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-organizational 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 deals with navigating the genuine tensions between industry and research organizations that stem from their differing roles. Specifically designed to ameliorate the organizational 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 application is envisaged 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 a mutually beneficial. Examples of such endeavours include coping with a changing climate (World Bank, 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 in cooperation across organizational boundaries. By designing an accessible tool-kit (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 in the consideration of financial risk (e.g. insurance, mortgages, catastrophe bonds).

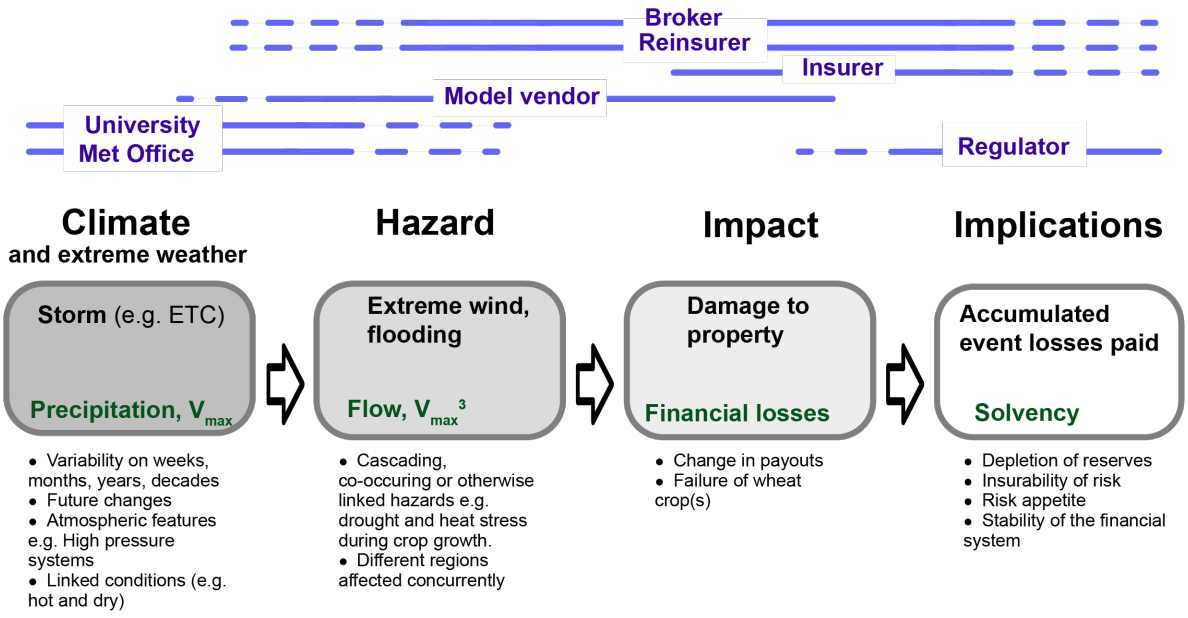

Figure 1: Schematic framework of the progression from scientific study of climate and extreme weather (left) to the implications if the risks that these represent are realised (right), synthesised from Fig. 1 of Hillier & Dixon (2020), Fig. 8 of Bevacqua et al (2021) and 'impact pathway' in Fig. 5 of 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 actions at each stage. To translate a selected piece risk-related science into (re)insurance this spectrum must be traversed, and as relevant organisations occupy distinct positions this diagram is a useful conceptualization 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.

Co-RISK originates in a recent, successfully completed collaborative project on mitigating jointly occurring flooding and extreme wind risks in the insurance sector dubbed 'TOGETHER' (Hadzilicos et al., 2021). TOGETHER's participants spanned the spectrum of relevant organisations from university to regulator (Figure 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 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 tool-kit or other training material that might assist many others to do 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 span the spectrum from hazard to impact (Figure 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, 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 development 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 Figure 2, and are further introduced below.

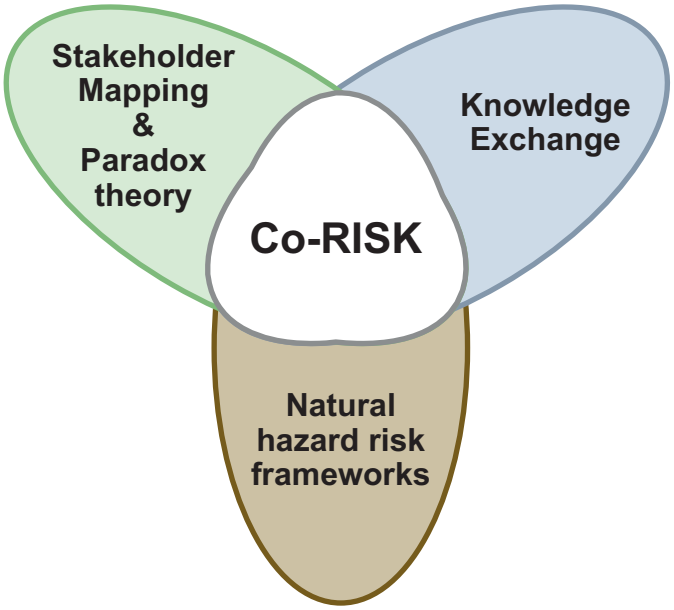

Figure 2 – Illustration of the knowledge domains that are combined in the creation of the Co-RISK toolkit. Its purpose is Knowledge Exchange, the translation of risk-related science into modified decisions, processes or policy in the wider world. Stakeholder mapping and paradox theory provide a means 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.

