PEARL Final Summary Report

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Executive Summary

Coastal floods are one of the most dangerous and harmful natural hazards affecting urban areas adjacent to shorelines. Rapid urbanisation combined with climate change and poor governance means a significant increase in the flood risk, posing a greater risk of devastation to coastal communities. The PEARL project addressed the threats posed in terms of flood prediction and control, by taking into account governance and socio-economic issues. The project developed novel technologies and methods for a holistic and cost-effective risk reduction framework, by linking risk and root cause assessment, event prediction, forecast and warning, development of adaptive structural and non-structural strategies and active stakeholder participation of real case studies in Europe and internationally.

To address the present challenges and needs, PEARL has developed several frameworks and tools that will be soon available through our website www.pearl-fp7.eu

- Risk and Root Cause Assessment framework through the understanding of formation of vulnerabilities and risk in coastal regions, the development of vulnerability assessment framework and the examination of possible root causes and their interdependencies;
- Development of extreme event scenarios and framework for estimation of hazards under extreme events through the development and use of novel multi-physics concepts and modelling tools;
- A Holistic and Multiple Risk Assessment due to individual and coinciding or multiple hazardous events;
- Improvement of the state of art in flood forecasting and early warning for coastal areas across the whole chain of early warning from data to warning dissemination;
- Identification of decision processes, risk perceptions and resilient strategies for developing a framework and an intelligent knowledge base, representing comprehensive repository of resilience measures and strategies and methods to evaluate their efficiency;
- An interactive web-based and planning platform providing PEARL processes, tools, methods and frameworks to stakeholders for developing risk management roadmaps and general guidance for decision support and policy development in order to enhance and maintain flood resilience.

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1 Project Summary

Preparing for Extreme and Rare Events in Coastal Regions (PEARL) is a four year project which involves 24 international partners. The main 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.

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

- First, risk management is a sociotechnical process, which cannot be studied by separating social and technical processes (i.e., parts) and designing them in isolation.
- Second, the relationships between the parts are mutual, emergent, dynamic and nonlinear and are guided by the self-organising capacities of each part and the (unpredictable) dynamics of their coevolution.
- Third, 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.

The project is structured around 8 Work Packages (WPs)

WP1 Aims to develop an understanding of the formation of vulnerabilities and risks in coastal regions by applying the extended FORIN (Forensic Investigations of Disasters) methodology and developing the vulnerability assessment framework. It addresses all possible root causes and their interdependencies in order to provide the basis to develop a framework for the holistic risk assessment work.

WP2 is focusing on novel methods and tools for hazard assessment considering scenarios of extreme events, climate change and individual and coinciding events.

WP3 is concerned with methods for the holistic assessment of risk due to individual and coinciding (or multiple) hazardous events.

WP4 deals specifically with advances in early warning systems, methodologies and tools. It also addresses different sources of uncertainties and the ways of how to approach uncertainty analysis.

WP5 aims to identify resilient strategies (i.e., protection, short- and-long term adaptation and mitigation strategies) and develop a knowledge base of existing and novel strategies and measures and the associated tools for their evaluation and assessment. It focuses on decision support for policy development and work on science-policy interfacing with an emphasis on risk governance.

All the developed concepts, methodologies and tools are tested and demonstrated in the case study work being coordinated in **WP6**. WP6 is also concerned with efficient data storage and management. It builds upon the existing EU initiatives and Directives for the management of data infrastructure as well as the experience and data infrastructure developed within previous projects.

WP7 focuses on dissemination and outreach, supporting an international knowledge and practice

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community, while fostering clustering activities with other projects.

WP8 deals with project management and coordination aspects, with direct input from a selected team of high profile international collaborators and advisors.

WPs 1 to 6 have contributed to the production of main science and technology results. Hence, the following section describes science and technology achievements of these six packages and discussion of **WP7** is included in Section 3 (Impacts and Dissemination). **WP8** has not been discussed in this final report.

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2 Main Science and Technology Results

2.1 Work Package 1- Understanding formation of vulnerabilities and risk in coastal regions

WP1 advances current state-of-the-art in the following key areas:

a. A new conceptual framework for understanding the root causes of local risk and loss

The PEARL project included Risk Root Cause Analysis (RRCA) in the design of an integrated flood risk assessment methodology as a keystone methodology for understanding the holistic drivers of risk, and the actors and decision-making pathways associated with driving risk in the socio-economic and governance domains, interacting with physical processes and informed by the nature of risk perceptions (Deliverable 1.1). The structural focus on 'root causes' aimed to move beyond conventional risk assessment models providing important overviews of current vulnerabilities, capacities and post-disaster conditions to tackle the underlying factors that explain why risks accumulate. This is critical to support movement from short-term, partial policy solutions to measures for sustainable reductions in disaster loss and damage.

The PEARL RRCA was adapted from the ICSU/UNISDR programme Integrated Research on Disaster Risk FORIN (Forensic Investigation of Disasters) approach to provide a novel structured methodology for investigating the root causes of small-scale but high-impact disasters which predominantly manifest at the local scale (Fraser et al. 2016). The RRCA shared FORIN's intent to deepen the spatial and temporal scales of disaster analysis and integrate a systematic understanding of the links between disasters and development (IRDR 2011; Oliver-Smith et al. 2016). By way of extension, the PEARL RRCA aimed not only to trace the historical root causes of disaster but also to reflect on the role of these factors in driving risks in the present and into the future. Through a systematic review of both FORIN and other cognate root cause analysis studies, the PEARL RRCA incorporated critical elements for understanding both the nature of risk but also highlighted the centrality of the governance context, and the role of the disasters cycle (as embedded in the governance context) in influencing risk accumulation or reduction processes (Fraser et al. 2016). By incorporating local risk and loss, the PEARL context brought a focus on the role of local actors as mediating institutions between local risk/loss and macro-level root causes – a long-standing gap in studies of disaster risk (ibid.).

The RRCA Framework was applied in four contexts. In three, primary fieldwork underpinned the development of an improved understanding of contemporary drivers of local risk and loss (see below). In the fourth, RRCA of the 1962 flooding in Hamburg, Germany, used desk-based analysis to demonstrate the importance of historic disasters in foregrounding contemporary conditions, confirming the inter-linkages between causal domains and the centrality of governance to root cause pathways (TUHH, 2017).

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b. A holistic methodology for understanding the root causes of local risk and loss

The principal contribution of the PEARL project was to situate root cause analysis within a systems approach to understanding local-level flood risks. The PEARL Holistic Risk Assessment Framework and Ontology (RAFT) connects the relevant system with the identification of key stakeholders using the root cause analysis methodology, generating the rules and behaviour for a formal model of actors. This blending of methodologies generated unique learning about the methodological challenges to Holistic Risk Assessment (Deliverable 1.3), but also illustrated the importance of RRCA in identifying a wider range of actors and institutions than previously incorporated in the model, and in prompting the inclusion of informal as well as formal institutions in the model structure. Challenges included combining data for short-run models of decision-making with long-run models of institutional change; quantifying social and subjective phenomena and using this to specify thresholds for decision-making; generalising data; specifying assumptions about system boundaries and the relative influence of actors and institutions within the system. This learning demonstrates the importance of retaining the two methods as independent parts of the whole, alongside their integration through model formulation.

PEARL RRCA supports the deployment of a flexible and context-appropriate suite of qualitative and quantitative methods for root cause analysis using the elements of the RRCA Framework. A paper supporting the application of such methods through accessible guidance and reflection based on all four PEARL case studies was published by the PEARL project (Deliverable 1.2).

The application of the PEARL RRCA reaffirms the importance of longitudinal research to understanding disaster causality (Oliver-Smith et al. 2016) as well as the need – particularly in investigating local risks and losses – to capture actor perspectives across scales and domains beyond the conventional reach of disaster risk management. Applying RRCA in PEARL pointed up the need to link historic approaches with methods to understand how such drivers project into future scenarios, and capture potential discontinuities. The PEARL RRCA approach of using disasters as focusing events to understand causal attribution through stakeholder viewpoints opens up new avenues for research methods to explore the role of stakeholder value in shaping understandings of attribution; the role of (intensive and extensive) events in revealing underlying, long-run processes (Mauelshagen, 2009) – especially where single events reveal highly localised risks; and methods for analysing cause-effect relations where inter-linked drivers are inseparable and causal chains stretch beyond the ability of actors to articulate their interlinkages. The application of the RRCA to the context of policy learning post-disaster also raised new questions about methods for investigating the influence of historic, present and futures-oriented ideas and visions on action and structure – with methodological innovation in this regard of potential relevance to further studies of recovery and reconstruction processes.

c. Improved understanding of the structural drivers of small-scale but high-impact risks at the local level

Analytic work deploying PEARL RRCA across local government jurisdictions affected by recurrent, small-scale but high-impact coastal flooding (Genoa, Italy; Rethymno, Crete and Dutch St Maarten, Caribbean), reveals the importance of local government risk management to the impacts of local-scale risks, and role of local institutions as intermediaries between geographically and temporally

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distant root causes and local expressions of damage and loss (a long-standing gap in studies of disaster risk).

Better understanding the causal drivers of small-scale risks is particularly important given their demonstrated significance to local human development outcomes as well as accumulated and aggregated disaster losses and damages, despite their relative analytic neglect in disasters studies (Marulanda et al. 2010; Zaidi 2018). PEARL analysis shows how the role of local institutions in mediating such losses is embedded in the politics of the relationships between local and sub-national, national and regional institutions around governance, regulation and resources. Institutional cultures and informal relationships and the different temporalities of institutional change that occur mediate the felt impacts of these relationships. Such relationships and commensurate pathways of institutional change condition the impact of structural changes such as global economic downturn, austerity and decentralisation on local expressions of loss and damage, but can also be re-shaped by structural factors.

PEARL research therefore challenges both globally-driven and exclusively locally-focussed accounts of the drivers of vulnerability and resilience. It seeks a new framing for root causes that emphasises the political mechanisms of institutional scale driving dynamic pressures and unsafe conditions at the local level. This has implications for the practice of disaster risk management, in particular how actions to support local agency require action across scales and domains. There is a need to be attentive to the context-specificity of formal and informal scalar relationships and temporal pathways of change, and aware of how actions in one domain may weaken the ability to respond to risk in another.

d. Developing risk root cause analysis to enhance understanding of post-disaster recovery, reconstruction and transformation processes

The PEARL RRCA framework incorporated Disaster Response, Recovery, Reconstruction and Transformation processes as both influencing the physical, socio-economic, governance and perception factors within a spatial entity and influenced by the historical physical, socio-economic, governance and perception context. These aspects contribute – either positively or negatively – to the current and future accumulation of risk (PEARL Deliverable 1.1).

In the context of a large-scale, national-level disaster in St Maarten in 2017, the RRCA Framework and analysis conducted under the framework on the island in 2016 provided a basis for new analyses of disaster reconstruction processes, contributing to wider debates about post-disaster recovery processes (as poorly understood in the disaster studies literature - Twigg, 2017) and supporting contemporary policy interest in a ‘Build Back Better’ approach to disaster response:

i. The Politics of Building Back Better: Understanding the Co-evolution of Ideas and Governance in processes of Policy Learning in Disaster Reconstruction

A new RRCA study undertaken in 2018 aimed to:

1) Re-test and validate the PEARL RRCA undertaken in St Maarten in 2015-2016 for the new context of a large-scale disaster (Hurricane Irma), and extend the analysis to French St Martin. Such analysis adds to existing assessments of loss and damage on the island to provide a holistic assessment of the drivers of loss and damage. The comparison of governance regimes under the same hazard

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context also allowed the premise of the PEARL RRCA about the centrality of governance, and earlier analysis about the importance of a politics of scale to local-level risk management, to be validated and developed.

2) Move from backward-looking to forward-looking analysis (in line with the PEARL RRCA framework's emphasis on understanding the expressions of root causes in the contemporary and future context) through the use of the RRCA framework to benchmark the scope of contemporary and futures-oriented plans, policies and intentions against root cause drivers. The study focusses on processes of decision-making, and the construction and use of expertise in decision-making, for reconstruction in the urban land use and housing sectors (identified by the RRCA as critical to risk exposure and vulnerability). The study moved from the broad context of the RRCA to a new framework for actor decision-making in a co-evolving system (the over-arching conceptual model for PEARL). This aimed to reveal the drivers of contemporary decision-making pathways, and related actors, but also capture the pre and post-Irma capacities, knowledges and futures-oriented visions (imaginaries) of reconstruction actors, the latter as a neglected aspect of studies of organisational change and policy learning.

The findings of the 2018 study move beyond the state of the art in debates about post-disaster politics and learning processes in post-disaster contexts. They show how the historic and contemporary co-evolution of institutional structures and power relations with ideas and visions related to risk, governance and sustainable development influence decision-making about the structural depth, spatial coverage and timeframe of policy responses to disaster. The research aims to re-focus research and policy attention on processes of policy learning as key to reconstruction outcomes. It also deepens thinking about the political opportunities and challenges for transformation through disaster risk reduction.

ii. Applying Survivor-Led Response Principles in SIDS: Lessons for Building Back Better in the Context of the SDGs

The second study on Dutch St Maarten (2018) opened up potential for PEARL RRCA to incorporate local perspectives, beyond the previous focus on expert opinion and the viewpoints of policy-makers. It focussed on the needs and priorities of CBOs and first responders post-Irma as a crucial bridge to community actors and perspectives, and in ensuring disaster preparedness and response is timely, joined-up and inclusive. Recent humanitarian directives – such as the Charter for Change and the World Humanitarian Summit's Grand Bargain – recognise and demand that international aid actors value local agents and ensure they can access a larger proportion of aid funding. This is particularly relevant in Dutch St Maarten, where there is a high prevalence of international government partners involved in the post-Irma response.

Bringing PEARL together with a 3-year UK Department for International Development (DFID) study 'Linking, Preparedness, Response and Resilience' (LPRR), the study allowed for direct comparison between needs and priorities in a high-income, but highly vulnerable, Small Island State and low income contexts experiencing disaster and protracted crisis. The findings provide a unique opportunity to interrogate the universal applicability of principles for Building Back Better in the context of operationalising the Sustainable Development Goals across low to high income country contexts.

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e. Household Survey: Gaining insight into citizen's perception of risk and behaviour

In two PEARL case study locations, namely Genoa (Italy) and Rethymno (Crete, Greece), a household survey was carried out. Information concerning susceptibility and capacities of a randomly selected sample of population was gathered. This included conclusions about the current state of the social system, which can be drawn by the collection and analysis of data like household structure, housing conditions or income. On basis of the questions covered, the aim was to collect data with regard to local coping and adaptive capacities. This not only provides knowledge on local natural hazards and resources, but also includes information about the specific learning ability and response. The survey also covered questions on the availability of information (e.g. early warning, evacuation routes), social networks and support from local authorities, as well as individual preparedness.

Some findings from the household survey (for more details please refer to Deliverable 1.3):

- Local origin as a factor which strengthens disaster response skills
- Lack of knowledge on how to achieve a higher level of preparedness to deal with extreme events in coastal regions
- Information deficit: Lack of knowledge on evacuation routes
- General assessment of early warnings reveals that they are either not perceived, or did not provide a sufficient time frame for reaction
- Reliance on authorities and preference for constructional implantation of protection measures.

The findings from the household survey reflect the perception of a sub-sample of the population in the respective case study areas. Due to the structure of the questionnaire, the majority of evaluation consists of descriptive statistics, which is of great value for further stakeholder involvement. The results give insight into local people´s view and therefore are used within the scope of the PEARL Learning and Action Alliances (for detailed information please refer to Sorg et al. 2015), which represent the viewpoint of stakeholders. The household survey complements the analysis of vulnerability with the view of exposed citizens. Ideally, findings will influence future managing and planning procedures by being integrated into decision-making processes.

f. Spatial Vulnerability Assessment with Census Data

It is state of the art to assess vulnerability and risk on a national or global scale. Inner city disparities are rarely considered though most relevant for local authorities and risk mitigation measures. For this purpose a transparent and comprehensive geo-referenced methodology was developed, which is flexible in terms of data.

The main elements of the modular hierarchical vulnerability structure are Susceptibility, Coping and Adaptation, which can be combined to a compound vulnerability index. In turn, the individual elements consist of several sub-indices. The advantage of this method is that all sub-indices can be represented separately or as a combination. In this way, a better understanding of the vulnerability structure can be achieved. The structure is following the approach of the WorldRiskIndex (see e.g. Birkmann 2016), which was developed by colleagues from UNU/IREUS.

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The PEARL vulnerability index (PeVi) was developed by IREUS with Genoa as leading case study (Sorg et al. 2018). In a first step the PeVi was calculated based on European census data and the methodology was also applied in Rethymno (Greece) and Hamburg (Germany) to show inner spatial disparities. In the PEARL context, the focus is on European coastal regions and the vulnerability assessment covers as many aspects as possible. In close cooperation with IREUS respective case study teams decided, based on their local knowledge, which components of the PeVI were crucial and which components, in turn, could be neglected. The data sets were individually determined for each case study location, with regard to local conditions. Since the availability of data was individual for each case study area, the definition of indicators was unique. None the less, the development of the compound index was transparent, which was ensured by short reports accompanying the maps.

In a final step, information from the vulnerability assessment was combined with hazard data for the holistic risk assessment.

g. Spatial Vulnerability Assessment with incorporation of Household Survey Data

The methodology of the PEARL vulnerability assessment was expanded to be able to combine data from different sources and knowledge bases on a local level. Findings from the household survey can be incorporated into the expanded calculation scheme. The methodology was applied and tested in the case study of Genoa (Italy).

