al., 2013). Action research involves concurrently taking action and doing research, linking these processes together by critical reflection. Included in this, then, are ideas of reflexivity (e.g. Bostrom et al., 2017) and self-reflection, as in pedagogical practice (e.g. Guthrie and McCracken, 2010). A mixed-methods approach was used (i.e. self-reflection, semi-structured interviews, round-table discussion, a workshop) to integrate, refine, and expand experience from the case study project into a more broadly applicable workshop-based toolkit. The three research phases were as follows, with phases 1 and 2 conducted virtually due to COVID-19 restrictions:

- *Phase 1: individual self-reflection*. The TOGETHER project, completed in April 2021, was taken as a case study (case study no. 1). Between 20 and 27 September 2021, five semi-structured interviews were conducted by the co-authors (John K. Hillier and Michiel van Meeteren) with the main participants from all five participating organisations (i.e. Aon, Bank of England, CatInsight, Loughborough University, Verisk). Applying thematic analysis (e.g. Dowling, 2015; Ward et al., 2009) to results from this phase was used to devise pre-structured mind maps (maps 1–3) that form the core of Co-RISK.

- *Phase 2: round-table discussions*. Two 2 h meetings by the TOGETHER project team (20 November 2021, 19 January 2022) were used to further the development of Co-RISK. Following up on selected topics from the one-on-one interviews provided the basis of guidance developed for Co-RISK facilitators (i.e. as key questions to prompt participants).

- *Phase 3: trial of the Co-RISK workshop*. After incorporating feedback from phase 2, Co-RISK was run with 12 participants representing most key organisations important to the (re)insurance sector (i.e. regulator, broker, (re)insurer, universities and research organisations, catastrophe model vendor) at Aon in London at 09:30–12:30 GMT on 28 March 2022. The evaluation of this trial workshop is by means of reflections written on the day by co-facilitators and a questionnaire for participants. The focus theme for this trial was "co-occurring natural hazards".

Overall, the intention of a multi-phase integrated approach was to engender confidence in insurance industry colleagues to participate in and otherwise be associated with Co-RISK by building a tool that is, and is perceived to be, fit for purpose.

4 Observations used to design Co-RISK

Research phases 1 and 2 were individual and group reflections and a discussion on TOGETHER, case study no. 1 (Hadzilicos et al., 2021; Appendix A). They produced results that are reported in Sect. 4.1–4.3 and were used to design, create, and evolve Co-RISK.

4.1 Reflections on case study no. 1

The TOGETHER project team consisted of members from the Bank of England (regulator), Aon (insurance broker), Verisk (risk modelling), and the Universities of Loughborough and Reading (research). Upon completion, the team reflected on the project (phase 1). Here, reflections are an overview of the collected opinion of these individuals and should not be attributed to any organisation they work for. All partners felt that the project was successful, producing a journal article (Hillier and Dixon, 2020), a co-written piece for the Bank Underground (Hadzilicos et al., 2021), and, in 2022, it directly led to a modification of the regulation of UK insurers, i.e. the flood–wind scenario in the Bank's General Insurance Stress Test (GIST) (Bank of England, 2022). Quantification of the implications (i.e. on solvency) of losses was seen as a strength, but it was felt that the immediate response could have been greater in the sector more widely. It was felt that there were a number of factors that led to the project being successful, and there were some things that could have been done better. These are listed below.

What made the project successful?

- There was a clear task with a well-defined scientific starting point, (Hillier et al., 2015; De Luca et al., 2017) requiring further study, that recognised industry need (Dixon et al., 2017; FloodRe, 2019) and identified regulatory tools, i.e. the General Insurance Stress Tests (Bank of England, 2019). This is important for a viable co-opetition project.

- There was a small and agile group of participants all familiar with the sector (i.e. insurance and reinsurance), underlining the importance of a shared frame of reference and thus societal embeddedness (Hess, 2004). A quote, "the strength was the group", underlines the importance of this.

- There was benefit for all parties. Although identified in an ad hoc way, the incentives need to be sufficient.

- There was good awareness of the positionality of others (e.g. concerns, motivations, timescales, sensitivities), indicative of network embeddedness.

- Trust already existed (e.g. that the academic would not sensationalise results). Critically, the regulator was closely engaged, and it was determined early on that all

would have to agree to any written output, also indicative of network embeddedness.

- There was a clearly identified contribution from all involved, which also leverages existing skills, practices, and data.
- There was some luck (i.e. in the "soft" part of the insurance cycle where resources are not so constrained).
- There were internal reviews of work done and critiquing by the project team.

What might have been done better?

- A more formal planning process and clearer criteria for success would have been beneficial.
- For flexibility, EDI (equality, diversity, and inclusivity), and additional benefit, each participant could have paired with a junior colleague.
- There could have been a process for external review to allow input, to increase sector buy-in, and to improve the work; this would need to be designed pragmatically to prevent significant delays.

All of these points raised are explicitly tackled within Co-RISK, either in pre-structured mind maps or the facilitator notes that accompany them as prompts to participants. Notably, Co-RISK answers the call for a more formal planning process. At this stage, it is possible to separate three broad stages of project planning.

1. *Map the organisational landscape*. What types of organisations are needed for projects on a given theme (e.g. UK co-occurring hazards)?
2. *Map the project landscape*. What specific organisations and/or individuals are needed for this particular project?
3. *Plan the project*. Who is going to do what, when, and why?

Whilst project creation (stages 1 and 2) was felt to be well handled on an ad hoc basis, a framework within which to plan the tasks in detail (i.e. stage 3) would have improved the efficiency of TOGETHER. In particular, for any future projects, it was felt that a mechanism to encourage good awareness of the positionality of others (e.g. concerns, motivations, timescales, sensitivities) would be useful so this was followed up on in more detail.

4.2 Dimensions to define stakeholder viewpoints

Thematic analysis during phase 2 of the research identified six factors of primary importance to do with positionality in a collaborative project that intends to translate risk-related science into modified actions.

- *Barriers/constraints*. Obtain a clear shared understanding of things that will not be possible or extremely problematic given the paradoxes and competitive interests of the parties, which might be cultural, institutional, or personal (Scott et al., 2018; Ward et al., 2009).
- *Concerns*. Ensure that concerns surrounding the project are properly articulated. These concerns could relate to potential actions by stakeholders, where these might be possible if certain conditions are in place, or how other stakeholders may react. Here, control mechanisms to enable the sharing of valuable and competition-sensitive data may sufficiently allay the paradoxical stress (Fernandez and Chiambaretto, 2016).
- *Motivations*. Stay aware of the variety of reasons why stakeholders agree to contribute to a project – perhaps a commercial or regulatory purpose for a firm or for personal fulfilment, career progression, or reputational benefit linking to enhanced societal and network embeddedness (Hess, 2004; Hillier et al., 2019b).
- *Outcomes*. Be conscious of the deliverables needed by each party, which may vary significantly (e.g. a publication; a computer-based tool; a testimonial evidencing an impact, i.e. change in actions).
- *Contributions*. This refers to what a stakeholder may be able to put into a project to help it achieve its outcomes (e.g. time, skills, licensed software), which may be more (e.g. data) or less (e.g. ability to chair or coordinate, reputation) tangible. To gain credit for participation, justifying a name on the outputs, each partner typically needs a defined contribution.
- *Insertion point(s) for the science*. Determine where in the process and institutions environmental scientific insights can make a difference. This particular endeavour should be precisely defined (e.g. a percentage change with regard to metric A used in management process B).

These factors, when distinguished and considered, act to define the positionality of the stakeholders (see Sect. 2.3). This typology and these dimensions were used to form the basis for three pre-structured mind maps (Maps 1–3) relating to the three broad stages of project planning identified in Sect. 4.1. It is not realistic, however, to expect workshop participants to spontaneously understand these abstract dimensions and their wider implications. These dimensions need to be translated into emergent themes and subsequently distilled into questions that might plausibly be used as prompts for Co-RISK workshop participants. They are analogous to guidance questions typical of stakeholder mapping exercises but are tailored to the purpose of Co-RISK, and are as follows.