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 implications of impacts (Figure 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 financial impacts of physical climate change (PRA, 2019), for instance, has 'Identify 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., 2019a). Frameworks in a (re)insurer led assessment of climate change implications included 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 of potentially 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), reaches to loss, but omit to quantify 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 and framework spanning from climate knowledge to its implications that is yet simple and useable as it is task-specific, in this case to create an impactful change from scientific research.

Stakeholder management and mapping are key skills in a multi-participant projects (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 (e.g. Walker et al., 2008). For Co-RISK, mapping is restricted to stakeholders' viewpoints on the project (e.g. concerns, motivations), and is aligned with the aim of overcoming possible inter-organisational tensions as described below.

The design of the Co-RISK toolkit was motivated by a pragmatic desire to organize, analyse and streamline the science-business interface in projects related to natural hazard risk. Particularly, it is designed to identify and allay the tensions that may arise within a collaborative project across the industry-science divide where organizational interests do not fully align. As such it incorporates insights from "paradox theory" (more in Section 2.2), a body of study in organizational studies that seeks to understand ways to overcome tensions in inter-organizational partnerships where cooperation between competing

organisations is mutually beneficial (Smith et al., 2017). Tensions are typically felt for both organisations and individual agents representing these organizations, which 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 (Figure 2) but, 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. Second, it is unusual in being intrinsically participatory. For instance, it does not involve the mapping *of* stakeholders by an outsider/'other' (e.g. Walker et al., 2008), rather the mapping is by stakeholders (including university-based researchers) for stakeholders. 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. Figure 1) – yet detailed.

This paper describes the action research approach used to design Co-RISK and evaluates its implementation in a 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 organization studies and economic geography is presented to understand the paradoxes and tensions inherent in collaborative university-industry projects (Section 2). Secondly, the action research methodology used to create and evaluate Co-RISK is described (Section 3). After this, the research results used to create Co-RISK are outlined (Section 4) and then Co-RISK toolkit is described and evaluated (Section 5). Finally, in Section 6 Co-RISK's performance in practice 'on the day' in its trail is evaluated, and Co-RISK's ability to ameliorate the organizational 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 organizational paradoxes, where trust between participants in organizational 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 specialized expert knowledge, bridging topical specialisms, regulatory and legal insights, historical transactions data, as well as 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 for 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/regulatory and environmental science experts (Weinkle, 2020). As these knowledges 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 partners among project participants. Scholars and practitioners are part of shared or overlapping communities of practice lubricated by being part of the same industry, or indeed being part of the same localized industry cluster (Noteboom, 2004). Financial centres, or world cities, have been identified as important clusters of highly specialized knowledge pertaining to financial products where interorganizational 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 Ch. 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 most (Timms et al., 2022). For primary insurers, who sell directly to individuals and companies, overpricing loses customers whilst under-pricing leads to financial loss. Similar applies for reinsurance (insurance for insurers). The companies providing advice and support (e.g. brokers) profit by arguing they do this better than their competitors who do similar. The PRA has dual aims, 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 wants 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., 2019b). 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 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 to start 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 a continuous management of paradoxical tensions.

2.2 The challenge of coopetition: Inter-organizational 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 (Section 2.1), there is ample reason to organize 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 so having a knowledge advantage can easily turn into a competitive advantage. In the insurance industry this might be historical claims data which is 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 organizational contradictions and paradoxes may be handled is studied in the field of 'paradox studies', a subfield of organization 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 organization (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-organizational 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 (Grabber, 2004; Hess, 2004; Van Meeteren, 2014). A shared sense of dos and don'ts 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 coopetition project to be successfully designed and enacted. Logistical or organisational mechanisms, such as non-disclosure agreements to share 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 organization 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, Data & Ethics

Starting with a retrospective reflection upon a collaborative case study project (Hadzilicos et al., 2021) and, with cycles of collaborative analysis ending with a trail 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&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 #1). Between 20th and 27th September 2021, 5 semi-structured interviews were conducted by the co-authors (Hillier, 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-hour meetings of the TOGETHER project team (20th Nov 2021, 19th Jan 2022) were used to further the development of Co-RISK. Following up on selected topics from the 1-to-1 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/research organisations, catastrophe model vendor) at Aon in London 09:30-12:30 on 28th 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 topic 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.

Ethics approval was obtained through the Ethics Review Sub-Committee at Loughborough University. Note that all text in Case Study #1, apart from the participants' reflections, is a precis (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 Section 5.2). Some specifics, such as names of organisations, can therefore be reported.

4. Results: To design Co-RISK

Research *Phases 1&2* were individual and group reflections and discussion on TOGTHER, Case Study project #1 (Hadzilicos et al, 2021; Appendix A). They produced results that are reported in Sections 4.1-4.3, and were used to design, create and evolve Co-RISK.