An initial literature review revealed the lack of data concerning coping and adaptive capacity on local-level. The data from the household survey was used to close this gap. All information can be displayed spatially explicit. Further statistical analysis was conducted to compare the census-data approach with the household survey enriched results. Both methods are relevant with regard to different research foci.

Literature review showed that a wide range of existing methods to assess vulnerability and risk focus on global or national scale. If vulnerability and risk is assessed on city level in the majority of cases, the assessment offers only one value per city instead of various values for different districts. Furthermore, most methodologies offer a rather limited selection of indicators and are case study specific. The PEARL vulnerability index was calculated for three case study areas with individual data availability and proofed to be both: flexible and transparent.

2.2 Work Package 2- Understanding formation of hazards under extreme events

WP2 advances current state-of-the-art in the following key areas:

a) Development and applications of a new integrated modelling framework (including a new multiscale adaptive unstructured atmospheric model, Spectral wave model, flooding model) for hazard assessment;
b) Development of a multi-scale integrated urban flooding modelling framework which has the capabilities for one dimensional (1D), two-dimensional (2D) and three-dimensional (3D) flooding modelling. It has an adaptive multi-scale mesh spatially and temporally and the necessary coupling abilities to simulate individually and coincidence of urban pluvial (heavy precipitation) and coastal flooding (high sea level);
c) Application of the new 3D urban flooding model to a Greve flooding event;

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d) Modelling extreme urban flooding events individually and in coincidence for the Greve case study. A comparison of results from the new integrated urban flood inundation model (Fluidity) and the MIKE Urban flooding model (a widely used commercial flooding software) has been carried out.
e) Elevan journal papers have been accepted or submitted or written, 5 conference presentations;
f) The first 3D flooding model and application to the Denmark flooding event;
g) The first adaptive unstructured mesh flooding model with cutting-edging numerical techniques (adaptive unstructured mesh, adaptive time stepping and parallel computing) (two papers have been published);
h) The first high order control-volume mesh to mesh interpolation method applied to arbitrary 2 or 3D meshes. This is critical for conservation and accurate coupling of natural hazard models. Paper published in journal of computational physics and has been one of the most downloaded papers within the journal over the first 6 months that it was published.
i) Development of a new theory for pipe flooding modelling based on an analogy between well modelling in reservoirs and pipe modelling in flooding.
j) The use of dynamically adaptive unstructured mesh adaptivity/optimization in space and time. This is demonstrated for flooding where it is shown that multi-scale capturing is possible, in which the multi-scale nature varies in time. In this example, we show an ability to pick out the drainage ditches when the flooding even reaches them, and they influence the dynamics of the simulations. This level of resolution would not be possible without this technology.
k) Conservation mesh to mesh interpolation for dynamic mesh optimization/adaptivity and model forcing using control volume and finite element methods - exchange of forcing between different models. This is the first conservative mesh to mesh interpolation method for general control volume methods. Without it one cannot have conservation of the forcing (e.g. heat momentum exchanges) between models. It is also the only way one can achieve conservation (of for example fluid volume) when using dynamic mesh optimization. It has been shown to be highly effective for mesh adaptivity and is used in all the mesh adaptive flooding results.
l) Adaptivity to buildings and topography during flooding processes - the building emerges when there is sufficient resolution as do complex topology features. This is a limitation of existing models as they often require uniform resolution of the buildings.
m) Mesh optimization for atmospheric modelling, see Savre et al. 2015. It is suggested that future work develop large initiatives to develop next generation atmospheric flow models based on anisotropic mesh optimization/adaptivity. Our collaborators in China are already developing this technology. However, this is a grand challenge problem and will take many years to refine this technology.
n) For the spectral wave modelling space-angle adaptivity with harr wavelets, see Adam et al 2014. This deals with a possible limitation of existing spectral wave models that place resolution uniformly least angle (and often in space also). This uniformity has a large memory/storage and CPU overhead associated with it and the current approach attempts to fix this limitation of spectral wave modelling.
o) Similar to 5) but for radiation modelling used in coupling to fluids/atmospheric flows based on goals (akin to hazard assessment goals), see Soucasse et al 2017.
p) Goal based approaches to identify sensitivities of hazards based on ensembles. This pinpoints the most sensitive parameters and regions of the modelling domain in space and time that effect natural hazards. The resulting sensitivities (or importance maps) can be used in model chains to also help pinpoint issues with individual models and to help produce optimized meshes (Power et. al 2006), optimize the placement of sensors in the domain (see Che et al. 2014) or help assimilate data or optimize design/management measures of natural hazards.

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q) New developments in Reduced Order Modelling (ROM): deep learning Non-Intrusive Reduced Order Modelling NIROM (see Xiao et al. 2017); parameterized NIROM to predict unseen cases (see Xiao 2017); sub-domain NIROM for large scale modelling (see Xiao submitted 2017) e.g. operation modelling needed for hazard mitigation; free surface flows with 3D modelling; ROM to scope parameters in natural hazards – uncertainty quantification. This is a major innovation and deals with the often computational speed issues involved in running large simulations and simulations needed for operational modelling (with data assimilation) or uncertainty quantification. For flooding we show that the simulations run several orders of magnitude faster than the full model. We hope to extend this approach to model atmospheric flows and are starting to develop major initiatives to model weather with partners across EU. We recommend this approach be applied to natural hazards through international collaboration.

2.3 Work Package 3- Holistic and Multiple Risk Assessment

WP3 advances current state-of-the-art in the following key areas:

a. Framework and ontology for holistic risk assessment (Deliverable 3.1)

The Ontology is the starting point for the formulation of the holistic risk assessment framework. The formulation of the Ontology started with a review of concepts and definitions that are embedded in the formulation of PEARL. This led to a PEARL mindmap of concepts. The Ontology has evolved from the mind map as a connected graph of concepts, which lists the central PEARL concepts and definitions. The definitions are based on two main sources: the IPCC report from 2012, and the draft PEARL glossary from UNESCO-IHE.

The Ontology serves two purposes: It forms a shared knowledge-base on flood risk assessment within the PEARL project and for usage in the PEARL tasks and methods, and it informs the agent-based models that are developed in PEARL. An intermediate step between the Ontology and the ABMs is the MAIA framework from Ghorbani (2013), which helps to decompose, structure and conceptualize socio-technical systems with an agent-oriented perspective. The next step is to structure the concepts and definitions from the Ontology in the MAIA framework. To accommodate this, the Ontology concepts are defined in terms of the other concepts in order to formalise the interrelations, and concept attributes will be listed as well (Figure 1).

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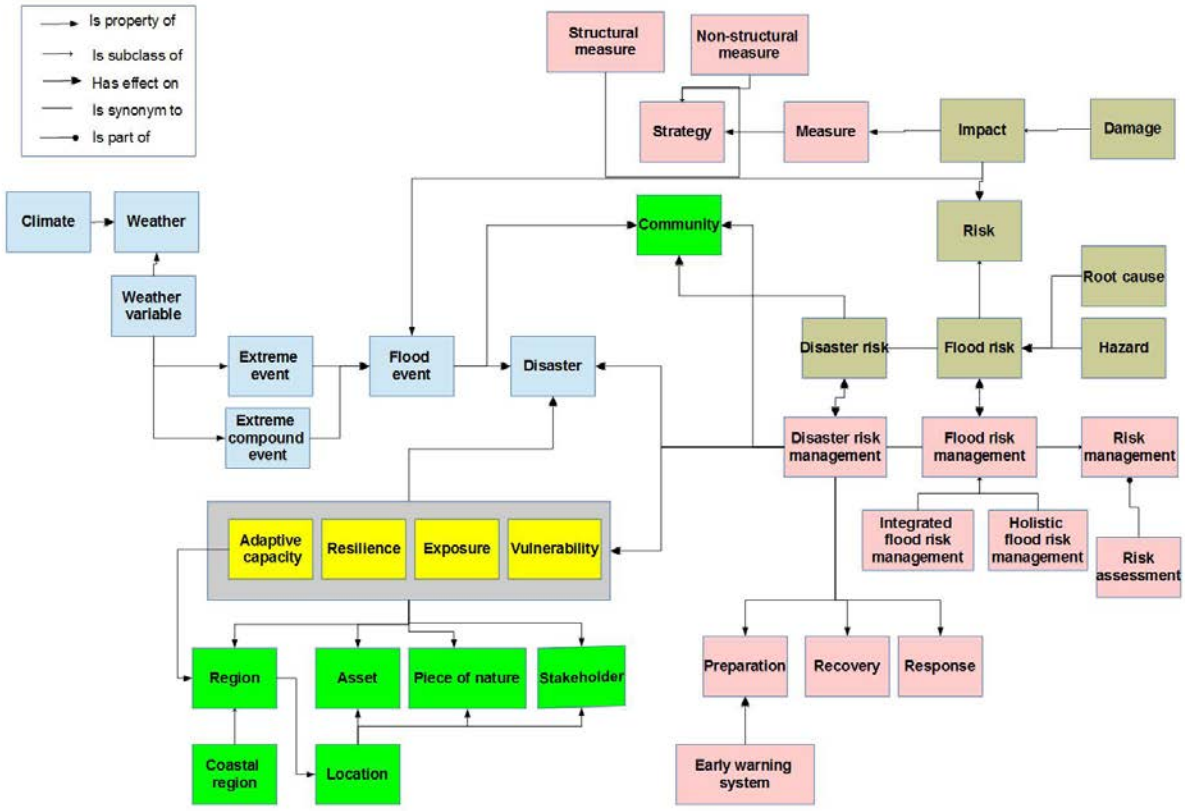

Figure 1: Graphical representation of the Ontology;

Within the holistic flood risk assessment (HFRA) developed a very first step is to gain understanding of drivers/root causes of hazard, vulnerability, exposure and risk by looking at a range of factors and their interdependencies and interrelations (see also Vojinovic, 2015). The drivers of hazard include natural and anthropogenic climate change or variability; whereas, drivers of exposure and vulnerability include socioeconomic pathways, climate change adaptation and mitigation actions and governance (IPCC, 2014a). The two sides of drivers are also related through different governance structures such as land-use policies and emissions. In this framework, the FORIN approach (IRDR, 2011) is used as a basis to scientifically investigate the disaster root causes and through process identifies relevant actors, domain knowledge, systems and theories. Figure 2 presents the overall framework for HFRA. The framework starts with the system definition, and continues with the identification of key stakeholders using the FORIN methodology. The analysis of the stakeholders together with the Ontology provide the input to the formalization of the MAIA metamodel. The MAIA framework generates the rules and behaviour for the agent-based models that are developed in PEARL. Once all Agent attributes, relations among the Agents and Agent actions and interactions are defined, an agent-based model can be formalised. After that, different initial conditions or scenarios can be assessed to quantify a range of different impacts and risk.

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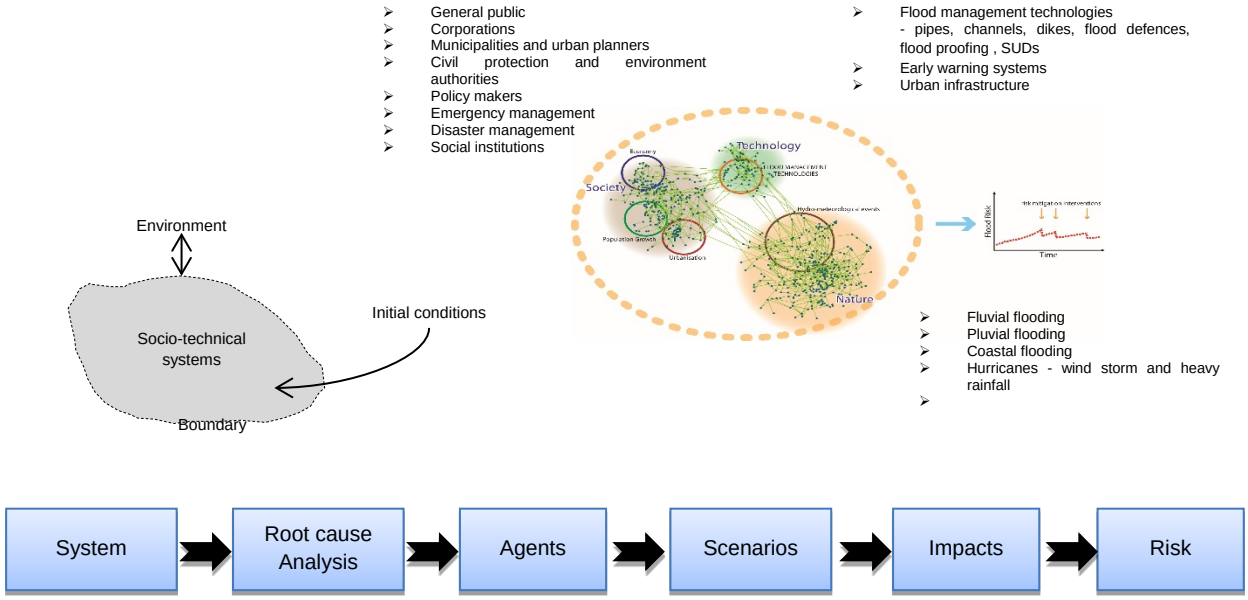

Figure 2: Illustration of the HFRA framework;

b. <u>Strategic and operational risk assessment, damage estimation, traffic modelling and risk cascading</u>

For strategic risk assessment an institutional analysis an ABM tool has been developed and demonstrated on the case study of St Maarten. The main advantage of that tool is its ability to dynamically link two different subsystems, i.e., the human subsystem and the flood subsystem, and to model their interaction, Figure 3. These are defined as follows:

- The human subsystem is defined as the combination of human beings (in a city scale this can also be referred to as residents), their social artefacts (i.e., social groups and ways of interactions within and between groups) and their physical artefacts such as buildings and infrastructure).

- The flood subsystem is defined as the combination of hydrologic (i.e., precipitation, infiltration, and runoff formation) and hydrodynamic processes (runoff routing and flood formation) and the urban environment including the topography, land cover and rivers.

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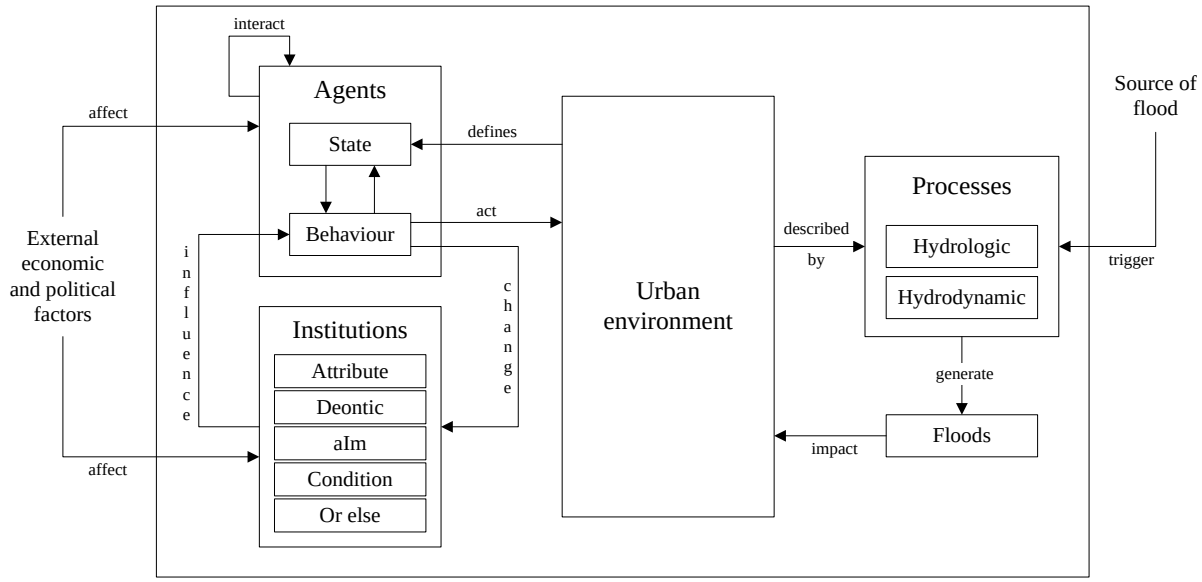

Figure 3: Strategic risk assessment framework with ABM: interactions between humans (agents and institutions), their urban environment (i.e., in the context of urban flooding) and floods (including flood generating physical processes). The drawing also defines system boundaries in which elements within the outer rectangle are related directly to local conditions and can influence each other whereas elements outside the rectangle affect but are not directly affected by those inside the rectangle

Modelling heterogeneous agents together with the institutions that shape their behavior using the above framework is a step forward in socio-hydrologic studies. With such framework it is possible to explicitly model the human and flood subsystems using knowledge from the respective domains, and link the two subsystems dynamically to study their co-evolution. The framework provides an interdisciplinary approach by allowing knowledge contributions from hydrologists/hydraulic engineers and social scientists. It also helps to conceptualize and model the whole system in one integrated model and analyze feedback between the subsystems. This, in turn, gives a broader perspective (i.e., the holistic perspective) for decision makers in their adoption of policies.

For operational risk assessment another form of an ABM tool was developed. The purpose of this ABM tool is to provide support in testing different evacuation scenarios and communication warnings strategies, Figure 4 Two general concepts were used during the implementation of this AMB tool: 1. The ABM has the ability to replicate daily behavioral pattern of a complex urban environment through interactions between humans (agents) with urban environment (agents). 2. The ABM includes a module where human cognition is represented in order to replicate human decision making process during evacuation from a flood event.

