D.(1.1) The Risk and Root Cause Analysis (RRCA) Framework

Work Package 1

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Abstract (for dissemination, 100 words)	This paper defines a framework for the holistic analysis of risk in PEARL as well as a specific risk and root cause analysis framework to guide research in Work Package 1 into the formation of risk and vulnerability in coastal regions. The paper then proposes methods to test a novel risk and root cause assessment framework through the in-depth investigation of case studies.
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Contents

1 Introduction

This paper presents work undertaken in Work Package 1 of the PEARL (Preparing for Extreme And Rare events in coastaL regions) project to define a framework for the holistic analysis of risk in PEARL as well as a specific root cause analysis framework to guide research in Work Package 1 into the formation of risk and vulnerability in coastal regions. The paper then proposes methods to test a novel risk and root cause assessment framework through the in-depth investigation of case studies.

The overall goal of PEARL is "to develop adaptive, sociotechnical risk management measures and strategies for coastal communities against extreme hydro-meteorological events minimising social, economic and environmental impacts and increasing the resilience of Coastal Regions in Europe." It advocates a holistic risk management approach based on the understanding that risk management is a socio-technical process, where the relationships between the parts are mutual, emergent, dynamic and non-linear and the strengthening of any one risk measure depends on the larger flood management process. In this context, the Risk and Root Cause Analysis Framework aims to enable systematic assessment of different root causes of risk, risk cascading and propagation of vulnerabilities at a greater depth than previous research. It also aims to improve understanding of the formation of risks and vulnerabilities in coastal regions, in particular those that give rise to small-scale events, albeit with high local impact.

This paper constitutes Deliverable number D1.1, the Draft PEARL RRCA Framework, which brings together the milestone objectives met in preparing the draft framework and a common methodology for investigating the framework. The paper summarises work derived from Tasks 1.1-1.3 under Work Package 1 of the PEARL architecture: understanding the formation of risks and vulnerabilities in coastal regions. The Tasks were:
Task 1.1: Conduct a desk study to identify the multi-dimensional drivers of vulnerability and risk (social, economic, ecological, cultural, political and infrastructural determinants of vulnerability) in coastal regions highly exposed to different hazards.
Task 1.2: Development of the PEARL RRCA framework (i.e., further enhancements of the FORIN methodology including integration with the UNU-EHS approach and improvement of the consideration of root causes and drivers of risk as stated in the Hyogo Framework of Action Mid Term Review including recovery and reconstruction).
Task 1.3: A structured literature review to assimilate existing literature on vulnerability analysis of flooding and recovery in coastal Europe. This will identify lessons learned and verify the appropriateness of the PEARL methodology to the European coastal context.

The paper serves as a basis for future research to be conducted in Work Package 1. The research framework contains a number of novel elements in the field of disaster risk research. It extends the use of FORIN methodology as a method for analysing root causes and brings together historical root cause analysis with a contemporary framework for understanding risk and assessing vulnerability, which can then form a basis for future scenario planning. As well as proposing methods to bring together a suite of tools (Qualitative root cause analysis, Agent-based modelling and Vulnerability assessment) to understand coastal risk, the paper also proposes the development of a potentially novel method for devising risk and root cause indicators, which could have a high impact given the potential to feed into current international discussions about root cause monitoring. The framework is then applied (through a preliminary empirical test) to the context of small-scale, local but high impact coastal disasters in Europe, where there has been little pan-European holistic analysis to date. The research will provide a guide as to the integration of root cause analysis and vulnerability assessments in management

and planning processes in coastal areas to reduce flood risks and ensure sustainable risk management decisions.

The paper also provides a frame for collaboration and exchange with other work packages in PEARL. This underlines the integrative approach of the project.

The paper is structured as follows: Section 2 presents the overall conceptual frame for PEARL and relevant definitions as developed in Work Package 1 to guide the integration of the PEARL work packages; Section 3 presents the Risk and Root Causes Analysis (RRCA) Framework, the basis for research in Work Package 1, including the history of its conceptual development; Section 4 provides a summary of empirical testing of the RRCA Framework to date; Section 5 lays out the methodological propositions for further field testing of the Framework; Section 6 presents the selection process for finalizing case study sites and Section 7 presents the next steps in the research process.

2 The PEARL Conceptual Framework

The framework to integrate conceptual work across the PEARL project is taken from the IPCC Fifth Assessment Report (2014), which in turn uses a schema derived for the IPCC Special Report on Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation (or SREX) (2012). The schema is presented in Figure 1 (below). The IPCC schema is a high-level and holistic schema which allows for the integration of work across a range of disciplinary domains with the requisite flexibility for the detailed application of respective scientific work within and across each domain. The conceptual alignment between this work and work in PEARL is discussed further below. Further, it is important to note that the decision to use the existing IPCC conceptualisation of risk and its drivers for work in PEARL also reflected a desire by PEARL researchers to align PEARL research with broader discussions on risk and climate change adaptation kick-started by the IPCC SREX report.

The IPCC schema depicts key concepts in disaster risk and adaptation, and the interaction of these with sustainable development. Understanding risk within this broader development context is also a key aim and element of PEARL. Further, the schema illustrates how the three elements of risk - hazards, vulnerability and exposure - are shaped by the interaction between both physical *and* socio-economic processes. This reflects long-standing work in the field of disaster studies that has stressed how disasters associated with a natural hazard event are the result not only of physical processes, but the combination of physical forces with economic, social, political and cultural factors (Blaikie et al. 1994). Again, this aligns strongly with the perspective taken in PEARL that a holistic, trans-disciplinary approach to understanding the drivers of risk – and their interaction – is necessary to forge effective and sustainable risk management solutions. The IPCC schema also provides a dynamic frame that can be applied across different scales and different contexts. The malleability of the frame makes it applicable to the specific context of PEARL, namely the investigation of extreme and rare coastal disasters which, in the European context, are small-scale in scope although high in local impact.

Alongside strong synergies with the proposed approach in PEARL, it is nevertheless the case that the IPCC model was developed to analyse risk in the context of disasters and climate change. The schema therefore reflects this emphasis, drawing attention to the role of climate change adaptation and mitigation policies and measures in driving processes of risk production, for example. PEARL focuses on near-time disaster risk, and commensurate disaster risk management policies and measures, although increasingly these will be coupled with climate change risk assessments and policy measures. The IPCC schema also highlights important feedback loops between climate change risk and development, for instance between contemporary socio-economic processes and anthropogenic climate change (through land use change). Although not a specific area of analysis for PEARL, in highlighting these feedbacks, the IPCC model points to further ways in which disaster responses are situated within wider development processes whose impacts need to be considered, and which may unfold over broader temporal and spatial scales.

What PEARL aims to develop, however, beyond the IPCC risk schema, is our understanding of how the drivers of risk (or the underlying physical and socioeconomic processes to the left and right of the IPCC model) interact and co-evolve across spatial and temporal scales. PEARL highlights how these processes are not only dynamic and continuous (as implied in the IPCC schema) but also complex, emergent and non-linear. Climate change elevates the levels of uncertainty in a given system, making the dynamics of its emergent parts more unpredictable, particularly in the long-run. These facets of PEARL are discussed further below in the context of Root Cause Analysis.

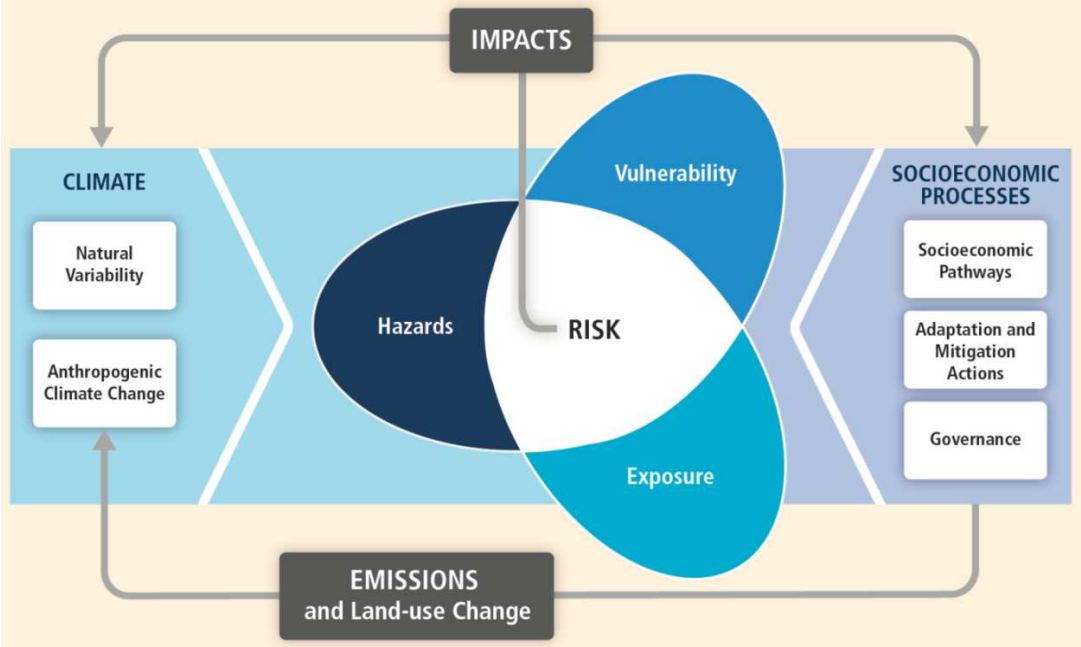

Fig. 1 The IPCC Model of Risk

Source: IPCC 2014

Although definitions of risk and its components vary and are debated in the literature around disaster risk, in line with the above, PEARL work packages therefore adopt the same definitional basis as the IPCC Fifth Assessment and SREX reports. Disaster risk is defined in line with the IPCC definition where "**Disaster risk** is the likelihood over a specified time period of severe alterations in the normal functioning of a community or a society due to hazardous physical events interacting with vulnerable social conditions, leading to widespread adverse human, material, economic, or environmental effects that require immediate emergency response to satisfy critical human needs and that may require external support for recovery." (2012 & 2014) PEARL then adopts the same central concept of **risk** as the IPCC SREX, where risk is defined as having three core elements which interact to generate impacts: hazard, exposure and vulnerability.

Following the SREX, **hazard** is defined as "The potential occurrence of a natural or human-induced physical event that may cause loss of life, injury, or other health impacts, as well as damage and loss to property, infrastructure, livelihoods, service provision, and environmental resources." (p.5, 2012) While the 5th Assessment Report 2014 expands this definition to include physical trends (to incorporate long-run changes in climate parameters) and physical impacts, the first are of less concern to PEARL while in PEARL hazards are seen as the trigger for impacts across the physical, socio-economic and governance spheres. The frequency, intensity and extent of such hazards exhibit both natural variation and variation due to anthropogenic climate change. **Exposure** is defined as "The presence of people; livelihoods; environmental services and resources; infrastructure; or economic, social, or cultural assets in places that could be adversely affected" (p.5, 2012), where assets refer to the resources that individuals or groups own, control or access. Exposure is treated as a separate element to capture the fact that it is both a function of the presence of physical hazard in a particular location and related to the vulnerability of particular populations or infrastructures. While **vulnerability** according to the SREX refers to "the propensity or predisposition to be adversely affected" two further elements are clarified in PEARL. Firstly, that the propensity to be affected not only refers to the concept of susceptibility but also to the capacity of actors and systems to prepare for, cope with and recover

from disaster events. Secondly, that vulnerability, as composed of susceptibility and capacity, is an inherent property of a given context and not just the outcome of a particular disaster event.

An extreme event – the focus of PEARL research – is defined in AR5 as one that is rare in a particular place at a particular time of year, where the event is as rare or rarer than the 10th or 90th percentile of an observed probability function. The characteristics of extreme weather will therefore vary from place to place. Extreme climate is when a pattern of extreme weather persists for some time.

Frameworks developed by PEARL researchers in other contexts also provide an anchor for the conceptual thinking developed in PEARL. However, these frameworks – the BBC and MOVE frameworks, discussed below – focus predominantly on vulnerability to risk. The aim of PEARL – and of the IPCC schema – is to highlight risk as the core element, of which vulnerability is a component part, thereby allowing for research in the multiple domains of hazard and vulnerability assessment to be represented.

The so-called BBC framework based on work by Birkmann, Bogardi and Cardona (see Fig. 2, below) contains many elements which overlap with the IPCC schema (Birkmann, 2006 and Birkmann, 2013). It also highlights the need to understand disaster risk in the context of sustainable development (represented by the three spheres environmental, social and economic); the need for a holistic approach to risk assessment and management; and provides a dynamic sense of the ongoing processes driving vulnerability and risk. However, the IPCC schema was felt to provide a simpler conceptualisation framework for PEARL, and one that differed on two conceptual features. First, the IPCC schema places a stronger emphasis on governance as a feature of the underlying development context for risk. This was felt to be more appropriate to the proposed work in PEARL. PEARL in turn focuses less on the environmental sphere, which is flagged and discussed more prominently in the BBC conceptualisation. Second, the IPCC schema, as partially discussed above, separates out risk (as the central feature) into its components of hazard, vulnerability and exposure as equally weighted parts. In particular, exposure is then situated in a way that it can be clearly understood as related to both hazard (with the hazard defining what particular units are exposed to) and to vulnerability (which also has a spatial dimension). The BBC Framework does capture the dual sense of vulnerability also retained for the PEARL project, however, in which vulnerability denotes both susceptibility and capacity.

The BBC Framework does, however, come closer than the IPCC schema in representing a causal sequence towards a particular disaster event in time. As a Framework concerned with disaster risk, rather than climate change adaptation, it acknowledges important feedback loops between disaster preparedness and management measures and the environmental, social and natural spheres underpinning risk and vulnerability. These dimensions of the framework were utilised in developing the Root Cause Framework for Work Package 1, discussed in the subsequent section.

