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PEARL - PREPARING FOR EXTREME AND RARE EVENTS IN COASTAL REGIONS

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ABSTRACT: Coastal floods are regarded as one of the most dangerous and harmful of all natural disasters. Rapid urbanization in coastal areas combined with climate change and poor governance can lead to a significant increase in the risk of local pluvial flooding coinciding with high water levels in rivers and high tide or storm surges from the sea, posing a greater risk of devastation in coastal communities.

There is a need to improve forecasting, prediction and early warning capabilities using state of art science and technology to help policy makers and emergency services to develop robust risk reduction strategies. However, forecasting and prediction is only part of the answer. Of equal importance is the ability to effectively warn the population in areas that will be affected. All warning systems feature multiple lines of communication enabling emergency messages to be sent to the emergency and rescue services, as well as to warning systems for the general public. For such systems to be effective, it is essential that they are integrated into broader management strategies and supported by appropriate institutional and organizational arrangements. Therefore, preparing for effective response to extreme events not only involves technology but also significantly social, economic, organizational and political considerations. Currently there is a clear indication of a lack of interaction between social aspects and technical measures and this appears to be a major hindrance for solving some of the greatest problems associated with floods and flood-related disasters.

To overcome these shortcomings, and based on the belief that problems are best solved by attempting to correct or eliminate root causes, as opposed to merely addressing the immediately obvious symptoms, the PEARL project aims at developing adaptive risk management strategies for coastal communities focusing on extreme hydro-meteorological events, with a multidisciplinary approach integrating social, environmental and technical research and innovation. It takes the holistic view of risk as an essentially sociotechnical problem which concerns not only technology but also our values and our beliefs.

Key Words: Coastal Flood Management, Holistic Risk Assessment

1. INTRODUCTION

Natural hazards such as earthquakes, hurricanes, tsunamis, widespread flooding, droughts, extremes of snowfalls and temperatures occur almost daily, mostly causing devastating losses and suffering. Out of all these hazards, floods in coastal regions are regarded as one of the most dangerous and harmful (Balica, 2012; IPCC 2007a, b). According to the International Disaster Database (EM-DAT: http://www.emdat.be/), incidence of coastal floods has shown the fastest rate of increase compared to other types of disasters (see also CRED 2004). However, although commonly referred to as “natural” disasters, most of the impacts of these events are not in fact the results of nature-related processes alone: they are often directly attributable to various social, economic, historical, political and even cultural issues. Rapid urbanization in coastal areas, combined with climate change and poor governance, can lead to a significant increase in the risk of local surface flooding (pluvial) coinciding with high water levels

in rivers (fluvial), and high tide or storm surges from the sea (coastal), therefore posing a greater risk of devastation in coastal communities (Djordjevic et al., 2011). Furthermore, the perception of flood impact on life and daily activities can be significantly different amongst the population. The level of knowledge and understanding of flood risk in a given area is directly related to people's decisions to either adjust their living to such a risk, or simply to ignore it. Both 2009 and 2011 UNISDR Global Assessment Reports on Disaster Risk Reduction strongly emphasize governance as a critical element in flood risk mitigation. In Europe, the Flood Directive (2007/60/EC) stresses the importance of assessing and mapping flood risk (Article 6). Some national initiatives, e.g. in the UK (Pitt, 2008), argue for the need to identify flood risk in a broad, multidisciplinary and comprehensive manner. The EC Directive 2008/114/EC emphasizes the need to improve protection of European critical infrastructures by gaining understanding of multiple interactions between their governance processes. These Directives, together with corresponding international legislation, recognize and explicitly require risk analysis to be utilized as a primary tool for management of natural hazards/floods, addressing the complexity of all aspects of the process to improve understanding of risk, in order to develop best practices to minimize impacts on the public and environment. The above observations confirm that disasters triggered by hydro-meteorological events (e.g. extreme winds, storm surges, coastal and estuarine floods) are interconnected and interrelated with both human activities and natural processes (Figure 1).

