Deliverable 7.4 International symposium flood risk management in coastal regions

Summary Report

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Abstract (for dissemination, 100 words)	The EC funded PEARL project demonstrates solutions to governments and water practitioners on adaptive risk management measures for coastal cities for extreme hydro-meteorological events. Using the Amsterdam International Water Week in October as the venue, PEARL organised 3 key activities at the event to disseminate the projects main outputs. AIWW provided a good opportunity to reach a wider, but relevant audience consisting of leaders from government, the private sector, academics and society all over the world, who could potentially use the outputs and experiences from PEARL. The AIWW event attracted over 1200 delegates from 89 countries.
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Summary

The EC funded PEARL project (http://www.pearl-fp7.eu/) demonstrates solutions to governments and water practitioners on adaptive risk management measures for coastal cities for extreme hydro-meteorological events (with the focus on floods and storm surges).

Using the Amsterdam International Water Week (AIWW) in October as the venue, PEARL organised 3 key activities at the event to disseminate the projects main outputs. AIWW provided a good opportunity to reach a wider, but relevant audience consisting of leaders from government, the private sector, academics and society all over the world, 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 team 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 are outlined in this summary report. A number of key points emerged from PEARL's activities at AIWW.

Firstly, context is extremely important. There is no one way to apply any one methodology or tool in a given context. Further, in areas where traditional data are not available (e.g. fine scale satellite data, data from sensor networks), more progress needs to be made in developing hydrometeorological models based on novel data points. This is especially the case in coastal cities located in typhoon and hurricane prone regions. As urban populations in coastal areas continue to grow, the impacts of these events will also continue to grow, prompting a critical need to address risk in coastal areas. These areas will require help to improve disaster preparedness, response and recovery. That being said, 2D/1D mesh models are giving finer grain risk modelling and forecasting capacity of storm surges and urban flooding under different adaptation measures and development scenarios. A key element to responding to coastal risk from extreme hydrometeorological events is public participation. Public participation is at the heart of the human centred approach to assessing vulnerability. By combining calculated risk with socially or culturally defined risk, different adaptation measures can be identified. Both the calculated and new method for risk calculation are valuable. While public participation is essential to fully understand the complex nature of vulnerability and risk, public participation is always challenging, especially in areas where there is no history of frequent public consultation. However, too much public participation can lead to fatigue. Each context will need to develop a tailored approach to public engagement and will need to adapt methodologies to appropriately engage citizens in risk assessments; identifying adaptation measures and preparing, responding and rebuilding after disaster strikes.

PEARL activities at AIWW 2017 comprised 3 events, briefly described below (presentations can be found in the annex).

Monday, 30th October 2017 | 9h-15h45
PEARL side event: Responding to risks of extreme events to advance climate change adaptation

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).

Wednesday, 1st November 2017 | 11h-12h30
Case session: Resilient Regions and Climate Change Adaptation

This session focussed on Europe, the Caribbean and Asia with examples of cases on how to develop adaptive, sociotechnical measures and strategies to cope with climate change events. Diverse solutions

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

Wednesday, 1st November 2017 | 12h30-14h00
PEARL lunch event: Roadmaps towards climate change adaptation

Case study representatives were invited to an 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.

Please note that findings from this event are not included in the report, as the event took a more meet and great with simultaneous discussions.

Contents

1 PEARL side event: Responding to risks of extreme events to advance climate change adaptation

1.1 Science behind PEARL framework

The first half of the PEARL side event focused on sharing the key innovations that have emerged from the science behind PEARL. Following an introduction by Dr. Zoran Vojinovic on the PEARL project, Christos Makropoulous chaired the thematic presentations on the science behind the PEARL framework. The presentations were structured around two main questions:

- What is innovative in the subject area?
- How is the related work undertaken in PEARL contributing to the cities?

1.1.1 *Methodological Innovation: Understanding the formation of vulnerabilities and risk in coastal regions – Presented by Dr. Mark Pelling*

Dr. Pelling presented the social scientific understanding that frames the questions behind PEARL and forms the theoretical understanding for **the formation of risk in coastal regions**. The 'industry standard' for understanding of the formation of risk is described by the intersection of Vulnerability, Exposure and Hazards (See Figure 1). This concept of risk requires an understanding of population and economic dynamics as well as the natural and physical world.