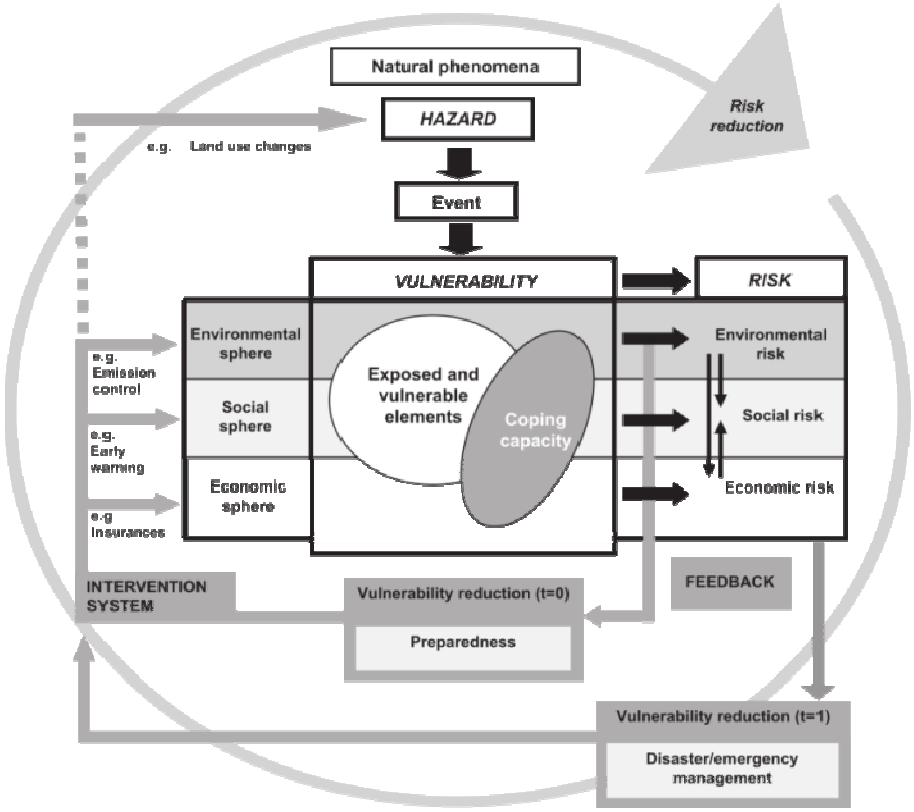

Fig. 2 The BBC Framework

Source: Birkmann 2006, and Birkmann 2013

The MOVE (Methods for the Improvement of Vulnerability Assessment in Europe) project also provides a holistic and multi-dimensional framework for representing the generic concept of vulnerability and its component parts within the context of risk assessment, governance and management (See Fig.3, below) (Birkmann et al. 2013; Birkmann et al. 2014). As for the IPCC schema, the Figure is meant to apply across scales as well as contexts. In identifying risk and its main elements, the MOVE figure again shows how vulnerability and exposure are inter-related but separate components, although hazard is not directly linked to exposure (which is seen as a property of the social domain affected by hazards). Again, the IPCC figure allows for risk to be represented as the central concept, with the three elements of hazard, vulnerability and exposure as mutually inter-related elements. The MOVE Framework again makes explicit the dual sense of vulnerability as susceptibility and as coping, however. In the MOVE Framework, as for the IPCC and BBC Frameworks, risk management and adaptation policies and measures modify the conditions in which vulnerability emerges.

The key difference between the MOVE Framework and the IPCC Framework, which in part governed the choice of the IPCC Framework to represent the core elements in PEARL, is that the MOVE Framework represents an operational, step-wise sequence of interactions to guide risk assessments. The IPCC Framework, however, represents a higher-level abstraction of the drivers of risk, within which the co-evolution of the component processes can be specified and understood.

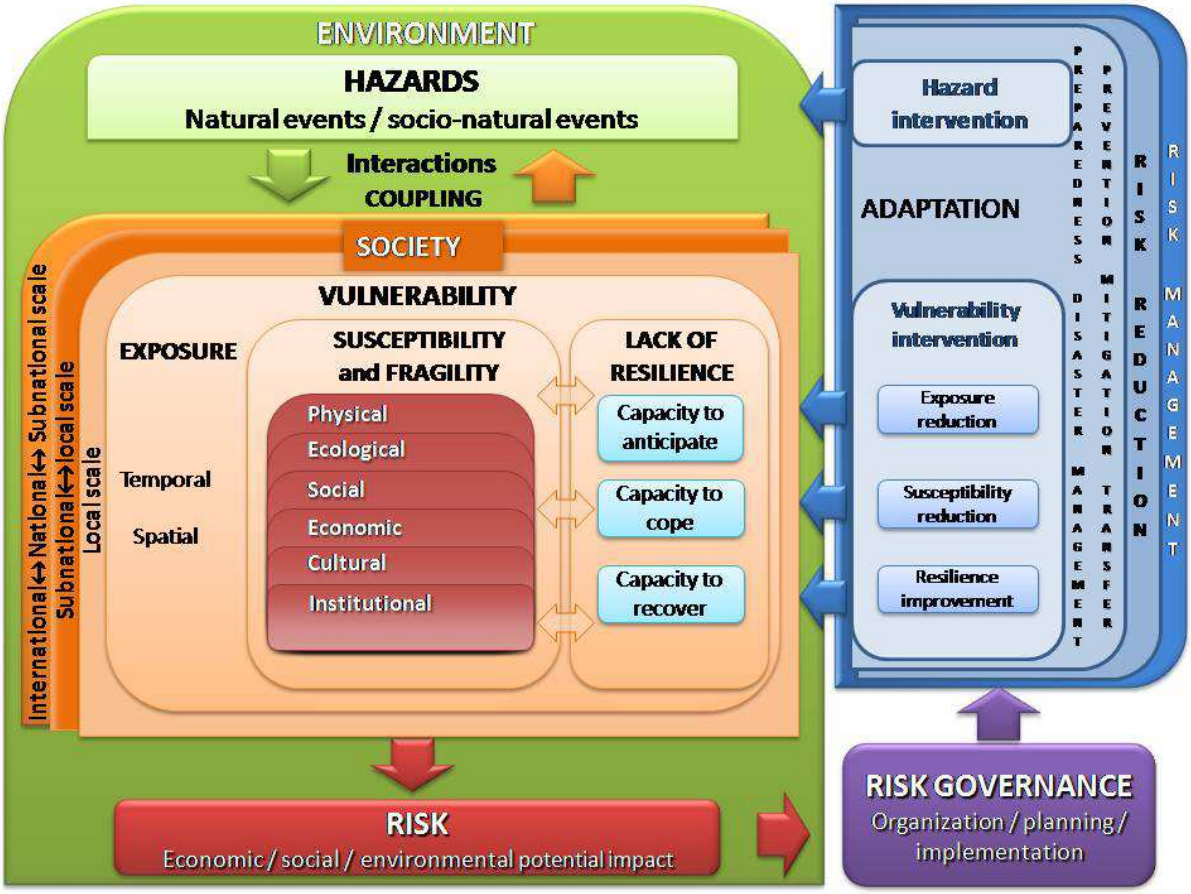

Fig. 3 The MOVE Framework for a holistic approach to disaster risk assessment and management

Source: MOVE project; Birkmann et al. 2013

3 The Risk and Root Cause Analysis (RRCA) Framework for PEARL

3.1 Background to the RRCA Framework

Risk analysis needs to address the interconnections and complexities between factors in different contexts and across different scales, in order to provide a basis for effective and sustainable solutions. Here, dedicated 'Root Cause Analysis' plays a critical role. The Risk and Root Cause Analysis (RRCA) framework proposed under PEARL aims to "enable systematic assessment of different root causes of risk, risk cascading and propagation of vulnerabilities at a greater depth than previous research […]" (PEARL DoW, European Commission Directorate-General for Research and Innovation 2013). There is still limited knowledge about disaster root causes. Existing disaster assessment and evaluation methodologies provide important overviews of current vulnerabilities, capacities and post-disaster conditions, but stop short of investigating *why* risks and vulnerabilities arise (DKKV 2012). The PEARL RRCA Framework therefore builds on existing Root Cause Analysis frameworks, as well as developing them so as to be appropriate to the context of extreme and rare coastal disaster events.

Root cause analysis has been described as "a structured investigation that aims to identify the true cause of a problem" as well as provide a basis for addressing it (DKKV 2012). In the context of disaster risk, two formal root cause assessment frameworks have been reviewed which are of relevance to PEARL.

The first, the FORIN (or the FORensic INvestigations of disasters) framework, promotes scientific investigations of disaster causes which, in line with the aims of PEARL, aim to shift the paradigm of disaster management policies towards more holistic, multi-disciplinary approaches. FORIN provides a framework for in-depth analysis of linkages between spatial and temporal scales of disaster analysis and that integrates a systematic understanding of the links between disasters and development. It provides a conceptual framework around which to structure core questions (See Fig. 4). The framework prioritises governance as a key driver of disaster risk, particularly questions of institutional responsibility and accountability and the policy choices made before, during and after disaster events.

Fig. 4 FORIN Conceptual Framework

Source: IRDR 2011

FORIN provides a broad and adaptable framework for the investigation of disaster root causes across scales and types of disaster. Studies that have formally adopted the FORIN approach stress its utility as an inter-disciplinary, comprehensive and inclusive approach.

Five key challenges to FORIN were nevertheless highlighted by the review undertaken by KCL (Fraser, Paterson and Pelling, 2014) that were then taken into the development of the PEARL RRCA Framework (see Section 3.2 for the presentation of the Framework). These are:
1. A stronger theorisation of, and greater precision of methods for investigating, the governance dimension of disaster causation,
2. A more central focus on the role of the disaster management cycle in perpetuating risk,
3. The connection of a backward-looking, historical perspective on disaster risk causation to a forward-looking, scenarios-based analysis,
4. The development of methods for analysing causal pathways and
5. The development of FORIN indicators for comparative analysis over time and through which to improve the policy update of FORIN.

An interesting development in the application of FORIN to date – and one examined further in the methodology section – is the use of FORIN methodology coupled with systems theory thinking in order to analyse causal relationships. Two 'FORIN' studies undertaken in Taiwan (See Fig.5) and Metro Manila used causal loop diagrams to map the processes behind disaster events, with the Manila study then developing a systems model to illustrate the strength of different causal interactions (Huang et al. 2013, Castillo 2013).

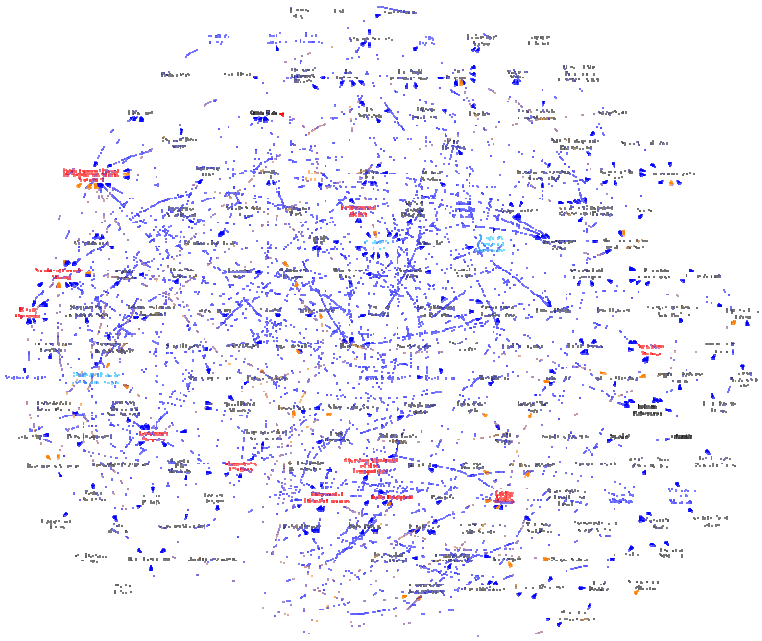

Fig. 5 Causal loop diagram in the context of a FORIN investigation

Source: Huang et al. 2013

In this study of Typhoon Marokot, which hit Southern Taiwan in 2009, the FORIN framework provided the foundation for analysis of the causes of the disaster and their inter-relationships. The study suggested that the disaster was not an independent event, but an outcome of interactions between different systems (people, organisations and infrastructure) and different phenomena (e.g. hazardous waste causing household damage) (Huang et al. 2013).

The second Root Cause Analysis framework, developed by UNU-EHS on behalf of DKKV[1], shares many of FORIN's aims and components. It also stresses that disaster risk root cause analysis entails identifying causes in a multi-dimensional and comprehensive manner. However, the DKKV framework makes additional distinctions to the FORIN framework. Importantly, it separates drivers from root causes, where drivers are the activities and processes that translate root causes into unsafe conditions, while root causes are the structures and processes that go beyond an individual crisis or event. The Disaster Risk Management process itself is incorporated as an element driving vulnerability (discussed further below). It also differentiates generic from place/hazard specific root causes. It groups causal pathways according to field (Development, Awareness and Perception, Governance, Political Environment and Physical and Environmental conditions) and unpacks the elements of vulnerability and their particular drivers. The results are assembled in a CRT (Current Reality Tree) which displays the interconnections and inter-linkages between them (see Fig.6).