4.1 Reflections on Case Study #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. 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) and co-written piece for the Bank Underground (Hadzilicos et al., 2021). Quantification of the implications (i.e. on solvency) of losses is a strength, but it was felt that 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?

- *Clear* task: A well-defined scientific starting point (Hillier et al., 2015; De Luca et al., 2017) requiring further study, recognised industry need (Dixon et al., 2017; FloodRe, 2019), and identified regulatory tool i.e. the General Insurance Stress Tests (Bank of England, 2019). This is important for a viable coopetition project.
- *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).
- *Benefit for all parties*, although identified in an *ad hoc* way, the stakes need to be sufficient.
- *Good awareness of positionality of others* (e.g. concerns, motivations, timescales, sensitivities), indicative of network embeddedness.

- *Trust already existed* (e.g. that the academic wouldn't sensationalize 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.
- *Clearly identified contribution from all*, which also leverages existing skills, practices and data.
- *Some luck* (i.e. in the 'soft' part of the insurance cycle where resource is not so constrained).
- *Internal reviews* of work done, and critique by project team.

What might have been done better?

- *A more formal planning process*, and clearer criteria for success.
- For flexibility, EDI (equality, diversity and inclusivity) and additional benefit, each partner could have paired with a junior colleague.
- *Process for external review* to allow input, to increase sector buy-in and improve the work, yet 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 organisation are needed for projects on a given theme (e.g. UK co-occurring hazards)?
2) *Map the project landscape* – What specific organisations / 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 & 2) were 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 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*: Things that will not be possible, or extremely problematic given the paradoxes and competitive interests of the partners, which might be cultural, institutional or personal (Scott et al., 2018; Ward et al., 2009).

- *Concerns*: Either about their actions, where these might be possible if certain conditions are in place, or about how other stakeholders may act. Here control mechanisms to enable the sharing of valuable and competition-sensitive data may sufficiently allay the paradoxical stress (Fernandez and Chiambaretto, 2016).
- *Motivations*: The variety of reasons to contribute to a project; perhaps a commercial or regulatory for a firm, or personal fulfilment, career progression or reputational benefit linking to enhanced societal and network embeddedness (Hess, 2004; Hillier et al., 2019a).
- *Outcomes*: Deliverables needed by each party, which may vary significantly (e.g. a publication, computer-based tool, testimonial evidencing an 'impact' i.e. change in actions).
- *Contributions* (e.g. time, skills, licensed software): What a stakeholder may be able to put into a project to help it achieve its outcomes, which may be more (e.g. data) or less (e.g. ability to chair/coordinate) 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*: A specific dimension for this specific endeavour, which should be precisely defined (e.g. a percentage change to metric *A* use in management process *B*).

These factors, when distinguished and considered, act to define the 'positionality' of the stakeholders (see Section 2.3). This typology, 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 Section 4.1. It is not realistic, however, to expect workshop participants to spontaneously understand well these dimensions and their wider implications, so emergent themes were 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 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?
- **Participant selection:** What types of organisation are core? 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*

- **Which 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/metrics:** *Exactly* what metrics or inputs are needed to make these changes?
- **Necessary analysis:** Typically, an evidential base will be more powerful an output that simply a viewpoint alone. So, what analysis will be done to provide the necessary inputs/metrics?

- **Participant selection:** A key quote from TOGETHER is '*The strength was the group*'. Can you see how to organise a group that will work?
- **Scientific research:** Is there an opportunity for a piece of new (novel) applied science?
- **Mitigating positionalities:** Have you identified means to mitigate any biases entities positionalities may bring, and tensions between firms?
- **Sector-specific experience:** Do all partners have sufficient experience in the sector?

It may also be useful to consider inter-personal positionalities. This is likely not something to write down (i.e. to be circulated later), but it's 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:** Have you found a pragmatic way, likely leveraging existing resources, of getting from scientific A to usable metric B?
- **Project management:** Who will chair/coordinate?
- **Publication –** How/when/if?
- **Agreed understanding:** How will you avoid misunderstandings/mistranslations?
- **Involvement of all:** Do all parties have at least one outcome/output to motivate them to stay involved? And, indeed, a task (e.g. specific analysis, writing/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 (e.g. on paradox theory) was added, along with an ice-breaker exercise to brain-storm 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, ensure that Co-RISK is applicable to topics 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').
- Keep the logistics simple (i.e. paper-based and not electronic).
- In-person would be preferred.

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) encourages the making of new contacts, iii) encourages 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&2* the Co-RISK workshop was created. This toolkit is described in Section 5.1. The main mind-map components (Maps 1-3) are retrospectively completed for the TOGETHER project as an illustration, and are shown in Section 5.2. Finally, results from research *Phase 3* are reported in Section 5.3 to allow an evaluation of Co-RISK from its real-world trial.

5.1 The Co-RISK 'toolkit'

Co-RISK's design, based on research *Phases 1&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 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 Figures 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 within experiential learning (Kolb, 2015).

In terms of stakeholder mapping and working to alleviate tensions within potential projects, as outlined in paradox theory (see Section 2), Co-RISK has several purposes aligning with its ostensible mission to output drafts of co-designed projects. For instance, throughout the 3-hour workshop, participants build understanding of the stance and abilities of key organisations (i.e.