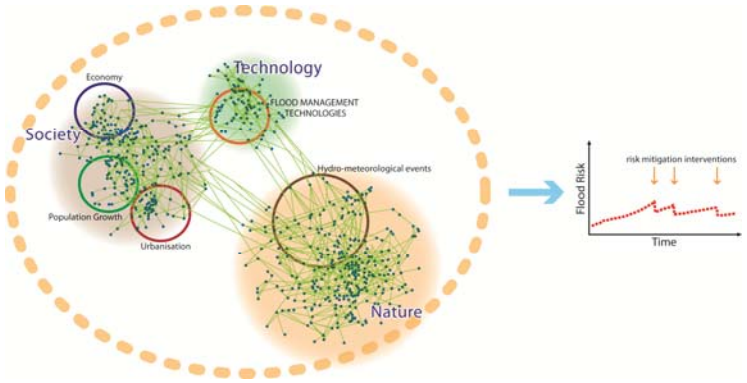

Figure 1: Formation and propagation of risk is a result from the co-evolutionary nonlinear process between the ever changing social, technical and natural processes. Dots represent sub-processes and activities and lines represent their interactions (Source: Vojinovic, 2014).

As such, disasters require holistic approaches to help us understand their complexity, in order to design and develop adaptive risk management approaches minimizing social and economic losses and environmental impacts, and increasing resilience to such events.

A particularly important part of the management of disasters due to extreme hydro-meteorological events is improving forecasting, prediction and early warning capabilities (especially over a range of spatial and temporal scales). This can be done using state of the art science and technology to help policy makers and emergency services to develop robust prevention, mitigation and preparedness strategies. Important as it may be, it is however only one part of the answer. Equally important is that these systems are integrated into broader management strategies (structural and non-structural, engineering and natural), supported by appropriate institutional and organizational arrangements (UNFCCC, 1999). This need is clearly recognized by the ISDR Hyogo Framework for Action 2005-15 (HFA), which identifies in its 4th priority area the need to 'Reduce underlying risk factors'. Moreover, preparing for effective response to extreme events involves more than technology: it must be based on knowledge of, and interventions in, interconnected social, economic, organizational and political considerations (see IRDR, 2009; Pelling 2010; Vojinovic and Abbott, 2012). The uncertainty brought by climate change elevates the importance of a holistic approach even further. It is in the interactions of connected considerations that adaptive capacity is created and constrained. The evidence available from current practice suggests however that there is a clear lack of interaction between social aspects and engineering in planning for resilience, and

this emerges as a major hindrance for solving problems associated with floods and flood-related disasters.

2. PEARL CONCEPT, OBJECTIVES AND OUTCOMES

Implemented since January 2014 through a multi-disciplinary Consortium of 24 international partners, the EU-funded project PEARL (Preparing for Extreme And Rare events in coastaL regions) has the main goal of developing adaptive, socio-technical risk management measures and strategies for coastal communities against extreme hydro-meteorological events, aiming at minimizing social, economic and environmental impacts and increasing the resilience of Coastal Regions in Europe.

2.1 PEARL Concept

To achieve its main goal, PEARL adopts a holistic risk management approach, based on the following three premises:

1. Risk management is a socio-technical process, which cannot be studied by separating social and technical processes (i.e., parts) and designing them in isolation.

2. Relationships between the parts are mutual, emergent, dynamic and nonlinear and are guided by the self-organizing capacities of each part and the (unpredictable) dynamics of their co-evolution.

3. The process of strengthening any kind of flood risk mitigation measure (such as forecasting, prediction and early warning capabilities) should be understood and studied within the context of the larger flood management process, which depends on interactions with other sub-processes at different levels.

At the flood management process level, we can identify a number of sub-processes, objects and actors which interact with each other. Figure 2 gives an example of a causal loop diagram depicting complexities and interdependencies/interactions within the flood management process. It also shows that the overall emerging phenomenon (i.e., the risk) is shaped by a myriad of sub-processes, objects and actors with none of them being in a position to control the whole process (i.e., the level of risk). This implies that the effective strengthening of forecasting, prediction and early warning capabilities must be approached from a much larger perspective: it is here that step changes in risk management will be gained.