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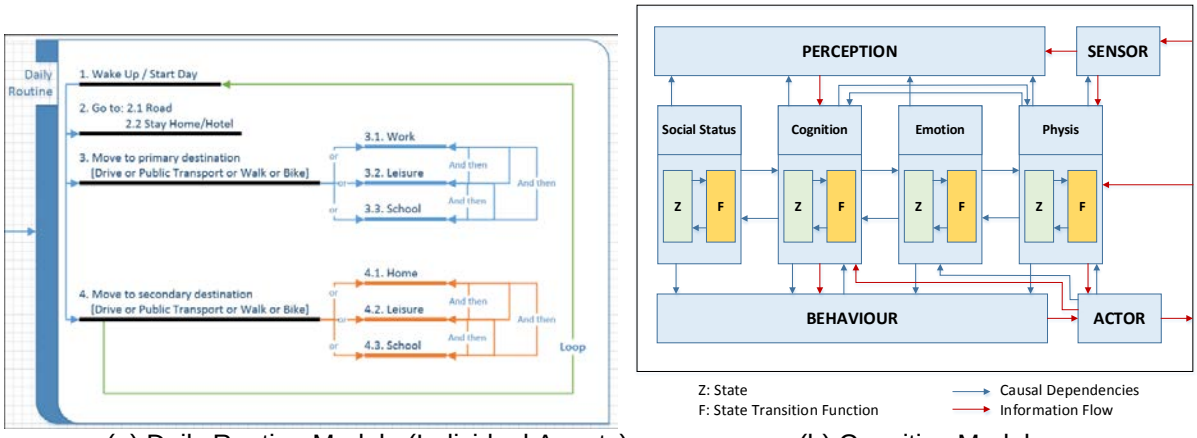

(a) Daily Routine Module (Individual Agents) (b) Cognitive Module

Figure 4: Behavioral modules within the operational risk assessment model;

The results obtained show that the ABM tool has the ability to capture social or human behavioral processes and interrelate them with flood hazards through the hydrodynamic model. When connected together these models offer a platform to study operational risk assessment for emergency planning.

For assessment of damages, PEARL goes beyond current state-of-the-art through development of novel approaches for direct and indirect damages. A tool that was developed in FP7 CORFU project has been extended in PEARL. The tool was developed using Python scripts within an ESRI ArcGIS software environment (ESRI Inc., 2011). Python is an open-source language that can be used in conjunction with different GIS software packages and the scripts developed can be easily translated for use with other GIS software packages by changing the syntax to match the corresponding functions in that software. The tool was developed to perform calculations by associating a building, a group of buildings, or an aggregated land-use area with a function that relates the hazard characteristics to the damage it causes, and then to use these functions to relate the observed or modelled hazard characteristics to an estimate of the damage. For assessment of indirect damages, a model that relates indirect and direct damages has been developed. Figure 5 illustrates the relationships between direct and indirect damages models developed in PEARL. These relationships allow to link direct and indirect damages such as business and traffic interruptions.

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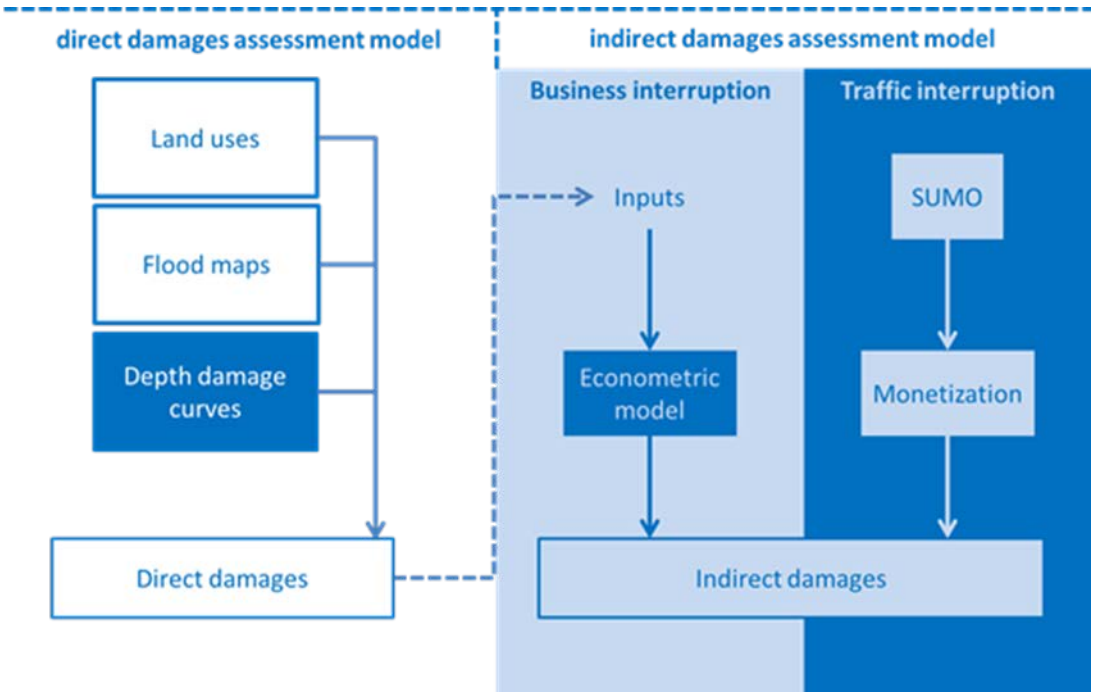

Figure 5: Estimation of direct and indirect damages;

c. Traffic modelling

To estimate direct flood impact for study areas with various scales, data format and availability, of study, a new tool linking hydraulic modelling results, assets and vulnerability information has been developed. PEARL flood-traffic integration tool was developed to provide a comprehensive assessment of the flood impacts on road transportation. This tool is the first of its kind that practically translates flood maps into a specific input for the traffic model SUMO. The tool integrates flood and road transportation modelling via two Python models that run in ArcGIS environment. Due to this date, flood and transport models have never been integrated in a dynamic way. The tool makes this possible by providing a consistent and homogeneous method to convert temporal varying flood propagation into temporal varying traffic supply in the SUMO model. Another aspect of the tool is that it allows multiple flooding and traffic scenarios to be easily set up and simulated. The tool has been applied in Marbella and Sint Maarten case study areas.

d. An improved model for flood impact assessment on public health (Deliverable 3.2)

PEARL advances existing health impact assessment methodologies by incorporating modelling of risk of primary infection during a flood event by linking the hydraulic models, which predict the extent of the flooding, to Quantitative Microbial Risk Assessment and by estimating the probability of infection for selected waterborne diseases." This work is based on an already existing health risk model, which was developed during the CORFU project (EU FP7, Grant Number 244047) and published by Mark et al. (2015). The CORFU model used the deterministic model MIKE Flood, which integrates the 1D hydraulic A/D sewer network model in MIKE Urban, and the 2D hydraulic surface

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A/D model MIKE21 to estimate the flood levels and the concentration of wastewater in Dhaka, Bangladesh. The estimation of the concentration of pathogenic microorganisms was based on measurements of Vibrio cholerae O1 El Tor. The results of the flood model were used as input for assessments of the human exposure to the pathogens and a manual quantitative microbial risk assessment (QMRA) to determine the probability of infection for four different exposure groups. In PEARL this earlier work was further enhanced by addressing the Rotavirus infection which was done for the case of Denmark, Figure 6.

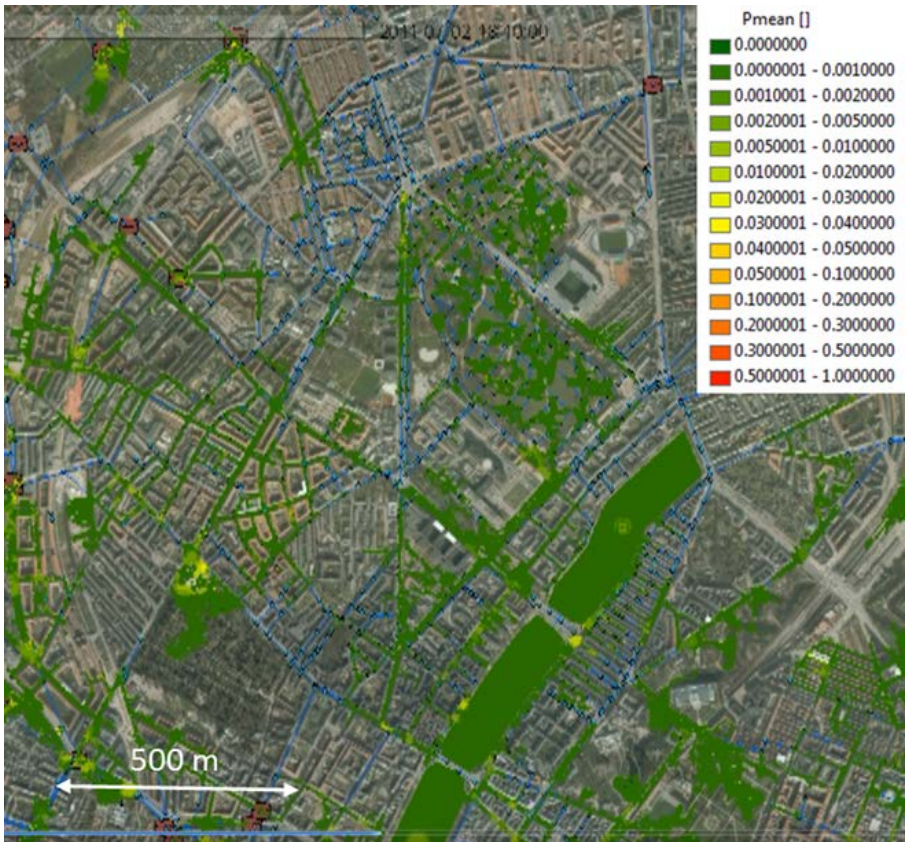

Figure 6: Modelled mean probability of rotavirus infection during the flooding in Nørrebro, Denmark, 18:05, 2 July 2011

In addition, a considerable work was carried out for the case study area in Thailand to reflect waterborne infections through flood hazard characteristics by combining flood depths, flood durations and concentrations of E.Coli, Figure 7.

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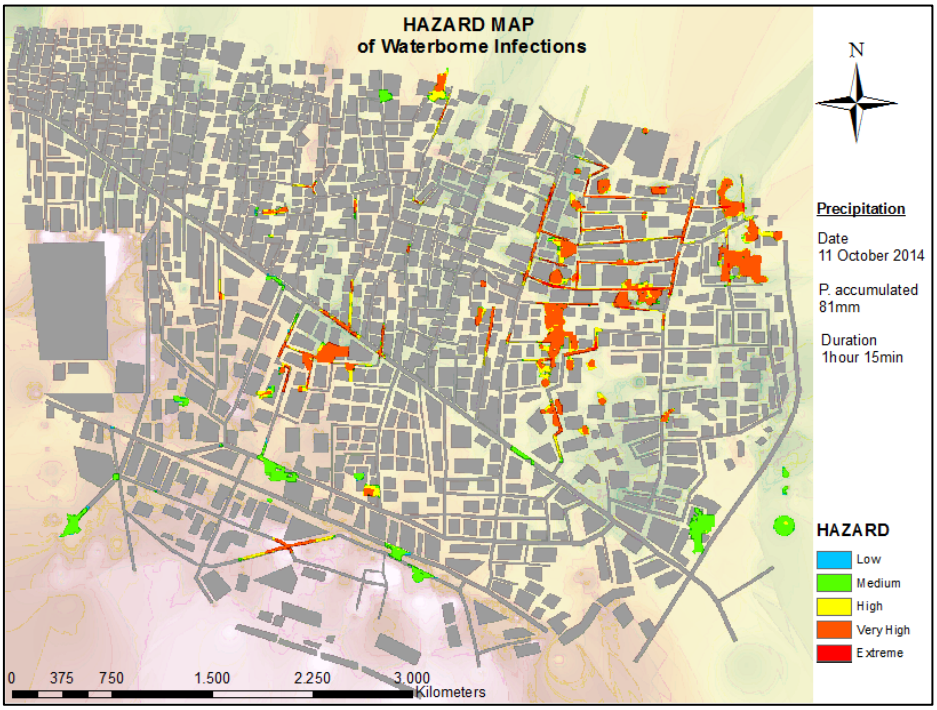

Figure 7: HAZARD MAP for waterborne infections 1

e. Risk visualization methods

PEARL advances risk visualization methods by exploring different techniques such as GIS maps, Cesium WebGL-based virtual globe and map engine, 3D animations and various charts (e.g., Spider Charts). Cesium provides a web-based tool to convert COLLADA models (COLLAborative Design Activity, an interchange file format for interactive 3D applications) to glTF for optimal use with Cesium.

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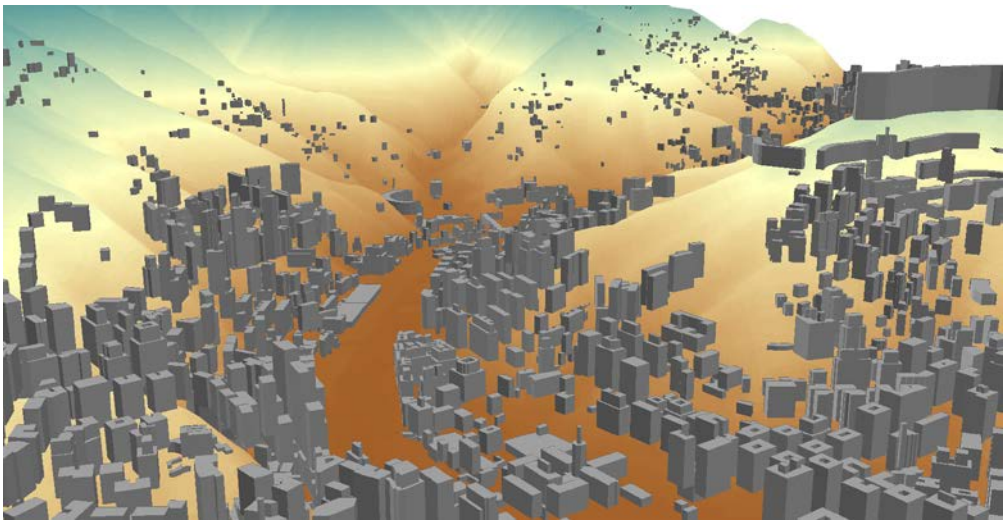

Figure 8: the visualization of the Genova case study Digital Elevation Model (Terrain Model + Buildings) through the ESRI tool Arc Scene

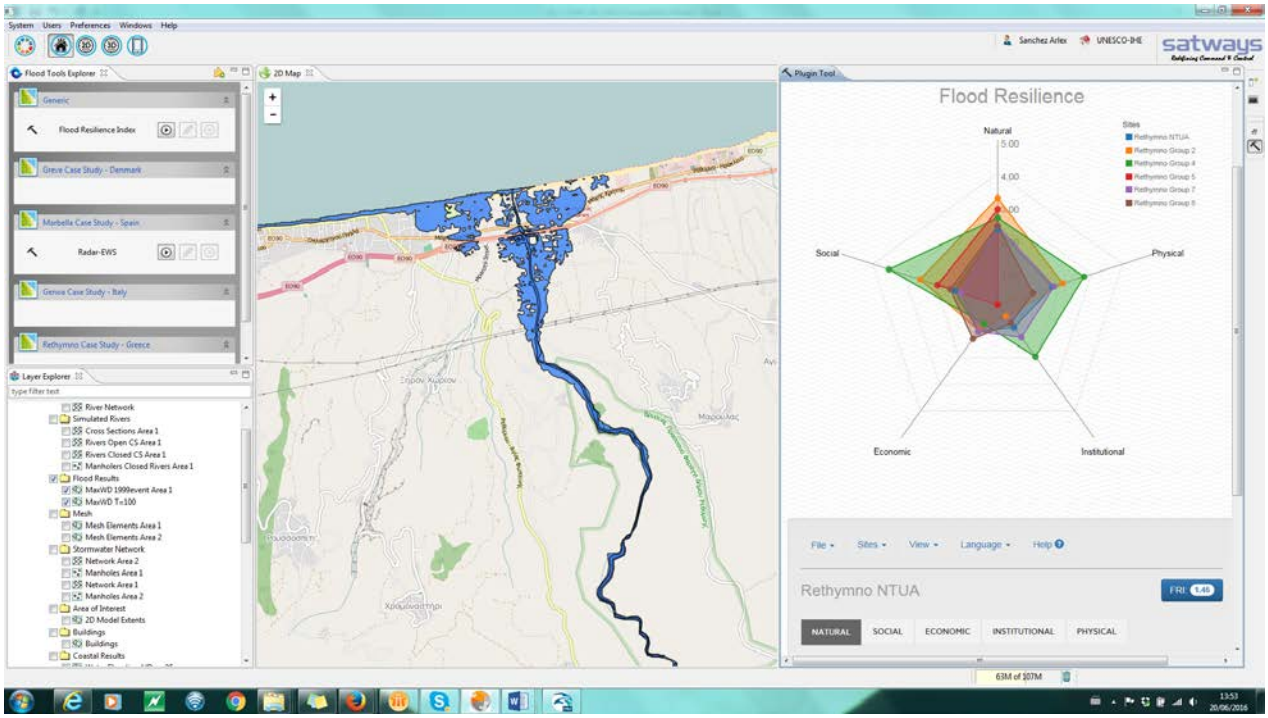

Figure 9: Flood extend and water depth derived from numerical models; The Flood Resilience Index was mapped using the spider charts;

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Figure 10: 3D animations for communication of flood model results;

2.4 Work Package 4 - Flood forecasting and early warning systems for coastal regions

WP4 advances current state-of-the-art in the following key areas:

a) Fast real-time early warning systems,
b) Novel methods for analyses of the propagation of uncertainty through a model chain, used for early warning,
c) A multi-agency command & control system prototype, capable to receive and manipulate early warning and alerting messages,
d) A platform prototype for early warning dissemination: The platform will be an early warning and alerting generator module based on EDXL-CAP,
e) Facilitation of informal-based dissemination during crisis, including mapping, citizen reporting and self-organising digital volunteers. The mean of dissemination was chosen to be generic, multi-language smartphone apps.