Map 1 – organisational landscape

- *Stakeholders.* Which types of stakeholder are there?
- *Organisational viewpoints.* Do you understand the viewpoints of all stakeholders and any tensions?
- *Partner selection.* What types of organisation are core and necessary to the intended project? Which are optional?
- *Power to motivate.* Who has the power to set the agenda and motivate action relating to this type of question?

Map 2 – project landscape

- *Tractable question.* Which specific, more focussed topic or issue have you selected?
- *Purpose of translating the science.* What exactly might the scientific insight change?
- *Necessary inputs or metrics.* Exactly what metrics or inputs are needed to make these changes?
- *Necessary analysis.* Typically, an evidential base will be more powerful an output than simply a viewpoint alone. So what analysis will be done to provide the necessary inputs or metrics?
- *Partner selection.* What specific organisations are core and necessary? Which are optional?
- *Participant selection.* What people will be necessary? Please consider the skills, viewpoints, and personality traits needed to form a small and agile group capable of conducting the project in addition to participants being able to represent their respective organisations.
- *Scientific research.* Is there an opportunity for a piece of new (novel) applied science?
- *Mitigating positionalities.* Have you identified means to mitigate any biases that entities' positionalities may bring and any tensions between firms?
- *Sector-specific experience.* Do all parties (partners and participants) have sufficient experience in the sector?

It may also be useful to consider interpersonal positionalities. This is likely not something to write down (i.e. to be circulated later), but it is necessary to consider individuals as well. A quote from TOGETHER highlights this: "You didn't have to worry about offending people. You could voice your opinion".

Map 3 – project plan

- *Tractable task.* A projects needs a core aim. Have you found a pragmatic way, likely leveraging existing resources, of getting from scientific insight A to usable metric B?
- *Project management.* It is key that everybody knows how the projects orchestration is going to work. Who will chair or coordinate the project?
- *Publication.* Managing expectations about publications is important, taking into account stakeholder preferences and positionality when answering questions of how, when, and whether publication will happen. Will this be internal only or external?
- *Agreed understanding.* How will you avoid misunderstandings or mistranslations?
- *Involvement of all.* Do all parties have at least one outcome or output to motivate them to stay involved? Furthermore, do all parties indeed have a task (e.g. specific analysis, writing or synthesis task) to do?

4.3 Internal review of and initial version of Co-RISK

Based upon the findings above, a Co-RISK workshop was conceived that used a sequence of three pre-structured mind maps, taking in turn the three broad stages of project planning. Some theory was added, along with an ice-breaker exercise to brainstorm potential project titles of most interest, and, in the last element of phase 2, this draft version of Co-RISK was internally reviewed by the TOGTHER participants. The main advice can be succinctly summarised.

- To be most useful, the final version of Co-RISK needs to ensure that it is applicable to themes other than co-occurring risk. Namely, it should work for any risk-related science.
- Facilitators should talk as little as possible, giving participants time to interact.
- Reduce the theory presented (e.g. on positionality), and keep the conversation on the concrete matters at hand adapted to the frame of reference of the participants.
- Keep the logistics simple (i.e. paper based and not electronic).
- In-person is preferable over online delivery.

Additionally, other considerations were included in the revised or β version of Co-RISK.

- At each table, ideally, one participant should represent each key stakeholder. If participants are known, some may be used to cover multiple hats.

- Try to put previously unconnected people together at a table to (i) avoid off-topic conversation, (ii) encourage the making of new contacts, and (iii) encourage engagement by avoiding the feeling of being outside established groups.

- Define the end of the workshop by a light-hearted competition between tables to style their final summary as a pitch for the best project.

5 Results: the Co-RISK toolkit and evaluation of its implementation

From research phases 1 and 2, the Co-RISK workshop was created. This toolkit is described in Sect. 5.1. The main mind-map components (maps 1–3) are retrospectively completed for the TOGETHER project as an illustration and are shown in Sect. 5.2. Finally, results from research phase 3 are reported in Sect. 5.3 to allow an evaluation of Co-RISK based on its real-world trial.

5.1 The Co-RISK toolkit

Co-RISK is an accessible (i.e. open access, paper based, zero cost) toolkit for use by stakeholder groups within workshops. It is provided in the Supplement and consists of the following:

1. Powerpoint slides that can be adapted to facilitate a Co-RISK workshop

2. notes on logistics

3. Co-RISK's facilitator notes for three tasks (e.g. questions to use a prompts)

4. blank, pre-structured maps for use in these tasks

5. an illustrative case study of a completed co-opetitive project including exemplar pre-filled maps.

Co-RISK's design, based on research phases 1 and 2, is driven by an interest in establishing future projects that translate risk-related science. Its philosophy is bottom-up and task based, using a participatory approach advocated as best practice (e.g. Reed, 2008).

In pedagogical terms the Co-RISK toolkit is based upon experiential learning (Kolb, 2015), namely gaining an understanding of how to better co-design a collaborative project by actually endeavouring to draft such a project. Its primary tools are three maps (maps 1–3), visual representations that spatially structure key information. Completed exemplars of these are in Figs. 3–5. Maps 1–3 are mind-maps (Lanzig, 1998; Romance and Vitale, 2010), although substantially pre-structured (e.g. boxes present, colours of writing assigned to specific topics of interest) and tailored to facilitate project design by drawing out key considerations whilst retaining some flexibility. Another pedagogical aspect of Co-RISK is that it contains a learning arc (e.g. Hutchinson, 2018), building from a customised form of stakeholder mapping (e.g. Walker et al., 2008) (i.e. simply identifying who needs to be involved) in map 1 to detailed project planning (e.g. BIS, 2010) in map 3 whilst revisiting similar themes in a cyclicity advocated for within experiential learning (Kolb, 2015).

In terms of stakeholder mapping and working to alleviate tensions within potential projects, as outlined in paradox theory (see Sect. 2), Co-RISK has several purposes aligning with its ostensible mission to output drafts of co-designed projects. For instance, throughout the 3 h workshop, participants build an understanding of the stance and abilities of key organisations (i.e. positionality) needed to answer their chosen question (e.g. do co-occurring flooding and extreme wind exacerbate joint risk?), which is both a means to an end (i.e. project planning and structuring) and a highly useful byproduct in itself. The main purposes are as follows:

1. to help identify those co-opetitive projects where inter-organisational paradoxes can be overcome beneficially for all stakeholders involved, primarily by building awareness of the positionality of the range of key organisations

2. to enhance personal embeddedness (i.e. ties to and knowledge of a community of practice)

3. to assist project partner and participant selection

4. to guide potential project management (e.g. rules of engagement).

Co-RISK is constructed around group work in tables of 4–6 participants. To incentivize participants to attend, there are three tangible outputs from each workshop: (1) two or three co-designed project drafts (i.e. one per table) to be circulated amongst participants; (2) a ranked list of the topics of most mutual interest to the cross-sector panel of participants with regard to the workshop's theme (e.g. co-occurring natural hazards); and (3) a list (if consent is given) of participants' contact details, connecting those with similar interests, providing the potential for actions be taken to progress work on drafted projects. The primary less tangible benefits to participants are intended to be a more holistic awareness of their sector (e.g. of organisations' positionality), an improved ability to design a collaborative project, and an opportunity to strengthen professional ties within a community of practice.

The specific practical aim of the Co-RISK toolkit is to facilitate the co-creation of potential collaborative projects to translate risk-related science into modified actions. To achieve this aim, it is necessary to fulfil four objectives, which is done through participants engaging in four facilitated exercises. Tasks 1–4 are outlined below. Tasks 2–4 identity the paradoxes and tensions that must be allayed if

the project is to be successful (Stadtler and Van Wassenhove, 2016), with task 4 focussing on ideas for how these might be handled. Full descriptions are in Co-RISK's facilitator notes (Supplement), including the questions used as prompts (also see Sect. 4.2) and exemplar completed maps from case study no. 1 (see Sect. 5.2). Maps 1 and 2 have two main elements, a box for each key stakeholder and space to identify and examine their stance with respect to the proposed work using six colour-coded dimensions describing their viewpoint and abilities. (i.e. positionality), as outlined in Sect. 3.