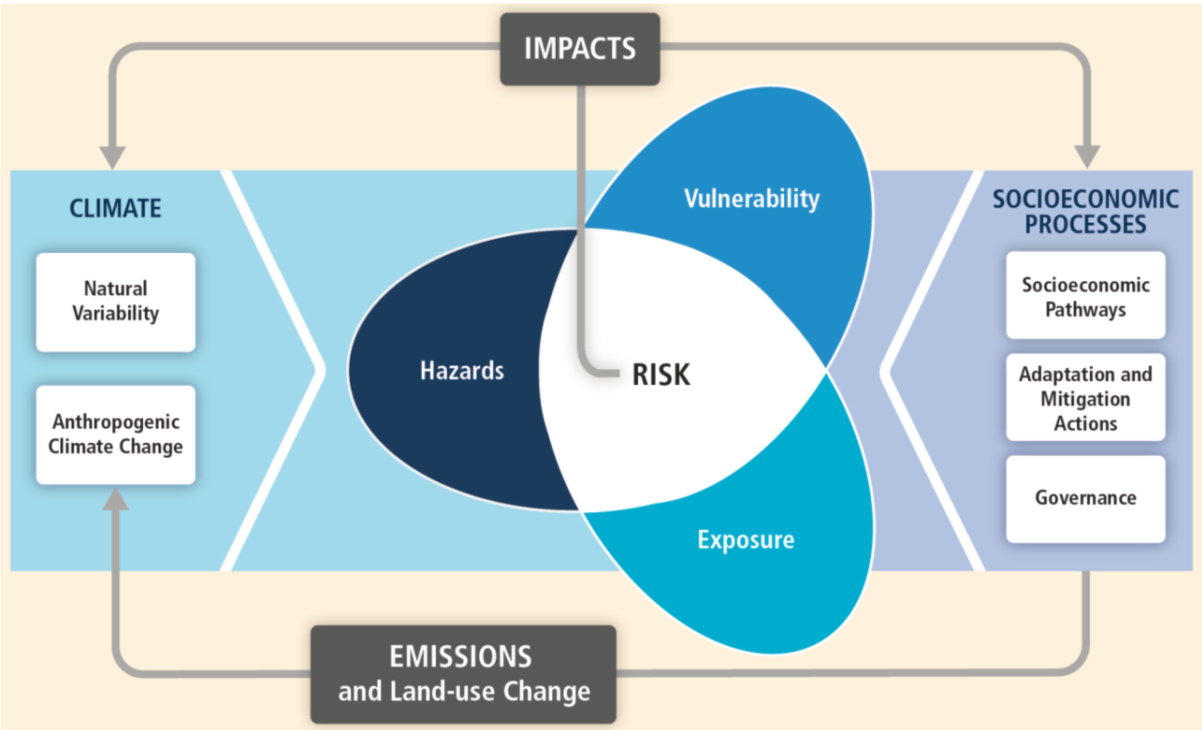


Figure 1 Conceptual framework: Risk as the interaction between physical and social systems

Risk is not static, thus, understanding risk cascades and the propagation of vulnerabilities requires working across scales and over historical time. The PEARL Risk Root Cause Assessment (RRCA)

Framework has been employed in the PEARL case studies to better understand this dynamic (See Figure 2).

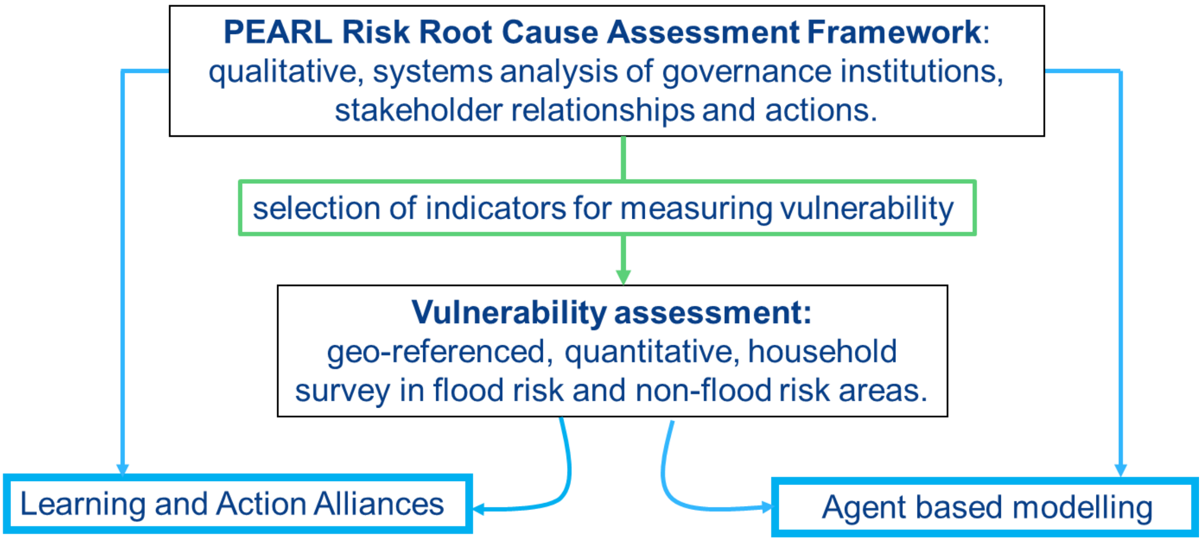


Figure 2 PEARL Risk Root Cause Assessment Framework

RRCA had previously been used as a back-casting process to understand root causes. PEARL took this back-casting process and introduced it to the agent based modelling team. Employing the RRCA enables a dynamic understanding of risk as a cascade, as a series of impulses. It opens the door to understanding the relationship between one event and the next.

1.1.1.1 RRCA methodology in practice

A critical step to employing the RRCA methodology is identifying relevant stakeholders and their interactions. Focusing on the interaction between stakeholders allows for identification of different policy areas that intersect, such as land use planning, early warning and evacuation, insurance and reconstruction. This leads to identification of institutions that shape preparedness and response to a given impact.

The PEARL RRCA Framework has allowed analysis of small-scale events; however it can be more difficult to track back from a small-scale event as opposed to larger scale disasters, such as hurricanes or earthquakes. Understanding risk from a pre- and post-disaster lens has helped to describe how policy evolves over time and has helped to improve understanding of intervening stakeholders.

1.1.1.2 Science in practice: RRCA and vulnerability assessments in practice in Rethymno, Crete and Genoa, Italy

The RRCA methodology was applied to the case of Rethymno, Crete. The results of this exercise revealed that development planning was heavily focused on economic growth, at the expense of infrastructure planning and raising risk awareness of new residents. The risk management culture is focused on single risks, such as earthquakes and wild fires, with limited understanding of multiple and intersecting risks. Certainly, austerity measures limited investment in resilience. However, historical tensions between civil society groups and local governments limited partnerships and the combining of resources, which has led to enhanced vulnerability to risk.