[1] DKKV (Deutsches Komitee für Katastrophenvorsorge / German Committee for Disaster Reduction)

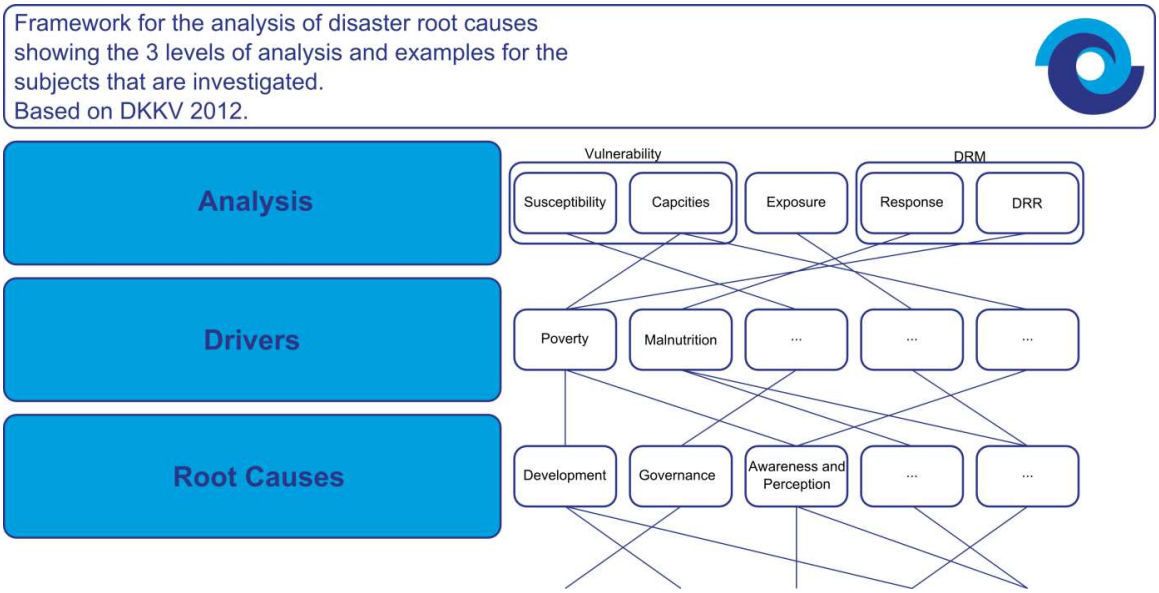

Fig. 6 Illustration of a CRT, DKKV Framework 2012

Source: Own draft based on DKKV 2012

As mentioned, where FORIN Root Cause Analysis emphasises a largely pre-disaster perspective, the DKKV framework incorporates a near-time vulnerability assessment undertaken in the post-disaster phase. Fig. 7 shows how these perspectives fit within the risk management cycle (preparedness, mitigation, response and recovery). Applied to the PEARL RRCA framework, this shifts existing use of the FORIN framework, which takes the disaster event as a starting point from which to look backwards, to taking the disaster as a focusing event from which to look backwards and forwards in time. Retaining the disaster as the starting point maximizes opportunity for narrative accounts to draw out attribution and illustrate the intervention of other drivers as time accumulates before and after an event.

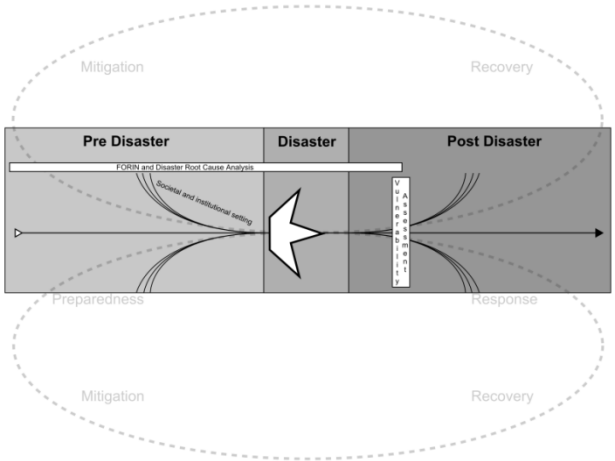

Fig. 7 The FORIN and DKKV RCAs in the context of the disasters cycle

Source: own draft.

However, the proposed RRCA framework aims to assess both the physical and socio-economic drivers of risk, and here goes beyond the DKKV approach.

In applying these existing frameworks to PEARL, it was important to recognise differing requirements of scale. While FORIN studies have so far concentrated on single, large disaster events, PEARL focusses on small-scale, possibly recurrent, but locally important, disasters. This application is currently untested in the literature, and requires investigation of how the nature of these hazard events might alter how risks cascade (between first order, second order and third order, or direct and indirect, impacts) and propagate (across scales and temporal perspectives). Further, the scale of institutional analysis in PEARL differs. Local government and associated local scale actors are the primary stakeholders for development and risk management decision-making in small scale events, with national and international actors secondary (although their influence is still important and will still be discussed in PEARL). In addition, in the context of PEARL, a number of core policy areas are defined as requiring a dedicated root cause analysis: risk management and land-use planning, early warning and evacuation and insurance and reconstruction (European Commission Directorate-General for Research and Innovation 2013).

The PEARL RRCA also aims to develop particular conceptual dimensions of the FORIN and DKKV approaches, namely the institutional analysis and our understanding of the causal pathways underpinning the occurrence of disasters. In particular through the work of WP1, the framework will be used to generate hypotheses about the institutional characteristics that underpin different outcomes and impacts, and how institutional capabilities to assess and manage risk (and the developmental drivers of risk) are shaped in the context of different political regimes (Pelling 2003), based on different forms of social contract (Pelling 2011), at different points in time (in particular when disasters open up ‘windows’ of opportunity for change) (Birkmann et al. 2010). Further, work based on the framework will consider how actions and decision-making are set within the interaction of social and ecological processes in ways that are dynamic, and potentially non-linear (Miller et al. 2010). This is discussed further below.

3.2 Presentation of the RRCA Framework

The following figure (Figure 8, below) sets out the proposed Risk and Root Cause Assessment Framework (RRCA) for PEARL. It is divided into three parts: (A) Overall concept, (B) Process, (C) Methodological Approach.

Central to the framework is the inseparability of risk from the underlying root causes (A). These are considered as manifestations of physical, governance, socio-economic and perception processes (B) that are disturbed by a physical event, affecting the remaining three spheres and causing a disaster. The process of responding to a disaster – the trajectories of response, recovery, reconstruction and transformation – both has its own antecedents in the historical context, as well as shaping the new context for risk production going forward. PEARL will assess the process of accumulating and producing risk before, during and after an event, look at the underlying drivers and root causes and – building on this historical perspective – inform future (planning) processes (C).

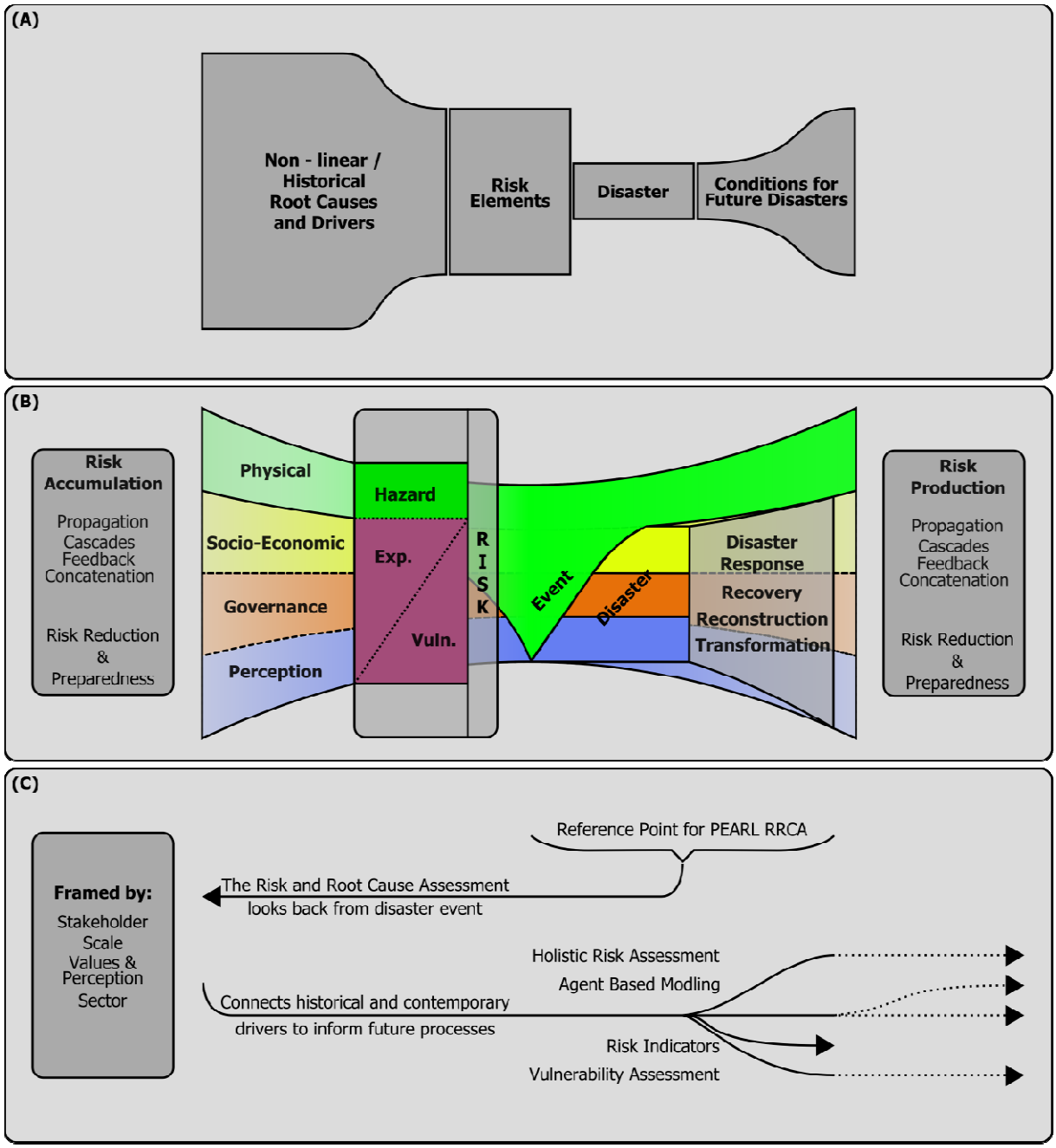

Fig. 8 Proposed RRCA Framework for PEARL

(A) Concept

The overall concept of the RRCA framework is that the historical **root causes** of **risk** are translated by the **drivers of hazard, vulnerability** and **exposure** into a situation of endangerment (risk). Risk at any given time is an evolving process that can be traced back to its root causes. The occurrence of a disaster and the disaster response sets the conditions for the future, and the magnitude and form of any future disasters.

(B) Process

The RRCA framework is centred on dynamic **physical, socio-economic, governance** and **perception** processes. These four are interlinked in a non-linear fashion and in continuous exchange. Therefore the **risk** – as a function of **hazard, exposure** and **vulnerability** – is displayed at a single point but could be assessed at any given time step (depending on the

availability of data). Investigating and learning from the interaction of root causes that lead to an expression of risk (or loss) at any one moment is the analytical focus of the PEARL RRCA. A disaster is signified in the model by the intersection of hazard with social processes. The hazard event impacts on these spheres causing losses and damages. All of these terms keep the IPCC definitions as discussed above in Section 2.

Following the disaster, **Disaster Response, Recovery, Reconstruction** and **Transformation** processes both influence the physical, socio-economic, governance and perception factors within a spatial entity and are influenced by the historical physical, socio-economic, governance and perception context. These aspects contribute – either positively or negatively – to the accumulation and production of risk. The disasters 'cycle' refers to the stages of pre- and post-disaster response, with appropriate actions at all stages necessary to mitigate disaster losses and damages. This cycle of **Risk Reduction and Preparedness** encompasses response, recovery, reconstruction and transformation as well as mitigation and preparedness measures taken in anticipation of a disaster event, but not necessarily following a disaster. Risk reduction and preparedness is therefore represented in both the Risk Accumulation and Risk Production boxes as a process that unfolds before and after an event. While the terms Risk reduction and preparedness are often used to refer to the application of a narrow set of pre-disaster management tools, here they are used in the fullest and most meaningful sense to describe the purpose of all disaster management tools, or the highest order goal of the disasters cycle.

We define disaster response and recovery in line with the definition provided by UNISDR, where response refers to "The provision of emergency services and public assistance during or immediately after a disaster in order to save lives, reduce health impacts, ensure public safety and meet the basic subsistence needs of the people affected." (UNISDR 2009) Recovery then refers to "The restoration, and improvement where appropriate, of facilities, livelihoods and living conditions of disaster-affected communities, including efforts to reduce disaster risk factors." (ibid.) Reconstruction is included in order to distinguish between the social process of recovery and the physical process of reconstruction, where it refers to the restoration and improvement of physical infrastructure. As discussed below with reference to the empirical testing of the RRCA Framework, these phases are not necessarily divided in a clear-cut fashion. Response actions may last into the recovery and reconstruction phase, and new response actions may become necessary if, for example, new, secondary hazards arise.

In taking disaster response, recovery and reconstruction measures valuable opportunities arise to reduce and prepare for risk in ways that not only build back to 'normal', or the state of affairs prior to the disaster event, but 'build back better', preventing the disaster from re-occurring, or at least to the same magnitude. This is captured by the inclusion of the term Transformation, to refer to the process of re-aligning the structures underpinning the disaster to ensure a resilient and sustainable future in a given context. The notion of resilience – the goal, or robustness of a particular system to cope with and recover from disaster events – is therefore subsumed by the term transformation. Sustainable refers not only to environmental sustainability but also social justice and equity, for both current and future generations.

The terms to the left and right of the figure indicate the dynamics of the way in which risks occur. **Risk propagation** refers to the influence of risk over wide spatial and temporal domains, or how risk may have systemic impacts which may not be easily identifiable and may manifest themselves at different points in time to the actual disaster event. **Risk cascading** refers to the cascade of effects of risk from first order, direct impacts to second order, indirect impacts and to third order, systemic risks. **Feedback** refers to the ways in which both the disaster and post-disaster processes (including disaster risk management itself) have impacts that may feed back into the underlying conditions for ongoing risk and subsequent disasters, potentially altering the nature of these conditions. **Concatenation** refers to situations where one extreme event

precipitates one or more other extreme events. **Risk accumulation** refers to the potential result of these processes, where risks concentrate across different spatial and temporal scales.

It is important to underline the possible non-linear nature of the processes underlying risk. In a risk cascade, for example, there is no necessary linear relationship between first order and second order impacts. The physical, socio-economic, governance and perception drivers of risk may inter-connect to create risk in non-linear ways. In addition, there is uncertainty at any given moment in time about future risks and disaster events either due to information deficits or disagreements about what is known or knowable. Such uncertainties shape how risks are estimated and affect decision-making and actions in the governance and socio-economic domains.