Task 1: brainstorm project topics of interest. The ostensible purpose of this task is to create a ranked list of the majority of topics of the most interest to the cross-sector panel of participants with regard to the workshop's theme, e.g. co-occurring natural hazards. What are the topics that participants would like to spend the session creating a draft project for? Why? First of all, this allows the identification of the co-opetitive opportunities within the group of participants. The topics selected need to be valuable enough for participants to engage with in order to make their contribution worthwhile if the project is not to dissolve without result (Bengtsson and Raza-Ullah, 2017). Its other purpose is to act as an ice-breaker, starting with brief introductions around each table, laying a foundation for the necessary trust relations within the group (i.e. enhanced embeddedness). Initially, this task is conducted separately at each table. Since tables are deliberately mixed (e.g. regulator, university-based scientist, (re)insurer, broker, catastrophe model vendor), the introductions also start to build awareness of the organisational landscape (i.e. positionality). Then having each participant explain their (pre-prepared) favourite topic – essentially an excuse to talk about a personal enthusiasm – is useful to promote continued engagement, and this typically generates the positive emotional responses necessary to overcome the tensions inherent to co-opetitive projects (Bengtsson and Raza-Ullah, 2017). Ideas are then collated from across all tables into a central list by facilitators. For the ranking of this list, each participant gets three votes, and, to make this resonate with industry participants, a premise is used wherein each participant has GBP 30 000 to invest in working on an idea, with one vote committing GBP 10 000 to a topic.

Task 2: map 1 – the organisational landscape. The purpose of this task is tailored yet broad stakeholder mapping, starting with a blank version of map 1 (see Fig. 3). Specifically, who are the types of people you need to involve in the types of projects identified in task 1? Why? And what is their broad stance or viewpoint, including the business interests of the organisation they represent (i.e. positionality)? Typical dimensions of simple two-dimensional stakeholder mapping are interest versus power or influence, but mapping can include a stakeholder's level of involvement or organisation type (e.g. regulation) (Mendelow, 1981; Walker et al., 2008). A pre-structured map (e.g. boxes present, colours of writing assigned to aspects of positionality) is used to make the exercise efficient and effective within a time-limited workshop. Dimensions used in the mapping (e.g. barriers, motivations, desired outcomes) are derived from research phases 1 and 2.

Task 3: map 2 – the project landscape. See Fig. 4. The purpose of this task is to revisit stakeholder mapping but now with greater specificity and detail, focussing on the single project allocated to the group's table (i.e. one off the list created in task 1). Who specifically would you intend to involve? Why? And what exactly is their positionality in this defined case? Greater clarity is required to refine who should be involved and to determine what specific contributions (e.g. skills, data) are needed and who is in a position to supply them in light of the role, constraints, and required outcomes. The selection of participants draws on the inter-organisational network knowledge of potential participants accumulated in previous collaborative projects (Grabher, 2004). The aim is to create a team with a good topical, cognitive, and social fit where negative emotions around distrust of opportunistic behaviour are minimised. Participants are forced to consider how exactly to get from a science-derived metric (e.g. correlation between seasonal precipitation and wind gusts in a climate model) to a highly specific point of insertion into decision-relevant policy or processes (e.g. percentage change in 200-year aggregate exceedance probability – AEP).

Task 4: map 3 – plan the project. The purpose of this task is to revisit the project from task 3 in yet more detail (e.g. tasks, determining team and leadership mechanism, timing). Using map 3 also functions as a stress test in terms of a pathway's ability to be charted from science to implementation (i.e. framework in Fig. 1) by making this pathway explicit (see Fig. 5). That is, how exactly are you going to make this project work? This activity forces projects, and therefore topics, to be sufficiently constrained and defined to be a plausibly tractable co-opetition project. To directly engage with science (i.e. a university-based researcher), a novel avenue of investigation into the physical world must be included, even if it is only a pilot study (see Hillier et al., 2019b).

5.2 Case study no. 1 – an illustration

Research in phases 1 and 2 allowed maps 1–3 (i.e. Figs. 3–5) to be completed in hindsight, as an illustration, for the TOGETHER project. Specifically, this included obtaining sign-off for open dissemination of these as part of a case study summary (case study no. 1) so that they can be made available to future Co-RISK participants as a two-page summary. These maps records what happened, but the plan evolved as the project progressed. Map 3, in particular, is strictly an exercise in hindsight. Limited space on the maps forces each point to be recorded in a concise way. This is by design. It masks complexity about in-depth thought that might be required later but encourages a holistic plan to be sketched out. Overall, the completed maps demonstrate their potential suitability for their intended task.

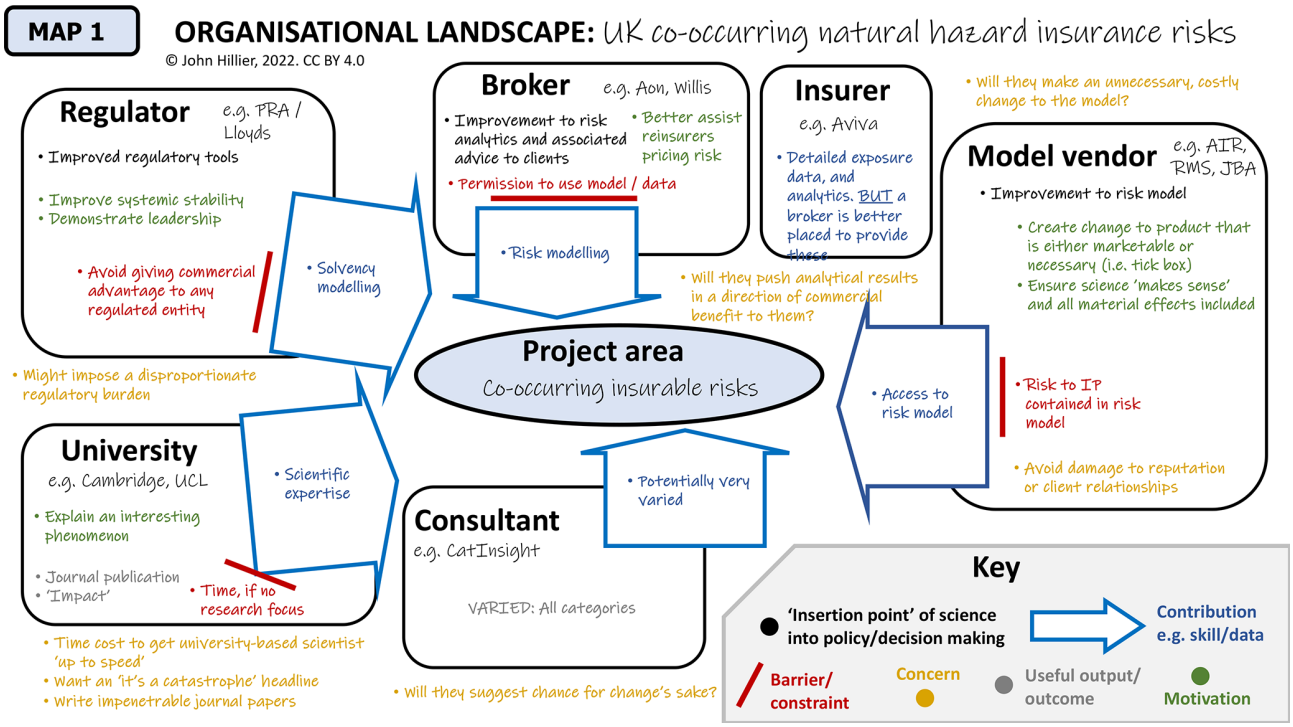

Figure 3. A mind-map, map 1 in the Co-RISK format, conceptualising types of stakeholders and their viewpoint in general terms on projects relating to the stated theme or project area. Created in hindsight to use case study no. 1 as an illustration for the trial Co-RISK workshop. This is also the basis for the blank and guidance used during that workshop. Concerns are inside boxes if they are about a stakeholder's own actions, and they are outside if they are the concerns of others about this stakeholder. The colour-coded typology is explained in main text.