These new developments were tested in the case studies: Greve, Denmark; Marbella, Spain; St. Lucia and The Elbe. The implementation in the case studies have demonstrated that real time flood

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forecasting and early warning in coastal regions are feasible and can provide warning to authorities and the public in advance of flooding in coastal cities.

The following describes the individual tools developed in WP4.

1. At the outset of the project, a very limited number of early warning systems for coastal flooding existed and only one system included simultaneous modelling of pluvial flood storm surges. Rainfall forecast methods, as input to the pluvial flood models, included deterministic: Numerical Weather Prediction, radar-based forecasting, artificial neural network modelling, and knowledge-based nowcasting. Probabilistic rainfall forecasting for real-time flood forecast was still an emerging area.
2. Modelling techniques for the simulation of coastal flooding (e.g. sea levels) consisted of two-dimensional (2D) models, mainly Cartesian, but also model with flexible calculation meshes, were applied. Three-dimensional (3D) hydrodynamic models, were also (rarely) used instead of 2D models for simulation of storm surges, in order to consider vertical stratification in the calculations and avoid the depth-averaging simplification with 2D models.
3. Inland flood modelling methods were typically physically-based hydrodynamic models simulating water depths and discharges, either as two-dimensional (2D) surface models or with underground drainage networks, in which case, coupled 1D-2D models were used.
4. All the early warning systems were deterministic, and little or no attention was on the propagations of uncertainty in the model chain in the early warning system. The early warning systems, had “slow computation; were not connected to professional system for dissemination of the warning to the responsible authorities and - the real-time warnings were not submitted to the public.
5. The planned advancements of WP 4 were state to establish state of art in flood forecasting and early warning for coastal areas across the whole chain of early warning from data to warning dissemination. Here focus was on improving the speed of state-of-art modelling tools for early warning, in order to achieve sufficient lead times for emergency actions. Including the use of emerging web technologies and real-time applications. After documentation of the speed and the improvement of the speed then customisation and the development of methods and concepts for fast flood simulations in areas with combined flood risks was developed, with focus on integrated flood risks like flooding both from coastal, fluvial and pluvial flooding.
6. In order to make the simulation results applicable for decision making, methods for uncertainty propagation were developed and the impacts on early warnings and real-time decision making were quantified. Further, decision making was supported through the development and implementation of a command and control system for service providers and decision makers. Finally, the formal and informal dissemination systems were developed for information from early warning systems at local regional, national and cross border scales: The dissemination systems consisted of web-based services and a mobile phone app.

The *first advancement* was report outlining the state-of-the-art within online tools and techniques for early warning systems (EWS). The purpose was to establish the foundation for WP4, and to assess and identify points of enhancement for methods used real-time flood forecasting and warning. The report presents a review and analysis of methodologies for real-time coastal flood modelling. The various components of flood EWS’s were identified, and possible enhancements for their use in fluvial, pluvial, and coastal flooding applications were discussed. In addition, state-of-the-art techniques for flood hazard mapping, which are widely used in EWS’s, were identified and presented. The tools and techniques for real-time flood modelling and early warning discussed in the report were exemplified by a review of existing systems and demonstrated through detailed presentations of case study applications under the PEARL project. Online real-time coastal flood modelling systems (state-of-the-art) were implemented in selected case studies. Modelling

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techniques for coastal flood warning were applied and tested through online real-time coastal flood warning systems in the PEARL case study cities of Greve in Denmark, Hamburg in Germany, and Castries in Saint Lucia.

For *the second advancement* presented and discussed options for achieving faster model simulations in the context of early flood warning. These options involved different aspects of the modelling process, from model conceptualisation and construction, to computational hardware capabilities. The various techniques were organised in two categories in the discussion:

Techniques for minimising computational load:

- Model (concept) simplification
- Model (construction) optimisation

Techniques for maximising computational power

- CPU parallelisation
- Hybrid/GPU computing

A systematic process for model speed-up was developed and tested successfully. The process entails model optimisation techniques preceding options involving hardware improvement. This is because high-performance computing capabilities are, yet, atypical in standard computers and would typically incur additional costs, and an optimal model setup can only be an advantage in improving model performance and maintaining accuracy.

The third advancement is the outcome of analyses on *advanced uncertainty methods and tools for early warning*, elaborated jointly by the project partners. Several aspects of uncertainty were explored associated with the measurement of precipitation and various components of an Early Warning Systems (EWS). The main sources of uncertainty in EWS along with the most important methodologies and tools for their analysis have been identified and discussed with respect to importance and impacts on real life usage. The methodologies have been categorized by source of uncertainty while their strengths and shortcomings have been addressed and references were given for further research. After that, a methodological framework for the quantification of uncertainty in precipitation forecasts, combining numerical weather predictions and satellite estimates has been presented. e same section a methodology for addressing radar precipitation uncertainty in nowcasting has been introduced and uncertainty propagation in model chains has been analysed identifying critical uncertainty propagation issues and bottlenecks. Finally, the above methodologies have been applied in two case studies in the cities of Marbella, Spain and Greve, Denmark. The EWS of Marbella demonstrates the ability of the system for uncertainty reduction by continuous adjustment of forecasts utilizing updated real-time information. In the Greve case study, uncertainty is quantified in probabilistic terms and visualized using innovative uncertainty visualization tools.

For *the fourth advancement* a command and control system was developed for flood warning decision making for service providers and decision makers. The command and control system was designed and developed and includes an alert routing software (ARS) which was been based on the Emergency Data Exchange Language (EDXL) specification. This alert router facilitates the implementation of standards for public alerting and hazard notification in disasters and emergency situations, and it allows the automatic distribution based on various rules but also provides the ability to ad-hoc distribution to recipients from the systems and actors registered on the online alert routing system. For testing and validation purposes the alert routing system has been interfaced with an existing Command & Control system for Emergency Responders (ENGAGE IMS/CAD) and the Marbella Case Study Flood Early Warning System, to demonstrate the ability to interlink Early Warning Service Providers and Emergency Responders.

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The platform for the Marbella Case Study Flood Early Warning System was developed using weather radar information, rain gauges and other sensors information in real time to feed a hydraulic model. Results can be explored through a web viewer and warnings received by email, SMS or EDXL-CAP messages connecting to the command and control mentioned above. This work improved the state of art in flood forecasting and early warning for coastal areas across the whole chain of early warning from data to warning dissemination.

The fifth advancement focussed on prototypes where new methodologies, concepts and tools for effective dissemination of early warnings were developed. Several smartphones and web-based technologies were developed in this task. These contain functionalities such as:

- Creation of flood observation messages that include images, Pearl knowledge-based categories and geo-locations.
    - Data available by a web service (API).
- Data acquisition
    - Forecasted rainfall and sea water levels.
    - Flood forecasting.
- Evacuation information
    - Shelter locations.
    - Routing to shelters.
    - Shelter information like status and contacting information.
- Request emergency assistance.

The technologies have been applied to specific case-study areas of the Pearl project and are disseminated as prototypes through the usual channels e.g. Play Store, websites and portals.

The software includes showcases of new information sources such as crowd sourcing social data, flood levels, forecast data, object data (shelters) and more. These sources can be used by citizens and authorities in early warning and during flooding situations. The tools also provide interactions with the data, making it possible to observe posts of other users, and numerical forecasts to evaluate whether user-locations are prone to flooding and eventually evacuation routing options in case of floods.

2.5 Work Package 5 - Decision support and policy development for strengthening resilience of coastal regions

WP5 advances current state-of-the-art in the following key areas:

a) Advancements of stakeholder engagement in the process of developing risk management roadmaps while supporting this process with novel concepts and tools from both social research and ICT technologies and transforming the decision environment form a reactive one to an interactive one. Analyse key stakeholders, decision processes, risk perceptions and information flows while identifying leverage points and appropriate scales/contexts in which PEARL support would result in the most pronounces impact
b) Collection and assessment of measures and strategies by building on existing work and projects, analysis of the whole set of conditions that are decisive for the selection of a (set) of measure(s), including traditional engineering, but also environmental and operational measures and strategies

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c) Encapsulation of collected knowledge on resilience measures in a flexible knowledge base, which will allow end-users to navigate from their observed problem to a selection (screening) of possible options/interventions worth considering (through modelling and other work). The knowledge base was foreseen to enable the combination of measures and the associated criteria and provide an evaluation context of the collected measures against the PEARL- FRI and associated indicators. Knowledge base's development was to be fulfilled by using open source tools and to be designed based a generic structure i.e. to be extensible and reusable beyond the end of the project.
d) Support of exploration of alternative intervention options through a toolbox that would include advanced multi-criteria decision analysis methods and efficient multi-objective optimisation algorithms towards measures and strategies' selection and a multi-criteria decision analysis approach for dealing with problems having criteria under various uncertainties
e) Development of an online collaborative learning and planning platform which would allow stakeholders to interact with the key PEARL tools and deliverables and use them for the development of risk management roadmaps for the case study areas. Stakeholders would learn better when they would be able to experiment in a safe environment in which they could visualise the effect of different examined scenarios, alternative risk futures and their decisions. In terms of ICT, the platform's development framework would incorporate the latest industry standards, ensuring interoperability, flexibility and seamless integration of relevant data and knowledge to the stakeholders' normal workflow.

The first advancement that project achieved was towards the PEARL LAA methodological framework and its application in the case study areas. The organisation of the LAAs was built around 3 groups of interactive activities (i. system analysis, ii. collaborative design, iii. governance) that contributed to collaborative planning via three threads (i. establishing facts, ii. creating common images, iii. setting common ambitions) and three streams (i. analysing and addressing problems, ii. developing and proposing solutions, iii. influence politics by seeking political commitment or binging participants together). The proposed framework was tailored to each case study area's uniqueness on circumstances and background and the workshops took local conditions and individual challenges/conflicts into account. The process of stakeholder engagement was adaptive to the past and current experiences in the targeted region e.g. stakeholders fatigue, social and cultural sensitivities, politics and priorities. Stakeholders analysis revealed key players which participated in an interactive process, conflicts, gaps in communications and/or good collaboration among the different services were raised and discussed. Apart from bringing individuals and/or organisations who are involved in or effected by decision making processes in the context of risk management in the same table, stakeholder engagement proved how valuable can be in gaining knowledge related to flood events from physical, socio-economic and governance perspective, citizens and authorities risk perception, as well as information in terms of root causes of disasters. In terms of risk assessment, the LAA members provided the knowledge of the evolution of flood problems and the way the community/authorities have been dealing with it throughout the years and what are the plans for the future. Having in place processes and mechanisms for effective stakeholder engagement, such as the LAA, is a prerequisite for developing broad ownership and encouraging participation i.e. making engagement current social practice, when people are able to understand, support and practically experience.

The second advancement is related to the FRI resilience framework methodology which was revised and enhanced to ensure that all relevant aspects for the analysis of extreme events in coastal regions

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and the associated multi hazards are covered providing, in this a way, decision makers with an easily accessible methodology for the quantification of urban flood resilience. The approach was applied and tested in several EU and non-EU cases at different micro or macro scales i.e. city, district, block and parcel. The complexity of an urban system has been tackled by defining 5 district dimensions i.e. natural, physical, economic, social and institutional. Each dimension has a set of parameters that correspond to indicators, which highlight the most important characteristics of a sub-system and enable the quantification of flood resilience. Essential to this second advancement was the operationalisation of the PEARL FRI methodology through the development of the PEARL FRI Tool and its integration to a software application. By using the tool, users are able to estimate the resilience of a city for a specific flood event (or flood type event) in five dimensions, visualize the results in a spider diagram but most importantly to identify resilience measures which would increase the dimension's and overall city's resilience in case they were implemented since each indicator has been linked with PEARL KB's available measures and strategies. Using such tool, not only enables the quantification of resilience to help the concept to become more tangible and usable within the evaluation of different strategies, but it also provides different authorities and stakeholders with a way to interact and exchange perceptions while comparing the spider charts which are the results of their individual assessments.

Third advancement under WP5 is the PEARL KB which is a flexible and easy to use Knowledge Base that allows users to navigate from their observed problem to a selection (filtering) of possible options/interventions worth considering. It consists mainly of a) a component to calculate the Flood Resilience Index (FRI) and assess the resilience of a city against extreme events, b) search functionality enabling the identification of engineering, environmental and operational measures for adaptation and mitigation, c) possibility to inspect the results of documented applications of resilience measures around the globe and d) a repository of publications metadata and other sources that describe resilience measures and document their effectiveness. The PEARL KB uses well-established and state-of-art technologies. It has been built on top of object-relational database management system, it is capable to handle workloads of large applications with many concurrent users, while it comes with a free and open source license. It is capable to support complex database-driven websites and includes an object-relational mapper. The KB is easily expandable and supported by a variety of software tools and frameworks. Its conceptual data model enables the establishment of links among all KB's items i.e. users can be easily navigated throughout the whole content. Embedded graphic elements enhance users experience who are able to apply interactively multiple criteria for filtering purposes e.g. problem type, measure type, spatial scale, land use, etc. on the top of free textual search, lists, pivot tables and georeferenced information on a map. Discrete user's roles e.g. administrator and data providers give flexibility in allocation of certain privileges and capabilities. The developed back up plan ensures its content and functions and in case of an emergency, system operation can be restored within two working days. Among primary KB's advantages are its generic structure and the fact that can be usable across all case studies, extensible in the design and content and reusable beyond the end of the project.

The PEARL Toolbox forms the fourth project advancement under the current WP, a toolbox which was developed to support selection of resilience strategies while assisting the exploration of alternative intervention options. The toolbox documents available optimisation algorithms and multi-criteria decision analysis algorithms for the users to explore. Additional and primary asset within the toolbox is an alternative tool for the selection of flood measures focusing on the combination of green

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and grey infrastructures which has been developed within the PEARL framework and enables the selection, evaluation and placement of different green-grey practices (or measures) for retrofitting urban drainage systems. The selection tool is accompanied with an implementation tool which allow stakeholders to answer multiple choice questions about flood type and local characteristics and to choose weights in order to describe local preferences regarding co-benefits, and to define the most important goals for the case under study. Final and major advancement in measures' selection is the developed PEARL institutional Agent Based Model which enables the simulation of authorities' decision making for the selection of resilience strategies. The proposed ABM supported and supports the exploration of alternative interventions options (incl. (a) engineering (b) environmental (c) operational strategies stored onto the PEARL KB) by the members of the LAA but most importantly provides a way of exploration of all decisive factors interfering in all processes between measure selection and actual measure implementation (including possible implementation of annual flood preparatory actions) such as funding, level of collaboration/communication of responsible authorities, local priorities and preferences, etc. This generic multi-criteria analysis approach and tool for dealing measure selection under uncertainty and randomness provides an innovative way in simulating the authorities' decision-making process for the selection of resilience strategies and assesses the performance of the case study area under different socio-economic and flood events scenarios.

For the final advancement, PEARL delivered the PEARL interactive web-based learning and planning platform (WebLP) which is an online rich client application that provides a user-friendly interface between PEARL products and outcomes and the members of the local LAAs in the case study areas. It is accessible to stakeholders either directly or through expert workshop facilitators and allows for the visualization of the effect of alternative choices on their risk situation and its propagation through time under different scenarios. The WebLP is an Enterprise Multi-Tier software system consisting of several modules and providing the necessary mechanism to be easily extended with additional ones. It supports different user profiles that have access to different parts of the client application and integrates a series of autonomous and differentiated tools that have been developed in other PEARL work packages and consolidates different disciples and expertise through remote web or local plugins. The WebLP is a GIS based application allowing a customized experience in which different combination of choices by the stakeholders defined through a scenario manager extract different modelling results from the platform's database. Data can be static e.g. provided by the authorities and used or derived from the flood modelling work, but also dynamic data e.g. flood reports collected by the PearlDetective crowdsourcing application. The developed modular and extensible framework incorporates the latest industry standards and provides extensibility via a well-defined Application Programming Interface to other domains and natural hazards outside and beyond the end of the PEARL project.

Close interconnection and integration of developed systems have been achieved providing the users with an enhanced experience and a consolidated environment where they can access all tools during decision-making processes. Under one web environment, users are able access generic tools i.e. the PEARL online FRI tool, the PEARL KB and the PEARL institutional ABM Tool simulating authorities' decision making for the selection of resilience strategies. Under the case study specific plugins, are the Radar Early Warning System of Marbella and the risk and damage assessment results produced through the application of different modelling processes and frameworks within the case study work.

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Within PEARL, the joint exploitation of the state-of-art tools along with closed stakeholders' engagement resulted in the development of risk management roadmaps, specifically designed for the case study needs and with the consensus of local stakeholders, supporting novel concepts and tools from both social/engineering research and ICT technologies.

2.6 Work Package 6 - Decision support and policy development for strengthening resilience of coastal regions

WP6 advances current state-of-the-art in the following key areas:

a) Metadata Catalogue (Geoportal),
b) Advances in the case study work.