'positionality') needed to answer their chosen question (e.g. Does co-occurring flooding and extreme wind exacerbate joint risk?), which is both an means to an end (i.e. project planning and structuring) and a highly useful by-product in itself. The main purposes are:

1. To help identify those co-opetitive projects where inter-organizational 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 selection.
4. To guide potential project management (e.g. 'rules of engagement')

Co-RISK is constructed around groupwork in tables of 4-6 participants. To incentivise 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 most the topics of most mutual interest to the cross-sector panel of participants on the workshops topic e.g. '*Co-occurring natural hazards*'; (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 are 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 (Supplementary Material), including the questions used as prompts (also see Section 4.2), and exemplar completed Maps from Case Study #1 (see Section 5.2). Maps 1 & 2 have two main elements, a box for each key stakeholder and space to identified 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 Section 3.

TASK 1: *Brainstorm project topics of interest*. The ostensible purpose of this task is to create a ranked list of most the topics of most interest to the cross-sector panel of participants on the workshop's topic 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, it allows identification of the co-optetive opportunities within the group of participants. The topics selected need to be valuable enough for participants to engage with, 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 icebreaker, starting with brief introductions around each table, laying a foundation for the necessary trust relations within the group (i.e. enhances embeddedness). 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 generate the positive emotional responses necessary to overcome the tensions inherent in coopetitive projects (Bengtsson and Raza-Ullah, 2017). Ideas are then collated for the workshop (all tables) and ranked on the premise that each participant has £30,000 to invest in working on an idea and a raised hand commits £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 Figure 3). Namely, who are the types of people you need to involve in the types of project identified in TASK 1? Why? And, what is their broad stance or viewpoint, including the business interests of the organization they represent (i.e. positionality)? Typical dimensions of simply two-dimensional stakeholder mapping are 'interest' versus 'power' or 'influence', but mapping can include 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) derive from research *Phases 1&2*.

TASK 3: *Map 2 – the project landscape* (see Figure 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 by, 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-organizational 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 minimized. 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 insertion points into decision-relevant policy or process (e.g. % change in 200 year 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, determine team and leadership mechanism, timing), which also functions as a stress-test that a pathway can be charted from science to implementation (i.e. framework in Figure 1) by making this explicit using Map 3 (see Figure 5). Namely, how exactly are you going to make this project work? This activity forces projects, and therefore topics, to be sufficiently constrained and defined to plausibly be a tractable coopetition 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., 2019a).

5.2 Case Study #1 – An illustration

Research in *Phases 1 & 2* allowed Maps 1-3 (i.e. Figure 3 to Figure 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 #1) so that they can be made available to future Co-RISK participants as a 2-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 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.