5.3 Participant evaluation of Co-RISK

The theme of the first Co-RISK workshop was co-occurring natural hazards. This broader theme was selected as it encompasses the TOGETHER project and thus sits within the expertise and interests of the lead organiser and host (Hillier, Aon). Evaluation of this real-world trial of the Co-RISK toolkit is based on participants' responses ($n = 12$), integrated with reflections noted on the day by the two co-facilitators (university, industry) when discussed in Sect. 6.1. Industry participants ($n = 8$) were experienced in the (re)insurance sector, with careers ranging from 4 to 15 years, and, despite numbers being reduced by illness (i.e. COVID), each key organisation type (regulator, university-based scientist, model vendor, (re)insurer or broker) was represented at each of the three tables. Figure 6 displays participants' quantitative evaluation of Co-RISK.

When asked "was the Co-RISK workshop useful?", participants ranked six aspects of possible benefit on a Likert scale from 1 (not useful) to 5 (extremely useful). Most commonly, Co-RISK was ranked as 4 (very useful; thick horizontal bar in column **a** of Fig. 6). Most aspects (i.e. connecting with new people, identifying colleagues of similar interests, improved understanding of organisations' positionality and dimensions of positionality, and improved understanding of how to design a joint project) are statistically indistinguishable from participants' overall rank, with only the value of drafted projects themselves being lower, seen as simply useful (i.e. between moderately and very in column **b** of Fig. 6). Participants with significant experience (i.e. ≥ 10 years) in the insurance sector felt a lower level of benefit than the average of the whole cohort (blue square vs. triangle, column **a** of Fig. 6) but found it solidly useful (i.e. between moderately and very useful). Less experienced participants found Co-RISK very useful (blue triangles).

When asked "would you do a Co-RISK workshop again?", participants ranked on a scale from 1 (no) to 5 (certainly). Averaged across the three sub-questions (i.e. participate again with the same subject, participate with a different subject, participate again with a different subject, host), participants' ranks ranged from 2.7 (between unlikely and perhaps) to 5.0, with a mean of 3.8, closest to 4 (i.e. probably). A total of 9 of 12 (i.e. 75 %) of the participants would either probably or certainly participate in another Co-RISK session. Notably, the two participants who rated participating again as unlikely were experienced (i.e. ≥ 10 years) in the sector. Hosting future sessions is less likely than participating again. This is unsurprising given the greater investment of effort and reputation required to host rather than attend an event in a co-opetitive scenario (e.g. an individual's drive to negotiate a theme with internal and external stakeholders,

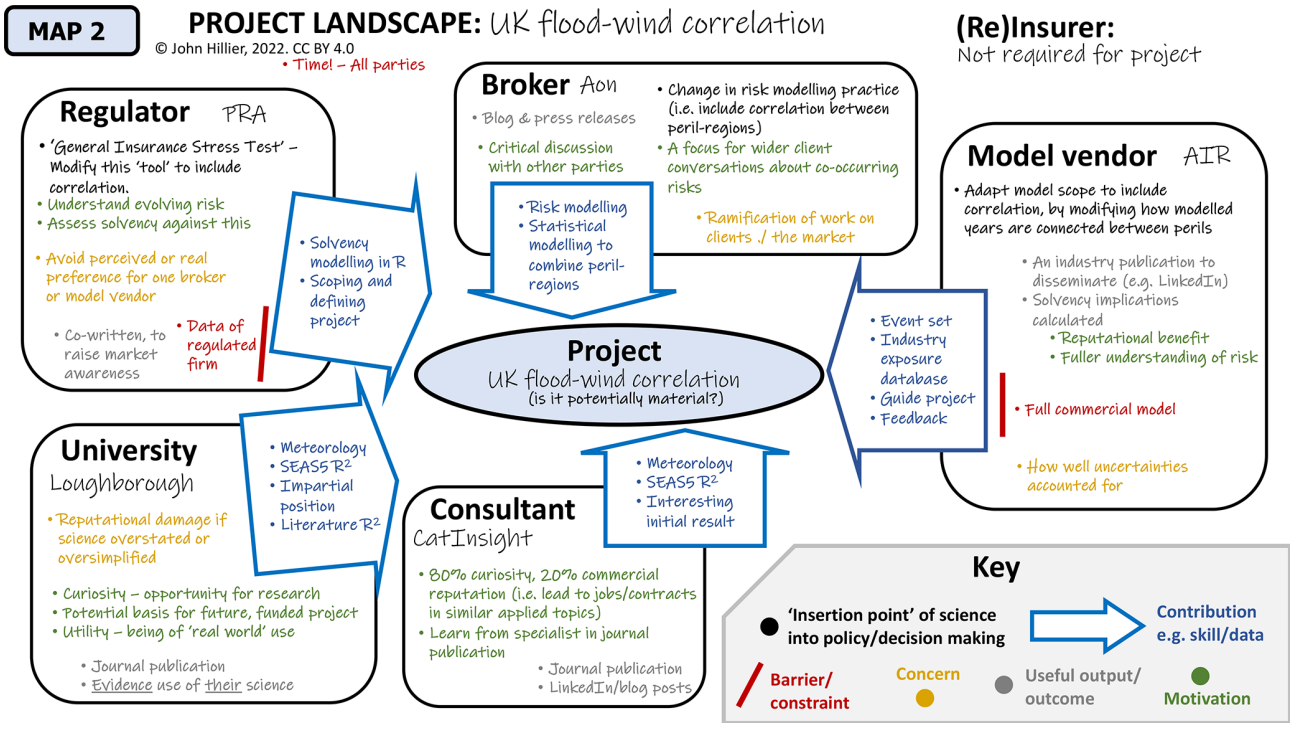

Figure 4. A mind-map, map 2 in the Co-RISK format, conceptualising in hindsight the stakeholders of the TOGETHER project together with their contributions, motivations, barriers, and concerns. Perhaps most importantly, the map identifies specific outcomes or outputs and insertion points denoting exactly where science might be incorporated into policy, practice, or decision making. Map 2 was created using case study no. 1 as an illustration for the Co-RISK workshop. This is also the basis for the blank and guidance versions of the map in the Co-RISK material – see Supplement. AIR has now rebranded to Verisk. Colour-coded typology explained in main text.

time spent in organising, significant use of personal capital, cost of room and refreshments).

The evaluation form (see Supplement) also encouraged qualitative responses, which were assessed in a thematic analysis. Participant IDs are in square brackets, e.g. [7] following the relevant quote. The first theme within the comments was about the tools (i.e. maps 1–3), how readily they are able to be used, and the level of facilitation, with feeling broadly summarised by one comment.

> Generally this (workshop) works really well to facilitate useful discussions . . . although filling in the sheets is difficult. [3]

Agreement on the utility of the maps is echoed elsewhere, although university-based scientists more readily saw the benefit in learning about positionalities of organisations in the insurance sector (maps 1 and 2), and (re)insurers saw more benefit from the project planning (map 3).

> Maps 1 and 2 were useful in developing understanding of stakeholders. (2 – scientist)
>
> Project time-line (i.e. map 3) more useful (4 – (re)insurer)

A number of challenges in filling in the maps were highlighted. These include not being familiar with the sector [2,3], not understanding the six dimensions of positionality defined in Sect. 4.2 and used in the maps [3], and difficulty in distinguishing the purpose of the different maps [11]. Some participants viewed positively a structure to the tasks that had room for adaptation [1], while others thought it would be good if tasks could "be more specific" [4]. One comment suggests a solution, greater support through increased facilitation, although this has implications for the duration of the workshop, time pressure, and attendance (e.g. of more senior participants).

> Unclear difference between map 1, map 2, and map 3. Might need more clear steer and transition support facilitation. [11]

The strongest theme within participants' comments was a desire for more time (e.g. a whole-day workshop), either to develop the projects further [2,4,5,6,8] or to network [1]. However, a tension was also noted in that a half-day, with the workshop length trialled, was probably the maximum possible time to spare out of a working day. It was suggested that this dilemma might be ameliorated by insisting on more preparation, perhaps taking topic suggestions before the workshop [4,5]. However, it is notable that, despite being given this option well in advance, none of the participants attempted to work up an idea before the in-person session.