The PEARL vulnerability assessment considers vulnerability in 4 key areas: (1) Social (2) Cultural (3) Physical (4) Economic. Within these key areas, vulnerability is understood as the balance between

Susceptibility, Coping Capacity and Adaptive Capacity. To illustrate the importance of a more human-centred approach to assessing vulnerability, two different versions of vulnerability maps were created based on the case of Genoa, Italy. Only census data was used to assess levels of vulnerability within the city in the first map. The second map was generated based on input from census data and the PEARL household survey. Both versions of the vulnerability assessment are valuable and are useful for developing indicators for measuring vulnerability and for assessing smaller-scale instances of vulnerability (hotspots within hotspots). An added benefit of overlaying the household survey data is that self-assessment of vulnerability can lead to the development of different localized indicators for risk.

The findings from the RRCA and vulnerability assessments can be fed back into the broader root cause analysis and risk framework. The findings can also act as input into agent-based modelling activities and inform the learning and action alliances (collaborative modelling). Of course there are challenges of translating theory to practice. Differentiating vulnerability according to the four aforementioned key areas theoretically leads to a more nuanced understanding of vulnerability, but can be difficult to assess in practice. It can also be challenging to track the impact of fast changes and their cascading effect. Perhaps one of the most critical issues is how to frame PEARL research so it appeals to the interests of local actors.

1.1.2 Hazard modelling innovation – Presented by Dr. Chris Pain

Dr. Pain presented the advancements in hazard modelling that have resulted from PEARL. The following summarises the main highlights from his presentation.

1.1.2.1 Unstructured mesh method

The unstructured mesh method offers the ability to capture transient and complex flow dynamics as the flow evolves. It offers the ability to resolve across scales and allows for greater resolution of the coastline and areas of socioeconomic importance. This is the key characteristic that distinguished the unstructured mesh method from locally nested static mesh methods (e.g. Adaptive Mesh Methods (AMR)).

The unstructured mesh method was applied in the case of Greve, Denmark. The output from the flow model is able to combine flooding from precipitation and waves. Based on the representation of buildings and bathymetry, this modelling method allows adjustment of resolution where needed. The model is able to adapt from 10 m to 5 m resolution, which is fine enough to pick out very small channels. Further, the model can be run on state-of-the-art parallel computers. This means that the load can be balanced on each computer and minimises the communication between them.

1.1.2.2 3D Space-time adapt

This modelling approach produces outputs that show a different time scale in different locations. This space-time approach is based on the understanding that since there are different resolutions in space, the time resolution should be potentially very different as well. This method was applied in the case of Greve, Denmark, as well.

1.1.2.3 New implicit pipe modelling

The new implicit pipe modelling method is based on an analogy with oil and gas reservoir modelling and offers the capacity to run rapid reduced order modelling. This means that large areas can be modelled in great detail. The model type is very affordable and can run simulations in seconds. For example, an entire flood model only took one week to run.

1.1.2.4 Large scale - new generation air pollution model

The large scale - new generation air pollution model is based on an adaptive focus resolution method, which has been tested in 55 Chinese cities. Dr. Pain is working closely with Water Environment &

Reuse Foundation (WERF) developers to further develop this new generation of atmospheric model capabilities.

1.1.3 *Risk assessment innovation – Presented by Dr. Zoran Vojinovic*

Dr. Vojinovic presented on advancements in holistic risk assessment that have resulted from PEARL. The following summarises the key messages on risk assessment framework, methodologies and tools.

1.1.3.1 Holistic view of risk – Frameworks

The first step towards developing a holistic view of risk is defining the sociotechnical system. Sociotechnical systems may create and propagate vulnerabilities. Interactions within the sociotechnical system can increase or decrease risk depending on how the risk is dealt with. Of course, it is likely that extreme hydrometeorological events lead to extreme impacts; however, non-extreme events may also lead to significant impacts due to cascading risks over time. Once the sociotechnical system has been defined; the root cause analysis is applied; actors and agents involved are identified (agent based models); scenarios for risk are developed; a host of different impacts are analysed. From this process, it is then possible to assess risk.

Of course, multiple hazards can threaten a sociotechnical system simultaneously. To address multiple hazards, PEARL looked into different flood types and analysed projected impacts based on various models. Hazards can pose multiple impacts, so it is important to assess the impact of different variables. These variables can include water depth, velocities, flood duration and concentrations (e.g. for example, pathogens). PEARL conducted a **multi-hazard analysis** to map risk in Bangkok, Thailand. Risk maps were developed to map water depth, duration and E.coli concentrations as a result of flooding. Based on these variables, 2 risk maps were developed mapping the risk of waterborne infections at peak hours and for off-peak hours. The process of integrating urban flooding and water quality models with quantitative microbial risk assessments to produce illness probability values is seen as innovative PEARL output. This methodology was also tested in Greve, Denmark. A map was developed showing water depth and from this, a sewage dilution map was developed.

Just as there can be multiple hazards threatening a system and multiple variables to consider when assessing impact; vulnerability can be analysed according to different facets of vulnerability and the direct and indirect damages that result. PEARL conducted **multi-vulnerability analyses** to map direct and indirect impacts/damages for tangible (built environment) and intangible (spiritual and religious importance) components. Direct impacts can be mapped showing cost damages for example. Indirect impacts can be mapped showing damages differentiated by land use type (e.g. industry, offices,) or by business activity (e.g. agriculture, manufacturing).

As elaborated in section 1.1.1.2, when conducting a **vulnerability assessment**, PEARL assessed vulnerability according to 4 key areas: (1) Social (2) Cultural (3) Economic (4) Physical. Social vulnerability was assessed in the case study areas via a series of interviews and cultural vulnerability was assessed in collaboration with UNESCO. If you combine hazards and vulnerability assessments (combining all 4 areas of vulnerability), the result is calculated risk. However, calculated risk does not necessarily align with perceived risk. In order to ensure that PEARL outputs are relevant to local contexts, the views of local people were incorporated into the calculated risk assessments via a methodology called **social calibration**.