(C) Methodological Approach

The reference point for the PEARL RRCA is the study of disaster impacts and losses and post-disaster development trajectories. This focal point in time is bracketed in the RRCA Figure. It provides a critical 'window' through which the historical drivers of risk can be assessed, and their manifestations in the contemporary context analysed. This perspective is then used to inform future risk scenarios. The interpretation of the event, disaster and post-disaster processes is framed by the perspectives and values of the stakeholders interviewed, the sectors analysed and the scale of the analysis. The Risk and Root Cause Assessment, with its focus on bringing a historical perspective into the present, feeds into other methodologies in PEARL which will be used to benchmark and project future risks. These are a) a vulnerability assessment b) an agent-based model and c) risk and root cause indicators which can be used to assess efforts to address disaster root causes over time.

4 Testing the PEARL RRCA Framework

During the development of the PEARL RRCA Approach, its comprehensiveness and robustness was tested through a systematic review of the secondary literature on coastal flooding events in Europe. The existing literature on root causes is limited and itself not comprehensive, with social and political dimensions in particular being under-recorded. Therefore, the aim was not to match the proposed methodology with the data revealed through the literature but to make sure that the approach is able to capture at least those data relevant to root cause analysis that are available from the case study literature.

The studies were found using relevant key words in search engines (e.g. coastal flood Europe, coastal disaster Europe) as well as searching by event, after a list of historic flooding events in Europe was compiled on the basis of the expertise of PEARL researchers. Aligning with PEARL's study priorities, the case studies selected were all from coastal areas in EU countries, and included coastal, riverine and pluvial flooding. This included both extreme historic events as well as small-scale events (the scope was broadened as there were so few studies on small-scale events). Differences attributable to the scale of the disaster, the different institutional regimes for the different types of flooding and across different historical periods were noted in the analysis. The authors selected case studies on the basis of their potential to offer in-depth and holistic insights into the causal factors behind specific flood events. These are often only manifest in a disaster, further limiting the case study base to studies of disaster events, but serve to show how disaster events can provide the starting point or window into the analysis of root causes. For these reasons, studies focussed only on modelling physical drivers and root causes, on piloting risk and vulnerability assessments without 'ground-truthing' them against actual events, and general policy reviews were excluded. A list of the case study areas and associated literature is presented in Annex 1.

The following thematic grid was devised to guide the systematic review of the case studies, based on a draft version of the Framework (some elements of the final Framework were therefore missing).

Category of root cause	Pathway	Analytical orientation	Risk processes (e.g. propagating, cascading, feedback)
Drivers of hazard	Physical	Historic	
		Contemporary	
		Future	
	Socio-economic	Historic	
		Contemporary	
		Future	
	Governance (Including DRM cycle)	Historic	
		Contemporary	
		Future	
Drivers of exposure	Physical	Historic	
		Contemporary	
		Future	
	Socio-economic	Historic	
		Contemporary	
		Future	
	Governance (Including DRM cycle)	Historic	
		Contemporary	
		Future	
Drivers of vulnerability	Physical	Historic	
		Contemporary	
		Future	
	Socio-economic	Historic	
		Contemporary	
		Future	
	Governance (Including DRM cycle)	Historic	
		Contemporary	
		Future	

Table 1 Thematic grid used to guide testing of the PEARL RRCA Approach

4.1 Results

The following two tables (2 and 3) present the findings of the review, in terms of the insights revealed for the different elements of the draft RRCA Approach. The following section then discusses how further insights from the review led to the refinement of the RRCA Approach into its current form.

Category of root cause	Pathway	Temporal expression	Manifestation for European coastal flooding events	Risk processes evident in European case studies, e.g. propagating, cascading, feedback
Drivers of hazard	Physical	Historic	Longer-term dynamics of physical processes, e.g. erosion altering natural protection, changing sea levels	Feedback: e.g. coastal erosion drives de-population, reducing tax base of local authority and ability to act on flooding
		Contemporary	Combination physical processes, e.g. storm with spring tides, and interaction with longer-term dynamics of physical processes	
		Future	Changes in storm tracks, sea-level rise (additional influence of climate change)	
	Socio-economic	Historic	Human intervention in environmental landscape alters parameters of hazard, e.g. subsidence caused by industrial activity or drainage, discharge from sewerage systems in wet weather, deepening waterways for port access	Feedbacks: e.g. deepening waterways to enhance port infrastructure requires higher dykes, which causes faster tidal intrusion
		Contemporary		

		Future		
	Governance (Including DRM cycle)	Historic	Human intervention in environmental landscape alters parameters of hazard e.g. construction bridges, barriers, dykes	Feedback
		Contemporary		
		Future		
Drivers of exposure	Physical	Historic	Inadequacy of existing defences	
		Contemporary	Inadequacy of existing defences	
		Future		
	Socio-economic	Historic	Urbanisation even in 'controlled' areas, driven by lower prices (relative to cities) as well as high end development and regeneration projects	
		Contemporary		
		Future		
	Governance (Including DRM cycle)	Historic	Planning and land use decisions (also reactive rather than proactive); pressure on local authorities from developers; lack integration housing policy and risk policies; levee effect from defence construction; physical protection	Feedback: sea defence construction encourages exposure

			model in policy ignores socio-economic factors shaping exposure	
		Contemporary		
		Future		
Drivers of vulnerability	Physical	Historic		
		Contemporary		
		Future		
	Socio-economic	Historic	Elderly, children, private renters and council tenants disproportionately affected (although links not automatic); Poor quality shelter under government programme for retired workers; Lack of risk awareness as new populations moved into coastal areas, people feel protected by defences, and lack of recent history of flooding; Economy not prepared to deal with shocks	Cascading: inhabitants moved away from nearby town, affecting socio-economic development Propagating: impacts on SMEs (exacerbated by insufficient insurance and increased premiums due to disaster) disrupt supply chains and infrastructure
		Contemporary		
		Future		
	Governance (Including DRM cycle)	Historic	Decentralisation of responsibility to local authorities without financial capacity, privatisation	

			fragments responsibility e.g. for water management	
		Contemporary	Lack of alignment housing and planning policy with risk management, policy focus on growth neglects non-structural measures and vulnerability reduction	
		Future	Ongoing institutional fragmentation and lack of clarity over responsibilities in some contexts	

Table 2 Core findings of literature review: the drivers of European coastal flooding events

The third table (Table 3, below) focuses in more depth on the role of disaster risk management measures in risk production, given the interest of PEARL researchers in developing the FORIN methodology to account for the part played by the Disaster Risk Management cycle. The table highlights challenges to DRM practices in the European case study contexts that are attributed in the studies to the aggravation of loss and damage from flooding events, breaking them down according to the phases of the DRM cycle. In particular, it reveals how lack of local capacity, unclear or restricted institutional responsibilities and lack of societal awareness and engagement with societal actors have hampered DRM efforts across the cases studied.

Reduction and Preparedness	*Response (emergency)*	*Recovery (long-term)*
Lack of relevant forecasts and / or warnings	Physical isolation of affected areas	Responsibilities of and frameworks for private actors unclear
Risk assessments out of step with changes in physical conditions	Missing data in risk assessments e.g. knowledge of inhabitants	Relocation and / or structural measures contested by inhabitants
Failure to use forecasts effectively	Lack of communication of evacuation routes	
Physical defences out of date	Lack of training and awareness of emergency	

and / or not well maintained	procedures among officials in charge	
Risk assessments and policies focussed on other types of flooding	Lack of evacuation plan	
Measures limited to structural solutions, based on quantitative risk assessments	Better early warning would give people more time to evacuate	
Lack of clear responsibility / limited public responsibility for coastal defences		
Lack of social awareness of risks		

Table 3 Challenges to DRM in the cases of European local-scale disasters

4.2 Implications for the PEARL RRCA Approach

The literature search and review confirmed a lacuna both in scholarship about coastal flooding risk in Europe and in scholarship taking a holistic perspective on European disaster risk, integrating across disciplines and considering the social aspects of risk. A number of papers commented on the pre-dominance of a technical, structural paradigm in prevailing disaster management regimes. Where there have been shifts away from this paradigm in national policy documents and guidance towards multi-stakeholder governance and non-structural as well as structural measures, in part prompted by the EU Flood Directive, this has yet to be implemented by other tiers of governance. This confirms the relevance and importance of PEARL in the current context and of the need for integrated research approaches.

The analysis confirmed the central tenets of the FORIN approach, namely the embeddedness of disaster events in historically configured physical, socio-economic and governmental processes and the multi-faceted and inter-connected nature of these different dimensions of root causes. The exercise also confirmed and developed additional aspects of the PEARL Risk and Root Cause Analysis Framework:

First, **the presence of feedbacks and of cascading and propagating impacts even where disaster events occurred at the local scale** and their footprint remained quite localised. However, these are hard to observe and have been given little consideration in the existing literature.

Second, the distinct profile of **the drivers of small-scale events** (the majority of cases studied here) which, compared to extreme events, evoke less national government involvement.

Third, the **key features of different governance arrangements** that give rise to risk. In particular, the case studies highlighted the role of local government as key, and of decentralisation and privatisation processes as potentially weakening the public sector's ability to plan for and manage risk at this scale. As the case studies of the 2010 Xynthia storm in France

showed, local governments also faced greater pressure and had stronger ties with developers and property interests, which potentially exacerbated exposure. The analysis also highlighted the importance of history and culture in shaping different risk management systems and relevant forms of governance – even in a common European context. The French system for DRM remains far more fragmented than the English, for example. In developing the RRCA Framework going forward these facets of governance will be further investigated, and their links to broader, framing debates about the social contract underpinning disaster governance explored (Pelling 2011).

Fourth, it should be noted that in almost every case studied, **the disaster event catalysed new policy actions and reconfigured relationships between relevant actors**, from the erection of the Thames barrier following the 1953 North Sea Flood to the emergence of local flood action groups in the Outer Hebrides following the storm of 2005. This discontinuity is important to note, as it points to the limitations of historical analysis alone if FORIN methods are to be used to reduce future risk, and also the importance of understanding the feedbacks from the disaster event itself.

Finally, the studies highlighted that, despite the linear **presentation of stages of the Disaster Risk Management cycle**, they may in fact overlap (where, for example, concatenating hazards mean that emergency response management is still active at a later stage, as was the case for waste management following the Xynthia storm). Particular stages are also not uniformly experienced (as highlighted by Whittle et al. 2010 in their analysis of people's experiences of recovery after the 2007 Hull floods, where recovery was far from a constant improvement, but more a variable state over time). This is acknowledged in the revised PEARL RRCA framework figure, which places all post-disaster phases together, but it is important to note. Multi-hazard interactions are also important to bear in mind as the PEARL RRCA methodology is developed.

The analysis also raised important considerations for the PEARL RRCA framework which were incorporated into the existing version:

- The need to account for contestation between different actors at different scales over the nature of causal factors, and therefore the appropriate solutions in a given case. This relates to the different values that different groups may place upon aspects of a landscape – such as communities who value a coastal landscape for its agricultural potential while environmental experts are concerned with the sustainability of the landscape as a habitat. In numerous cases, conflicts over appropriate risk measures served to limit the effectiveness of the outcome.
- The interactions between scales, with cases pointing up the importance of these dynamics – and particularly the interplay between local and national governments – to the production of risk.
- It is important to stress that the term vulnerability includes the notion of capacity as well as susceptibility. Several case studies point to key institutional attributes of capacity, but also raise important questions about why particular institutional contexts provide more capacity for risk management than others (departments that had more recently experienced flooding events were better prepared for the Xynthia storm, for example).
- The case studies also brought to the fore the role of risk perception and awareness as a critical factor in driving risk (connected to, but separate from socio-economic change). This was flagged more prominently in the revised framework.

5 Methodology for Risk and Root Cause Analysis

This section provides an overview of the methodologies the PEARL team will apply in selected case study areas. As described in the PEARL DoW (European Commission Directorate-General for Research and Innovation 2013) all available case study areas have been or are recurrently affected by coastal flooding but the drivers and root causes of the risk arising from the flooding will be context-specific to each case. Thus the applied assessment methods can be defined for all on a generic level but have to be adjusted for each case.

As a basis for the practical work the PEARL methodology draws on the existing FORIN approaches which will be extended according to the needs of PEARL. A key principle of the FORIN methodology is the inclusion of multiple stakeholders from different disciplinary perspectives. FORIN identifies four types of analysis: critical cause analysis, meta-analysis (literature review across multiple cases to establish common causal pathways), longitudinal analysis (observations of comparable events or events in comparable places) and scenario analysis (analysis on the basis of a possible future event). The existing collection of methods envisioned to support FORIN remain appropriate for empiricising the RRCA conceptual framework developed above. Critical cause analysis, meta-analysis, longitudinal analysis and scenarios all meet the potential demands of providing structured data collection, with scope for qualitative/narrative accounts of root cause processes and quantitative descriptions of risk status. Both map processes of risk accumulation onto development pathways.

The proposed PEARL methodology includes a focus on the spatial distribution of vulnerability, the contemporary root causes of risk (building on DKKV 2012), and their historical coevolution as explained through the FORIN method. This is a shift from the original FORIN method which was primarily interested in explaining the past causes of a recent event and learning lessons from this.

The PEARL RRCA methodology will inform two key research exercises in PEARL:
1: The results are to inform agent based modelling (ABM) that will aim to reproduce the behaviour of risk actors and their interaction within each other and the environment. This requires that we develop a method that focuses on agents to (a) identify risk management actors (local government, state agencies, civil society groups, property owners etc.), (b) distil from the data important linkages and points of influence and interaction (which may be indirect), and (c) provide examples of interaction amongst the population of actors as examples of a coevolving field of agents interacting also with the surrounding physical, socio-economic, value and risk perception and governance environments.
2: The RRCA analysis will form the starting point for a quantitative vulnerability assessment. The RRCA Framework will structure the vulnerability assessment and RRCA outputs will shape the hypotheses the vulnerability assessment works within its analysis. The fact that institutional processes highlighted in the RRCA impact on contemporary expressions of vulnerability of affected communities and infrastructures is a core proposition of the RRCA framework.