As seen in Figure 2, the main elements of flood risk management continuously interact between them creating nested loops of cause and effects. This realization is crucial to the PEARL project. This perspective however may raise the following question: If everything is connected to everything else, how can we ever hope to understand anything? Our response draws from the understandings brought by complexity theory: individual elements are "nested" within the interacting whole, they co-evolve together (Norgaard, 1994) – both in development and application. This recognition opens analysis beyond the direct objects or actors of concern (risk forecasting, early warning, land-use planning technology and systems, for example), and into the relationships between them. Some have considered this in terms of the intensity of interactions between the most dominant processes and their associated actors. This builds on a fast growing literature on socio-technical problems, (including Callon, 1986; Byrne, 1998; Latour, 2005; Boelens, 2009a; Boelens, 2009b; Vojinovic and Abbott, 2012; Vojinovic, 2014; van Dam, 2013). It goes beyond the traditional integrated view which examines input-output to emphasize the importance of relationships, interactions and interdependences lying between different processes and actors (which may relate to nature, society and technology). In short, the holistic approach adopted by PEARL (in response to a very real practical challenge that has long constrained risk management) also opens opportunities for a meaningful exploration of the contribution that trans-disciplinary research can offer to risk management. Therefore, the challenge for PEARL is to develop concepts and tools that can enable us to understand process dynamics related to flood risk management from such a co-evolutionary perspective, and to learn through this perspective how to develop more adaptive and resilient risk management strategies for coastal regions. It is through the holistic lens that we can better understand

where strategic technological improvements may lie. We need to understand technological limits but also their position in coevolving systems.

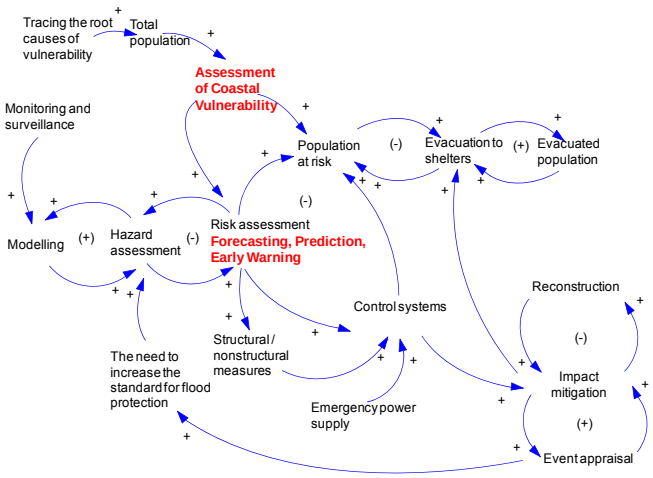

Figure 2: Illustration of the complexity of the coastal flood risk management process and interdependences of various sub-processes (or parts) within the larger process. The functioning of the flood risk management process depends on interactions (with positive and negative feedbacks) with other sub-processes from within and outside of its boundaries - which can be referred to as nesting (Source: Vojinovic, 2014);

PEARL substantially progresses beyond the state of art in a series of domains, including the development of a holistic risk governance approach based on co-evolutionary systems thinking. A novelty presented by PEARL is rethinking root causes of vulnerability via the extended FORIN methodology (IRDR, 2011), which has been developed by the International Council for Science project (ICSU, 2008), Integrated Research on Disaster Risk (IRDR) in partnership with the International Social Science Council (ISSC), and the United Nations International Strategy for Disaster Reduction (UN-ISDR). Within this process, PEARL is developing and testing new concepts and tools for strategic and operational planning purposes, event prediction, forecast and early warning technologies for management of critical infrastructures (e.g. ports, drainage systems, flood defences or coastal barriers). At the same time, PEARL is developing adaptive and resilient strategies utilising structural and non-structural measures, ecosystems-based approaches and promoting active stakeholder participation.

2.2 PEARL Objectives

The PEARL approach considers all fundamentals in the risk governance cycle focusing on the enhancement of forecasting, prediction and early warning capabilities and the building of resilience and reduction of risk through learning from experience and the avoidance of past mistakes. As such, it takes a comprehensive look at causal factors of risk that can lead to a disaster to better shape warning, response and reconstruction activities.