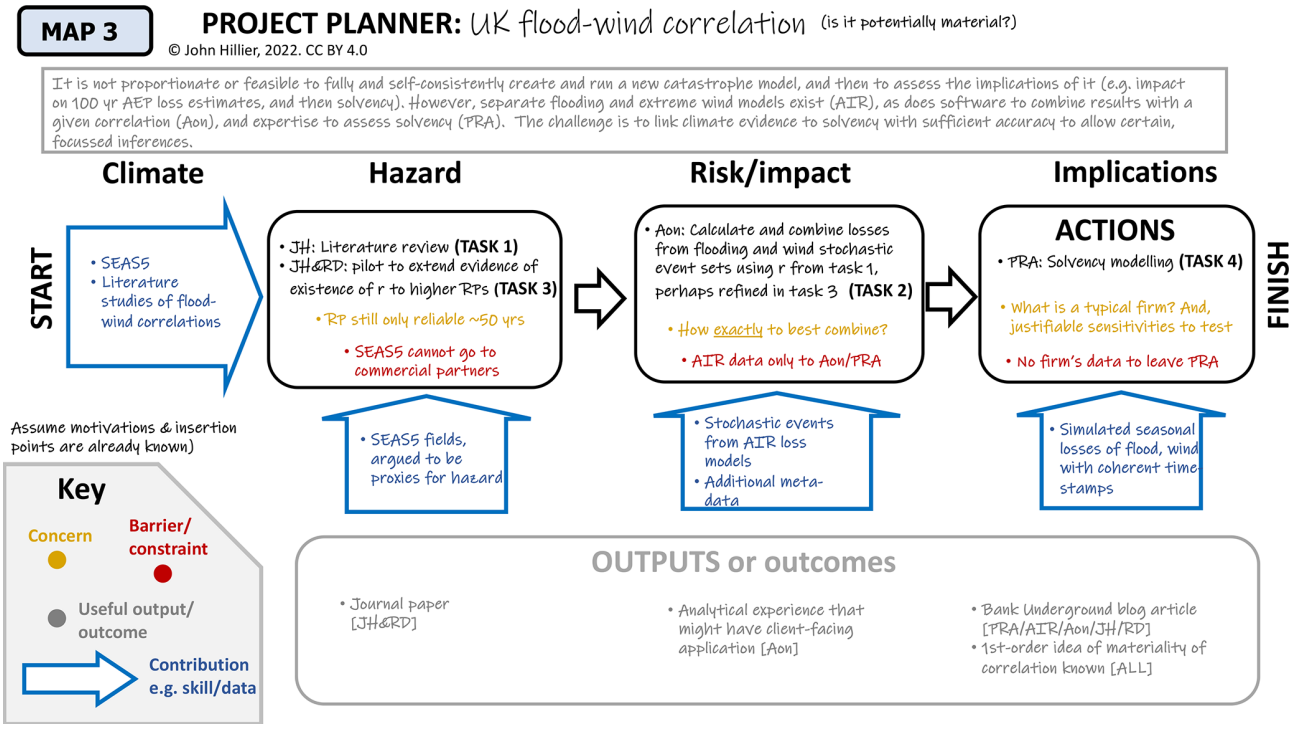

Figure 5. A planner created in hindsight for tasks and actions in a case study no. 1 project (TOGETHER), framed as a natural hazard risk framework that progresses from climate to implications (Fig. 1). It is tailored to a specified project in a bottom-up approach. Important elements include a pragmatic project design (top grey box) and tasks and outcomes relevant to each stakeholder (bottom). The plan accounts for restrictions (e.g. on data or information, which, in detailed form, can only pass between certain partners). This is also the basis for the blank and guidance versions of the map in the Co-RISK material – see Supplement.

In other comments, participants liked the opportunity to network, but [8] felt that a broader spectrum of the industry might be represented (e.g. small- and medium-sized enterprises – SMEs) and that more senior participants would be desirable [8,10]. Furthermore, it was suggested that it is worth considering removing unfamiliar terms (e.g. positionality) that might cause cognitive friction [5]. Framing the wrap-up summaries for the projects as a light-hearted "dragon's den" pitch for the best project was disliked by a few – "See little advantage to voting for the best project in the end" [6] – but was liked by most participants as a mechanism to retain participants' interest whilst using minimal extra time.

6 Discussion

Given Co-RISK's intention as a usable toolkit, with a broader ambition to aid the flow of environmental science into natural hazard risk assessment, two questions are selected for discussion. Did it work in practice, as a facilitated workshop, on the day? And, more broadly, what is its contribution to the ongoing endeavour of the translation of risk-related science? Note that quotes and direct attribution are not used for the evaluation of TOGETHER (research phases 1 and 2) as appropriate anonymisation would not be possible.

6.1 Co-RISK's performance in practice on the day

For Co-RISK, success was, broadly, to achieve sufficient buy-in and additionally to provide the three specific and tangible benefits promised to attendees (i.e. a list of participants' details to share, a ranked list of hot topics, and two to three drafted co-designed projects) alongside three intangible ones (i.e. opportunity to initiate and strengthen professional ties, a more holistic awareness of the sector, and thus an improved ability to design a collaborative project).

Co-RISK was trialled and well-received, most commonly rated as very useful, and a distinct majority of participants (i.e. 75 %) would either probably or certainly participate in another Co-RISK session (Sect. 5.3, Fig. 6). Moreover, it was hosted in a meeting room in the client suite of the London office of an international reinsurance broker (i.e. Aon), with Aon staff assisting facilitation, suggesting that it was deemed to have sufficient reputational and practical benefit to justify this. Similarly, despite last-minute non-attendance due to COVID, multiple (i.e. three) participants were attracted to represent each key organisation in the sector (regulator, university-based scientist, model vendor, (re)insurer or bro-

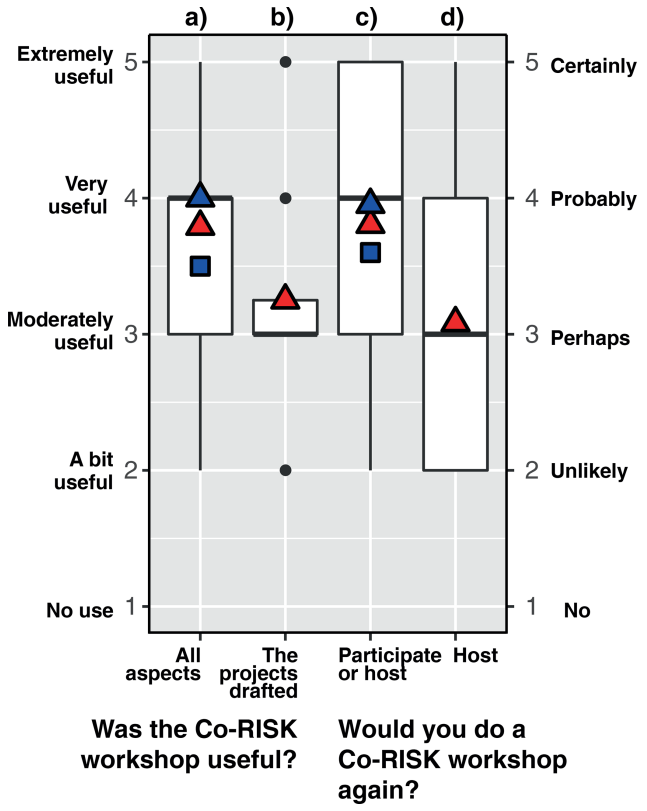

Figure 6. Participants' responses in evaluating Co-RISK on how useful the workshop was (Q3a–f) in a variety of respects (see main text) and on whether or not they would be likely to attend (Q4a, b) or host (Q4c) another Co-RISK workshop. Ranks given and their descriptions are on the y axes. Boxplots show quartiles 2 and 3 as white boxes, with a thick bar at the median and lines to the extremes with black dots for outliers. Red triangles are means. Blue markers are means distinguishing two subsets of participants; those with more experience in insurance (i.e. $\geq$ 10 years) are blue squares, whilst those with less experience are blue triangles. All differences shown are statistically significant (i.e. $p < 0.05$ – two-sided tests; t test; and Wilcoxon, a.k.a. Mann–Whitney test), except for the difference in likelihood for attending a Co-RISK workshop again for more vs. less experienced participants (Pearson's r, $p < 0.1$, for rank vs. years experience).

ker). So, broadly, judged in terms of achieving sufficient buy-in, this trial of Co-RISK was a success.