The following table (Table 4) outlines the research techniques that will be deployed for these three main outputs. The use of these techniques is described in further detail in the following sections.

		Assessments		
		RRCA	Vulnerability Assessment	Agent Based Modeling Input
Techniques	Secondary Analysis of Core Documents	X	X	X
	Expert Interviews	X	X	X
	Household Survey		X	X
	Geospatial Data		X	X
	Statistical Data		X	X
	Oral History Analysis	X		X

Table 4: Proposed techniques for Work Package 1 research

In the following sections the main methods will be introduced and the practical application outlined.

5.1 The RRCA Method: An agent-centred analytical method for the RRCA Framework

The aim of the RRCA Method is to undertake an in-depth qualitative investigation of the root causes and drivers of risk for historical flooding events, but also to ascertain how historical forces relate to contemporary expressions of risk and vulnerability. The steps are as follow:

The first step is a desk-based literature review of the academic, policy and media literature as well as of written contributions from experts and influential figures in relevant government, civil society and private sector organisations and from affected stakeholders. This information will be used to construct a narrative history of the focal disaster event. The review will be structured around each of the elements incorporated in the conceptual framework diagram and be presented in a narrative form that allows comparative reading across case studies. The narrative will allow an initial identification of root causes, drivers and conditions of endangerment across the four domains of physical, socio-economic, governance and values and perceptions. It will also isolate primary and secondary actors from the viewpoint of the actors/organisations included and, as far as possible, identify key aspects of agent behaviour according to the structure of the agent-based model. It will report on how far these aspects of the RRCA framework are said to have evolved (including through recovery and reconstruction processes) up to the present time. It will make transparent what and whose views are reflected in the report – these are likely to be the most organised and articulate viewpoints – and propose additional informants, including those whose views might reveal alternative or marginalised explanations.

The second step is to undertake key informant interviews and any additional document analysis to provide focussed analysis on the emergent themes. The identification of key respondents for interviewing and any purposeful sampling will depend upon the scale of an event and relative resources of the research team, including local partner teams who will guide the identification of the most relevant informants. The aim will be to interview a broad range of actors, from across the disaster management cycle of responsibility – from those in civil defence and emergency services to those involved in broader community, economic and social planning, as well as local political leaders and affected stakeholders and households. Informants may include those at the international or other higher scales of governance. To construct a historical analysis it will be beneficial to interview retired staff. Any sampling and potential biases will be made transparent in reporting the methodology. The work being done in WP5 to convene stakeholder groups provides a forum for individual interviews as well as collective stakeholder mapping exercises, which will widen the scope of the work and ensure the involvement of local stakeholders from the start of the research process.

The form of the interviews will be a series of semi-structured oral histories across different organisations, partially structured around key historical moments as defined for the context. Oral histories – as well as life histories with affected individuals (see below) – provide depth and detail, allowing for complexity and diverse pathways to emerge (Lewis 2008; Baulch and Scott 2006). They also allow for a possible ‘re-historicising’ of policy narratives which, as Lewis points out, “is important because powerful policy actors may downplay history in order to present their ideas as novel” (p.561) and a way of understanding the inter-play between agency and structure (Lewis 2008). In this study, respondents will be questioned about the strategies adopted at key historical moments, the interaction between context and agency and the values that motivated actions at these junctures, as well as any impacts or outcomes of decisions. However, two practical limitations on this method are the huge volume of work processing relatively few interviews entails (limiting the number of interviews it is practicably possible to undertake) and the fact that informants vary in their capacity to ‘perform’ these kinds of narrative (Lewis 2008). Even if the sample size is small, therefore, it is important to try and capture a diverse set of views and to invest in researching who the right informants might be. In addition, the project is interested in contemporary and future risk production, and the extent to which identified historical root causes remain key to contemporary perceptions of risk production. This cannot be probed in

the same way. Informants will therefore also be asked about features of the contemporary risk and risk management context, and the outlook for any key variables.

In addition to informant interviews in key institutions, the work will include interviews with affected stakeholders, whether by sector (e.g. port, tourism) and / or directly affected population groups, including people who are no longer resident in the area of risk. These interviews provide important information about agent relationships, and also provide a frame for the identification of input variables for the vulnerability assessment. As for the institutional interviews, verification and triangulation is important where possible, given that people are expressing opinions, may project current patterns of behaviour into the past and be vague on certain points or topics (Baulch and Scott 2006).

In analysing the information, quantitative social network mapping exercises allow us to abstract and simplify complex relationships, and describe their forms and features (DiGregorio 2011). While the Agent-Based Model provides a highly sophisticated network model for understanding agent behaviour and generating possible future scenarios, simple network maps (which can be generated using the same Atlas.ti software package as the qualitative analysis) will also be produced by the Work Package 1 team to aid comparative analysis through visualisations of the material and provide an initial representation of actor relationships that can serve as a platform for the agent-based model. These network maps remain contextualised – unlike the general agent-based models – and will be presented in stakeholder discussions in the case study areas for verification.

Data from the Method could also inform a series of causal loop diagrams, illustrating the links between inputs (root causes and drivers) and outputs. More sophisticated network analysis that enables us to prioritise drivers and separate off types of causal pathway, is highly apt for multi-causal, non-linear fields (Rocha 2010). However, this level of analysis would require technical expertise and resources beyond the planned scope of PEARL.

As well as more quantitative forms of analysis, the accompanying qualitative work is also vital in highlighting the attributes of actors that influence relationships, the content and meaning embedded in networks, any dynamic shifts in networks and relationships of power that influence network behaviour and outcomes (DiGregorio 2011). The analysis will include the analysis of discourses in order to understand their influence on the behaviour and social practices of agents and institutions, and how discourses reinforce and are reinforced by power relations between actors (Gill 2000). Interview notes (and transcripts where it is possible and appropriate to audio-record interviews) and relevant textual documents will be entered and coded in Atlas.ti software, although care must be taken not to lose the contextual meanings of texts when they are categorised in this way (Maxwell, 2009).

An independent and comparative analysis of the institutional determinants of risk is expected and will be of publishable quality and constructed to allow comparative analysis using the PEARL RRCA conceptual framework.

As well as informing the Agent Based Model, the RRCA Method will inform the Vulnerability Assessment. As mentioned in the introduction there is a tension between the need to link contemporary expressions of vulnerability to the historical processes of their production, and relying on pre-set indicator sets which, in context, may not be connected with these processes. Further, some of the ways in which vulnerability is expressed do not map easily onto spatial indicators, for example, the ways in which social and institutional networks influence household sensitivity to disaster events. Three elements of the RRCA method will support the construction of the Vulnerability Assessment:

1. At the scale of affected stakeholders, a small subset of open, qualitative interviews is undertaken prior to the quantitative assessment in order to orient this work. For example, demographic mobility in a location may be more important or as important an indicator of vulnerability than demographic structure. These proposals go beyond established relationships between qualitative and quantitative approaches that tend to allow for qualitative work to supplement and enrich quantitative exercises. Qualitative work can also reveal important facets of vulnerability that cannot be captured in – and may challenge the assumptions of - spatially-oriented, indicator-based frameworks. Work for the FP7 Embrace project, for example, challenges the assumed linkage between health and old age in influencing vulnerability to heatwaves, exploring how vulnerability in the everyday experiences of elderly people themselves is shaped by social networks, which are not easily spatially mapped (Norbert and Pelling forthcoming). It also highlights the role of meaning, identity and emotion in the formation of vulnerability. A study undertaken after the 2007 Hull floods in the UK in which informants used diaries to record their experiences of the recovery process concluded that it was the interaction between certain social characteristics and specific circumstances that determined when and how people were vulnerable, that vulnerability was highly dynamic and was related to the ways in which the recovery process was managed (Whittle et al. 2010). The point is that this type of data not only potentially re-shapes the data to be captured in the indicator-based framework, but provides important additional information which it may not be possible to capture in the quantitative assessment.
2. Time series data, whether indicator-based or spatial data, could also be used where it is available so that underlying shifts in the elements of risk come to the fore. The historical picture revealed through this exercise could be placed alongside the narratives generated in the RRCA Method to suggest possible associations between historical, institutional drivers and risk outcomes. This exercise alone would not, however, establish causal relationships (where attribution from outcomes data is difficult) or tell us about the direction of causation. It is also important not to project past associations into the present or future. It will be during the research process that integrating time series data in vulnerability assessments will be explored and the practical constraints to doing so (such as the time costs) will become apparent.
3. A final way of using the FORIN work to inform vulnerability analysis would also be to produce vulnerability risk maps from static data and then hold a workshop where FORIN root causes are also presented and stakeholders are asked to award values to different causal attributes (or in some other way differentiate between the different vulnerability input variables and output descriptions for each location). This approach would retain the complexity of root causes but would need careful structuring to prevent a skip into assumed and past relationships being projected into the future. There is also a strong possibility of stakeholder bias, with institutional stakeholders likely to downplay the institutional role in influencing negative outcomes, and overplay positive effects. The use of this method will depend on stakeholder expertise, interest and availability.

On the back of the outlined methods, it is possible to compare ‘standard’ indicators and those generated through a ‘FORIN informed’ analysis and potentially quantify the additional effect of ‘FORIN indicators’ in capturing historical losses.

The next stage of the process is to coordinate the methodological process to reflect the overlapping interests across work packages and streamline the case study analysis process. All

researchers working in work packages 1, 3 and 5 will have the opportunity to give input on the methodological proposals. Based on these discussions the guidelines for the interviews and the questionnaires will be designed and the content of stakeholder workshops developed. This ensures that PEARL arrives at a comprehensive Risk and Root Cause Assessment.

The work proposed in Work Package 1 has already been scrutinized by the Kings College London Research Ethics Panel and full approval given. In its submission to the panel, PEARL researchers drafted a consent form and information sheet to be given to informants prior to interview (see the Annexes for these forms). This will need to be translated according to the case study locations. In line with the recommendations of the Panel, further consideration will be given to secure storage of any raw data, to ensure any conditions of anonymity are met, and the transparency and traceability of data is maintained.

5.2 Output 1: Informing the agent-based model for PEARL

Using the agent-centred method highlighted above, the work of RRCA Method will inform the Holistic and Multiple Risk Assessment undertaken in Work Package 3. This involves the development of RAFT (or a Risk Assessment Framework and onTology) that enables describing and addressing risk using holistic and multiple perspectives. RAFT will focus on gaining understanding of the structure and behaviour of the system as a whole and it will allow accumulation of knowledge to develop a holistic view on risk, its formation, propagation and cascading. This builds upon the RRCA Method, which will identify relevant actors and their interactions. RAFT then informs the development of first generation prototype agent-based models (ABM) of an evolving urban system, where flood risk is imminent, measures may or may not be taken, and the effect of strategy, governance and decisions may be tested at high-level with respect to their long-term effect on flood risk. The primary aim of the ABM modelling approach is to emulate, rather than to calculate (optimal) states of the system and to explore the possible development paths (i.e., possible states of the system or possible futures). This will in turn be used in WP6 to evaluate which development paths are acceptable and which are not.

The agent-based perspective of the RRCA work not only allows for fresh analysis of root causes, but fits with the agent-based model to be developed in PEARL. Work is already ongoing to align the conceptual structure and definitions produced in WP1 with the assessment and modelling exercises in WP3. The methods for data collection and analysis in the RRCA will be also aligned with the model requirements. The interview structure will be designed to inform the structure of the agent-based modelling exercise, which is based on a specific conceptual platform for understanding agent behaviour. Further, the semi-structured approach and the use of computer-aided software such as Atlas.ti to code and organise data allows the RRCA approach to be synergised with the work of agent-based modellers (Ghorbani et al. forthcoming).

5.3 Output 2: A quantitative, geo-referenced vulnerability assessment

The established FORIN approach and the revisions proposed to it sit within a tradition of political ecology research that emphasises social determinants of vulnerability. Consequently we propose our logic for the selection of vulnerability indictors draw from this tradition too. This view is well expressed in the work of Birkmann (2013: 97, drawing from Wisner 2002 and Wisner et al. 2004) that states "[...] vulnerability assessment[s] should focus on the likelihood of injury, loss, disruption of livelihood and other harm in an extreme event" and that this encompasses the "[...] identification of the variables that make people vulnerable and that show major differences in the susceptibility, coping and adaptive capacity of the people". This allows the elements of vulnerability (and hence of risk) to be assessed across broader spatial scales and in comparative metrics, and integrated with hazards data.

As mentioned in the introduction a compound index as a result of the quantitative vulnerability assessment will be designed drawing on definitions used by the IPCC (2014) and building on research methods that are widely acknowledged in the scientific literature. Therefore the three components of vulnerability (susceptibility, coping capacity, adaptive capacity) will be assessed separately via suitable indicators.

Examples for such assessments (although in some cases as sub-part of an overall risk assessment) can be found in the scientific literature as well as in reports and in grey literature (see amongst others O'Brien et al. 2004, Adger 2006, Pelling 2013). Birkmann et al (2010) and Depietri et al (2013) present local applications for cities in Germany and Spain, Greiving (2013) develops an approach for European regions and Cardona and Careno (2013) as well as Welle et al. (2013) provide assessment methods that can be applied on a national or sub-national level.

For the assessment the three components of vulnerability will be juxtaposed to the four spheres of the societal processes introduced in the RRCA framework (see Table 5).

			Societal Processes (based on RRCA framework)			
			Socio-Economic	Governance	Values & Perception	Physical
Components of Risk (IPCC 2014)	Vulnerability	Susceptibility				
		Adaptive Capacity				
		Coping Capacity				
		Exposure / Hazard				

Table 5 Matrix covering the components of risk and societal processes as basis for the PEARL vulnerability assessment

Source: own draft

Looking at the vulnerability in the case study region the assessment will sideline physical processes and concentrate on the susceptibility, adaptive capacity, and coping capacity at a given time which is the result of socio-economic, governance, and perception processes as drivers, and root causes (see the RRCA Method). These exercises are highly dependent on data availability which determines the scale of analysis at the same time. The aim is to calculate results on a scale as fine as possible (maximum borough level).