Specifically, PEARL is:

- developing a holistic risk governance framework (and supporting tools) based on the co-evolutionary systems thinking;
- increasing the understanding of dominant root causes of vulnerabilities and risk in coastal regions through an enhanced FORIN approach;

- developing novel concepts and models to better understand the co-evolution of disasters due to extreme hydro-meteorological events under climate change and the consequent socio-technical risks;

- developing novel technologies and methods related to monitoring, modeling, forecasting and disseminating warnings and enriching the knowledge-base of possible responses that can improve strategic and operational flood risk management – firmly embedded into the social, technical, institutional, organizational and economic realities faced by coastal communities;

- providing the means to strengthen risk governance and the role of various actors involved in the preparation of risk reduction plans, such as governing authorities, municipalities and local communities. PEARL pays particular attention on the development of means for empowering stakeholders and trust-building between the public and the responsible agencies and authorities through innovative methods of learning & action alliances and collaborative modeling;

- building a pan-European knowledge base that gathers real case studies and demonstrations of best practice across the EU to support capacity development for the delivery of cost-effective risk-reduction plans and to disseminate knowledge within the EU and beyond. In that sense, PEARL also contributes to the development and revision of flood risk management plans in coastal areas that are due in 2015 and are to be revised every six years as stated in 2007/60/EC (article 7). In this context, what is important to stress is that PEARL is also contributing to the possible revision of next phases of the Floods Directive, by transferring into the EU international experience from Asia, and especially Japan (post Fukushima) and Thailand (post Great Thailand Floods of 2011).

The focus on relationships between systems components advocated by PEARL places an additional emphasis and time resource on interaction between consortium members. This is an effort to move beyond existing experiences of inter-disciplinary towards a trans-disciplinary mode – and is itself a contribution to moving the design of research programs beyond the state of the art. Relationship building takes time and requires focused activity; case studies therefore play an important role as foci for trans-disciplinary mode and coproduction. The project is drawing on seven EU case study areas: Greve (DK), Liverpool (UK), Hamburg (DE), Charente-Maritime/Xynthia (FR), Liguria (IT), Marbella (ES) and Rethymno (GR). Moreover, Through its international/associated partners, PEARL is also drawing upon international experience of extreme events including, 2011 Thailand Floods - particularly in the area of Ayutthaya region, 2011 Great East Japan Tsunami, 2007 Cyclone Krosa and 2009 Cyclone Morakot (China, Taiwan, Myanmar), and some major Hurricanes from the Caribbean Island States (St Maarten, BVI and St Lucia) such as Leni, Lewis and Omar.

Although the focus of the project is on extreme hydro-meteorological events, it is also highly relevant to the management of the other major hazard for coastal communities, namely tsunamis: these share a number of overlapping attributes (e.g. assessment of vulnerabilities and impacts, development of response strategies, use of early warning systems, governance and community involvement) and hence synergies need to be explored. For this purpose, the project has developed interfaces with relevant ongoing tsunami work such as ASTARTE and RISCKIT.

2.3 PEARL OUTCOMES

Based on a clear understanding of the current state of art, PEARL has identified a number of key issues that need to be addressed to close the gap between what is possible today and the way forward in flood risk management, with a particular focus on Coastal Areas. The main progress beyond the state of the art aspired within PEARL is grouped under seven main topics, as in the following.

2.3.1 Understanding and modeling vulnerability and risk

The targeted progress in this field is a significant improvement of knowledge and understanding in terms of formation of vulnerabilities and risk in coastal regions, by developing the PEARL Risk and Root Cause Assessment (RRCA) approach. RRCA extends FORIN in three directions, each responding to a gap in

methods and knowledge: (a) Refining the scaled analysis of disaster causation; (b) Including response and reconstruction as periods generating impact and (c) Integrating quantitative and discursive assessment of vulnerability.

2.3.2 Understanding and modeling hazards

One of the key PEARL outcomes is an innovative methodology for analyzing and modeling floods from all sources with specific emphasis on cases where flooding may occur from more than one source, using two different approaches: (a) by identifying gaps in knowledge and technology for developing relevant interfaces for "gluing" the existing commercial and public domain software packages, and (b) by developing a completely new approach (framework) in which all types of floods would be dealt with within the same modeling environment.