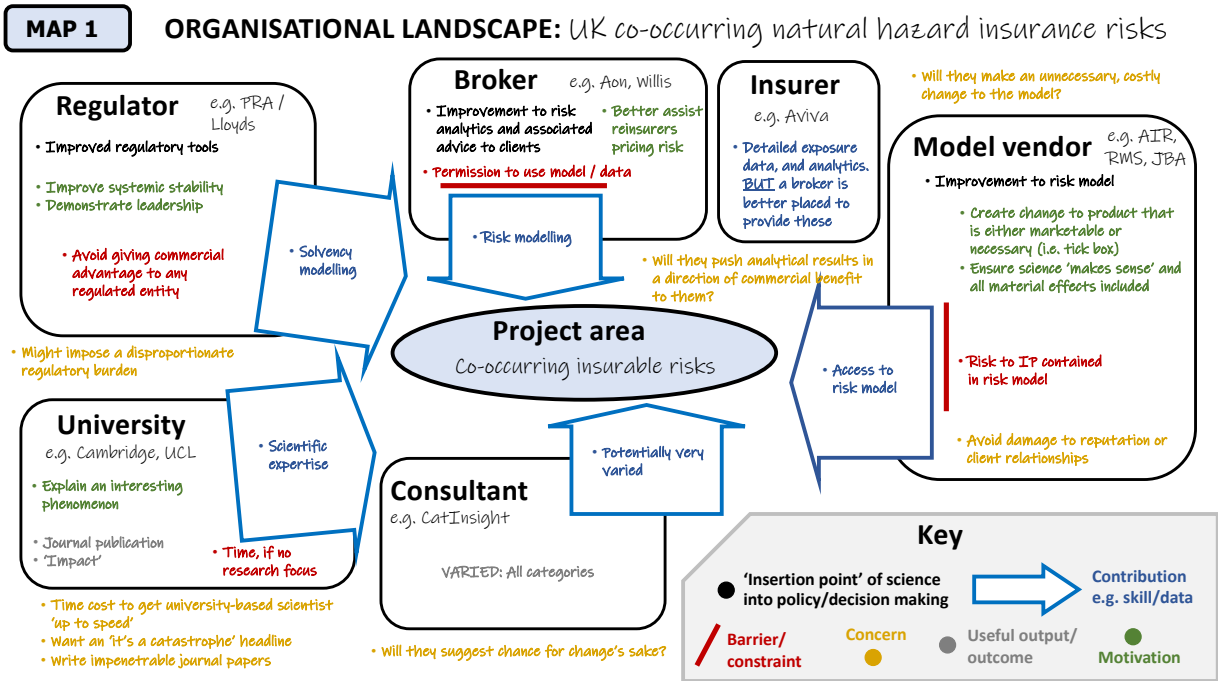

Figure 3: A mind-map, 'Map 1' in the Co-RISK format, conceptualizing types of stakeholders and their viewpoint in general terms on projects relating to the stated theme or project area. Created in hindsight to use Case Study #1 as an illustration for the trial Co-RISK workshop. This is also the basis for the blank and guidance used during that workshop. Concerns are inside boxes if about own actions, and outside if they are concerns of others about this stakeholder. Colour-coded typology explained in main text.

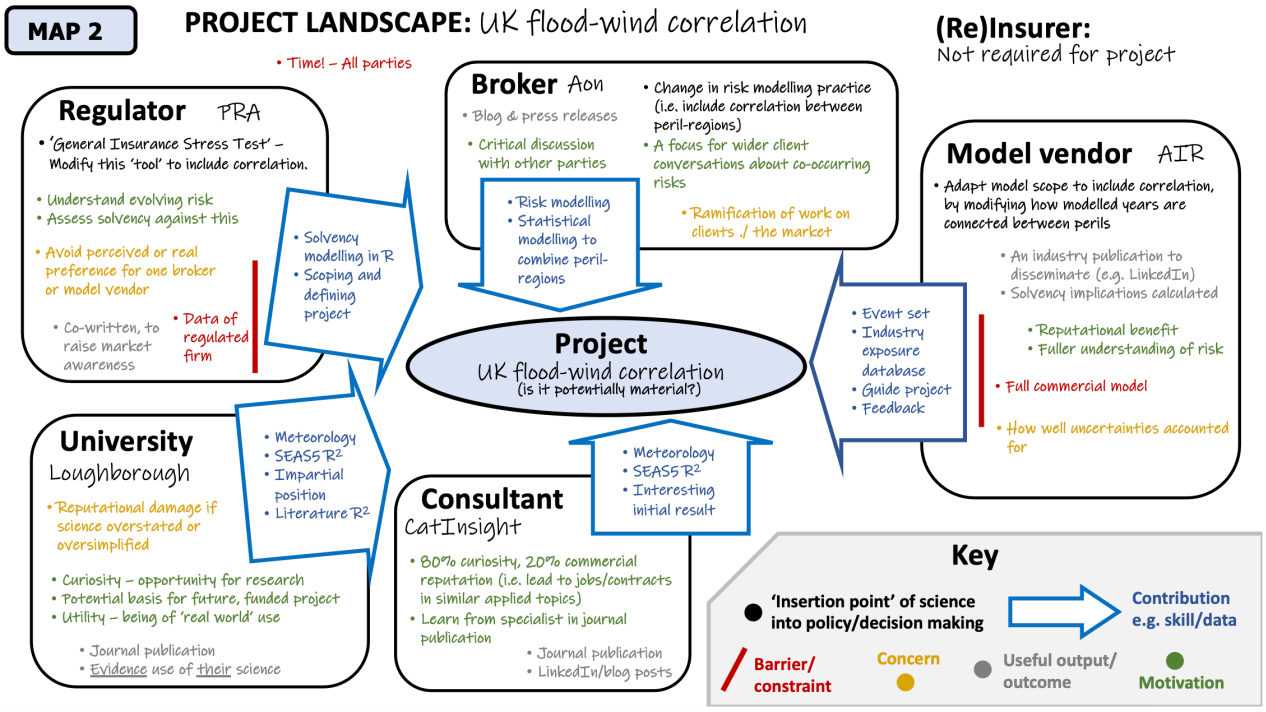

Figure 4: A mind-map, 'Map 2' in the Co-RISK format, conceptualizing in hindsight the stakeholders of the TOGETHER project together with their contributions, motivations, barriers, and concerns. Perhaps most importantly, the map identifies specific outcomes/outputs and 'insertion points' denoting exactly where science might likely be incorporated into policy, practice or decision making. Map 2 created using Case Study #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 Supplementary Material. AIR has now rebranded to Verisk. Colour-coded typology explained in main text.