For the implementation of the holistic frameworks with the associated methods and tools, a high level of coordination was required taking into account the timely data availability, appropriate formats and quality of the data for the considered models as well as the adequate storage of the data and outputs and their evaluation. In a multidisciplinary project such as PEARL, data, methods and tools are rather heterogeneous, requiring high amount of different data types and formats being geo data, time series or narratives, which have to be exchanged between different models. However, very often the data issue is underestimated leading to the lack of coordination across different instances and models, lack of standardised formats for data exchange incompatible information and information systems or fragmented or redundant information available (e.g. Hiemcke, 2011). An efficient data management was needed from the initial project phase considering all relevant initiatives and Directives at the national and EU level.

PEARL established coordinated data management procedures and activities from the initial project phase. The PEARL Metadata Catalogue has been developed and made available to the project participants at an early project stage (Month 6). Before the metadata catalogue platform is developed, Metadata Online Survey website was developed in order to collect the initial information about the data availability and requirements (demand / supply) and the users' expectations (http://pearl.wb.tu-harburg.de/surveys/). All project partners were invited to participate. The developed PEARL Metadata Catalogue (Geoportal) is the website where data producers can register their geospatial resources for other PEARL project partners to discover and consume and is available at http://pearl.wb.tu-harburg.de/geoportal/catalog/main/home.page. The portal does not duplicate these resources but stores the metadata of the resources as well as the information on how to access those resources. The catalogue has been populated and occasionally updated with the metadata from all PEARL case study areas and will be further available to the project partners even beyond PEARL.

PEARL liaised and cross-fertilise its activities on the case study work with other relevant projects and in initiatives such as the FP7 Project RISC KIT where the output from the hazard modelling from both projects have been cross-analysed and further discussed in the Italian Case study (Liguria Floods). Also, fruitful collaborations with the institutions outside of PEARL could be achieved. Such collaboration has been between the German Case Study partners (Elbe Estuary/ The City of Hamburg) and the Columbia University, USA where the experiences from the post assessment and analyses of the Hurricane Sandy (2012) could be used and cross referenced with the PEARL methods.

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In order to derive the corresponding lessons learned in the implementation of the PEARL holistic risk management approach, a common ground for their analysis has been defined in parallel to the activities in the case study areas. The outputs in the case study areas have been analysed based on their applicability, transferability and upscaling, acceptance by the stakeholders and further potential for improvements considering the baselines and key research needs in the individual case study areas. Further, the outputs have been cross linked, identifying some common ground between the cases (such as the small coastal communities e.g. Rethymno, Greece or Marbella, Spain vs. large cities e.g. Hamburg in the Elbe Estuary Germany) also delivering some generic lessons learned for the development and implementation of the holistic methods and tools for flood risk management.

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3 Impact and dissemination

3.1 Case Study Impacts

Most of PEARL's impacts have been realised through the case study work and through dealings with local stakeholders. Some highlights of impacts achieved through case study work are:

- In Genoa, Italy, RRCA revealed the vital role of structural mitigation works in protecting against rapid-onset flooding. Despite a change in the criteria for funding allocation and the creation of new institutional units to reduce hydrogeological risk, the interplay between legal and financial issues generated a deadlock that prevented local authorities from effectively reducing risk. The research has led to practical recommendations about how data about funding flows for flood protection from different sources can be improved in order to maximise the use of funds and better monitor and track spending.
- In Rethymno, Crete, mapping undertaken by local stakeholders was validated by the RRCA, but the RRCA also elaborated relevant causal relationships and their dynamics, highlighting the need to take advantage of a new moment of political opening in Greece's history to involve civil society actors in the development of more holistic flood management policies. While the RRCA highlights the need to engage stakeholders across all levels, this can be challenging: in Rethymno attempts to include national-level stakeholders in a participatory action-learning alliance were abandoned as due to political changes and the financial crisis in Greece personnel in national-level ministries of importance were either absent or unwilling to participate. Also, information and awareness on flood risk has been improved at a local scale among authorities and more emphasis was given to active stakeholders' engagement in flood risk management through the LAAs. Local authorities and different groups of active citizens have been reached within PEARL project through several technical meetings and LAA workshops and citizens actual risk perception has been gained after a door to door survey conducted within PEARL and was communicated to responsible authorities. Suggested future measures by local authorities which aimed at solving local flood problems have been jointly discussed and assessed with the PEARL members and within research activities.
- For St Maarten, following the aftermath of Hurricane Irma, action research enabled to better define rebuilding priorities (livelihood support; better co-ordination of the response; vulnerability and social protection; and psychosocial support) and relevant recommendations for improved community support to be highlighted to local, national and international recovery and reconstruction actors. The process of research also provided a rare opportunity for the local stakeholders to engage, share experience and collaborate. Furthermore, PEARL models were used in scenario analysis and development of various resilience measures (which range from engineering to policy related) that can strengthened island's resilience. These models continue to be used for all reconstruction activities on the island.

3.2 Tools

In terms of the tools developed the stakeholders from case study areas are able to use online webGIS system which provides an access to some of the PEARL outcomes (e.g., PEARL WebLP), online repository of resilience measures and their applications around the world (PEARL KB), an

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easy to use tool to interact with key stakeholders and grasp their perception on city's flood resilience (PEARL online FRI tool), a toolbox for measures' selections (PEARL Toolbox, ABM SAS, etc.).

In terms of the exploitation of results the following achievements have been realised:

- Knowledge and tools obtained in this project have been inserted as a foreground in a large number of projects and EU H2020 and LIFE (pending) proposals by the project partners
- Data collected and flood risk analysis results are available to local authorities responsible for the implementation of the EU Flood Directive in order to support their argument and have their case study included in the areas of potential significant flood risk during the 1st review stage (the case study of Greece)
- Partners are using the acquired knowledge in their consultancy work and their future developments
- Partners are exploiting the PEARL methodologies e.g. vulnerability and risk assessment and the Flood Resilience Index methodology calculation in the framework of lectures carried out at academic level

3.3 Publications

In terms of the publications, throughout the project timeframe, the PEARL consortium has produced a large number of publications, reports, presentations, technical outputs, case studies, etc. As such, a communication and dissemination approach was adopted to provide guidance on increasing the awareness and understanding of the project goals and objectives to a broad range of stakeholders. The approach enables a high level of engagement and participation from stakeholders, as well as a means for the PEARL consortium to influence a wider audience through the dissemination of project activities and learning. The strategy helps position PEARL, and all its constituents, as a leader in the field of adaptive risk management for coastal regions.

Research in PEARL on the root causes of local risk and loss has been published in the Journal of Extreme Events (Methodological framework (2016); Genoa case study (2017)). Scientific articles are forthcoming addressing (1) The historic role of intermediary institutions in mediating risk in Rethymno, Genoa and Dutch St Maarten; (2) The impact of contrasting local-national governance arrangements on recovery actions to address root causes in Dutch St Maarten and French St Martin post-Irma and (3) The applicability of lessons from building back better in crisis-scenarios in the South to middle- and high-income states.

Some examples of documents that are publically available for download:

1. http://www.uni-stuttgart.de/ireus/dateiuploads/PEARL-POLICY-BRIEF_RRCA_Oct2017.pdf (Policy brief on applying the RRCA in disaster risk reduction)
2. https://www.kcl.ac.uk/sspp/departments/geography/research/Research-Domains/Contested-Development/workingpapers.aspx (PEARL RRCA case study reports for Rethymno, Genoa and Dutch St Maarten, 2016)

A forthcoming Christian Aid publication further analyses findings from the PEARL Dutch St Maarten CBO workshop in order to highlight the applicability of the LPRR principles to a high-income state. This publication will be marketed through Christian Aid channels – and therefore to an NGO-audience – and sit within the searchable LPRR body of evidence.

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The research has been widely shared among the academic and practitioner communities working on disaster risk reduction and climate change adaptation through conference and poster presentations (Royal Geographic Society UK, London, Exeter and Cardiff, 2014, 2016 and 2018; UNISDR Science and Technology Conference, Geneva, 2016; Adaptation Futures, Rotterdam, 2016; Oxfam Resilient Solutions Symposium 2017; Amsterdam International Water week, 2017; UK Alliance for Disaster Research, Bristol, 2018; 6th International Conference on Building Resilience, Lisbon, 2018).

PEARL research in the Caribbean also supported a plenary address and 19th William G Demas memorial Lecture by Prof. Mark Pelling, 'From social resilience to survivor led reconstruction', given to the 48th Annual meeting of the Board of Governors, Caribbean Development Bank, 30 May 2018, and covered in the *Jamaica Observer* (29 May), *The Grenada Advocate* (1 June) and *Loop News* (1 and 6 June).

In addition, the research contributed to ICSU/UNISDR programme Integrated Research on Disaster Risk workshops and publications (2014 – 2017), including a brochure on root cause analysis circulated at Third UN World Conference on Disaster Risk Reduction, Sendai, Japan, March 2015. It has informed publically-accessible blogs about urban resilience building (https://views-voices.oxfam.org.uk/general/2017/07/resilience-thinking-urban-development) and the root causes of disaster impacts post-Irma (https://www.odi.org/comment/10543-hurricane-irma-when-everything-goes-quiet), as well as international media commentary by Arabella Fraser for the Overseas Development Institute, UK, following Hurricane Irma (BBC World News, Sky News; September 2017), and local and regional radio commentary by Jason Collodi, Christian Aid, in Dutch St Maarten (Island 92; April 2018, http://pjil.streamon.fm/listen-pl-3681#.WtniHOHcgzk.facebook).

In addition to all of the above, the communication and dissemination approach that took place during the project time frame, and will continue after, particularly targets decision makers at the EU, national and regional level responsible for coastal regions. However, PEARL also engages with professionals, research community and public and private stakeholders with a view to enhancing the impact of research and to foster dialogue and debate.

Through internationally established and recongised dissemination pathways (project website, social media and traditional media presence, open access journals and publications, participation in local and international events, PEARL will ensure broad dissemination and access to its outcomes and outputs.

To ensure proper attainment of the expected impacts and to convey them to the relevant audiences, the project communication and dissemination strategy build on the broad network of the project partners and their involvement at international, EU and regional levels.

The following communication and dissemination highlights within the WP7 that have contributed to the potential impact of PEARL are:

- PEARL Website,
- PEARL Brochure,
- E/learning platform,
- Science-Policy interfaces,
- International Symposium on Flood Risk Management in Coastal Regions,
- Wider publicity.

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3.3.1 PEARL Website

The PEARL project website (http://www.pearl-fp7.eu/) provides general information about the project, displays main achievements and products of each WP and case study, and informs about latest news on PEARL and international events concerning coastal flood management. It also contains links to relevant projects under the European Union's Seventh Framework Programme for Research, Technological Development and Demonstration, namely RISC-KIT and ASTARTE. These are used as an opportunity for cross collaboration and to further disseminate PEARL outputs.

Below is an overview of the sessions and views for the project website from 1 January 2017 to 30 April 2018 (as well as analytics from the start of the project to the end; 1 July 2015 to 30 April 2018). The results suggest a continuous stream of traffic to the website from across the world. This has helped PEARL reach a positive impact through enabling access on a global level to PEARL outputs.

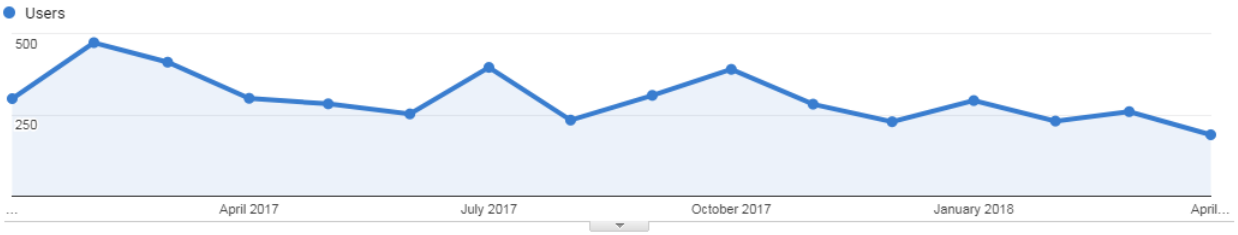
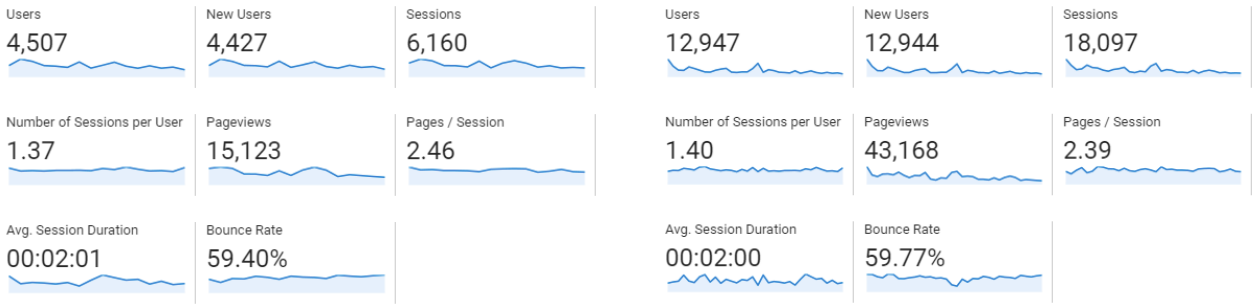


Figure 11. Monthly user overview (1 Jan. 2017 – 30 Apr. 2018)

Figure 12. Monthly user overview (1 Jul. 2015 – 30 Apr. 2018)



(a) (b)

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Figure 13. (a) Total number of user visits (4,507) (1 Jan. 2017 – 30 Apr. 2018)

(b) Total number of user visits (12,947) (1 Jul. 2015 – 30 Apr. 2018)

	Country	Users	% Users
1.	United States	515	11.30%
2.	Netherlands	442	9.70%
3.	Russia	363	7.97%
4.	United Kingdom	352	7.73%
5.	India	295	6.47%
6.	Germany	287	6.30%
7.	Spain	194	4.26%
8.	Italy	162	3.56%
9.	Greece	155	3.40%
10.	France	105	2.30%

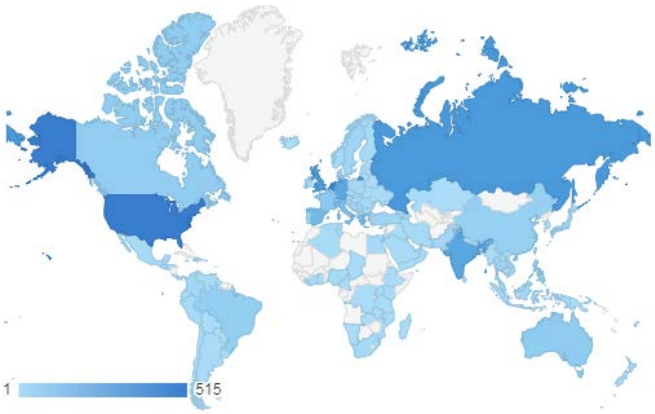

Figure 14. Distribution of users by country (1 Jan. 2017 – 30 Apr. 2018);

	Country	Users	% Users
1.	United States	1,646	12.59%
2.	United Kingdom	1,177	9.00%
3.	Russia	1,123	8.59%
4.	Netherlands	892	6.82%
5.	Germany	744	5.69%
6.	(not set)	738	5.64%
7.	Spain	571	4.37%
8.	India	515	3.94%
9.	Italy	466	3.56%
10.	Greece	429	3.28%

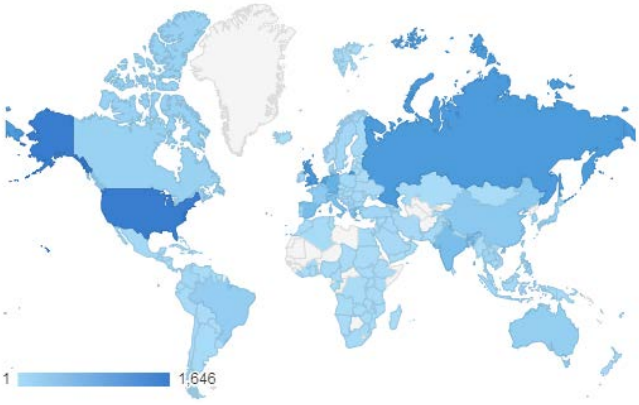

Figure 15. Distribution of users by country (1 Jul. 2015 – 30 Apr. 2018)

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3.3.2 PEARL brochure

A brochure (see Figure 5) was produced, giving a general overview of the project, its structure, case studies, expected outcomes, and partners. It provides an introduction of the PEARL project, useful during events. This ensure a consistent profiling of the PEARL project to audiences by the consortium. The project brochure was distributed at different international meetings by all partners.

Figure 16. PEARL flyer

3.3.3 Social networking

PEARL has maintained a strong presence on traditional social media channels, namely Twitter (see Figure 5a), Facebook (see Figure 5b) and LinkedIn (see Figure 5c). Facebook and Twitter are used to promote project outcomes and events, as well as any relevant news generally related to the topic of coastal flood management. The purpose is to target the wider public using non-technical language. The steady growth over the years (136 followers on Twitter, 293 likes on Facebook and 150 connections/members on LinkedIn) shows the relevance of PEARL and the growing online presence of PEARL. The growth is an opportunity to reach to wider and more broad audience group than possible through professional PEARL partner networks.