2.3.3 Holistic and multiple risk assessment

The developed risk assessment framework identifies those interconnected processes in which the failure of a part (or a process) can trigger the failure of successive parts (i.e. risk cascading) and the uncertainties that may propagate throughout this process. Further to that, PEARL is exploring the perceptions of flood impacts and flood risk in selected case studies, specifically investigating the factors shaping risk perceptions and how these in turn influence the level of preparedness of communities and the flood risk management strategies finally adopted.

2.3.4 Early warning systems and technologies

PEARL ensures the closing of the gap between warning and action by emergency services, through work on the key development of the Common Alerting Protocol (CAP). Furthermore, PEARL is focusing on the improvement of dissemination of Early Warning, considering two approaches for dissemination, namely the formal-based and the informal-based: the first one consists of hierarchically transferring information about the crisis management to the relevant levels of command to ensure a proper, organized crisis response; while the second does not have a clear communication line, but instead it relies on the interaction among individuals (crowd-based).

2.3.5 Resilience strategies

PEARL is achieving a significant improvement on (and better management of) the knowledge base of appropriate measures and strategies for coastal flood management. This includes engineering, environmental, operational strategies and governance arrangements, aimed at improving the resilience of Coastal Regions, and associating them with a wealth of new contextual information to help users identify what is relevant in their case.

2.3.6 Stakeholder Involvement and decision making process

PEARL is pushing forward the state of art of stakeholder engagement in the process of developing risk management roadmaps, supporting this process with novel concepts and tools from both social research and ICT technologies. This is achieved including work on the emerging concepts of collaborative modeling and learning & action alliances (LAA) to engage stakeholders along three axis: establishing facts, creating common images and setting shared ambitions followed by action-oriented work around developing solutions, using common criteria and articulated preferences and trade-offs on shared modeling platforms.

2.3.7 Science Policy interface and outreach

Through the involvement of two global hubs in science communication, standardization and science-policy-practice interface, i.e. the World Meteorological Organization (WMO) and the International Water Association (IWA), PEARL enhances communities' involvement and collaboration on the flood risk management for Coastal Regions though a host of dissemination pathways.

3. PEARL IMPACTS

PEARL will provide the means to establish a pan-European harmonized risk management governance system that can make coastal communities more resilient and adaptable against extreme hydro-meteorological events, and also facilitate the sharing of best practice. PEARL aims at developing and implementing innovative methods and tools to model socio-technical systems and to convey the results to the end-users in an efficient way. The project has a strong social and institutional as well as technological component, and as such it is believed to address the full spectrum of expected developments with a potential for a significant impact on risk governance science and practices in Coastal Regions.

PEARL supports all 4 strategic objectives of Risk Reduction identified in the 2009 UNISDR Global Assessment Report on Disaster Risk Reduction. In particular, it develops a holistic risk management framework directly anchored on local societies and sound governance. Also, PEARL directly addresses the current lack of interaction between social aspects and engineering, which emerges as a major hindrance for acceptance of sound strategies associated with floods and flood-related disasters, placing resilience at the heart of the research by developing a holistic risk assessment including risk cascading effects, as well as by developing an intelligent knowledge base, which represents a comprehensive repository of resilience measures and strategies, and methods to evaluate their efficiency.

Other impacts of PEARL would include the design of cost-effective risk-reduction plans, based on the proposed tools and solutions, and an improved risk governance and preparedness through the provision of timely information and warnings to decision-makers. Furthermore, PEARL provides support for governance at both strategic planning and operational planning scales to effectively prevent, cope and recover from flooding. The project also improves the speed of state-of-art modeling tools for early warning, in order to achieve sufficient lead times for emergency actions and further develop the use of emerging web technologies and real-time applications. PEARL is advancing and evaluating the linking between early warning service providers and decision makers' command and control systems, and improves both formal and informal dissemination of information from early warning systems. Last but not least, PEARL applies and evaluates new paradigms and technologies based on smart devices for early warning. As such PEARL advances contribute to the complete chain of early warning systems, from forecasts and data, to modeling and warning dissemination with particular emphasis on warnings that can reach stakeholders fast and with the appropriate understanding of uncertainty involved in the whole early warning chain.