The specific benefits to participants were also delivered. Tangible benefits – the list of contact details, the list of 11 hot topics, and three jointly drafted co-opetitive project proposals – were successfully created and circulated to attendees. Moreover, participants dominantly felt Co-RISK to have been useful (very or moderately) in delivering the promised intangible benefits (Sect. 5.3, Fig. 6), in particular the networking opportunity; as one participant remarked, "The community is not great at doing these events." Two main tensions, however, can be identified in feedback and facilitators' self-reflection: (i) duration of the workshop and (ii) balancing expectations of groups of attendees.

Dominantly, participants wanted more time (e.g. a whole-day workshop) and greater participation from senior colleagues. This is in tension with participants with more industry experience (i.e. $\geq$ 10 years) who felt Co-RISK added less value for them, likely due to their higher self-assessed level of prior knowledge (i.e. of organisations and their positionality), and would be less likely to participate again. A second tension is that scientists from outside insurance more readily saw the benefit in learning about positionalities of organisations in the insurance sector (maps 1 and 2), and (re)insurers saw the benefit of project planning (map 3). The latter of these tensions can be readily dealt with by means of a fuller explanation by the facilitators; the former (i.e. time) is a more difficult challenge.

The feedback "filling in the sheets is difficult" [3] mainly emphasises the need for Co-RISK in that the actuality of planning co-opetitive projects to translate risk-related science *is* difficult. However, at least partly, it reflects the limited duration (3 h) allowed for the ambitious aim of full-spectrum project planning (i.e. conception to detailed planning), with facilitators' reflections mirroring those of participants.

> Stronger facilitation would be useful, but it would take more time … e.g. guide the participants through the map, checking that they've got all the elements (e.g. of positionality) on their maps, using all the prompts. [facilitator 1]

> Participants need to be strongly encouraged to clearly define the scope of their project. [facilitator 2]

> Posing specific questions (e.g. Who pays? Who implements?) to groups is useful to guide their thinking. [facilitator 2]

In the β-test trial, with thoughts and discussion clearly flowing well (e.g. for map 1), it was decided to minimise facilitator interruptions, although having time for both facilitation and discussion would have been preferable. Facilitators also noted that swapping tables, such that a second group of participants could review a plan, would likely produce more robust project plans. Indeed, reviewing the project drafts confirms that they could benefit from more work, perhaps explaining why the value of drafted projects themselves was rated lower than other elements of Co-RISK (i.e. useful). This may also be why none of the projects have been taken forward (i.e. kicked-off workstreams), to the authors' knowledge, in the 18 months following the β-test workshop. Co-RISK's ambition to jointly draft actionable collaborative projects from scratch within a single workshop is therefore apparently too ambitious.

To produce genuinely actionable project plans, the future challenge is to rapidly capture the attention of more senior

staff who might champion the uptake of a project, whilst other staff spend more time on the detail. Perhaps the solution is two-fold. First, use the 3 h Co-RISK workshop as an exercise in scoping a theme, network building, familiarity raising with regard to a sector, and considering possible rules of engagement. Then, to actually produce actionable projects, run Co-RISK as a working group with a series of meetings, kicked off by a compressed high-impact scoping exercise for more senior staff (i.e. 10 hot topics and map 3 only to plot projects on a graph of desirable vs. tractable).

6.2 Positionality, paradoxes, and Co-RISK's contribution

Co-RISK's primary contribution is in encouraging practice, not in developing new theoretical insight. It synthesises insights from a number of domains of knowledge for the purpose of the translation of risk-related science so that each future project team does not need to do this anew. Knowledge exchange projects have a cognitive dimension: do participants understand one another? They also have a power dimension; for instance, how does one deal with opportunistic behaviour, collective action dilemmas, and information asymmetry? While the cognitive dimension is well recognised in the stakeholder engagement literature (Phillipson et al., 2012; Bamzai-Dodson et al., 2021), the power dimension is less so (although, see Kujala et al., 2022). Co-RISK is specially designed to deal with this power dimension by ameliorating the organisational paradoxes that commonly occur in interactions between academia and finance. This subsection elaborates upon how it does this for several particulars identified above and ends by summarising Co-RISK's contribution to geoscience communication.

6.2.1 Identification of potentially viable co-opetitive projects and building awareness of positionality

Co-RISK's ambition is to jointly draft or co-design actionable collaborative projects between firms and research institutes (e.g. universities) that may have different priorities, namely co-opetitive projects. To do this, Co-RISK is designed to attempt to tackle many tasks simultaneously (e.g. acting as a facilitated focus to get a spectrum of organisations in tension in a room, upskilling potential participants with regard to the sector and scoping potential project topics of interest). In line with the paradox theory literature, accepting and not rejecting that tensions exist in these projects is a first step towards developing new and creative strategies to handle them (Stadtler and Van Wassenhove, 2016; Lewis, 2000; Clegg et al., 2002). Thus, identifying potentially viable co-opetitive projects requires participants to build their awareness of the positionality of all key organisations that will necessarily be involved.

Sometimes, there is significant cognitive distance between participants with differing backgrounds and experience in different organisations, leading to concerns about potential partners (Fig. 3, orange text outside boxes) that might be well or poorly founded. Illustratively, firms need a tangible input to a project (e.g. TOGETHER, Sect. 4.2) to claim credit later and are thus keen (rather than reluctant) to commit resources to a valuable project. This is perhaps surprising (e.g. to a university-based academic), which mirrors the incomplete knowledge in industry of what drives and motivates a modern university-based scientist (e.g. Hillier et al., 2019b; Lam, 2011). Positionality is complex (e.g. maps 2 and 3), but Co-RISK demonstrably increases awareness of it (Sect. 6.1) and, indeed, is designed to do so through participatory discussion in small groups of four to six, aided by facilitator prompts. An illustrative prompt is "Do you understand the viewpoints of all stakeholders and any tensions?". However, the majority of prompts are turned to this purpose in a progressive learning arc (Sect. 5.1).

6.2.2 Build personal embeddedness

A necessary part of building a team for a co-opetitve project is embeddedness or knowing about the sector within which the project will be applied. As evidenced by the Co-RISK β test, this naturally grows with time for practitioners but is particularly pertinent for projects translating science-related matters to natural hazard risks as projects must be broader to include scientists (e.g. university based, Met Office). In this, Co-RISK participants felt that it helped, but doing it through in-person, small-group discussions would also help to build trust (i.e. trust that a scientist will not do anything unexpected and detrimental as they do not know otherwise).

6.2.3 Project partner selection

Another one of the functions of Co-RISK is to assist with partner selection; selection of compatible partners is an established suggestion to mitigate project tensions (Gulati, 1995; Kim and Parkhe, 2009). Maps 2 and 3 provide a forum for discussing partner combinations that might work considering their positionality (e.g. skills, barriers such as involvement of direct competitors) for a hypothetical rather than a (as yet) solidly intended project. Why is this necessary? In short, embeddedness (Grabher, 2004; Hess, 2004). With relationships between individuals and firms continuing after any given co-opetitive project, it is unwise to show preference for one partner, which could be interpreted as shunning another. One solution is facilitating the co-opetitive project by using an intermediary to coordinate (Stadtler and Van Wassenhove, 2016), a university-based and government-funded Knowledge Exchange Fellow (Hillier) in the case of TOGETHER and Co-RISK. Illustratively, the regulator (Bank of England, PRA) must "avoid perceived or real preference for any one broker or model vendor" (map 2) and as such asked Hillier to approach potential partners for TOGETHER. Similarly, to avoid expressing preferences (e.g. for one client insurer or model vendor), Aon hosted and provided staff to assist fa-

cilitating but did not invite the participants nor market the Co-RISK workshop as an official Aon event. Coordination and lead facilitation was done by Hillier.