The overarching aim of PEARL is to enhance resilience in coastal regions to extreme and rare events. As such, the frameworks and methodologies developed by PEARL should support the analysis of governance and policies in place at each of the case study areas. The **institutional modelling** developed by PEARL feeds into the agent based models that show hazards and risks associated with different policies, development codes and land planning, for example.

PEARL has also developed a **framework for analysing cascading events or risk**. The framework follows every single step of how a disaster evolves in time and space. PEARL tested the framework to the case of Bangkok, Thailand. The exercise involved modelling hazards and analysis of critical

infrastructure. The tool HAZUR was used to analyse cascading events in Bangkok, which tracked how these events unfold over time.

1.1.4 Synergies with other EC Projects – Presented by Marc Velasco

Mr. Velasco presented on the RESCCUE project, a Horizon 2020 funded project which focuses on urban resilience to cope with climate change. Urban resilience describes how cities return back to their normal state after an impact. The main aim of the project is to better understand how cities can address, monitor and reduce urban risk. Similar to PEARL, RESCCUE has a diverse consortium of partners from research, public and private sectors and utilities. Addressing urban resilience involves numerous actors, but it can be challenging to work with a diverse set of actors whose priorities not all may align. The RESCCUE project also has a focus on understanding cascading risk/impact.

The cities involved in the project include Barcelona, Bristol and Lisbon. These cities were strategically selected as they are each part of '100 Resilient Cities', which means each city has a group of people within each council that are working on resilience and committed to what the project is trying to achieve. Tapping into the already existing engagement around resilience has facilitated access to data and gaining access to the right people. Importantly, the outcomes of the RESCCUE project will have a direct application in practice, as the outcomes will feed into the Resilience Action Plans being developed for each city.

The RESCCUE project has worked with its partner cities to develop climate change scenarios, feed this into models, detect vulnerabilities and impacts via the HAZUR tool (cascading effects), identify adaptation strategies and develop resilience action plans. Although HAZUR is not a detailed tool, it is helpful for identifying interdependencies at the city scale. To learn more about the project, visit the rescue.eu and explore different perspectives on resilience through the bi-weekly blog series.

Marc Velasco presenting on RESCCUE

1.1.5 *Panel and plenary discussion: Scientific research applied in case study areas (bridging science and practice)*

Panellists reflected on key challenges around science and practice related to urban resilience, with inputs from the audience. The following outlines these reflections and interactions.

Marc Velasco (RESCCUE project) identified that having municipalities on board within a project is crucial. However it can be challenging to align the project timeframe with the municipal timeframes. For example, the delivery date of the resilience action plans is not aligned with the target dates of the project, which points to the broader challenge of combining technical and social aspects.

Zoran Vojinovic (IHE Delft) stated that there is always a gap of 10-15 years from science to application. The big question is how do we reduce this gap? Based on the PEARL experience engaging with diverse partners, a project can have varying degrees of willingness to participate and contribute from different stakeholders. Part of closing the gap between science and practice is improving stakeholder engagement. Some PEARL partners are eager to receive further support from PEARL. For example, St Maarten has expressed interest in receiving more support following the devastation of hurricane Irma

Chris Pain (Imperial College London) agreed that bridging the gap between science and policy is not easy, but there is progress being made. This includes setting up the APRIL group on atmospheric collaboration with London Imperial College. The group is working with international partners in the US and China who are open to new technologies and willing to put money and resources into research. China may develop a new Earth simulator which is specifically designed to run the models that have been developed within the PEARL project at the different case study areas. Also important in bridging the gap are public engagement, conferences, international events, training through universities, and opening of visualization centres to ensure people are more willing to take on new technologies

Dr Lai (WRA Taiwan) talked about how it is important to increase pressure on politicians through transparency. Consequently visualizing results is important and this can be through different media. For example, movies, simulations to educate and increase awareness in public about extreme events and social media and websites to post information on extreme events. Increased access to risk information needs to be a priority.

General Q&A

Ministry of Foreign Affairs of Saudi Arabia: How can cities that are not impacted now, mitigate future impacts?

Zoran Vojinovic explained that it is possible by applying the same concepts and tools to different locations that have not experienced an extreme event like St Maarten. Therefore, looking at different scenarios is important, for example considering how land will become developed in the future and then assessing the risk with these changes.

Mark Pelling indicated the importance of political power in informing policy. For example in St Maarten, patronage played an important role in determining policy and not party lines, so if those not linked to key people have little influence. Part of the role as researchers is to build scenarios based on current stakeholders, but also open up space for new stakeholders.

1.2 Science to practice: Creating roadmaps A

The second part of the PEARL side event had presentations on case studies; the particular solutions developed for each case and elaborating how the different tools have been adapted to different contexts.

1.2.1 *Sutat Weesakul, HAII, Thailand: Ayutthaya*

Dr. Sutat Weesakul presenting the Ayutthaya case study

Case site description:
Ayutthaya contains a designated UNESCO World Heritage Site. The city is surrounded by dikes, but this was not sufficient to protect against the 2011 flooding event. The city suffers from pluvial flooding during the monsoon season. The root cause of the pluvial flooding can be attributed to the frequency of extreme hydrometeorological conditions; topography; and lack of mitigation policies and measures.

PEARL contributions in Ayutthaya:
In order to better understand flood risk, hazard maps were developed to demonstrate 3 levels of risk to flooding (low-med-high). Next, the multidimensional structure of vulnerability was analysed, considering physical, economic, cultural and social aspects. The final flood risk map that was developed was a product of the combined vulnerability map and the hazard map.