The indicators describing the components of vulnerability on the ground are set by the results of the RRCA Method, with the vulnerability assessment meant to "[test] hypotheses of risk causality

(hazards, land use, built environment, development paths, values and perceptions, lack of accountability, governance and others), developed under T1.4”´(PEARL DoW, European Commission Directorate-General for Research and Innovation 2013). Nevertheless the vulnerability assessment can also be conducted as a stand-alone exercise to inform policy makers, planners and managers or to be integrated in future planning and management processes.

Thus suitable statistical information has to be selected accordingly. Based on that - as originally proposed - quantitative data gathering will map indicators using (1) existing data bases on the respective scale, (2) geo-spatial information (such as land use, population density, etc.), (3) expert interviews (to gather information e.g. on local conditions and also data sources and availability) and (4) household surveys to get a representative overview of the susceptibilities and capacities of the households on a spatial scale.

In the course of data acquisition the researcher team will employ several sources and techniques (including data validation). Here a strong collaboration with the research teams working on other work packages (3, and 5) is necessary.

1. Statistical and geospatial data will be provided by the stakeholders and local representatives.
2. Additional statistical and geospatial data (e.g. land use data) will be accessed through open data bases such as the CORINE (http://www.eea.europa.eu/data-and-maps/) land cover data set.
3. The initial expert interviews will be coupled with the research undertaken under the RRCA Method.
4. Further interviews will be conducted by the research team of WP1. These interviews will be semi-structured and – like all interviews conducted in under WP1 – aim at providing results to other tasks within PEARL (e.g. ABM in WP3).
5. The design and roll-out of the household surveys will encompass the following steps
    5.1. Development of the questionnaire, statistical validation and first ground-test will be done by the WP1 team.
    5.2. The household data sets will be provided by local representatives (e.g. by statistical offices). Here it is essential that the data sets are representative for a number of spatial entities (as discussed above as fine as possible resolution is the aspiration). The sample size is dependent on the population and the number of spatial entities at the respective scale.
    5.3. The survey will be conducted by students of local universities under the direct supervision of the PEARL researcher team (the survey will be anonymously conducted and no names will be used during the survey). Here it is important to provide an in-depth introduction to the topic and the techniques needed for the survey. Hence it will be aimed at embedding this exercise in a course at the respective university. If this should not be feasible in one of the case study areas the responsible partners will explore the opportunity to employ local academics the support the field research. The local teams will also transfer the data surveyed to a digital format that can be transferred over to software for statistical analysis (e.g. SPSS).
    5.4. The analysis of the data sets will be done using a statistical analysis tool. The statistical validation of the results will be tested.
    5.5. The results can then be used to accomplish the statistic and geospatial information mentioned above.
6. The statistical validation of all data sets will be done separately to ensure their equipartition and liability.

The results of the vulnerability assessment will - presented in maps or ranked lists - be tractable to policy-makers at the respective scales and can be integrated in ongoing or future spatial planning or management processes. Furthermore the results will feed into the PEARL holistic risk assessment (WP3).

5.4 Developing indicators to track root causes

In addition to the RRCA Method and other assessment techniques described above, Work Package 1 will seek to develop quantifiable indicators that can represent the contribution of historical factors to contemporary vulnerability and risk. Where possible, the PEARL methodology seeks to establish the linkage in its connection of the RRCA Method with vulnerability assessment, but this proposed additional output goes further in making the most salient root causes themselves the objects of an indicator framework. On the back of initial case study results, a methodology of transferable indicators for assessing the linkages between root causes (in history and scale) and contemporary expressions of vulnerability and risk status would be developed which could be further tested in remaining case studies.

This approach will build on a long history of studies that already use indicators to assess vulnerability and risk, the manifestations of root causes. Here, selected indicators will be examined as a basis for translating the PEARL RRCA into an indicator system. Examples of various indicator based indices can be found on different levels and scales. For example Cardona and Careno (2013) present a "System of indicators of disaster risk and risk management of the Americas" that has been developed on behalf of the IDB (Inter-America Development Bank), Birkmann et al. (2011) developed the World Risk Index, and Foa (2014) published the "Household Risk Perception Indices" as a background paper for the "World Development Report 2014" (World Bank 2013). All these indices use quantifiable indicators to evaluate the vulnerability / risk of communities, regions or countries. Thus the outcome of root causes as a statement of the actual situation is covered but a clear link to their development is missing. The research in PEARL faces two major challenges. The first is how to integrate root causes into indicators based monitoring systems. The second builds on the question Pelling (2013) raised "[…] how can high-resolution assessments best feed into development and disaster risk reduction decision-making" and should therefore concentrate on which root causes and determinants of vulnerability/risk are needed to inform future plannning and decision making processes. Furthermore the review of the Hyogo Framework for Action and the development of HFA 2 – the post-2015 international framework for disasters reduction – provides PEARL an opportunity to contribute to a new international framework for monitoring efforts to tackle disaster root causes, the least well performing aspect of the monitoring framework set up under HFA 1. The development of an ISDR indicator set – the first comprehensive global approach to assessing root causes –gives this concrete form. In terms of making the method in PEARL able to support the HFAII agenda, currently the monitoring system of the HFA only focuses on the national scale but the renewed approach within the post-2015 framework seems likely to call for an applications to the sub-national regional level, to be assessed by national representatives. This is helpful for the methodology developed and deployed through PEARL, which focuses on local expressions of contemporary vulnerability, but is connected to root causes that each up and out to the regional, national and global.

Further compatibility can already be guided by early statements from UNISDR, which suggest that UNISDR conceives the root causes of risk as a product of risk knowledge and governance (two domains already in our methodology); UNISDR conceives of root causes leading to expressions of risk and resilience (pathways also envisaged in the PEARL RRCA Framework); and UNISDR conceives of the final outcomes of risk and resilience being expressed in impact and loss. The distinction between these two is not clear but again PEARL needs to be able to construct relationships between historical governance and risk knowledge, risk and resilience, loss and impact.

UNISDR (2014[2]) also includes a list of high-level drivers of risk: badly planned and managed urban and regional development, poverty and inequality, environmental degradation, climate

[2] The document is a "draft for consultation" and is not representative for the work of UNISDR yet.

change, governance, risk. These cover a wide range of variables that can increase or decrease the vulnerability of any given spatial entity. However, there is no sequence in the assessed set of indicators – thus the researcher has to differentiate causes and effects for each case. This allows for context and variability between data and cases, but also allows ambiguity to enter at the stage of analysis. PEARL has an opportunity here to provide analytical protocols that others might follow. This can include simple questions that researchers could ask of the data and their relationships.

6 Case Study Selection

The selection of case studies is essential for the success of the work package since the testing of the RRCA framework and the development of policy recommendations is dependent on the results of the field research. The aim is to choose:

- 3 to 4 locations
- At least 2 of which will be situated in Europe, with at most 2 non-European cases
- At least 2 cases in which the RRCA assessment will take place alongside the vulnerability assessment and hazard analysis, feeding into a holistic risk analysis

By applying the research approaches and methods, transferring the results to policy recommendations, and using the stakeholder meetings (in the context of the LAAs) as a distribution platform the project will feed back its results in the planning and managing processes in the case study areas. The extent of this feedback is highly dependent on the interest, and capacities of the local stakeholders. The minimum feedback is the discussion of the PEARL results with the stakeholders in the last round of workshops under the umbrella of the LAAs.

At the time of completing this deliverable paper, the selection process was not fully complete as further discussions with case study partner and local representatives were required. Nevertheless, Table 6 sets out the generic criteria for case selection. Generally the case study selection is dependent on the fact that the hazard related conditions allow for a comprehensive study, on data availability, and on the willingness of stakeholders to cooperate on the respective topics. Another criterion is the availability of resources (time/research budget) on the case study partner side. This is essential to make sure that the case study partners are able to organize and facilitate the stakeholder workshops, to support the field work and to support the research team by, for instance, by translating relevant policy and scientific publications, and by interpreting interviews.

General criteria	Recent flooding event with high local implication (local impact and involvement of local stakeholders)	History of flooding impacts at local scale of ongoing concern	Presence of local flood management systems and ability to interview local flood managers	Availability of data in language accessible to PEARL researchers or availability of resources for an adequate translation	Team members involved in partnerships with local stakeholders (LAAs)	Alignment of Work Package teams in case study area	Possibilities for stakeholder engagement and interest in collaboration	Availability of statistical data
Motivation	Event from which to draw out attribution based on local narratives	Ability to assess impact of historical root causes on contemporary and future scenarios	To explore the governance dimensions of root causes across different types of institutional regime	To enable effective research	To enable effective research and dissemination of results	To enable the construction of holistic risk assessments in at least two case study areas	To enable effective research and wide dissemination of results	To enable the application of vulnerability assessments
Case study 1								
Case study 2								

Table 6: Overview of criteria for case study selection

This table is used for the communication with the stakeholder partners, and for internal communication. The completed table will be used for the final case study selection. While this report is drafted there has no final decision been made. A completed version of the table will be presented in the next deliverable of WP1.

7 Next Steps

The most important next step is the finalization of the case study selection process for the field research in work package 1. This will take place by end October 2014.

During the planning phase close collaboration with PEARL partners involved in the field research is needed. Hence a close interaction with representatives of work package 3 and 5 has been initiated. Table 7 lists all relevant PEARL milestones that have a connection with the field research under work package 1. The main goal of this collaboration is to ensure that the work in the case study areas is as efficient as possible, that each stakeholder meeting and workshop covers as many interests of the PEARL consortium as possible and that the results of the field study are as comprehensive as possible.

WP	Submission*	Task	Project Month	Calendar Month
		Work Package 1		
1	MS1	Formulation of the draft RRCA framework	6	July 2014
1	MS2	Formulation of methodology for RRCA including quantitative and qualitative vulnerability assessment	9	September 2014
1	D1.1	Report describing a draft PEARL RRCA framework	10	October 2014
1	MS3	Actor interactions given as inputs into the agent-based models - generic	18	July 2015
1	MS4	Actor interactions given as inputs into the agent-based models - case studies specific	24	December 2015
1	MS25	Completion of two case study analysis and vulnerability assessments	24	December 2015
1	D1.2	Final PEARL framework and source book	30	July 2016
1	D1.3	Final report describing the full RRCA methodology and its applicability	36	December 2016
		Other Work Packages		
3	MS9	A concept for holistic and multiple risk assessment developed	12	December 2014
5	MS15	A demo version of the knowledge base tested on a case study	24	December 2015
5	MS16	Completion of the second round of workshops	24	December 2015

**MS=Milestone; D=Deliverable*

Table 7: Relevant submissions for PEARL research activities in the WP1 case study areas

Further next steps in WP1:

Selection of research methods and documentation

Alongside the selection of the research areas, the set of research methods for the WP1 field research will be developed. This will encompass qualitative and quantitative research methods covering the needs of WP1 but also the result of the collaboration with the work packages 3 and 5. This will ensure that the stakeholder meetings and group discussions are the most efficient uses of stakeholders' time.

Furthermore the research team will develop common methods templates and streamlined documentation systems for primary documents and secondary analysis documents across the

research methods. This ensures the comparability and transferability of methods and results between case study areas and the phases of the WP 1 research (RRCA, ABM input, vulnerability assessment, and indicator set-up). This is of particular importance to ensure that data sets surveyed in one phase can be used in another phase, and in other contexts respectively.

Development of hypotheses for field research
Building on an in-depth literature review concerning the case study areas and on the RRCA framework a set of research hypotheses will be developed for the first round of case study activities. These will encompass the expected outcome of the stakeholder workshops under the umbrella of 'Learning and Action Alliances' (LAAs), a draft of the root cause analysis based on the literature review, and first assumptions on the spatial distribution of vulnerabilities in the case study area.

Building synergies with partner projects
It is the agreed aim of PEARL to build on, and reach synergies with partner projects where ever it is possible and seems useful. Based on the selection of case study areas WP1 researchers will explore overlaps and possible synergies especially with the FP7 project RISC-KIT which is active in some of the PEARL research locations (http://www.risckit.eu/np4/home.html).

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Annex A. FORIN Case Studies

The FORIN case studies were analysed for what they tell us about the strengths and limits of, and gaps in FORIN as applied to date. As can be seen from the table below, the strengths of the FORIN approach lie in its conception of disasters as inseparable from both development processes and everyday societal processes; comprehensive analysis that learns from the past to ground sustainable disaster management; inter-disciplinarily; the inclusion of multiple stakeholders; the adaptability of FORIN components and the range of methodological pathways, which allows for scenario analysis alongside historical methods. Limits included defining the scope of FORIN and allowing for the analysis of changes in imperceptible 'climate normals' alongside disaster events. Common gaps included methods and concepts for analysing causal relationships.