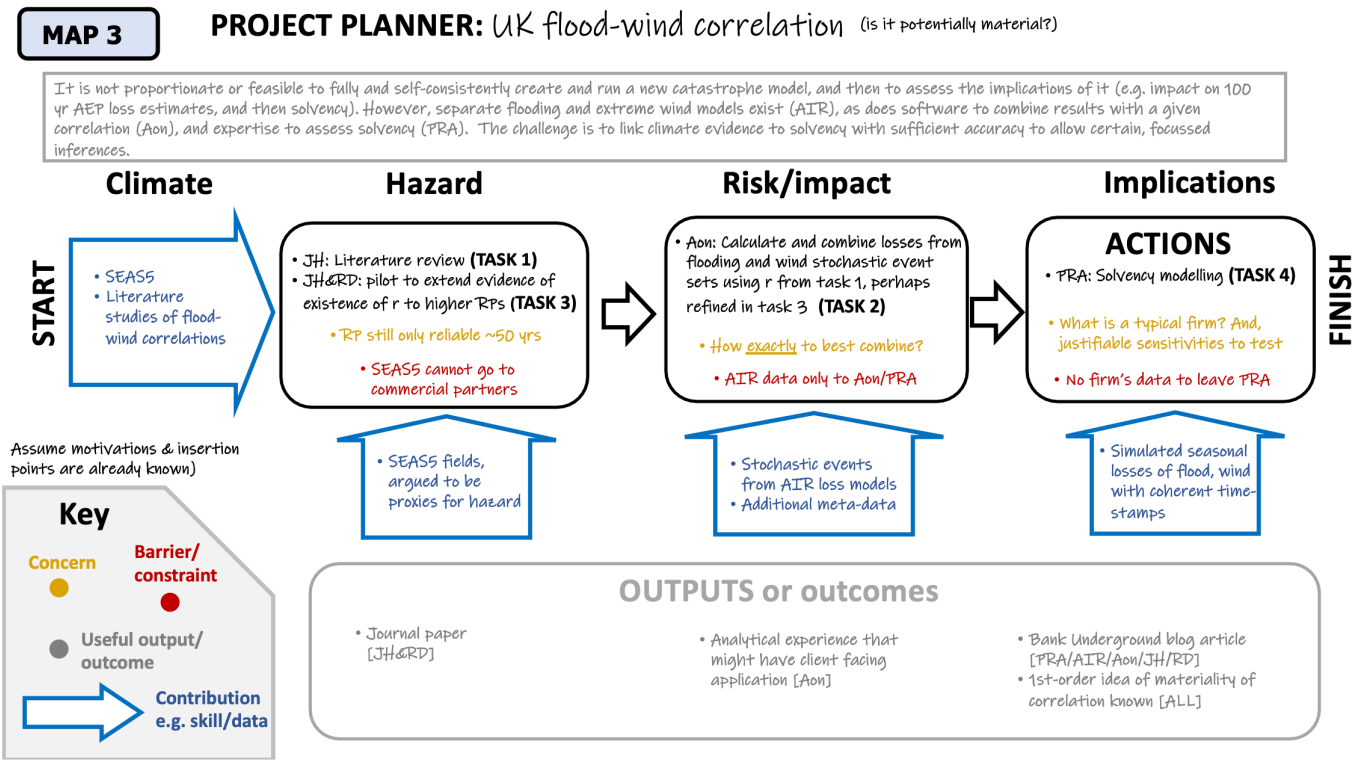

Figure 5: A planner created in hindsight for tasks and actions in a Case Study #1 project (TOGETHER), framed as a natural hazard risk framework that progresses from climate to implications (Figure 1). It is tailored to a specified project in a bottom-up approach. Important elements include a pragmatic 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 Supplementary Material.

5.3 Participant evaluation of Co-RISK

The topic of the first Co-RISK workshop was '*Co-occurring natural hazards*'. 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 Section 6.1. Industry participants (n = 8) were experienced in the (re)insurance sector, 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/broker) was represented at each of the three tables. Figure 6 displays participants' quantitative evaluation of Co-RISK.

Asked 'Was the Co-RISK workshop useful?', participants ranked 6 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', Figure 6a thick horizontal bar). 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'). Participants with significant (i.e. ≥10 years) in the insurance sector felt a lower level of benefit (blue square *vs* triangle, Figure 6a), but found it solidly useful (i.e. between 'moderately' and 'very' useful)

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, and 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'). 9 of 12 (i.e. 75%) of 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, unsurprisingly, less likely than participating again.