Key outcomes from PEARL methodology:
In an effort to limit the amount of water that flows into the city via the main river, a bypass channel was introduced. Many structural measures have been implemented on a more local level. The measures included: increasing dyke height; increasing canal retention and pumping capacity; the development of multiple scenarios based on the different measures and combination compared to the 2011 flooding event.

The risk scenarios exercise was helpful in outlining which mitigation measures would be most effective. In total, three scenarios proved to be most effective and confirmed that a combination approach with structural and non-structural measures at the regional and local level, and encouraging mixed land use offers the greatest mitigating effect against flooding. However, it has been challenging to follow a participatory process and government stakeholders have a clear bias towards structural measures. It is important for citizens to participate in risk assessments and scenario building exercises so that the resource is seen to belong to them and not to the government.

Q&A
Q from Zoran Vojinovic: What are the main challenges with stakeholders?
A: Building common consensus. It is important to not start from the problem, weakness and trends, but rather with the opportunities.

Q from Christos Makropoulous: What are the next steps for materializing the plan?
A: The government will invest in the bypass channel. But our role is to work with the people so that they know about the flooding issues; however the government works with a different lens.

1.2.2 Archontia Lykou, NTUA, Greece: Rethymno, Crete

Archontia Lykou presenting the Crete case study

Adapting the PEARL process to Rethymno:
The major objective for implementing the PEARL project in Rethymno is, among others, to equip authorities with tools for decision making. PEARL is focused on the urban area of Rethymno in the north of Crete. The first step was to conduct a complete risk assessment, which also required looking into areas further upstream. Stakeholders were invited to contribute to all stages of PEARL projects through plenty of activities, discussions, focus groups and questionnaires. Communication and closed collaboration was achieved, enabling the researchers to gain field knowledge. Most flooding events over the years were related to rainfall and violent wave overtopping. Nevertheless, ignorance of citizens who cover drains also impacts evolution of flood risk.

A risk and root cause assessment was conducted via 18 face-to-face interviews focused on the 1999 flood event. This exercise demonstrated that poor infrastructure maintenance; weak governance capacity; institutional fragmentation at higher levels of government and a bias towards post disaster response over pre-disaster mitigation and planning measures were contributing to flooding risk.

The vulnerability assessment revealed that there were differences in belief between authorities and citizens. To capture this complexity, a vulnerability map was created based on the spatial vulnerability assessment and analysis with different indicators. Models, both 1-D and 2-D, were developed to model flooding due to hydrometeorological events/hazards. From this point, hazard and risk maps of different scenarios were developed.

Key outcomes from PEARL methodology:
As a result of the risk assessment exercises and modelling outputs related to the coastal zone, a curved breakwater and detached breakwater system was designed by optimising the distance from the coast and the impact on sediment transport. Further, in terms of flood risk management at the city scale, a roadmap was jointly developed with stakeholders through the LAAs where16 different activities were suggested to be implemented in the future in order to enhance decision making processes and flood risk governance, to strengthen information and raising flood risk awareness and assisting in city’s flood preparations and protection.
The PEARL Detective app was also developed (by Hydrologic) and applied in Rethymno, which allows users to create flood reports which are shared with responsible authorities. The PEARL Knowledge Base (pearl-kb.hydro.ntua.gr) was also developed, providing support in the selection of resilience

measures along with the PEARL Toolbox and the ABM SAS. The PEARL WebLP (developed by Satways and enriched and integrated with other systems by NTUA) gives access to all tools assisting measures selection, enables navigation through the available data and flood reports but also the exploration of different scenarios through the available maps (produced from the modelling work). The most significant achievement produced within PEARL was the results of the risk assessment developed via local learning & action alliances.

Q&A
Q: Why did it turn out that the east part of island was more vulnerable than the old city?
A: There is no urban planning there. Due to morphology (low-lying areas), located near swamps. Development in that area is moving faster than infrastructure can respond. During past flood events that were most severe, they have constructed 3 flood dams and upgraded drainage network in the old town and have done nothing in the eastern part.

Q: Were you able to engage with holiday owners/residents? Were there challenges interacting with civil society?
A: Most of the work was done through the household survey. Our work in the learning and action alliances consisted of authorities connected to flooding and did not include authorities and citizens. After presenting the results, the mayor recognised that it is their fault that citizens did not know about the issues. Christos Markopoulos further added that there were quite a lot of citizen groups that took part in the early stages of the project

Q: What can you say about the possibility of a flood warning system?
A: Stakeholders want it, but do not have forecasting for the area. This information is only available from the national weather forecast company, but have 1 single cell for the whole city i.e. low spatial resolution, so it is not possible to forecast based on this.

Q: What about in terms of the models that you have?
A: We would need to utilise all of the techniques that DHI has taught them, among others, in order to lessen computation time and loads and make it possible to utilise models' set up within an Early Warning System. Models need to be faster and provide results especially for the west part where the spatial complexity and models' geometry is too detailed in the old town i.e. requiring several days to run and provide results.

1.2.3 Peter Fröhle, TUHH: Hamburg

Peter Fröhle presenting the Hamburg case study

Case study description:
The city of Hamburg is situated on the Elbe River, 100 km away from the Elbe Estuary on the North Sea. The city is prone to 3 types of flooding: (1) Coastal flooding (2) Extreme local precipitation events (3) Extreme precipitation at the catchment level. The city of Hamburg has a history of involving

stakeholders in flood management and neighbourhood and regional planning, through 2 previous projects (KLIMZUG-Nord and IBA Labor). This laid the groundwork for the PEARL project. However, due to this history of involving large groups of stakeholders, it was challenging to frequently bring them together again for the purposes of the PEARL project.