Summary of the strengths, limits and gaps in FORIN in case study applications of the approach

Study	Strengths of FORIN	Limits of FORIN	Gaps in FORIN
Naruchaikusol, Beckman & Mocjizuki 2013	Allows for investigation inter-play disaster risk and development processes at different scales and effects of cumulative decision-making at these scales Scenario method allows integration of predictive methods		
Huang et al. 2013	Conceptual view of disaster as inseparable from everyday and wider development and societal processes; disasters as result of the outcome of interaction between different systems and different phenomena Inter-disciplinary framework, importance of historical approach for policy learning, allows for synthesis of societal dynamics, pre, during and post	If disaster is perceived of as societal disturbance, where limits of 'disaster' end, how to define relevant stakeholders, what are the criteria for setting a generic framework across different disaster types, what are the implications for policy from this comprehensive view	Authors turn to systems theory for conceptual and methodological basis for the analysis of causal pathways; use to establish most critical phenomena and main 'storylines' that explain their relationship

	disaster, assists comprehensive scenario planning		
Castillo et al. 2013	Use of comprehensive, inter-disciplinary approach that integrates perspectives of different stakeholders Adaptability of hypotheses, objectives and methods of FORIN to context of climate change (Also innovation of the FORIN narrative allowed for preliminary studies to be produced)	Influence of long-run changes in climate 'normals' Practical challenges of inter-sectoral work	Models used to enhance the predictive capacities of the FORIN approach, allowing analysis of common variables affecting risk and resilience to disasters and climate change Objectives modified to include element related to transformational change The original FORIN framework was also modified to include a more explicit characterisation of risk (as the holistic analysis of hazard, exposure and vulnerability in the past, the present and projected into the future), the research cycle itself and capacity building as a core element by which the research results are implemented. The report also included modifications made to the core questions to adapt them for the context of climate change.
Faustino-Eslava et al. 2013	Use of FORIN as a predictive tool even where there is no history of disaster Inclusion of multiple		

	stakeholders in discussions of risk mitigation measures		
Fujiwara, Sagara & ICHARM studies of GEJET			Questions around damage to infrastructure networks, and damage propagation between networks

Source: own draft

Annex B. List of cases reviewed for literature review

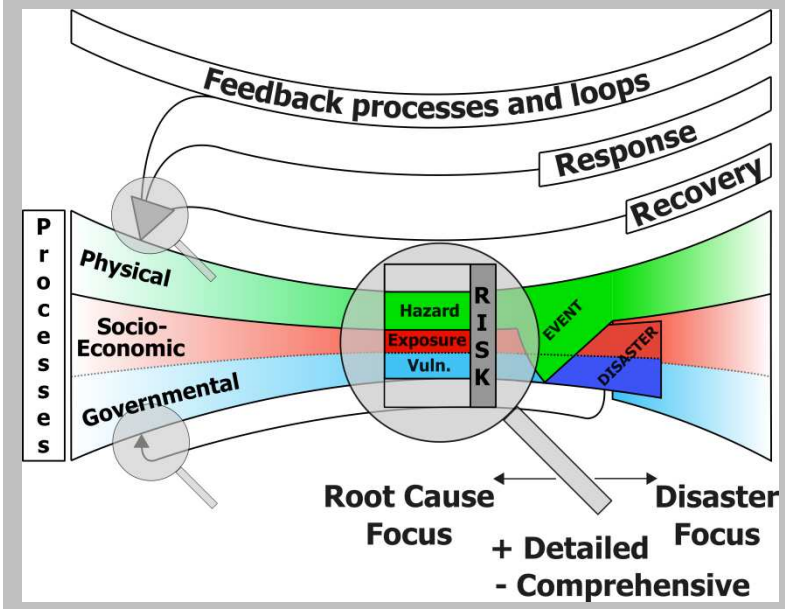
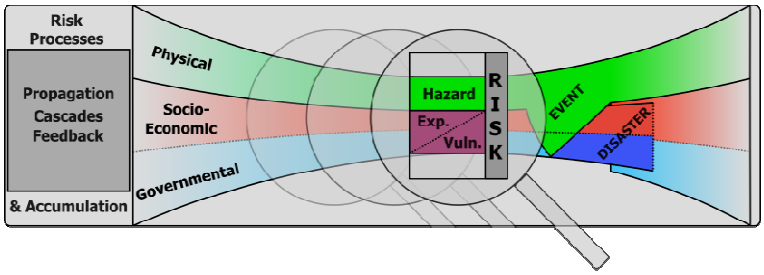
Case	Relevant literature
1953 North Sea flood, East coast UK and Netherlands	Lumbroso and Vinet, 2011
	Gerritson 2005
Southern Netherlands	Jonkman et al. 2008
2010 Xynthia storm, West coast France	Genovese et al. 2013
	Lumbroso and Vinet, 2011
2002 and subsequent events, Dublin, Cork and Galway, Ireland	Jeffers 2014, 2013a & b, 2011
2005 Outer Hebrides, Scotland	Muir et al. 2013
	Young et al. 2014
2002 Kristianstaad, Sweden, and 2002 and 2007 Greve, Denmark	Francke 2008
2007 Hull, UK	Whittle et al. 2010
	Coultard et al. 2007
	Coultard et al. 2010
Thames estuary, UK	Lewis and Kelman 2009
Copenhagen, Denmark	Hallegatte et al. 2011
	Pederson et al. 2012
Elbe estuary, Germany	Storch 2008
1990 Towyn, Wales	Riley and Meadows 1995
Poland	Kundzewizc 2014
Yser river and Belgian coast, Belgium	Kellens et al. 2013
Scottish coast including Saltcoats, Ayrshire, and St Andrews Links	James Hutton Institute 2012
2009 Cockermouth, UK	Wedawatta 2012
Vistula delta plan, Poland; Elbe estuary, Germany; Plymouth to Exe, UK; Santander Bay, Spain; Scheldt Estuary Belgium / Netherlands; Varna Coast, Bulgaria; Gironde estuary, France; Po delta and coast, Italy	De Vries et al. 2011

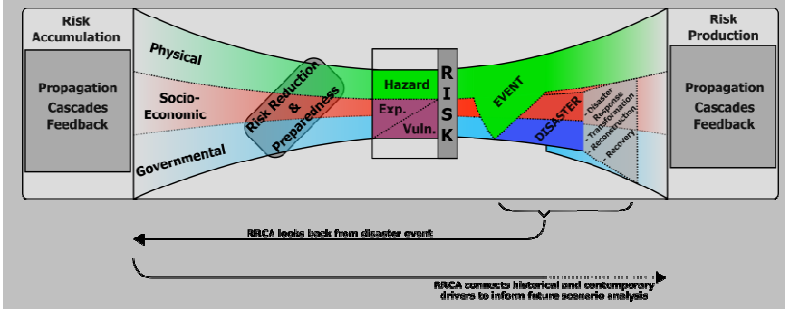
Source: own draft

Annex C. Development of the RRCA Framework Figure

This annex shows the development of the RRCA framework to the state that is presented in this report. Building on the basic idea to connect a physical event that causes a disaster (based on the risk as on overall concept) with the root causes for the actual situation during this disaster in various spheres constructing a society and hence with the root causes for the risk the RRCA framework and the figure representing the framework respectively have been developed further over the research in work package 1.

Development of the RRCA framework over the initial phase of the PEARL project

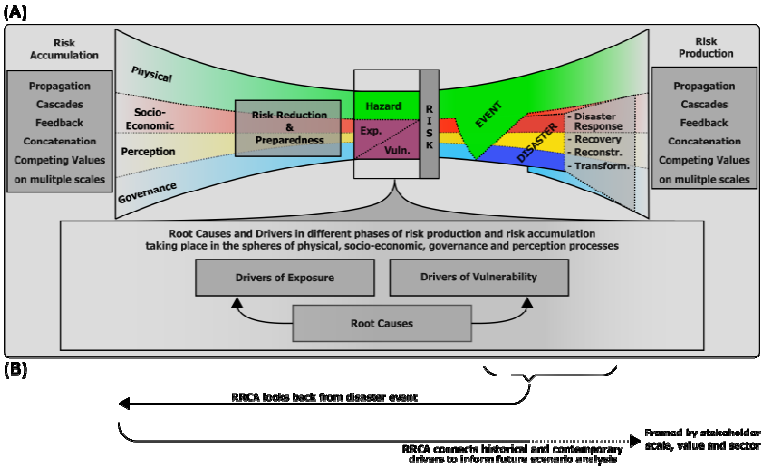
Figure RRCA framework	Selected updates of the figure
	**Version 4** The ongoing socio-economic processes are displayed seperated in three spheres (physical, socio-economic, governmental). These spheres are disturbed by an event that results in a disaster. The extend/impact of the disaster is determined by the hazard, the exposure of assets, values or people and their vulnerability. Feedback processes lead back from the disaster, the response, and the recovery phase and indicate that these phases already set the basis for the further development of the society. The loupe indicates that the PEARL RRCA framework can be more and less detailed and will look back and forth in time centered on a disaster event. All later version of the figure built on this basic idea.
	**Version 6** The feedback process parts have made way for the underlying „Risk Processes and Accumulation“ processes that are now lying under the general development of the three spheres. Here propagation, cascades, and feedbacks are embedded.



Version 12

Risk accumulation and production now parenthesize the processes while risk reduction and preparedness shape the societal processes. In the aftermath of the disaster processes of disaster response, transformation, reconstruction, and recovery shape the development.

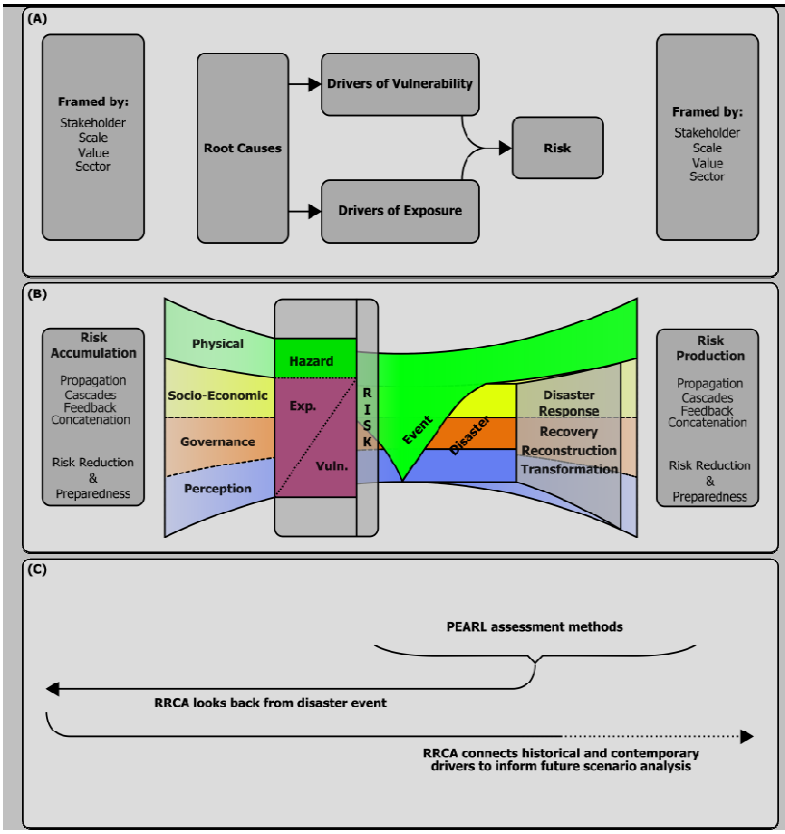
In this figure the RRCA framework methods are introduced. Here it get clear that the RRCA is going to look back from a disaster event to assess the disaster root causes and connect these with contemporary drivers to inform future planning and management.



Version 14

At this stage two extensions are introduced:

1. The conceptual approach of the RRCA framework has been added (Root causes, drivers of vulnerabilits, and drivers of exposure)
2. The methodological part (B) is separated and the framing by stakeholders, the scale and values is introduced.



Version 17

The three parts (conceptual approach, processes, methods) are separated in three sections (a,b,c).

In part B the processes of risk reduction and preparedness are now part of risk production and risk accumulation. Both aspects reduce or raise the risk while risk is produced and accumulated. Hence both should be part of the boxes indicating the risk processes.

Version 18 (latest version to date)

Source: Own drafts

Annex D. Research ethics consent forms

CONSENT FORM FOR PARTICIPANTS IN RESEARCH STUDIES

Please complete this form after you have read the Information Sheet and/or listened to an explanation about the research.

Title of Study: Preparing for extreme and rare events in coastal regions

King's College Research Ethics Committee Ref:_____

Thank you for considering taking part in this research. The person organising the research must explain the project to you before you agree to take part. If you have any questions arising from the Information Sheet or explanation already given to you, please ask the researcher before you decide whether to join in. You will be given a copy of this Consent Form to keep and refer to at any time.

I confirm that I understand that by ticking/initialling each box I am consenting to this element of the study. I understand that it will be assumed that unticked/initialled boxes mean that I DO NOT consent to that part of the study. I understand that by not giving consent for any one element I may be deemed ineligible for the study.

Please tic or initial

or ☐

1. ***I confirm that I have read and understood the information sheet dated [INSERT DATE AND VERSION NUMBER](tobe inserted based on finalisation of the information sheet according to case study site and stakeholder) for the above study. I have had the opportunity to consider the information and asked questions which have been answered satisfactorily.** ☐

2. ***I understand that my participation is voluntary and that I am free to withdraw at any time without giving any reason. Furthermore, I understand that I will be able to withdraw my data up to [*insert date if stated on Information Sheet*] OR [insert text clearly defining time limit e.g. "the point of publication" OR "the time of transcription" OR "2 weeks after my interview"(to be concluded depending on timing of research)** ☐

3. ***I consent to the processing of my personal information for the purposes explained to me. I understand that such information will be handled in accordance with the terms of the UK Data Protection Act 1998.(to be modified according to country of case study site)** ☐

4. ***I understand that my information may be subject to review by responsible individuals from Kings College London for monitoring and audit purposes.** ☐

5. **Anonymity is optional for this research. Please select from the following 3 options:** ☐

    a. **I agree to be fully identified** ☐

b. I agree to be partially identified (my job role and organisation will be cited, but not my name)

c. I wish to remain anonymous ☐

6. I agree to be contacted in the future by King's College London researchers who would like to invite me to participate in follow up studies to this project, or in future studies of a similar nature. ☐

7. I agree that the research team may use my data for future research and understand that any such use of identifiable data would be reviewed and approved by a research ethics committee. (In such cases, as with this project, data would/would not be identifiable in any report). ☐

8. I understand that the information I have submitted will be published as a report and I wish to receive a copy of it. ☐

9. I consent to my interview being audio/video recorded. ☐

_____	_____	_____
Name of Participant	**Date**	**Signature**
_____	_____	_____
Name of Researcher	**Date**	**Signature**

INFORMATION SHEET FOR PARTICIPANTS

REC Reference Number:[INSERT ONCE PROVIDED BY REVIEW BODY]

YOU WILL BE GIVEN A COPY OF THIS INFORMATION SHEET

Title of study

Preparing for extreme and rare events in coastal regions (PEARL)

Invitation Paragraph

We are writing to enquire whether you would be available to participate in interviews being carried out as part of the PEARL project, for which x (case study site) is a key site for the research.