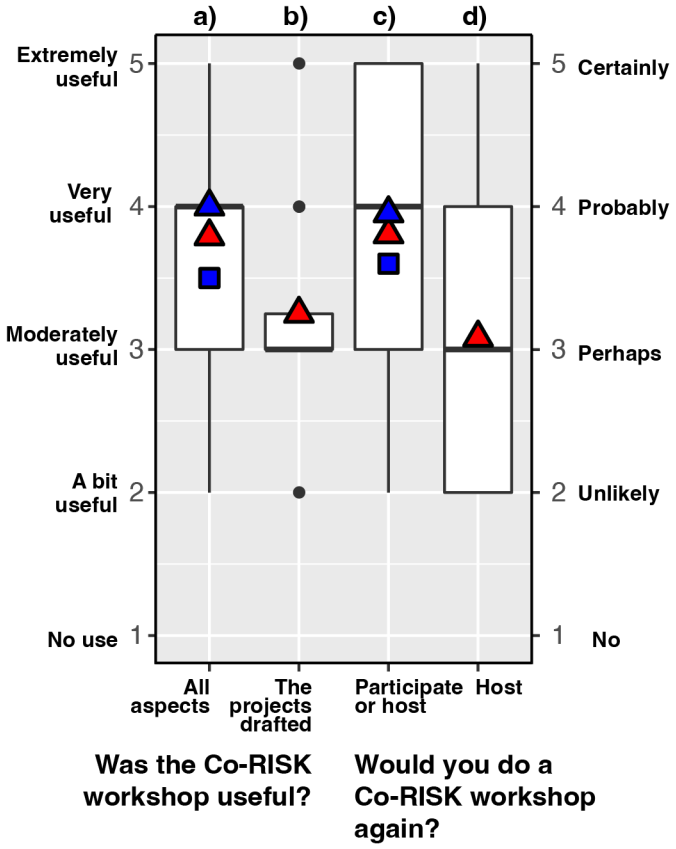

Figure 6: Participants' responses in evaluating Co-RISK on how useful the workshop was (Q3a-f) in a variety of respects (see main text), and on whether or not they would be likely to attend (Q4a,b) or host (Q4c) another Co-RISK workshop. Ranks given and their descriptions are on the y axes. Boxplots show quartiles 2&3 as a white box, a thick bar at the median, lines to extremes with black dots for outliers. Red triangles are means. Blue markers are means distinguishing participants with more experience in insurance (i.e. >= 10 years, squares) from those with less experience (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 re-attendance between more and less experienced participants (Pearson's r, $p < 0.1$, for rank *vs* years experience).

The evaluation form (see Supplementary Material) also encouraged qualitative responses, which were assessed in a thematic analysis. Participant IDs are in square brackets e.g. [7], and quotes in italics. The first theme within 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 and 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&2) and (re)insurers the project planning (Map 3).

'Maps 1&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, such as not being familiar with sector [2,3], distinguishing dimensions of positionality (e.g. 'contributions' from 'outputs' [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], others thought it would be good to 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 network [1]. However, a tension was also noted in that a half-day, the workshop length trialled, was probably the maximum it is possible 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 the option well in advance, none of the participants attempted to work up an idea before the in-person session.

In other comments, participants like the opportunity to network, but [8] felt that a broader spectrum of the industry might be represented (e.g. SMEs) and that more senior participants would be desirable [8,10]. And, 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 'dragons-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 mechanism to retain participants' interest whilst using minimal extra time.

6. Discussion

Given an intention that Co-RISK is 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&2*) as appropriate anonymisation would not be possible.

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

For Co-RISK, success was to achieve sufficient buy-in to actually happen, and additionally to provide the three tangible benefits promised to attendees (i.e. a list of participants details to share, a ranked list of 'hot' topics, and 2-3 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 it as 'very useful', and a distinct majority of participants (i.e. 75%) would either 'probably' or 'certainly' participate in another Co-RISK session (Section 5.3, Figure 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., 3) participants were attracted to represent each key organisation in the sector (regulator, university-based scientist, model vendor, (re)insurer/broker). So, broadly, Co-RISK was a success.

The specific benefits to participants were also delivered. Tangible benefits, the list of contact details, list of '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 (Section 5.3, Figure 6), in particular the networking opportunity; as one participant remarked '*the community is not great a 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. ≥ 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&2) and (re)insurers saw the benefit of project planning (Map 3). The latter of these tensions can be readily dealt with by 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 (3h) 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 the value of drafted projects themselves was rated lower than other elements of Co-RISK (i.e. 'useful') and that none of the projects, have been taken forwards (i.e. kicked-off workstreams) after the 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 3h Co-RISK as an exercise in scoping a topic, network building, familiarity raising about a sector and considering possible 'rules of engagement'. Then, to actually produce actionable projects, running 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. 'hot' ten topics and Map #3 only, to plot projects on a graph of desirable *vs* tractable, respectively).

6.2 Positionality, Paradoxes and Co-RISK's contribution

Co-RISK's primary contribution is in practice not in 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. Specifically, it is designed to ameliorate the organizational paradox. This subsection elaborates upon how is 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 & 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 about the sector, scoping potential project topics of interest). In line with the 'paradox theory' literature, accepting 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 it will be necessary to involve.

Sometimes, there is significant cognitive distance between participants with differing backgrounds and experience of different organisations, leading to concerns about potential partners (Figure 3, orange text outside boxes) that might be well or poorly founded. Illustratively, firms need a tangible input to a project (e.g. TOGETHER, Section 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., 2019a; Lam, 2011). Positionality is complex (e.g. Maps 2&3), but Co-RISK demonstrably increases awareness of it (Section 6.1), and indeed is designed to do so through participatory discussion in small groups of 4-6 aided by facilitator prompts. An illustrative prompt is '*Do you understand the viewpoints of all stakeholders, and any tensions?*' although the majority of prompts are turned to this purpose in a progressive learning arc (Section 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 apply. As evidenced by the Co-RISK β-test, this naturally grows with time for practitioners, but is particularly pertinent for projects translating science related 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 also help to build trust (i.e. trust that a scientist won't do anything unexpected and detrimental as they don't know otherwise).