4. REFERENCES

Balica, S.F Wright, N.G., van der Meulen, F., 2012: "A Flood Vulnerability Index for Coastal Cities and Its Use in Assessing Climate Change Impacts", *Journal of the International Society for the Prevention and Mitigation of Natural Hazards*, 64:1, 73-105.

Boelens, L., 2009a*: The Urban Connection: An actor relational approach to urban planning*, O10 publishers, Rotterdam, the Netherlands.

Boelens, L., 2009b: "Theorizing practice and practicing theory: Outlines for an actor-relational-approach in planning" *Planning Theory* 9:1, 28-62.

Byrne, D., 1998: *Complexity theory and the social sciences: An introduction*, Routledge, London, UK.

Callon, M., 1986: "The Sociology of an Actor-Network: The Case of the Electric Vehicle." In Callon, Law & Rip (eds.) *Mapping the Dynamics of Science and Technology: Sociology of Science in the real World*. MacMillan Press, London, UK.

Center for Research on the Epidemiology of Disasters (CRED), 2004: *Thirty Years of Natural Disasters 1974-2003: The Numbers, 2004*. Presses universitaires de Louvain, Leuven, Belgium.

Council Directive 2008/114/EC of 8 December 2008 on the Identification and Designation of European Critical Infrastructures and the Assessment of the Need to Improve their Protection. Available at http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2008:345:0075:0082:EN:PDF [Accessed 30 April 2014]

Djordjević, S., Butler D., Gourbesville P., Mark, O. and Pasche E., 2011: "New Policies to Deal with Climate Change and Other Drivers Impacting on Resilience to Flooding in Urban Areas: the CORFU Approach" *Environmental Science & Policy*, 14:7, 864-873.

Flood Directive 2007/60/EC of the European Parliament and of the Council of 23 October 2007 on the Assessment and Management of Flood Risks. Available at http://ec.europa.eu/environment/water/flood_risk/index.htm [Accessed 30 April 2014]

Integrated Research on Disaster Risk (IRDR), 2009: *Report of the ad hoc Working Group, IRDR Forensic Investigations*. International Council for Science, Toronto, Canada.

Integrated Research on Disaster Risk (IRDR), 2011: *Forensic Investigations of Disasters: The FORIN Project* IRDR FORIN Publication No. 1, Integrated Research on Disaster Risk, Beijing, China.

Intergovernmental Panel on Climate Change (IPCC), 2007a: *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge University Press, Cambridge, UK and New York, USA.

Intergovernmental Panel on Climate Change (IPCC), 2007b: *Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge University Press, Cambridge, UK.

International Council for Science (ICSU), 2008: *A Science Plan for Integrated Research on Disaster Risk: Addressing the Challenge of Natural and Human Induced Environmental Hazards*. International Council for Science, Paris, France.

Latour, B., 2005: *Reassembling the Social: an Introduction to Actor-Network-Theory*, Oxford University Press, New York, USA.

Norgaard, RB, 1994: *Development betrayed: the end of progress and a coevolutionary revisioning of the future*. Routledge, London, UK.

Pelling, M., 2010: *Adaptation to Climate Change: From Resilience to Transformation*, Routledge, London, UK.

Pitt, M., 2008: *The Pitt Review - Learning Lessons from the 2007 floods.* Cabinet Office, London, UK.

United Nations Framework Convention on Climate Change (UNFCCC), 1999: *Coastal Adaptation Technologies*. Technical Paper, UNFCCC, Bonn, Germany.

Van Dam, K.H., Nikolic, I., and Lukszo, Z. (eds.), 2013: *Agent-Based Modelling of Socio-Technical Systems*. Agent-Based Social Systems, vol. 9, Springer, New York, USA.

Vojinovic Z and Abbott M, 2012: *Flood Risk and Social Justice: From Quantitative to Qualitative Flood Risk Assessment and Mitigation*, Urban Hydroinformatics, IWA Publishing, London, UK.

Vojinovic Z, 2014: *Flood Risk: The Holistic Perspective, from Integrated to Interactive Planning for Flood Resilience*, IWA Publishing, London, UK.