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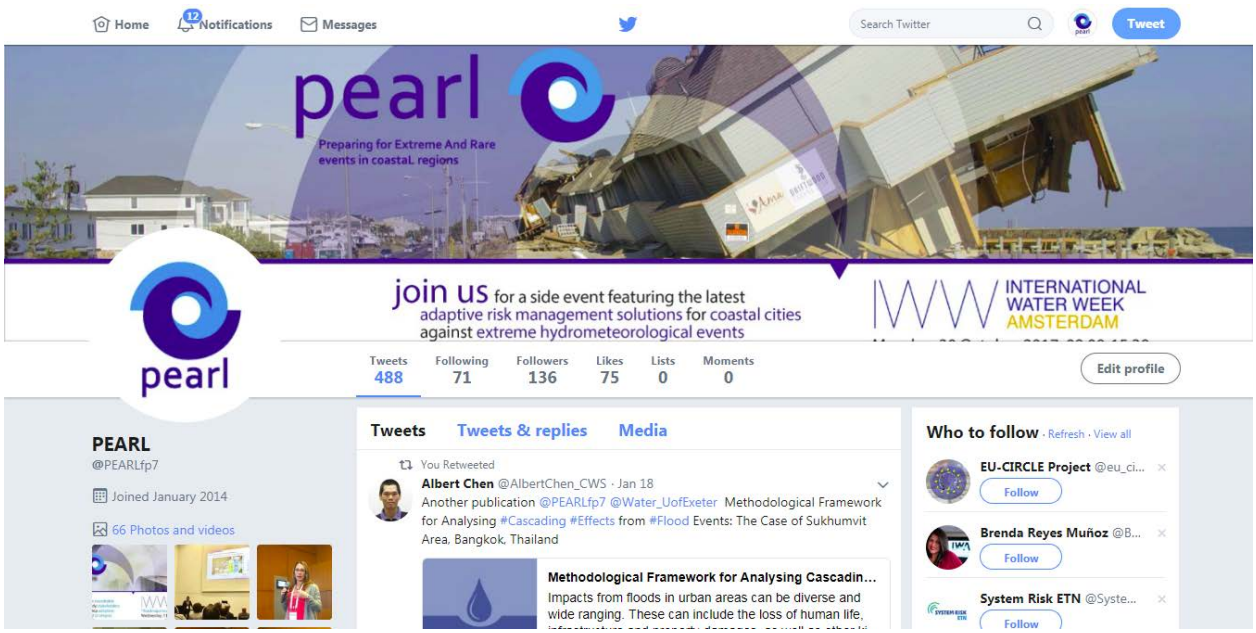

Figure 17. PEARL Twitter account

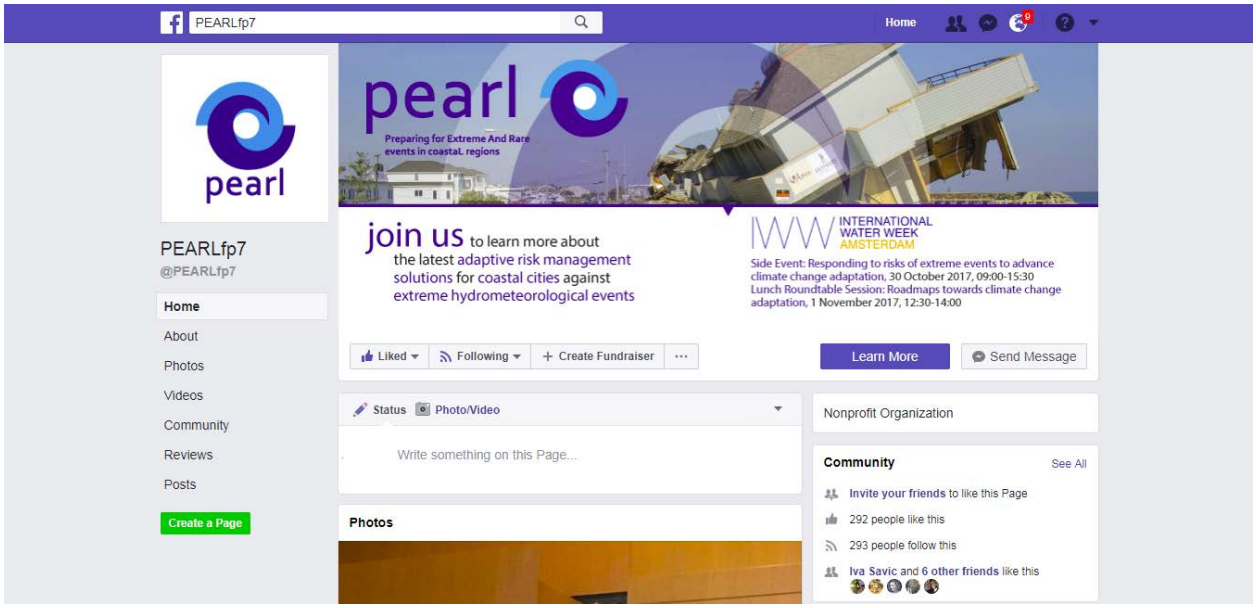

Figure 18. PEARL Facebook Page

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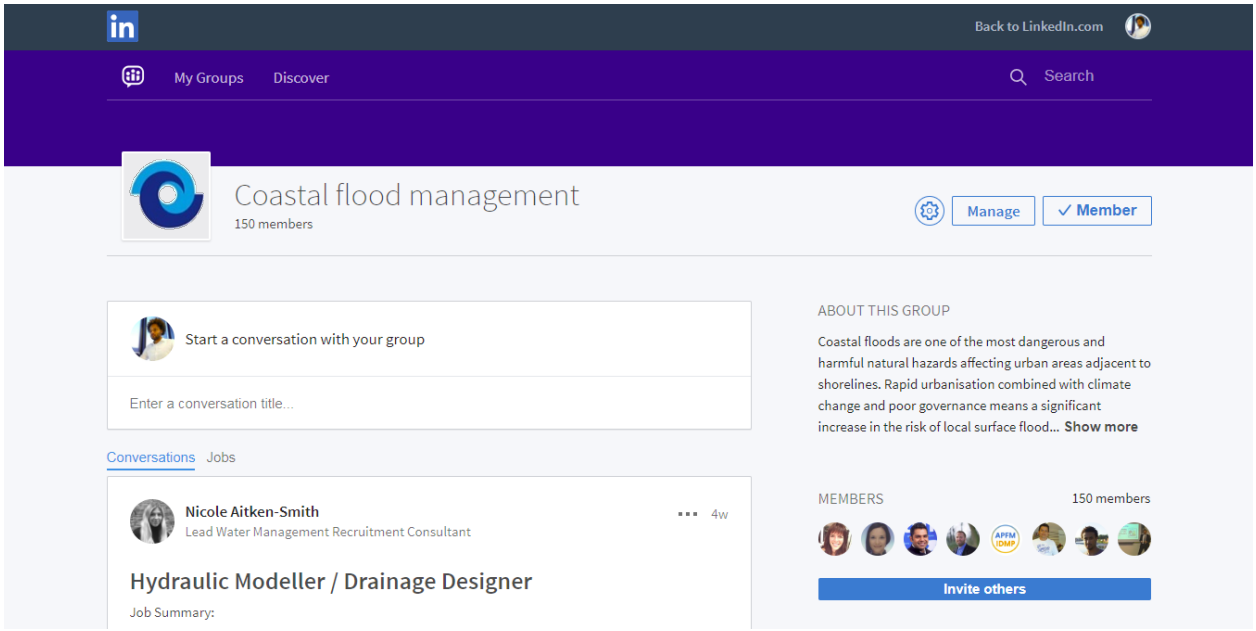

Figure 19. PEARL LinkedIn group (Coastal flood management);

Figure 5c. PEARL LinkedIn group (Coastal flood management);

3.3.4 E-learning platform

An e-learning platform has been developed through UNESCO-IHE. Content has been added to the e-learning course with useful and relevant content. The e-learning platform aims to contribute to capacity building of professionals involved in disaster risk management from extreme hydro-meteorological events. The module represents the means to disseminate the concepts developed within PEARL. It draws upon the theory and practice concerning multi hazards, holistic risk assessment, development of strategies and selection of measures, and their implementation. It also contains a pool of case studies in Europe and also internationally from which the audience can learn about the practical implications of the developed outputs in PEARL.

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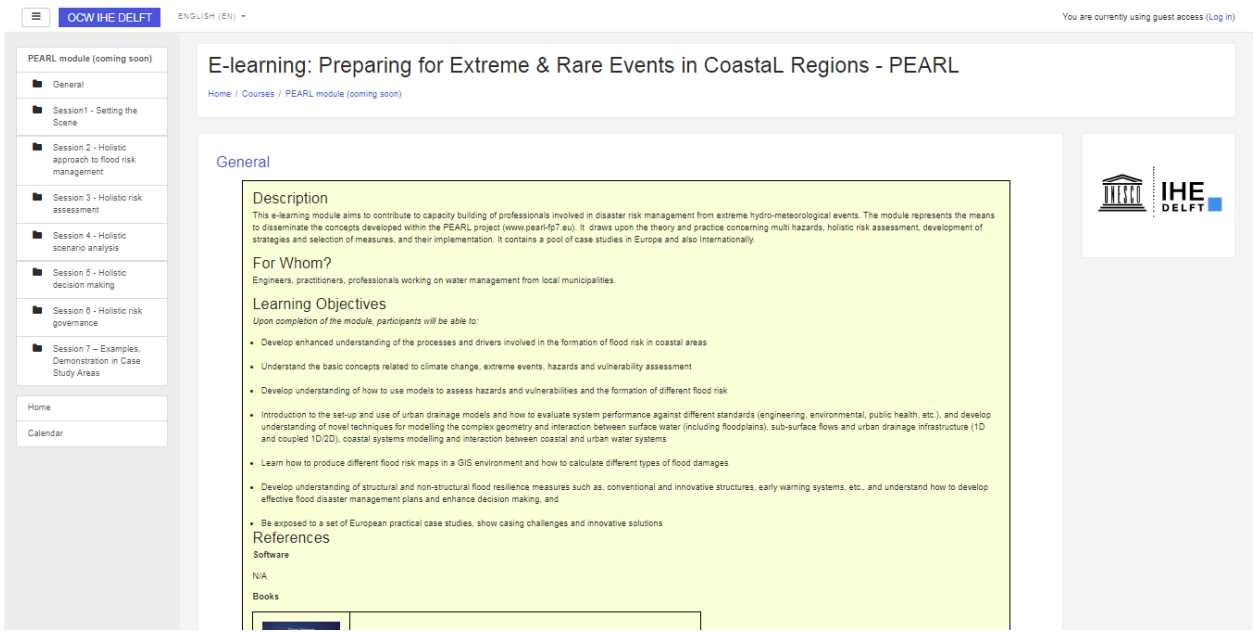

Figure 20. E-learning platform

3.3.5 Science-Policy interfaces:

A joint Policy Brief was developed by PEARL and RISC-Kit projects titled "Disaster Risk Reduction Strategies in EU Coastal Areas". The policy brief is available on both project websites. A second policy brief ("Tailored stakeholder engagement") addresses the approaches to tailoring stakeholder engagement to improve and direct the development of outputs from PEARL. The types of engagement were shaped by context from collaborative learning action alliance workshops to identify and understand flood risks, and to focus co-development of early warning systems with key government agencies. Stakeholders have been involved from the outset of PEARL and are identified as part of the team. The successes of various tailored approaches to stakeholder engagement across the PEARL stakeholders holds important lessons for future initiatives. It is also the key to ensuring uptake, increasing ownership and creating sustainability beyond the project.

The development of technical briefs was also initiated to complement the policy briefs. The technical briefs help to expand the scope within task 7.3 by establishing a different link between PEARL's scientific knowledge and EU Policy beyond the policy briefs, while still achieving the same objective as the policy briefs. The technical briefs have been a useful way to provide and advocate for certain policy recommendations and demonstrate the various outputs of PEARL in a way that is different and accessible to a wider audience.

A technical brief on Early Warning Systems has been produced with contributions from relevant partners as well as on Risk root cause analysis.

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(a);

(b)

Figure 21. (a) Policy brief: Disaster Risk Reduction Strategies in EU Coastal Areas

(b) Policy brief: Tailored stakeholder engagement

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(a); (b);

Figure 22. (a) Technical brief: Early warning system

(b) Technical/Policy brief: Risk root cause analysis

3.3.6 International Symposium on Flood Risk Management in Coastal Regions

An international event took place during the Amsterdam International Water Week (AIWW) from 30 October to 3 November 2017. Using AIWW as the venue, PEARL organised 3 key activities at the event to disseminate the project's main outputs.

- *PEARL side event: Responding to risks of extreme events to advance climate change adaptation* (Monday, 30th October 2017 | 9h-15h45)
  In this event, the science behind the PEARL framework and its application in case study cities across Europe, Asia and the Caribbean was presented. Bridging science to practice was demonstrated in the form of roadmaps where presenters discussed the way forward to building resilience and adapting to climate change in cities such as Hamburg (Germany), Genova (Italy), Rethymno (Greece), Greve (Denmark), Les Boucholeurs (France), Marbella (Spain), the Islands of St Maarten and St Lucia, Ayuthaya and Bangkok (Thailand), and Tainan (Taiwan).

- *Case session: Resilient Regions and Climate Change Adaptation* (Wednesday, 1st November 2017 | 11h-12h30)
  This session focused on Europe, the Caribbean and Asia with examples of cases on how to develop adaptive, sociotechnical measures and strategies to cope with climate change

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events. Diverse solutions were presented from organisations working in the PEARL case study areas. This session was led by the PEARL consortium.

- *PEARL lunch event: Roadmaps towards climate change adaptation* (Wednesday, 1st November 2017 | 12h30-14h00)
  Case study representatives were invited to informal world-café-style roundtable discussions delving into actions towards climate change adaptation for their respective cities. The session provided participants with the opportunity to probe further into informal discussion over lunch around roadmaps for the development of adaptive, sociotechnical measures and strategies.

AIWW provided a good opportunity to reach a wider, global but relevant audience consisting of leaders from government, the private sector, academics and society, who could potentially use the outputs and experiences from PEARL. The AIWW event attracted over 1200 delegates from 89 countries.

Over the course of the 2 days spent at AIWW, the PEARL consortium presented the different methods that were employed and tools developed at the different case study sites to respond and adapt to the increased risk of extreme events in coastal regions. The PEARL events also gave the opportunity for other organisations pushing forward coastal adaptation to climate change and extreme events to present their cases. The information presented covered many contexts and presented numerous novel approaches, which were captured in a summary report.

3.3.7 Wider publicity

The PEARL project was given wider publicity through media and at international events as well as through the publication of journals in notable open access publishers. The full list is available in A1. List of scientific (peer reviewed) publications and A2. List of dissemination activities.

The address of the project public website, if applicable as well as relevant contact details.

- Project website: http://www.pearl-fp7.eu/
- Social media presence: Twitter, Facebook and LinkedIn

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A1. List of scientific (peer reviewed) publications

No	Title	Main author	Title of the periodical or the series	Number, date or frequency	Publisher	Place of publication	Year of Publication	Relevant pages	Permanent identifiers (if available)	Is/Will open access provided to this publication
1	A risk reduction framework towards extreme and rare events in coastal regions: the case study of Rethymno, Crete	Makropoulos, Christos	Regional Environmental Change				2014			
2	Statistical Analysis on the Long-term Observations of Typhoon Waves in the Taiwan Sea	Doong, D.J.	Journal of Marine Science and Technology	23(6)			2015	893-900	DOI:10.6119/JMST-015-0610-7	Yes
3	An immersed-shell method for modelling fluid-structure interactions	Vire A	Philosophical Transactions A Mathematical Physical and Engineering Sciences	37	The Royal Sociatey Publishing		2015		ISSN:1364-503X	Yes
4	Towards a new multiscale air quality transport model using the fully unstructured anisotropic adaptive mesh technology of Fluidity (version 4.1.9)	J. Zheng	Geoscientific Model Development	8(10)	Copernicus Publications		2015		doi.org/10.5194/gmd-8-3421-2015	Yes
5	Non-intrusive reduced order modelling of fluid-structure interactions	Xiao D	Computer Methods In Applied Mechanics and Engineering	303	Elsevier		2016	35-54	ISSN:0045-7825	Yes
6	Application of the immersed-body method to simulate wave-structure interactions	Vire A	European Journal of Mechanics B-fluids	55	Elsevier		2016	330-339	ISSN:0997-7546	Yes
7	Adaptive Haar wavelets for the angular discretisation of spectral wave models	Adam A	Journal of Computational Physics	305	Elsevier		2016	521-538	ISSN:0021-9991	Yes
8	Development of a New Generation of Flood Inundation Maps – A Case Study of the Coastal City of Tainan, Taiwan	Doong, D.J.	Hydroinformatics and Urban Water Systems	8(11)	Water		2016		DOI:10.3390/w8110521	Yes

No	Title	Main author	Title of the periodical or the series	Number, date or frequency	Publisher	Place of publication	Year of Publication	Relevant pages	Permanent identifiers (if available)	Is/Will open access provided to this publication
9	Developing Frameworks to Understand Disaster Causation: From Forensic Disaster Investigation to Risk Root Cause Analysis	Fraser, A.	Journal of Extreme Events	3(2)	World Scientific		2016		doi.org/10.1142/S2345737616500081	Yes
10	Higher-order conservative interpolation between control-volume meshes: Application to advection and multiphase flow problems with dynamic mesh adaptivity	Adam A	Journal of Computational Physics	321	Elsevier		2016	512-531	ISSN:1090-2716	Yes
11	Application of a three-dimensional unstructured-mesh finite-element flooding model and comparison with two-dimensional approaches	Ting Zhang	Water Resources Management	30(2)	Springer		2016	823-841	ISSN:1573-1650	Yes
12	Evolutionary and Holistic Assessment of Green-Grey Infrastructure for CSO Reduction	Alves A	Hydroinformatics and Urban Water Systems	8(9): 402	Water		2016		DOI:10.3390/w8090402	Yes
13	Development of a New Generation of Flood Inundation Maps—A Case Study of the Coastal City of Tainan, Taiwan	Dong-Jiing Doong	Hydroinformatics and Urban Water Systems	8(11): 521	Water		2016		DOI:10.3390/w8110521	Yes
14	The Potential of Agent Based Models for Testing City Evacuation Strategies Under a Flood Event	Medina, N.	Procedia Engineering	154	Elsevier		2016	765-772	doi.org/10.1016/j.proeng.2016.07.581	Yes
15	Holistic approach to flood risk assessment in areas with cultural heritage: a practical application in Ayutthaya, Thailand	Vojinovic, Z.	Natural Hazard	81(1)	Springer		2016	589–616	ISSN:1573-0840	Yes
16	An integrated wave modelling framework for extreme and rare events for climate change in	Tsoukala V.	Oceanologia	58(2)	Elsevier		2016	71-89	DOI:10.1016/j.oceano.2016.01.002	Yes