Sensitivities such as these also feed into the number of partners for a co-opetitive project. A "small and agile group" (Sect. 4.1) in which "You didn't have to worry about offending people … You could voice your opinion" (Sect. 4.2) was seen as a reason why TOGETHER was successful. In these insights from participants in TOGETHER, a small group and the ability to freely voice thoughts are closely tied together in that there are no two direct competitors (i.e. performing exactly equivalent roles) in the room when sensitive project details are discussed (e.g. two brokers or two model vendors). Whilst not resolving this paradox, Co-RISK is designed to assist by putting a mitigation in place through the mechanism of a facilitator prompt (see Sect. 4.2) explicitly directing participants to consider organisations' sensitivities for map 1. The alternative is a large industry initiative or project where all parties who want to can join in, although the obvious compromises here are organisational overhead and agility.

A final consideration for partner selection relates to the power dynamics (e.g. Kujala et al., 2022), specifically targeted by the prompt for map 1: who has the power to set the agenda and motivate action relating to this type of question? Specifically, core or optional are defined by more than skills that can be contributed. For TOGETHER, interviews and discussions highlight that the involvement of the Bank of England (PRA) as sector regulator was a strong motivator for the involvement of others. Whilst start-up firms might be reticent (Fahy, 2022), this motivation is unsurprising for the established insurance organisations in TOGETHER as such firms typically prefer to engage to frame and translate (Gilad, 2012) or at least to be aware of upcoming approaches to regulation. Aligned with this, reciprocally, the PRA strongly wanted an output that was co-written with (i.e. with buy-in from) the sector (map 2) to avoid unilaterally pre-determining topics and overly driving the sector's agenda when others have considerable expertise that can be brought to bear (e.g. environmental science, risk modelling). They appear to note and are careful in applying their ability to set the agenda. How organisations handle this power to catalyse or steer debate and action will vary by scientific area and by industrial sector.

It should be noted that Co-RISK was trialled within an existing project ecology in the insurance sector, where the cognitive distance between participants was relatively low at the outset, and there was a degree of trust already established between the participants. This situation enabled us to focus on the power dimension and stress test its mechanisms to tackle organisational paradoxes when evaluating the Co-RISK tool. Nevertheless, in future applications, it is likely that cognitive distances will be greater, making this dimension more important as potential misunderstandings can complicate any organisational paradoxes. Consequently it is paramount that a degree of epistemological pluralism (Miller et al., 2008; Raymond et al., 2010) is accommodated when extending Co-RISK to different sectors, cultures, countries, or types of environmental challenges. Key elements of epistemological pluralism are (i) refraining from insider jargon, including scientific jargon; (ii) being open to local knowledge; and (iii) indeed, striving towards conceptual sobriety, i.e. clarity through conceptual simplicity to demystify rather than complicate, when discussing the concrete innovation at hand (Van Meeteren and Bassens, 2024).

6.2.4 Rules of engagement

A very useful way of mitigating tensions is to establish a project structure and rules for the partnership (Stadtler and Van Wassenhove, 2016). Using an intermediary (e.g. consultant, independently run workshop) to coordinate a project or having a limited project scope knowledge exchange, perhaps using non-disclosure agreements to handle information flow, are useful mechanisms in co-opetitive project design (Bengtsson and Kock, 2000; Oxley and Sampson, 2004). Even with public dissemination of results jointly agreed upon (maps 1 and 2), publication demonstrates why a pre-agreed structure is vital when translating risk-related science. University involvement increases complexity compared to that of typical inter-firm co-opetitive projects. Even over-simplifying results carries a reputational risk for university-based scientists (map 2), with making publication conditional on results (e.g. wanting a high vs. a low value) an ethical red-line, whilst firms (e.g. brokers) worry about the "ramifications of work on clients/the market". In TOGETHER, the agreement was that nothing was to be released until all parties agreed to an acceptable presentation of the results, trusting that this could be agreement could be reached. Who was best placed to publish and the number of firms to publish were both debated before the final route was settled upon.

Within this, a process for determining acceptability is also needed. For TOGETHER, internal review by each project partner was used. External peer review, equivalent to that of academic journals, where independent editors adjudicate, would have provided additional reassurance of quality and rigour, but the necessary use of competitors as reviewers caused concern. In this set-up, reviewers could potentially delay or stop publication for commercial reasons. Academic peer review itself, for instance, a format designed to include the output of industry projects (i.e. *GC Insights* – https://www.geoscience-communication.net/about/news_and_press/2021-07-23_new-manuscript-type-gc-insights.html, last access: 20 November 2023), was not possible as the particular usage of proprietary data prevented sufficient transparency (e.g. open data). An alternative from a cross-industry specialist working group with 24 contributors (PRA, 2019) allowed reviewers to suggest changes but with editors' decisions and alterations being final. The need for early and ongoing discussion, however, is clearly

demonstrated, with an explicit facilitator's prompt built into Co-RISK's map 3.

6.2.5 Co-RISK's contribution

Co-RISK is differentiated in a number of ways from existing work and so adds value in addition to being a tool that is needed and did not exist. First, it draws on natural hazard risk frameworks, stakeholder mapping, and paradox theory (Fig. 2); however, as far as the authors are aware, the toolkit is unique in its combination of them for the purpose of enhancing the translation of risk-related science into modified actions via the co-creation of collaborative projects. The advantage of this is that it is not necessary for future workers to adapt or blend general or related tools or frameworks themselves, perhaps something that might be duplicated a number of times. Illustratively, some dimensions of positionality (e.g. barriers, concerns) identified for TOGETHER in Sect. 4.2 are well recognised in the fields of organisation studies and economic geography, but the set has not been brought together in a context similar to this. Moreover, the inclusion of academic interests broadens the scope of the discussion of paradox and tension in co-opetition frameworks further than the usual inter-firm frame. Second, Co-RISK is unusual in being intrinsically participatory. For instance, it does not involve the mapping of stakeholders by an outsider or other (e.g. Walker et al., 2008); rather, the mapping is by stakeholders (including university-based researchers) for stakeholders. This participatory approach is in line with best pedagogical practice in the sphere of knowledge exchange (Reed, 2008), avoids translation errors between participants and a third party doing the analysis, and has the advantage to participants of increasing their skills (e.g. awareness of positionality) and thus their suitability to be in a project. Third, Co-RISK sits on a higher level of abstraction than a framework, so a diversity of stakeholders and research problems can be accommodated, depending on the context and risk quantification required. It is a toolkit (i.e. training material) to create task-specific frameworks, allowing for the creation of project plans of usable complexity that are holistic – spanning the whole spectrum from weather and climate to their implications (i.e. Fig. 1) – yet detailed. In doing so, it avoids the perceived proliferation frameworks, either increasingly complex generalisations or task-specific frameworks, i.e. to which the response might readily be "Not another multi-hazard risk framework!". As such, it is possible to position it as not (just) another natural hazard risk framework.

So, we believe that Co-RISK is a novel toolkit with a strong theoretical and practical basis to be highly useful, even if a wider range of delivery options (e.g. as a quick scoping exercise or extended into a multi-event series for a working group) need to be explored.

7 Conclusions

Co-RISK is novel in its synthesis of fields of study (i.e. natural hazard risk frameworks, paradox theory, stakeholder mapping), tailored to the purpose of aiding in the translation of risk-related science, and is a toolkit for this purpose. It, or a similar tool, is needed as embeddedness (familiarity with a sector) is necessary yet not sufficient for partners of a co-opetitive project (i.e. for joint benefit but including those with competing interests) due to complex positionality (e.g. skills to contribute, barriers, and motivations) that creates tensions or paradoxes requiring solutions to mitigate them.

From reflections, interviews, and a β-test trial, it has been demonstrated that a Co-RISK workshop held in person can assist with co-designing and planning a co-opetitive project, although expecting to create actionable projects from scratch in a 3 h session is too ambitious. In addition, the following conclusions can be drawn:

- A Co-RISK workshop can assemble potential project partners, be a scoping exercise for topics of interest, and build embeddedness (familiarity with a sector) and positionality (awareness of the viewpoints of other organisations), particularly for less experienced individuals; these are critical elements of a viable project.
- It is the start, not the end, of a collaborative journey.
- To actually draft actionable projects, a working group series of meetings might be necessary.
- For previously defined projects, Co-RISK might be a useful basis for discussing many details (e.g. sensitivities, possible contributions) that may later hinder the smooth progress of projects or render them unviable.
- Co-RISK originates in the consideration of financial risk (e.g. insurance, mortgages, catastrophe bonds). Ultimately, application to a variety of sectors is envisaged, including infrastructure (e.g. rail, road, telecommunications, power).