Adapting the PEARL process to Hamburg
Based on Hamburg's previous experiences involving and understanding stakeholders, stakeholder involvement for PEARL consisted of a tailored approach. Key stakeholders were selected which are involved in flood risk management in Hamburg and the wider catchment. PEARL aimed to offer benefits on an operational and strategic level through the development of technical tools and stakeholder involvement.

Key outcomes from PEARL methodology:
A hazard assessment was conducted to improve understanding of storm events and high precipitation events. This resulted in a storm surge simulator which is statistically based on real data collected at gauges along the Elbe River. The simulator demonstrates the complexity of flooding. For example, different events with the same probability of occurrence can produce different water levels and occur over different durations. The resulting impact involves direct and indirect impacts to the built environment and critical infrastructure.

Understanding the evolution of risk over time was also an important outcome of the PEARL project in Hamburg. By integrating changes in land use development in flood prone areas in the absence of mitigation measures, flood risk scenarios were developed.

An early warning system was also developed for the complete Elbe River to Hamburg area. This involved moving from gauge readings to a hydrodynamic numerical model. The model is capable of providing simulations every 30 minutes. The model was tested and confirmed during a recent flooding event in Hamburg. The forecasting model can be combined with a damage model to forecast the damage to flood protection infrastructure and the consequences.

Improving flood protection must also be coupled with an assessment of an evacuation process. A model was developed for Elbe Island of Wilhelmsburg, an area in Hamburg that is prone to flooding. The Kalypso Evacuation model allowed for a detailed analysis of evacuation procedures and expected evacuation pathways. The model shows that evacuation pathways are submerged during flooding events, which means that evacuation needs to take place before the breach in flood protection systems. The Kalypso evacuation model includes how people move from any given point to safety points to be evacuated to the hinterland.

The results from the PEARL outputs have created a functioning early warning procedure in Hamburg. The hazard modelling and combined hazards will be integrated into future planning. Adapting the PEARL methodology to Hamburg has shown that the Elbe Estuary is a very complex system and that tailored stakeholder involvement is key to success.

Q&A
Q: from Christos Makropoulous: Hamburg has been pioneering the learning and action alliance (LAA) work, but then fatigue occurred. Do you see this as an evolution of a time window of LAA work? For example, in 5 years' time, will we end up with the same problem? Is it particular to Hamburg?

A: There is no direct answer to this. We saw this development in Hamburg and we knew that the stakeholder invitations would be ignored, so it required a new approach. This is related to two things: the base has been laid for LAA and the workload required for participation in LAA must be limited – cannot be invited to large meetings with questions largely coming from newcomers. The next step would require a real concrete problem that needs to be solved or an evolution of the LAA methodology.

A: Ratishha: We were lucky we had intensive stakeholder involvement. They started planning and had objectives and we identified where their interests were and to what extent involved. You need

legitimacy of the group (concrete problem with funds available), have the authority and mandate to act on objectives.

1.2.4 Nina Domingo, DHI: Greve

Case study description:
Greve is located in the east of Denmark, where the population is concentrated along the coast – which is the focus of this PEARL case study site. Greve is threatened with floods due to rainfall and storm surges. The pluvial flooding events in 2002 and 2007 were particularly severe.

Adapting the PEARL process to Greve:
The PEARL project focused on improving flood estimation under extreme events and implementing an early warning system for Greve. A methodology for analysing individual and concurrent events was necessary, since flooding has resulted from a series of extreme pluvial events in the past. For the early warning system, it was important to increase the simulation speed necessary for an early warning system. The models developed for Greve were made possible by the good availability of data and were adapted to Danish metrics for estimating future rainfall.

Key outcomes from PEARL methodology:
The coastal flood model incorporated a 1-D sewer network model (calculates runoff) and a 2-D surface model. The model can then show rainfall and water level boundaries, which allows for modelling of sea level and rainfall impacts. Both event types (rainfall and sea level) involve derivation of event time series. The model allows you to assess how probable is it for both events to occur at the same time? How likely is a 100 year sea level rise event to occur at the same time as a 2-year rainfall event?

The coastal flood warning system that was developed for Greve acquires rainfall and sea level forecasts and is based on a combined 1D-2D flexible mesh flood model. A website for information dissemination was also developed and can be accessed here: http://greve.dhigroup.com.

Data was collected from 2 measurement locations which provide sea level measurements to calibrate the model. When compared to a recent storm event for sea level rise, the coastal flood model that was developed has reasonable performance.

Assessing flood impact was conducted for individual and concurrent events in Greve, where a new damage assessment tool (CADSS) was developed by DHI. The effect of model type (flexible mesh vs. rigid mesh) on the damage calculation was assessed and showed that both model types show similar results in damage. Since this is the case, due to the modelling speed, flexible mesh to run a damage assessment should be used because it will be faster.

The coastal flooding model can also be used to simulate the impacts of different flood mitigation measure. Then, using the damage assessment tool, it is possible to calculate damage, calculate risks and then calculate effectiveness and efficiency of the proposed measures.

1.2.5 Nina Domingo, DHI: St. Lucia


Nina Domingo presenting the St. Lucia case study

Case study description:
St. Lucia is an island located in the Eastern Caribbean and Castries is the PEARL case study site. St. Lucia is in a hurricane-prone region, where the main hazards include extreme rainfall, flash floods storm surges and concurrent events.

Adapting the PEARL process to St. Lucia:
The choice of including St. Lucia in the PEARL case studies was to investigate to what extent coastal modelling tools and a flood forecasting system could be developed, given the limited availability of data. The experience of adapting the PEARL methodology has shown that even with limited data, a model can be adjusted that may not be state-of-the-art, but is fit for purpose. This shows that models can be streamlined or customized, depending on data availability.