No	Title	Main author	Title of the periodical or the series	Number, date or frequency	Publisher	Place of publication	Year of Publication	Relevant pages	Permanent identifiers (if available)	Is/Will open access provided to this publication
	coastal areas the case of Rethymno, Crete									
17	Providing Evidence-Based, Intelligent Support for Flood Resilient Planning and Policy: The PEARL Knowledge Base	Karavokiros, G.	Water Journal	8(9)	Multidisciplinary Digital Publishing Institute (MDPI)		2016		DOI:10.3390/w8090392	Yes
18	Two-dimensional evaluation of ATHAM-Fluidity, a nonhydrostatic atmospheric model using mixed continuous/discontinuous finite-elements and anisotropic grid adaptivity	Julien Savre	Journal of Monthly Weather Review	144	American Meteorological Society (AMS) Publications		2016		doi.org/10.1175/MWR-D-15-0398.1	Yes
19	Understanding Institutional Deadlocks in Disaster Risk Reduction: The Financial and Legal Risk Root Causes in Genova, Italy	Anna Scolobig	Jouranl of Extreme Events	4(2)	World Scientific		2017		doi.org/10.1142/S2345737617500105	Yes
20	Combining Ecosystem Services with Cost-Benefit Analysis for Selection of Green and Grey Infrastructure for Flood Protection in a Cultural Setting	Vojinovic, Z.	Environments: Consideration of Ecosystem Services and Function for Sustainable Water Use	4(1)	Multidisciplinary Digital Publishing Institute (MDPI)		2017		ISSN:2076-3298	Yes
21	Unstructured mesh adaptivity for urban flooding modelling. Ocean Modelling	Hu, R.	Journal of Hydrology	560	Elsevier		2017	354-363	DOI:10.1016/j.jhydrol.2018.02.078	Yes
22	Numerical simulation of floods from multiple sources using an adaptive unstructured mesh method applied to Greve in Denmark	Hu, R.	Water Resources Research	4(1)			2017		DOI:10.1142/S2345737617500105	
23	Towards non-intrusive reduced order 3D free-surface flow modelling	D. Xiao	Ocean Engineering	140	Elsevier		2017	155-168	doi.org/10.1016/j.oceaneng.2017.05.020	Yes

No	Title	Main author	Title of the periodical or the series	Number, date or frequency	Publisher	Place of publication	Year of Publication	Relevant pages	Permanent identifiers (if available)	Is/Will open access provided to this publication
24	A goal-based angular adaptivity method for thermal radiation modelling in non grey media	Laurent Soucasse, Steven Dargaville, Andrew G Buchan, Christopher C, Pain	Journal of Quantitative Spectroscopy and Radiative Transfer	200	Elsevier		2017	215-224	doi.org/10.1016/j.jqsrt.2017.06.015	
25	Model identification of reduced order fluid dynamics systems using deep learning	Zhenghai Wang, D.Xiao, F.Fang, R.Govindan, C.Pain, Y.Guo	International Journal for Numerical Methods in Fluids				2017		doi.org/10.1002/fld.4416	
26	Capturing the multifaceted phenomena of socio-economic vulnerability	Sorg, L., Medina, N., Feldmeyer, D., Sanchez, S., Vojinovic, Z., Birkman, J., Marchese, A	Natural Hazards	92(1)	Springer		2018	257-282	ISSN:1573-0840	yes
27	Multi-criteria approach for selection of green and grey infrastructure to reduce flood risk and increase co-benefits. Journal of Water Resources Management	Alves, A.; Gersonius, B.; Sanchez, A.; Vojinovic, Z.; Kapelan, Z.	Water Resources Management	*7*	Springer Professional		2018		www.springerprofessional.de/en/multi-criteria-approach-for-selection-of-green-and-grey-infrastr/15540230	yes
28	Combining co-benefits and stakeholders perceptions into green infrastructure selection for flood risk reduction	Alves, A.; Patiño Gómez, J.; Vojinovic, Z.; Sanchez, A.; Weesakul, S.	Environments	10(81)	Multidisciplinary Digital Publishing Institute (MDPI)		2018		http://www.mdpi.com/2076-3298/5/2/29	yes
29	Methodological Framework for Analysing Cascading Effects from Flood Events: The Case of Sukhumvit Area, Bangkok,	Hilly, G.; Vojinovic, Z.; Weesakul, S.; Sanchez, A.;	Water		Multidisciplinary Digital Publishing Institute (MDPI)		2018		http://www.mdpi.com/2073-4441/10/1/81	yes

No	Title	Main author	Title of the periodical or the series	Number, date or frequency	Publisher	Place of publication	Year of Publication	Relevant pages	Permanent identifiers (if available)	Is/Will open access provided to this publication
	Thailand	Hoang, D.N.; Djordjevic, S.; Chen, A.S.; Evans, B.								

A2. List of dissemination activities

No	Type of activities	Main leader	Title	Date/Period	Place	Type of audience	Size of audience	Countries addressed	Comment
1	Conference		AdaptToClimate	27-28 March 2014	Nicosia, Cyprus				Presentation, paper: • Improving Resilience Against Extreme and Rare Events in Coastal Regions: An Initial Methodological Proposal – The Case Study of the City of Rethymno (Makropoulos C.; Tsoukala V.; Lykou A.; Chodros M.; Manojlovic N.; Vojinovic Z.)
2	Conference		Flood Damage Survey and Assessment Seminar: New Insights from Research and Practice	11-12 April 2014	Bastia Umbra, Italy				Presentation
3	Conference		European Maritime Day 2014	19-20 May 2014	Bremen, Germany				Workshop
4	Conference		International Conference for Disaster Management	19 June 2014	Havana, Cuba				Presentation
5	Conference		11th International Conference on Hydroinformatics	17-21 August 2014	New York, USA				4 presentations, 4 papers: • Holistic Flood Risk Assessment in Coastal Areas – The PEARL Approach (Vojinovic Z, Y Abebe, A Sanchez, N Medina, I Nikolic, N Manojlovic, C Makropoulos, M Pelling, M Abbott) • Merging Quantitative and Qualitative Analyses for Flood Risk Assessment at Heritage Sites, the case of Ayutthaya, Thailand (Vojinovic Z, D Golub, S Weesakul, W Keerakamolchai, S Hirunsalee, V Meesuk, A Sanchez, S Kumara, N Manojlovic, M Abbott) • FloodAlert: A Simplified Radar-Based EWS for Urban Flood Warning (Llort X, R Sánchez-Diezma, Á Rodríguez, D Sancho, M Berenguer, D Sempere-Torres) • Hidromet: A Cloud-Based EWS

No	Type of activities	Main leader	Title	Date/Period	Place	Type of audience	Size of audience	Countries addressed	Comment
									Platform for Real Time Urban Flood Warning (Rodríguez A, X Llort, D Sancho, R Sánchez-Diezma, R Bella, V Gómez)
6	Conference		13th IAHR/IWA International Conference on Urban Drainage	7-11 September 2014	Sarawak, Malaysian Borneo	Urban water managers, water professional, scientists, researchers, NGO	1000+	Global	
7	Conference		6th International Conference on Flood Management	16-18 September 2014	São Paulo, Brazil				Presentation; Poster • Pearl – Preparing for Extreme and Rare Events in Coastal Regions (Teruggi G, Z Vojinovic, N Manojlovic, C Makropoulos)
8	Conference		IWA World Water Congress & Exhibition	21-26 September 2014	Lisbon, Portugal	Water, environment and related professionals	1000+	Global	Discussion on PEARL at the "Basins of the Future Steering Committee Meeting"; Brochure distributed at the exhibition
9	Workshop		Raingain workshop	October 2014	Exeter, UK				3D urban flooding modelling presented (T. Zhang, F. Fang, C.C.Pain, C.Maksimović)
10	Workshop		IRDR Workshop	November 2014	Paris, France				KCL Review of FORIN Method for Root Cause Analysis and PEARL approach presented
11	Conference		2nd International Ocean Research Conference	17-21 November 2014	Barcelona, Spain				Presentation
12	Conference		DAAD Science Tour 2014	1 December 2014	Hamburg, Germany				Presentation
13	Workshop		LIFE+IMAGINE workshop	30 January 2015	Genoa, Italy				Presentation; Poster
14	Workshop		TICASS workshop	20 February 2015	Genoa, Italy				Presentation; Poster; Poster abstract
15	Conference		3rd WCDRR	14-18 March	Sendai, Japan				One to one publicity
16	Conference		European Geosciences Union - General Assembly 2015	12-17 April 2015	Vienna, Austria				Poster presentation • Holistic flood risk assessment using

No	Type of activities	Main leader	Title	Date/Period	Place	Type of audience	Size of audience	Countries addressed	Comment
									agent-based modelling: the case of Sint Maarten Island (Abebe, Y.A., Vojinovic, Z., Nikolic, I., Hammond, M., Sanchez, A. and Pelling, M.)
17	Conference		SUMO User Conference 2015	7-8 May 2015	Berlin-Adlershof, Germany				Presentation; Paper • Flood Impacts on Road Transportation Using Microscopic Traffic Modelling Technique (Pyatkova K , AS Chen , S Djordjević , D Butler , Z Vojinović, YA Abebe, M Hammond)
18	Conference		XV World Water Congress	25-29 May 2015	Edinburgh, Scotland				One to one publicity
19	Conference		XVII World Meteorological Congress	25 May-12 June 2015	Geneva, Switzerland				
20	Conference		36th IAHR World Congress	28 June-3 July 2015	The Hague, The Netherlands				Presentation and papers: • Introduction to PEARL (Vojinovic Z.) • Development of the Risk Assessment Framework and onTology (RAFT) (Vojinovic Z.) • Holistic Flood Risk Management in the Elbe Estuary- the PEARL Approach (Gruhn A, P Fröhle, S Shaikh, D Antanaskovic, I Gershovich, E Nehlsen, Z Vojinovic) • Automated runoff coefficient computation in urban drainage systems using Google satellite images and fuzzy classification (Medina, N., Sanchez, A., Vojinovic, Z.) • Assessing the implications for urban drainage infrastructure of future scenarios of urban growth with cellular automata (Sanchez, A., Vojinovic, Z., Medina, N., Mynett, A.) • Managing flood risk in coastal cities through an integrated modelling framework supporting stakeholders' involvement: the case of Rethymno, Crete (Makropoulos C.; Tsoukala V.; Belibbasakis K.; Lykou A.; Chondros

No	Type of activities	Main leader	Title	Date/Period	Place	Type of audience	Size of audience	Countries addressed	Comment
									M.; Gourgoura P.; Nikolopoulos D.)
21	Forum		1st Forum on Green Development on the practical implementation of the Resilience in cities	11 Novemebr 2016	Tainan, Taiwan				Peter Fröhle- Presentation on the Resilient Cities-The Hamburg Case
22	Conference		International Conference on Hydroscience & Engineering	11 November 2016	Tainan, Taiwan				Peter Fröhle – Presentation during the dedicated PEARL workshop
23	Conference		Amsterdam International Water Week	2-6 November 2015	Amsterdam, the Netherlands		1000+	Global	Presentation on “The PEARL knowledge base platform for resilience measures and strategies, and on the integration of PEARL results into the planning and policy making processes”
24	Project meeting		Final Project Meeting of Thalis CCSEAWAVS Project	12 November 2015	Thessaloniki, Greece				Presentation on “The PEARL project: aims, actions and CS”
25	Conference		the UNISDR Science and Technology Conference on the Implementation of the Sendai Framework for Disaster Risk Reduction	January 2016	Geneva, Switzerland				Poster presentation
26	Conference		European Geosciences Union - General Assembly 2016	17-22 April 2016	Vienna, Austria				Conference presentation, • Studying extreme coastal precipitation events with the new LES model ATHAM-Fluidity”; The research partner Prof. C.H. Tsai participated to the EGU General Assembly 2017 in Vienna to present the results obtained in this project Paper: • Agent based models for testing city evacuation strategies under a flood event as strategy to reduce flood risk (Medina, N.; Sanchez, A.; Nikolic, I.; Vojinovic, Z.)
27	Symposium		TRUC – PEARL - RISC-KIT Symposium	9 May 2016	Delft, The Netherlands				The Symposium was held between TRUC, RISC-KIT PEARL projects with the aim of establishing a dialogue between these international projects that share the aim of building a holistic science and policy approach for risk management workshops

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									help establish a dialogues.
28	Summer school		ASTARTE & PEARL Joint Summer School	3-7 June 2016	Rethymno, Crete, Greece				The Joint Summer School was a course addressed to young professionals giving them the opportunity to discuss most recent research with a team of international scientists. Through field visits, the participants were able to see first-hand the application of investigation results.
29	Workshop		2nd Stakeholders workshop (LAA)	7-8 June 2016	Rethymno, Crete, Greece				Workshop held - Preparing coastal regions for extreme and rare events
30	Conference		12th International Conference on Hydroinformatics	21-26 August 2016	Incheon, South Korea				Papers: • Agent-based simulation for flood risk assessment (Abebe, Y.A., Ghorbani, A., Vojinovic, Z., Nikolic, I. and Sanchez, A.) • The Potential of Agent Based Models for Testing City Evacuation Strategies Under a Flood Event (Medina, N.; Sanchez, A.; Vojinovic, Z.) • A Model-based Framework for Selection and Development of Multi-functional and Adaptive Strategies to Cope with Urban Floods (Alves A.; Sanchez A.; Gersonius B.; Vojinovic Z.)
31	Conference		INSPIRE Conference 2016	September 2016	Barcelona, Spain				GISIG organised a workshop on the harmonization of data for coastal planning and natural risk management, participated by around 30 people from the ICT and environment domain at EU level.
32	Conference		IWA World Water Congress	10 October 2016	Brisbane, Australia	Water, environment and related professionals	1000+	Global	Workshop held - Strategies for building climate resilience in coastal areas with presentation on “The PEARL Online Toolkit for Flood Resilient Planning with examples from Rethymno, Crete, Greece” ; Video Demos on “The PEARL Knowledge Base”, “The PEARL online KB FRI tool” and “The PEARL WebLP” ; Hands-on demonstration of “The PEARL Knowledge Base”

No	Type of activities	Main leader	Title	Date/Period	Place	Type of audience	Size of audience	Countries addressed	Comment
33	Conference		12th International Conference on Hydroscience & Engineering	6-10 November 2016	Tainan, Taiwan				Mini Symposium: Presentation and Video demonstration on “Planning for Resilience in Coastal Cities: The PEARL online decision support and stakeholder engagement platform and knowledge base” Paper: • An Operational Hydrodynamic-numerical Model of the Elbe Estuary with Telemac-2D Based on Predicted Water Levels (Shaikh S., Gershovich I., Manojlovic N., Gruhn A., Fröhle P.)
34	Conference		1st CLIMATEUROPE Festival	5-7 April 2017	Valencia, Spain				presentation of PEARL
35	Conference		European Geosciences Union General Assembly 2017	23-28 April 2017	Vienna, Austria				Presentation: • Studying extreme coastal precipitation events with the new LES model ATHAM-Fluidity (James O'Neill et al) • Floodings during a typhoon event with the consideration of future sea-level rises (Jhang, S.H., Tsai, C.H., Doong, D.J., Simulation)
36	Symposium		International Symposium SUSTAINABILITY IN THE ENDLESS CITY	26-28 April 2017	Stuttgart, Germany				International Perspectives on the IBA City Region Stuttgart" & Expert Group Workshop
37	Conference		Heat stress and extreme precipitation events – how to make cities resilient	9 May 2017	Stuttgart, Germany				Workshop held: “Hitzestau und Starkniederschläge: Städte und Gemeinden klimafit Machen”
38	Conference		Conference of the Italian Mapping Association (AIC)	10-12 May 2017	Genoa, Italy				PEARL presentation by Alessandra Marchese at the Conference of the Italian Mapping Association (AIC) titled “Mapping and Blue Growth”
39	Workshop		Workshop on urban climate adaptation strategies	11 May 2017	Munich, Germany				Workshop held: “Kommunale Klimawandelanpassung. Herausforderungen, Instrumente, Praxisbeispiele und Erfahrungsaustauscd” (Local climate change adaptation. Challenges, tools, practical examples and exchange of experience)