6.2.3 Project partner selection

Another one of the functions of Co-RISK is to assist with partner selection, 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 an (as yet) solidly intended project. Why is this necessary? In short, embeddedness (Grabber, 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 facilitating, 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'* (Section 4.1), in which *'You didn't have to worry about offending people. You could voice your opinion'* (Section 4.2), were seen as reasons TOGETHER was successful. In these insights of participants of TOGETHER, a small group and the ability to freely voice thoughts closely tie together in that there are no two direct competitors (i.e. performing exactly equivalent roles) in the room when sensitive project detail is 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 Section 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 participant selection relates to the power dynamics, 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*? Namely, 'core' or 'optional' is defined by more than skills that can be contributed. For TOGETHER, interviews and discussion highlight that, unsurprisingly, the involvement of the Bank of England (PRA) as sector regulator was a strong motivator for the involvement of others. 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 be careful applying,

their ability to set the agenda. How organisations handle this power to catalyse or steer debate and action will vary by scientific topic and by industrial sector.

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 limited project scope knowledge exchange perhaps using non-disclosure agreements to handle information flow are useful in mechanisms in co-opetitive project design (Bengtsson and Kock, 2000; Oxley and Sampson, 2004). Even with public dissemination of results jointly agreed (Maps 1 & 2), publication demonstrates why a pre-agreed structure is vital when translating risk-related science. University involvement increases complexity over that of typical inter-firm co-opetitive project. 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 '*ramifications of work on clients / the market*'. In TOGETHER, the agreement was that nothing to be released until all parties agreed to an acceptable presentation of the results, trusting that this could be found. Who was best placed to publish and number of firms to publish were both debated before the final route was settled upon.

Within this, a process for determining 'acceptable' 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 rigor, but the necessary use of competitors are 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 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), 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 facilitators 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 (Figure 2) but, 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 etc …) identified for TOGETHER in Section 4.2 are well recognized 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 discussion of paradox and tension in co-opetition frameworks out from 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/'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 participant of increasing their skills (e.g. awareness of positionality) and thus 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. Figure 1) – yet detailed. In doing so it avoids the perceived proliferation frameworks, either increasingly complex generalisations or task-specific, i.e. to which the response might readily be *'not another multi-hazard risk framework!*'. As such, it is possible to for a position for 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 deliver 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 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 a 'co-opetitive' project (i.e. for joint benefit but including those of 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-hour 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, which 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).

Supporting material

- 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. adapt, build on, redistribute) but credit should be given to the creator. Specifically, a 2-3 sentence communication to the lead author (Hillier) containing non-sensitive specifics of use (e.g. date, location, participant numbers, purpose and. outcome) would greatly appreciated as evidence to justify the funding used to create Co-RISK.
- Anonymised responses evaluating the Co-RISK toolkit β version.

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Appendix 1: 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. 'correlate') across risks is appropriately depicted in the models (re)insurers use. This section is a brief precis of a 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 J. K. Hillier (Hadzilicos et al., 2021).

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 (Figure 7; Hillier & 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 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 altering as climate changes.

The project's key message is summarized 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 (Section 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.

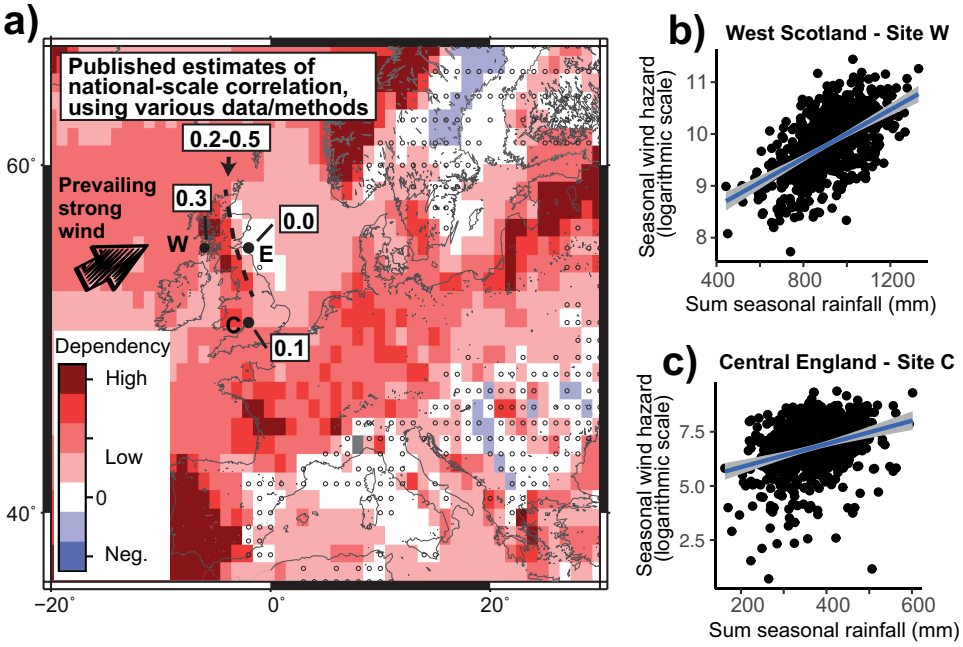

Figure 7: Spatial dependency of proxies for flooding and wind damage in Europe, based on Hillier & Dixon (2020) with minor modifications from the presentation in Bank Underground summary of the TOGETHER project (Hadzilicos et al., 2021) – image © CC BY 4.0 Hillier 2021. a) Map of dependency, coloured 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). b) and c) a scatter plots of the underlying data for Sites W and C, respectively.