Key outcomes from PEARL methodology:
When developing the coastal flood model, no information was available on the sewer system, so it was not possible to develop a 1D-2D model. There was, however, information available on terrain. The resulting 2D flood model uses flexible mesh. A similar website for information dissemination for coastal flood warning was created for St. Lucia as was created for Greve. The website can be accessed here: http://stlucia.dhigroup.com. The dissemination website for St. Lucia was based on different data sources, as compared to Greve.

The flood model developed for Castries built on previous models developed for the area that calculated flood risk based on rainfall data. The new flood model simulates rainfall and sea level. The new model also reflects the presence of buildings. To do this, buildings were simulated as impervious to flow.

It was not easy to measure model performance – it required a little creativity. Performance was measured by comparing photographs of flooding events to the simulated levels obtained by the model. This performance exercise showed that flooding was being over-estimated by the 2D flood model, but since the photographs are from after the flood event, there is still uncertainty on the accuracy of the model.

Q&A
Q: When you increase resolution, you get more flooding in the hinterland. Does this happen for you?
A: You can have more detail in finer resolution with time varying flexible model. If you know the main flow back, then you should make them more detailed than the other parts.

Q: For the model with only 2D, for low return period, the model may assume that there is a lot of water in the sewer system
A: Low-return events were not applied. Since we took out buildings, the model assumes that rainfall collected on the roofs is being processed by the sewer system.

Q: On Castries, how well did the model capture the informal and formal land use? It will determine the policy implications of the work.
A: The main area that was reflected were the formal areas. The informal areas were included after we expanded the boundaries. So the formal area was more represented in the model.

Q From Chris Pain: About flexible mesh vs the adaptive mesh, is there an argument for reducing the time for producing a suitable mesh for a particular area is more important than producing faster simulations?
A: To have an optimised 2D model with an optimised mesh, you spend quite a lot of time developing the mesh. For adaptive mesh, you think about it in a different way. We are thinking about developing a standard method for how to make the same mesh for application in a certain area.

1.3 Science to practice: Creating Roadmaps B

1.3.1 *Zoran Vojinovic, IHE Delft: St. Maarten*

Case study description:

St. Maarten is located on a Caribbean island east of Puerto Rico. The northern part of the island is the French St. Martin territory and the Dutch St. Maarten territory is located on the southern half of the island. The island is one of the most affected following Hurricane Irma and frequently experiences storms and floods. Flooding events can bring both wide-scale or localised, but severe impacts.

Due to this jurisdictional division on the island, there are different rules for land planning, sewage and flood management. An important question is how to manage both areas together? The flooding risk in St. Maarten has increased over the years due to rapid development, poor planning (reactive planning). In fact, land planning authorities do not consider risk in the development plans. The situation is compounded by a lack of funds.

Adapting the PEARL process to St. Maarten:

A hazard and vulnerability assessment was first conducted. The main hazards facing the island include flash floods. Flash floods can occur and disappear within a few hours, so it is difficult to track the occurrence of flash flooding by satellite. The island also faces pluvial and coastal flooding, as well as wind hazards. Based on the hazard and vulnerability assessment, the PEARL project focused on developing a risk assessment for the island. From this basis, risk mitigation strategies and demonstration tools were developed. As data availability is a challenge, rainfall data was borrowed from near-by islands.

Key outcomes from PEARL methodology:

A 1D/2D stormwater model was developed for St. Maarten. Modelling storm water is highly complex due to the varied surface terrain characteristics on St. Maarten (lined/natural channels, culverts, road with higher curbs, open waterways). A 1D/2D model was developed by integrating LIDAR data to model stormwater in ‘channels’ on the southern part of the island. In order to model future flooding scenarios, development scenarios were created for St. Maarten. Next, in the absence of available data to validate the storm water model, the PEARL project needed to find a creative way to validate the model. In lieu of this data, flooding height perception was collected from citizens to validate the storm water model.

For the risk assessment component, an analysis was conducted on the drainage system in southern part of the island. The map that was created shows the capacity of different sections of the drainage system to cope with different return events. With this information, the local government can see where to target investment in infrastructure improvement, for example. Flood maps were also developed which map show water velocity and depth and can be used to quantify the impact from a specific event. A hurricane model was also developed to simulate previous hurricane events.

In trying to assess the root cause of vulnerability, it was discovered that development on the island is controlled by a few influential families, which suggests that policy and institutional interventions would see limited affect unless this concentration of influential power is addressed. Risk mitigation strategies that were developed for the island include ponds, mixing green and grey infrastructure. Based on these interventions, their impact on flooding reduction can be modelled. Also, when the hazard and risk assessment for buildings maps are overlaid, this can help identify areas for positioning shelters for the future.

In the aftermath of Hurricane Irma, the St. Maarten government is requesting assistance. What is required will be a scoping process of the damage caused; this will include differentiating the wind and water related impacts. As part of the scoping process, an impact assessment is needed. So far, the Red Cross has provided initial damage assessments, and the storm surge was modelled to be between 1.5-2 m. In a comparison between flood and wind related impacts; wind was by far more damaging, as the eye of the hurricane passed directly over the island, while it was a category 5 hurricane. The initial damage assessment conducted by the Red Cross was carried out by first creating an inventory of building materials (wood, concrete, etc.) and based on aerial photography, developing an impact assessment. However, this needs to be verified on the ground because the

initial assessment was said to be over-exaggerated. Once the full scoping exercise has been completed, recommendations need to be provided from an impact assessment. The official involvement of the PEARL team will depend on whether or not the EC grants a no funds extension to the project and pending the availability of enough unspent project funds.