No	Type of activities	Main leader	Title	Date/Period	Place	Type of audience	Size of audience	Countries addressed	Comment
40	Debate		Debate	23 June 2017					"3. Mainauer Nachhaltigkeitsdialog" (Sustainability debate with German stakeholders)
41	Conference		INSPIRE Conference 2017	6-8 September 2017	Strasbourg, France				Contacts established with the ICT and environment domain at EU level
42	Conference		14th IWA/IAHR International Conference on Urban Drainage	10-15 September 2017	Prague, Czech Republic	Urban water managers, water professional, scientists, researchers, NGO	1000+	Global	2 papers: • Selecting Optimal Configurations of Green and Grey Infrastructure for Flood Risk Reduction (Alves, A.; Sanchez, A.; Vojinovic, Z.; Kapelan, Z.) • Advanced urban flood EWS integrating radar nowcasting and 1D/2D modelling in real time (Russo, B, P. Sánchez, X. Llort and Á. Rodríguez)
43	Conference		Amsterdam International Water Week	30 October - 1 November ,2017	Amsterdam, The Netherlands		1000+	Global	PEARL side event: Responding to risks of extreme events to advance climate change adaptation ; Case session: Resilient Regions and Climate Change Adaptation ; PEARL lunch event: Roadmaps towards climate change adaptation
44	MSc Programme		UNU-MERIT – MSc programme on Public Policy and Human Development	March 2018	Maastricht, The Netherlands				Presented PEARL methods and tools at the UNU-MERIT
45	Conference paper	Gourgoura P.	14th international Conference on Environmental Science and Technology (CEST 2015)	3-5 September 2015					Learning and Action Alliances: a tool for flood risk governance in coastal area. The case of Rethymno, Crete (Gourgoura P., Blätgen T., Lykou A., Birkman J., Makropoulos C.)
46	Conference paper	Abebe, Y.A.	8th International Congress on Environmental Modelling and Software (iEMSs2016)	10-14 July 2016	Toulouse, France				Institutional analysis for flood risk reduction: A coupled agent-based-flood models method (Abebe, Y.A., Ghorbani, A., Vojinovic, Z., Nikolic, I. and Sanchez, A.)
47	Conference paper	Martzikos N.	35th International Conference on Coastal Engineering	17-22 July 2016	Istanbul, Turkey				Extended analysis of thresholds and classification for storm impacts at Rethymno (Martzikos N.; Lykou A.;

No	Type of activities	Main leader	Title	Date/Period	Place	Type of audience	Size of audience	Countries addressed	Comment
									Makropoulos C.; Tsoukala V)
48	Conference paper	Kragiopoulou E.	13th International Conference on Protection and Restoration of the Environment	3 - 8 July 2016	Mykonos island, Greece				Managing flood risk and wave run-up in the coastal zone of Rethymno (Kragiopoulou E.; Skarlatou E.; Lykou A.; Makropoulos C.; Tsoukala V.)
49	Conference paper	Medina, N.	Water Security and Climate Change: Challenges and Opportunities in Asia	29 November - 01 December / 2016	Bangkok, Thailand				The use of agent based models for climate change adaptation and development of large-scale evacuation strategies for flood risk mitigation (Medina, N.; Sanchez, A.; Vojinovic, Z.; Alves, A.)
50	Conference paper	D. Xiao	SIAM Conference on Computational Science & Engineering	14-18 March 2015	Salt Lake City				Nonintrusive reduced order modelling and applications for multiphase problems and free surface flows (D. Xiao, C.C. Pain, F. Fang, I.M. Navon, A. Muggeridge, P. Salinas A)
51	Conference paper	F. Fang	SIAM conference on Computational Science and Engineering	14-18 March 2015	Salt Lake City				Goal-Based ROM Adjoint for Optimal Sensor Locations and Data Assimilation (F. Fang, D.Xiao, C.C. Pain, I.M.Navon)
52	Conference paper	Alessandra Marchese	Mapping and Blue Growth	10-12 May 2017					Integrazione di dati multi-sorgente a supporto della gestione costiera in un clima che cambia (Alessandra Marchese)
53	Conference paper	T. Blätgen	10 Deutsche Klimatagung (10th German Climate Change Congress)	21-24 September 2015					Erweiterung der Grundlage einer anpassenden und angepassten räumlichen Planung - Methodik und Erkenntnisse im Zusammenhang von extremen Flutereignissen betroffener Küstenstädte in Europa (T. Blätgen, N. Manojlovic, A. Gruhn, A. Fraser, J. Birkmann, P. Fröhle)
54	Conference paper	Arabella Fraser	RGS-IBG Annual International Conference 2015	2-4 September 2015					Rescaling Urban Risk Management: Exploring the Impacts of Economic Restructuring on Urban Risk in Genoa, Italy and Rethymno, Crete (Arabella Fraser and Mark Pelling)
55	Conference paper	C. Pain	NAFEMS	21 October 2014					Fluid, Solid and Radiation Modelling in Multphysics Systems (Key note) (C. Pain)
56	Conference paper	F. Fang							Recent developments in ocean predictive modelling and data assimilation (F. Fang, C.C.Pain et al)

No	Type of activities	Main leader	Title	Date/Period	Place	Type of audience	Size of audience	Countries addressed	Comment
57	Conference paper	ICL	RGS-IBG Annual International Conference	September 2016					Methods for assessing resilience and vulnerability to natural hazards and disasters', 'The PEARL Risk Assessment Framework: Building Methodologies For Holistic and Structural Solutions to Coastal Flooding
58	Conference paper	Naso, S.	3rd European Conference on Flood Risk Management (FLOODrisk 2016) https://doi.org/10.1051/e3sconf/20160708007	20 October 2016					A novel approach to flood risk assessment: the Exposure-Vulnerability matrices (Naso, S., Chen, A.S., Aronica, J.T., Djordjević)
59	Conference paper	Pyatkova K	EUSTO Final International Conference	2016					Assessing flood impacts on road transportation (Pyatkova K, Chen AS, DJordjevic S, Butler D, Savic DA)
60	Conference paper	Lykou A.	15th International Conference on Environmental Science and Technology (CEST)	31 August - 2 September, 2017	Rhodes, Greece				The PEARL-toolbox: supporting the decision making process in selecting flood resilience strategies (Lykou A., Koutiva I., Karavokiros G., Tsoukalas I., Pantazis C. and Makropoulos C.)
61	Conference paper	Medina, N.	IAHR World Congress	13-18 August 2017	Kuala Lumpur, Malaysia				Planning strategies for flood disaster risk prevention with human behaviour models (Medina, N., Sanchez, A., Vojinovic, Z.)
62	Conference paper	Vojinovic Z.	Water Security and Climate Change: Challenges and Opportunities in Asia	29 November - 1 December, 2016	Bangkok, Thailand				Towards holistic and multifunctional design of green infrastructure for climate change adaptation (Vojinovic Z., Keerakamolchai1 W, Sanchez A., Weesakul S., Meesuk V. and Babel, MS.)
63	Conference paper	Vojinovic Z.	Water Security and Climate Change: Challenges and Opportunities in Asia - AIT	29 November - 1 December, 2016	Bangkok, Thailand				Adaptation to climate change in areas with cultural heritage (Vojinovic Z., Golub D., Keerakamolchai W., Meesuk V., Sanchez A. and Weesakul S.)
64	Conference paper	Russo, B	V Jornadas de Ingeniería del Agua	2017	A Coruña, Spain				Integración de nowcasting radar y modelización 1D/2D en un sistema de alerta temprana para inundaciones en medio urbano (Russo, B, X. Llort, P. Sánchez and Á. Rodríguez)
65	Conference paper	Llort, X.	XXXIV edición de las Jornadas Técnicas AEAS	2017	Tarragona, Spain				Sistemas de alerta avanzados para inundaciones urbanas. Integración de

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									nowcasting radar y modelización 1D/2D en un caso real (Llort, X., B. Russo, Á. Rodríguez and P. Sánchez)
66	Conference paper	Kostaridis A.	to 2nd International workshop on Modelling of Physical, Economic and Social Systems for Resilience Assessment	14-16 December 2017	Italy				CIRP: A Multi-Hazard Impact Assessment Software for Critical Infrastructures (Kostaridis A., Antonopoulos S., Gkortsilas D., Troullinos M., Perlepes L., Moutzouris M., Lykou A., Koutiva I., Karavokiros G., Makropoulos C., Chen S.A., Vamvakeridou-Lyroudia L., Gibson J. M., & Diagourtas D.)
67	Conference paper	Shaikh, S.	HTG Conference	September 2017	Duisburg, Germany				Entwicklung eines operationellen 2D-Strömungsmodells der Unterelbe auf der Grundlage von stationsbasierten Wasserstandsvorhersagen des BSH (Shaikh, S., Müller-Navarra, S., Fröhle, P., Manojlovic, N., Gershovich I., Gruhn, A., Nehlsen, E.)
68	Conference paper	Gruhn A.	International Short Course And Conference On Applied Coastal Research 2017 (SCACR)	October 2017	Santander				Assessment of the temporal evolution of the flood risk as a part of the holistic risk assessment (Gruhn A., Manojlovic N., Fröhle P.)
69	Conference paper	Batica, Jelena	13th International Hydroinformatics Conference (HIC) 2018	1-6 July 2018	Palermo, Italy				Disaster Risk Reduction Management and resilience approach after Xynthia flood-case study Chantelaillon-Plage, France (Batica, Jelena, and Gourbesville, Philippe)
70	Conference paper	Elsa Aristodemoua	Environmental pollution https://doi.org/10.1016/j.envpol.2017.10.041	2017					How tall buildings affect turbulent air flows and dispersion of pollution within a neighbourhood (Elsa Aristodemoua, Luz Maria Boganegraa, Laetitia Mottet, Dimitrios Pavlidis, Achilleas Constantinou, Christopher Pain, Alan Robins, Helen ApSimon)
71	Media		MeteoWorld 2014/No.1	February 2014					Article in quarterly newsletter
72	Media		Rethemniotika Nea	July 2014	Crete, Rethymno, Greece				Article in local Newspaper “Rethemniotika Nea”: http://www.rethnea.gr/article.aspx?id=15927
73	Media		Kritiki Epitheorisi	July 2014	Crete,				Article in local Newspaper “Kritiki

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					Rethymno, Greece				Epitheorisi”
74	Media		Nea tv	July 2014	Crete, Rethymno, Greece				http://www.neatv.gr/el/25990/antimetopo-me-plimmires-mporei-na-erthei-to-rethimno.php
75	Media		Creta tv	July 2014	Crete, Rethymno, Greece				http://www.youtube.com/watch?v=aasy8mujBBA
76	Media		Goodnet	July 2014	Crete, Rethymno, Greece				Online newspaper: http://www.goodnet.gr/rethumno-trechonta/page/4/articles/sto-mikroskopio-i-diacheirisi-akraion-fainomenon-kai-sto-rethumno.html
77	Media		Cretapost	July 2014	Crete, Rethymno, Greece				Online newspaper: http://www.cretapost.gr/sto-mikroskopio-i-diachirisi-akreon-fenomenon/
78	Media		Meteo-news	July 2014	Crete, Rethymno, Greece				Online newspaper: http://www.meteo-news.gr/2014/07/antimetopo-me-plimmyres-mporei-na-erthei-to-rethymno.html
79	Media		IAHR NewsFlash Europe	April 2014					News announcement in monthly newsletter
80	Media		RTV Marbella	January 2016	Marbella, Spain				Video
81	Policy brief	RISC-Kit & PEARL	Disaster Risk Reduction strategies in EU coastal areas	October 2014	The Netherlands			Global	RISC-Kit & PEARL websites
82	Policy brief	PEARL	Tailored stakeholder engagement	May/June 2018	The Netherlands			Global (PEARL case studies)	PEARL websites
83	Policy brief	Borie et al.	Risk Root Cause Analysis for Disaster Risk Reduction	October 2017					http://www.uni-stuttgart.de/ireus/dateiuploads/PEARL-POLICY-BRIEF_RRCA_Oct2017.pdf
84	Other		National Cheng Kung University (NCKU)	Tainan, Taiwan	April 2017				The coordinator Prof. Zoran Vojinovic was invited by National Cheng Kung University (NCKU) as an adjunct Professor and gave the short term course (one week) “Flood Protection”

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85	Other		National Cheng Kung University (NCKU)	Tainan, Taiwan	May 2017				The WP6 leader Prof. Peter Froehle was also invited by National Cheng Kung University (NCKU) as an adjunct Professor and gave the short term course (one week) “Coastal Protection”
86	Other		ANYWHERE H2020 project)						HYDS is partner of the new H2020 project ANYWHERE (http://anywhere-h2020.eu) which aims to empower exposed responder institutions and citizens to enhance their anticipation and pro-active capacity of response to face extreme and high-impact weather and climate events. Connections with PEARL are done. DHI and SATWAYS, both partners of PEARL have been included in the Industry board of ANYWHERE.
87	Other		Cardiff University						ICL invited to talk to the engineering faculty about PEARL developments and tools
88	Other			Paris, France	10 October				Mathias (ICL) keynote on Reduced Order Modelling
89	Other		Nuclear Institute Summer Conference		18 October				ICL key note on environmental modelling
90	Working Paper	Fraser, A.	Risk Root Cause Analysis Report St Maarten, Dutch Caribbean		2016				King’s College London Environment, Politics and Development Working Paper No. 74 (https://www.kcl.ac.uk/sspp/departments/geography/research/Research-Domains/Contested-Development/Working-Papers-/KCLWorkingPaper-PEARL-Risk-and-Root-Cause-Analysis-St-Maarten.pdf)
91	IRDR document	KCL	KCL FORIN Review and Case Study Analysis		March 2015				IRDR document on root cause analysis (Third UN World Conference on Disaster Risk Reduction, Sendai, Japan)
92	Working Paper	Mavrogenis, S.	Risk Root Cause Analysis Paper for PEARL: The Case of Rethymno, Crete		2016				King’s College London Environment, Politics and Development Working Paper No. 73 (https://www.kcl.ac.uk/sspp/departments/geography/research/Research-Domains/Contested-

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									Development/Working-Papers-/KCLWorkingPaper-PEARL-Risk-and-Root-Cause-Analysis-Rethymno-Crete.pdf)
93	IRDR document	Scolobig, A.	Risk Root Cause Analysis Paper for PEARL: The Case of Genoa, Italy		2016				King's College London Environment, Politics and Development Working Paper No. 72 (https://www.kcl.ac.uk/sspp/departments/geography/research/Research-Domains/Contested-Development/Working-Papers-/KCLWorkingPaper-PEARL-Risk-and-Root-Cause-Analysis-Genoa-Italy.pdf)
94	Symposium	Abebe, Y.A., Ghorbani, A., Vojinovic, Z., Nikolic, I. and Sanchez, A.	Institutional modelling for flood risk management: A coupled agent-based-flood models method		3-4 October 2016				UNESCO-IHE PhD Symposium, Delft, The Netherlands
95	MSc. Thesis	Diez, R. F.	From deterministic to probabilistic-based flood forecasting of storm surges. Case: Greve, Denmark		2016				M.Sc. Thesis. Euroaquae, Polytech Nice Sophia-Antipolis, France
96	MSc. Thesis	Roman Soledad Berbel	Modelling flooding from the sea interacting with the drainage system under the influence of combined flood hazards to develop risk management strategies for the coastal region of Greve, Denmark		2014				Master of Science Thesis. EUROAQUAE-HydroInformatics and Water Management
97	MSc. Thesis	Keerakamolchai, W.	Towards a framework for multifunctional flood detention facilities design in a mixed land use area. The case of Ayutthaya World Heritage Site, Thailand		2014				MSc Thesis, UNESCO-IHE (The Netherlands) / Asian Institute of Technology (Thailand)
98	MSc. Thesis	Golub Daria	Towards a framework for participatory flood risk assessment in urban areas with cultural heritage: The case of the Historic City of Ayutthaya, Thailand		2014				Master of Science Thesis. Erasmus mundus Flood risk master
99	MSc. Thesis	Polania, J.	A methodology for health impact assessment during pluvial flooding: a case study of the Sukhumvit area in Bangkok, Thailand		2015				Master of Science Thesis. Asian Institute of Technology and UNESCO–IHE

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100	MSc. Thesis	Togarepi Phyllis	Towards a framework for impact assessment of future scenarios of urban growth		2016				Master of Science Thesis. Asian Institute of Technology and UNESCO–IHE.
101	MSc. Thesis	Bosch Maja	Institutional dimension of flood risk - Understanding institutional complexity in flood risk management for the case of St Maarten		2017				Master of Science Thesis for Industrial Ecology, TU Delft and Leiden University
102	MSc. Thesis	Patiño Gomez Jose Manuel	Assessment of Green Infrastructure Measures to Reduce Stormwater Runoff and Enhance Multiple Benefits in Urban Areas		2017				Master of Science Thesis. Urban Water Engineering and Management, AIT-Unesco-IHE
103	MSc. Thesis	Naser Abdul Majidi	Assessing the Effectiveness of Green Infrastructures on Urban Flood Reduction and Thermal Comfort Enhancement: A Case Study of Sukhumvit Area, Bangkok		2017				Master of Science Thesis. Urban Water Engineering and Management, AIT-Unesco-IHE
104	MSc. Thesis	Hilly Geofrey Gerald	Towards a Framework for Analysing Cascading Effects of Flood Impacts on Critical Infrastructure: The Case Study of Sukhumvit, Thailand		2017				Master of Science Thesis. Urban Water Engineering and Management, AIT-Unesco-IHE.
105	MSc. Thesis	Mutua Rhoda Mutanu	Health risk of waterborne infection in contaminated urban floodwater: the case study of Sukumvit in Bangkok, Thailand		2018				Master of Science Thesis. Urban Water Engineering and Management, AIT-Unesco-IHE.
106	MSc. Thesis	Maja Bosch	Institutional dimension of flood risk. Understanding institutional complexity in Flood Risk Management for the case of St Maarten		2017				Msc thesis. TU Delft