What is the purpose of the study?

The PEARL (Preparing for extreme and rare events in coastal regions) project is an EC funded project that aims to develop risk management strategies for coastal communities. Preparing for effective response to extreme events not only involves technology but also social, economic, organisational and political considerations. Part of the project therefore involves investigating the range of causal factors that have contributed to the exposure and vulnerability of different populations and infrastructures to extreme events. PEARL researchers are conducting interviews with a wide variety of stakeholders to examine these aspects.

Why have I been invited to take part?

X (local research partner in case study site) have identified your organisation as key to efforts to manage disaster risk in y (case study location) / your organisation has been identified as one of the main groups affected by x disaster.

Do I have to take part?

No – participation in the project is voluntary.

What will happen to me if I take part?

We will schedule an interview with you at a time and convenient location for you. If you agree, the interview will be audio or video recorded. The interview will last for 1-2 hours, but where inconvenient we can arrange to meet according to your schedule, or on several occasions.

Incentives (where relevant)

n/a

What are the possible risks of taking part?

None – see consent form for details about preferred anonymity and consent to recording the interview.

What are the possible benefits of taking part? (Not mandatory)

Will my taking part be kept confidential?

If you prefer to keep your participation confidential this will be respected at all times (and the procedures on the consent sheet followed). If you will allow us to list your name and organisation we would do so as part of a list of interviewees included as an annex to any research report we produce.

How is the project being funded?

The project is funded by the European Commission.

What will happen to the results of the study?

Interviews findings will be compiled into a case study report which will feed into further research papers and a sourcebook for policy makers in the EU. After we have completed all of the case studies, case study findings will be presented to the stakeholders interviewed for their verification and feedback. Original transcripts and notes of interviews will be coded so that the identity of the interviewee is only accessible to the project researchers, and stored securely.

Who should I contact for further information?

If you have any questions or require more information about this study, please contact me using the following contact details:

arabella.fraser@kcl.ac.uk / phone number relevant to the site location – also possible contact details of local research partners.

What if I have further questions, or if something goes wrong?

If this study has harmed you in any way or if you wish to make a complaint about the conduct of the study you can contact King's College London using the details below for further advice and information: rec@kcl.ac.uk

Thank you for reading this information sheet and for considering taking part in this research.

Annex E. Description of PEARL Case Studies

NOTE: The following descriptions are part of the PEARL DoW and summarize the situation in the case study areas.

Rethymno, Crete, Greece

The Port of Rethymno and the adjacent coastal area are sited at the prefecture of Rethymno, Crete, Greece. The harbour is located in the North, within the homonymous bay. It is a harbour of both free and commercial use and it has been separated into two parts: a) the western part (for commercial and passenger use and b) the eastern part (for passenger and visitor use). In the same area the Marina of Rethymno is also located on the eastern side, as well as the Old (Venetian) harbour of Rethymno.

The coastal zone of Rethymno is exposed throughout the year to strong N and NW winds (7-8Bf) with great fetches, resulting in the development of great waves. Changes in wind conditions – probably due to climate change - had resulted in causing storm events more frequently than in the past. More specifically extreme weather conditions with strong winds resulted in the creation of storm waves combined sometimes with flush floods form ephemeral streams. As a result of the extreme waves violent wave overtopping occurring along the windward breakwaters of the harbour and threats the stability of breakwaters as well as the safety of human population. Further huge quantities of seawater cause interruption in loading and unloading operations, damage to the port facilities and the cargo, traffic problems and damage to coastal shops and restaurants. Additionally, in the area adjacent to the harbour recreational beaches are exposed to erosion.

Elbe Estuary, Hamburg, Germany

The Elbe estuary (Figure below) is the tidal-influenced section of the river Elbe between the weir in Geesthacht (km 586) and Cuxhaven (km 728)- North sea, which encompasses three federal states- Länder being Hamburg, Schleswig-Holstein and Lower Saxony. The mean tidal range near the north sea at gauge Cuxhaven is about 2.95 metre and in Hamburg at gauge St. Pauli about 3.65 metres. This section of the Elbe estuary (Hamburg – North Sea) is one of the most important shipping routes of the Europe – Far East Route. Hamburg Port is one of the three major ports in Europe.

Due to the storm surges in the North Sea, the flood defence structures (e.g. dikes) are generally exposed from high water levels, waves and wind along the Elbe estuary. Due to climate change, higher water levels and waves can be expected (http://klimzug-nord.de). For this, hydrological and hydrodynamic loads especially on dikes entail a higher probability of failure mechanism like overtopping or overflow. Therefore, typical type of hazard is estuarine flood incl. risk of failure of flood protection infrastructure in the estuary due to extreme storm surges. Additionally, due to the heavy precipitation (higher hydrological loads expected from climate change) and the urbanisation of the hinterland risk of flooding of the hinterland can increase. This forms a complex system- estuary-flood defence structures hinterland, for which the appropriate strategies cannot be derived ad hoc.

Irish Sea, Liverpool, Great Britain

The Irish Sea (see figure) separates the islands of Ireland and Great Britain. It is connected to the Celtic Sea in the south by St George's Channel, and to the Atlantic Ocean in the north by the North Channel.

The sea is of significant economic importance to regional trade, shipping and transport, fishing, and power generation in the form of wind power and nuclear plants. Annual traffic between Great Britain and Ireland amounts to over 12 million passengers and 17 million tonnes of traded goods. There is an increased risk of devastation due to socio-economic factors as the floodrisk areas with fertile soil and access to communications are generally densely populated: many cities have developed at the coast. Driven by projected increases of sea level, more intense rainfall, and stronger winds, flood risks are anticipated to increase in the future and impact this region. In the UK, the coastline is 4500km long. 2,200 km2 (with 5% of the population), is at risk of coastal flooding: some large urban and agricultural areas, but also very many small more isolated areas. The capital value at risk is estimated at 250 billion euros.

Greve, Denmark

The study area covers the coastal area of Greve in eastern Denmark. It is a sub-urban area around 60 km2 in size and located about 20 km south of Copenhagen. Several streams in the area drain into Køge Bay in the East. These streams are integral parts of the drainage network, which is comprised of dense connections of underground pipes, open channels, manholes, basins, and outlets to the bay. The municipality has about 9 km of coastline along which the area is densely built-up with residential settlements and characterized by relatively flat terrain with elevations ranging from 2-6 m.

Understanding of the flood problem in the Greve area calls for holistic analyses of the interaction between the rural areas surrounding the city; urban drainage system (sewers and urban rivers) in conjunction with the storm surges and the associated impacts on the urban water system due to backwater preventing drainage into the sea. This includes modelling and understanding of joint probabilities between extreme rainfall and storm surges today and in the future.

Les Boucholeurs, France

“Les Boucholeurs” is a district of Châtelaillon-Plage located on the limit of Yves, one of two cities of the Charente-Maritime county. This district counts approximately 600 houses and has important activity in oyster and mussel farming.

The Atlantic coast is threatened by storm surges and potentially by the sea level rise. Those events could contribute to the failure mechanisms of the embankments and could generate increased water level on the rear part of this area, which is lower that the coast line itself.

Genoa, Italy

The Genoa case study concerns the coastal area and the Bisagno River Basin with a Population of 600.000. The focus of the case study is on the Bisagno mouth, streaming into urban area, and on the Fereggiano sub-basin. Flood prone areas have been evaluated for return period of 500yrs, 200yrs and 50yrs.

Extreme events affecting the Bisagno River Basin are: Heavy Precipitation (HP): The Mediterranean region is a clear example where large-scale flows and topography are contributing factors to the occurrence of heavy precipitation events. In the study area of the Liguria Region, localized extreme precipitation is produced by large-scale flow interaction with regional topography. Cyclones (C): they relate with a low pressure area (called also Genoa Low) insisting on the Genoa Gulf. The depressions bear rain, often intense, on the Liguria coast. Risks associated to the case studies: Flash Floods (FF), Pluvial Floods (PF) Combinations of Floods (CoF) , Coastal Floods including estuarial floods (CF).

Marbella, Spain

The city of Marbella is located in the southeastern part of Spain. With a population of around 130.000 inhabitants, it is the second city of the Málaga province. The city is located by the Mediterranean sea, and therefore, it is under the influence of Mediterranean climate, with dry and hot summers and wet and warm winters. Due to the weather and the attractive beaches of the area, tourism has become one of its main economic activities. Because of the tourism, the city experienced an important urban growth, which in many cases was not properly planned. As a consequence, flood vulnerability, and hence risk, have increased considerably in many areas. High economic damage potential: high-class resorts, four recreational ports, several golf clubs and lots of different kinds of facilities.

Meteorological phenomenon known as “gota fria” occurs often when a front of cold air at high altitude penetrates into the warm air, causing high intensity precipitation events, stormy periods that mainly occurring in autumn. Such rainfall events imply urban floods with short lead times, when the drainage network has not enough capacity to drain all the water runoff. Storm surges occur often creating important problems in recreational ports and increasing erosion problems in the numerous beaches of the city. Both situations are critical in the city because Marbella’s main activity is the tourism attracted by its beautiful shore. The combination of events is especially critical. When intense precipitations occur at the same time with storm surges, water can’t be discharged to the sea increasing the severity of floods in the coastal areas.

St. Lucia, The Caribbean

The study area is the administrative capital (Castries) of a small island nation (623Km2) in the Caribbean St. Lucia. The capital is built at the piedmont of the main drainage basin and is situated within the flood plans of the Castries River (main river). However, the core central business district of the capital is located on the right flood plain (north) of the Castries river. There are several other minor (ravines) waterways which drain into the Castries area which are connected and form an integral part of the drainage system which comprises of a network of covered box drains, underground pipes, culverts, open channels, detention pond and outlets which drains into the harbor. The study area is low lying and is approximately 0.45km2 with the surrounding areas at much higher elevations.

Flooding is perhaps the most frequently occurring natural disaster affecting island states like St. Lucia. It is most prevalent during tropical storms and hurricanes. These bring along heavy rains, strong winds and storm surges that can cause destructive flooding in both coastal and inland areas. Understanding of the flood problem in Castries calls for an integrated analysis of the interactions of runoff from the river basin with the storm surges and the associated impacts on the urban water system due to backwater preventing drainage into the sea. This includes modelling and understanding of joint probabilities between extreme rainfall and storm surges today and in the future. Although there has hardly been any loss of life due to flooding, the city would like a real time information and warning system including uncertainty estimates and emergency measures. This would have a dramatic impact on the socio-economic developments ahead.

NOTE: The following descriptions are not part of the DoW but based on the presentations of the PEARL partners responsible for the respective case study areas during the PEARL meeting in July 2014 (Crete).

St. Maarten, the Caribbean

The island of St. Maarten is situated east of Puerto Rico between the Atlantic Ocean (east) and the Caribbean Sea (west). It is administratively divided in two parts. The northern part is – with its main city Marigot – under French administration, the southern part in under Dutch control. Here the main city is Philipsburg which is build around a big salt water lagoon (Great Salt Pond). From the shoreline in the south, very steep slopes lead to the inner part of the island. The main parts of the city of Philipsburg are constructed on these slopes. The city as well as the rest of the island is going through a process of very rapid development which has led to a mainly reactive management system in which planning processes are trying to catch up with the latest developments. Under these circumstances the administration shows a considerable deficit in the effectiveness of its decision makings.

The entire island is exposed to a number of natural hazards of which flash floods, costal floods and high wind speeds are the most influential. Especially a combination of all three hazards caused some significant causalities and damages in the recent years. But the impacts of the hazards have been different in the two administrative regions. Among the various reasons for this fact are different building codes (and their adherence) and management systems two of the most important ones.

The research efforts in PEARL will be centred on the identification of the vulnerability and risk in the southern part of the island, as well as the root causes for these (perhaps in comparison to the northern part of the island), the validation of the transferability of best-practices or lessons learned from the northern part of the island, and the integration of the results into agent based modelling exercises to show the potential influence of altered management and planning systems.

A first agent based model for the city of Philipsburg is already in place taking into account the hazard side and some first policy issues. Furthermore the hazard data and digital elevation / terrain models are available.

Havana, Cuba

The city of Havana is the capital of Cuba (located between the Caribbean Sea and the Gulf of Mexico) and situated on the northern shore of the island. Since 1959 Cuba has a communist political system which shapes the management and planning processes on all levels.

The old town of Havana is a World Heritage Site. Due to its old building structure very susceptible to natural hazards. But against the background of a very long history of natural hazards (mostly pluvial and coastal flooding as a combined hazard and recurrent hurricanes – every year) there is a "culture of disaster management" in place with many experiences in the management of extreme events (the government is able to evacuate 4 million people in just 4 hours). In combination with an aging infrastructure these circumstances lead to relatively high damages but just a small number of causalities.

In Havana the research undertaken in PEARL can build on very good data availability and a broad knowledge base (due to community risk management the knowledge is widely spread among the population). Before the research can be started it has to be verified if the local, regional, and city stakeholders are willing to give information about problems and shortcomings in the management and planning system.

Ayutthaya, Thailand

The city of Ayutthaya is situated approximately 80 kilometres north of the city centre of Bangkok and along the Chao Phraya River (the largest river in Thailand). The old town is a World Heritage Site – hence the economic structure is, although diversified, dependent on touristic activities.

The flooding situation in the region of Ayutthaya emerges from combined influences of the tide in the Gulf of Thailand, rainfall, and river flooding. The flood management, the spatial planning and the living style amplify these impacts by leading to a dependency on dykes, and levees, and to a declining sense of the traditional way of living with the water.

The PEARL research can draw on a number of studies on flooding in the region of Ayutthaya, and on a broad data base. The research could be centred on the root causes of risk and vulnerabilities and on the improvement of future planning and management decisions against the background of the research.