Appendix A: The TOGETHER project – a motivation and evidence base for the Co-RISK toolkit

The TOGETHER project was the inspiration for creating the Co-RISK toolkit, and reflections upon TOGETHER were used to create the initial version of Co-RISK. A short description of the project is therefore useful background to Co-RISK. TOGETHER was born of the need to ensure that any likelihood of adverse scenarios occurring together (i.e. correlating) across risks is appropriately depicted in the models (re)insurers use. This section is a brief, precise report on TOGETHER, published in the Bank Underground blog of the Bank of England (Prudential Regulation Authority – PRA), co-authored by Aon, Verisk, CatInsight, and John K. Hillier (Hadzilicos et al., 2021).

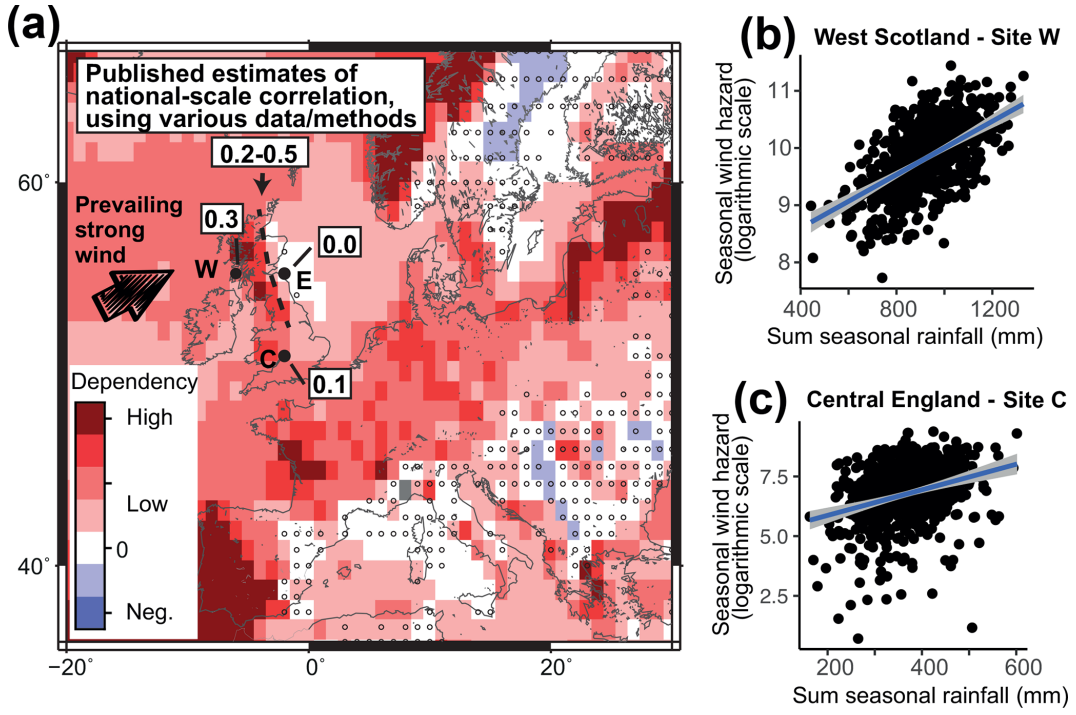

Figure A1. Spatial dependency of proxies for flooding and wind damage in Europe, based on Hillier and Dixon (2020), with minor modifications from the presentation in the Bank Underground summary of the TOGETHER project (Hadzilicos et al., 2021) – image © CC BY 4.0 Hillier 2021. **(a)** Map of dependency, coloured according to uplift in an impact-based proxy for wind hazard in wet vs. drier winters (October–March) in 600 years of SEAS5 hindcast data. Numbers are estimates of correlation (Pearson's r^2). Panels **(b)** and **(c)** are scatterplots of the underlying data for sites W and C, respectively.

All models are, by design, a simplification of the real world, and insurers need to decide carefully which aspects of the real world to incorporate. UK property is exposed to weather risk, but in 2021, only a few insurers assumed that the tendency for major windstorms to co-occur with inland floods during the winter season needed to be reflected within their model. A pilot study was conducted to consider whether or not UK insurers may need to reassess their modelling assumptions.

TOGETHER had three aspects. First, an analysis of a seasonal weather forecasting model (Fig. A1; Hillier and Dixon, 2020) identified more securely that major windstorm events tend to co-occur with inland floods on a seasonal timescale. Identifying a correlation is one thing, yet quantifying the potential financial impact to an insurance portfolio is another. So, second, a commercial catastrophe model, a type of software used by insurers to quantify the potential losses to their portfolios (see Mitchell-Wallace et al., 2017), was deployed (Verisk, Aon). This analysis found a 5 %–10 % effect on joint net losses (i.e. after reinsurance) for an extreme but plausible event (1-in-200-year return period). However, insurers' internal models are complex as they depict the range of potential risks that an insurer is exposed to. Hence, a change to the losses of a single model element such as natural hazard risk may – or may not – impact the firm's overall capital position, reflected in its solvency capital requirement (SCR). Thirdly, therefore, implications for an illustrative firm's SCR were modelled (PRA), finding a capital impact in the low single-digit percentages. From this work, the following main conclusions were drawn.

- This pilot study challenges the existing assumption, providing an initial indication that the correlation between windstorms and inland floods is underrepresented in insurers' models.

- Our test case showed that the neglected correlation might plausibly result in a low single-digit underestimation of insurers' capital allowance.

- This is not alarming by itself but indicates that an aggregation of underrepresented correlations could raise risk management concerns – if not capital ones – particularly as this could be changing as climate changes.

The project's key message is summarised in the report title "It's windy when it's wet: why UK insurers may need to reassess their modelling assumptions", and this has fed into a modification of the Bank's General Insurance Stress Test (GIST) for 2022 (Bank of England, 2022). Reflections upon the TOGETHER project (Sect. 4.1) provide a useful means

by which to highlight facets typical of and necessary to consider when planning collaborative projects to translate risk-related science into modified actions. These insights have guided the development of the Co-RISK toolkit.

Data availability. All data used or interpreted are in the figures, text, and/or Supplement.

Supplement.

- The Co-RISK toolkit β version, including maps (.pdf, .pptx), slide pack, and facilitator guidance, is provided for free and open use under a creative commons licence CC BY 4.0, noting that this allows for commercial use (e.g. adaption, building on, redistribution), but credit should be given to the creator. Specifically, a two to three sentence communication to the lead author (John K. Hillier) containing non-sensitive specifics of use (e.g. date, location, participant numbers, purpose, and outcome) would be greatly appreciated as evidence to justify the funding used to create Co-RISK.

- Anonymised responses evaluating the Co-RISK toolkit β version can be provided upon reasonable request.

The supplement related to this article is available online at: https://doi.org/10.5194/gc-7-35-2024-supplement.

Author contributions. JKH conceived the project, led the workshop, and created the figures. JKH and MvM jointly designed and conducted the data collection, and all aspects of the writing and analysis were done jointly.

Competing interests. At least one of the (co-)authors is a member of the editorial board of *Geoscience Communication*. The peer-review process was guided by an independent editor, and the authors also have no other competing interests to declare.

Ethical statement. Ethics approval was obtained through the Ethics Review Sub-Committee at Loughborough University. Note that all text in case study no. 1, apart from the participants' reflections, is a precise report (deliberately verbatim to the maximum extent possible) of a public domain blog post reporting on the TOGETHER project (Hadzilicos et al., 2021), and, in addition to research consent, each organisation (Aon, Bank of England, Verisk) has undertaken its own internal checks to ratify open-access dissemination in the Co-RISK toolkit (e.g. figures in Sect. 5.2). Some specifics, such as names of organisations, can therefore be reported.

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