Q&A

Q: Copernicus data was used to assess damages? How?

A: It was done by the Red Cross. Drones were used. It would be good to synergise our efforts. We had 2 extensive discussions, so we could begin to work together. The Red Cross have opened up their data bases and we can find out more.

Q: Are there massive differences between French and Dutch sides?

A: Greater damage on the French side and also experienced more flooding and the surge was higher on the North side. In previous hurricane cases, the Dutch side was more severely impacted. French side was able to control better the social tensions that result from the impacts. It will be important to keep in contact with the French side.

1.3.2 Eduardo Marrtinez Gomariz & Emma Reitg, CETAQUA: Marbella

Eduardo Martinez Gomariz (and Emma Reitg) present the Marbella case study

Case study description:

Marbella is a coastal Mediterranean city in Spain. Tourism is the main economic activity. The main issues affecting Marbella include urban flooding, erosion of beaches and jellyfish blooms. The upper part of the catchment in which Marbella is located is mostly rural (60%), while the lower part of the catchment where Marbella is located is urban (40%). The focus of PEARL activities has been in the lower part of the catchment.

Adapting the PEARL process to Marbella:

The PEARL project needed to adapt the modelling and risk assessment methodology to the context of Marbella. Consideration for the risk posed to pedestrians; integration of direct and indirect damages from flooding were important focal areas.

Key outcomes from PEARL methodology:

A 1D/2D coupled flood model was developed for the lower part of the catchment. Based on 3 severe rainfall events, the model was calibrated. The model was then used to design storms for 1 year, 10, 100 year rainfall events.

A risk assessment methodology was developed to assess the risk flooding posed to pedestrians. Based on the stability threshold experiment, a hazard criterion was determined (low, med, high risk criteria). The vulnerability criterion considered demographic characteristics to determine vulnerability: Age (%); Foreign People (%); People density. Now, by overlapping the hazard and vulnerability maps, a risk map was constructed. This risk map revealed that the highest risk for flooding occurs on the main street.

Developing a methodology for a damage assessment for direct and indirect effects was an important outcome of the PEARL project. For example, an indirect damage assessment was developed to consider business interruptions as a result of flooding. Different explanatory variables were considered in this assessment, including direct damages; unemployment; season of the year; business activities. This is done by transforming land uses into business activities and then indirect damages can be quantified based on econometric data. The damage assessment for business interruption can be run under 2 different simulations.

An indirect damage assessment was also conducted for traffic disruption, where the most important impact is the loss in time due to delayed traffic (reduction is speed as a result of flooding). Another important variable was found to be time of day (evening or morning).

Similar to other case study areas, flood forecasting is integrated into an online early warning system. This system will show forecasted rainfall for the next 2 hours, where certain forecasted rainfall will be related to a certain return period. Early warnings can be disseminated via SMS, email, etc.

When considering future scenarios, no significant changes in rainfall are predicted for Marbella. The risk and damages assessment can be compared for current and future scenarios based on different mitigation measures.

Q&A
Q: How were stakeholders involved in the methods? How will they adopt the tools?
A: We had some issues with our workshops. The first one was held at the city council of Marbella and identified the problems that they have there. Unfortunately, a second workshop was no feasible due political issues, however we are hoping to hold the 2nd workshop soon.

Q: For estimation of indirect damages, what is the minimum resolution?
A: 60 real plot events in Marbella. Input for indirect damages are direct damages. If we have a land use of industry, but depending on the land use that we took into account, we can give a weight.

1.3.3 *Wei-Cheng Lo and Dong-Jiing Doong, National Cheng Kung University: Tainan City, Taiwan*

Dong-Jiing Doong presenting the Tainan case study

Case study description:
Taiwan is located in an area that is seriously threatened by typhoons. The case study area of Tainan City is located in western Taiwan on the coast. During the winter period, the country receives the monsoon rain and during the summer, the country is hit with typhoons. Due to the high sediment load in the 5 rivers that flow through Tainan, over the last 300 years, the coast line has grown dramatically. However, in recent times, due to dam construction, coastal erosion has become a significant issue. Tainan has numerous hydraulic structures and there is access to good data. The current trend that has emerged from this data collection shows that heavy rainfall is occurring more frequently. There are a series of complicated drainage channels, which can only support rainfall events with a return period of 25 years. This is insufficient, as 90% of annual rainfall occurs during the summer. The current drainage channels were originally constructed for irrigation but are now used for drainage. The government has invested in more than 300 flood mitigation projects.

Adapting the PEARL process to Tainan:
The current design standards cannot protect against short-term, high intensity rainfall. This key challenge is compounded by an increase in rainfall, a highly urbanised landscape and the threat of sea level rise.

Key outcomes from PEARL methodology:
The Water Resources Bureau of Tainan City Government has proposed an Integrated Flood Prevention Strategy. The strategy attempts to address flooding starting with a root cause analysis, which considers the upstream and downstream and both engineering and non-engineering mitigation measures. Moving forward, flood prevention should not fight nature (co-existence with water) and future development in the city should reduce development in sensitive areas.

Structural mitigation measures:
The planned structural mitigation measures will be implemented on a regional and city-wide scale. The existing highway that runs along the coast in Tainan will be adapted to act as the second flood defence for the city. The drainage channels within the city need to be better integrated and their capacity optimised. They were built 1-by-1 over a period of 30 years.

Non-structural measures:
Improvements in disaster forecasting will also lead to early warning and evacuation system development. This is being achieved by developing different types of disaster maps, public awareness, evacuation training and law support. For the flood inundation maps, this means moving from coarse to fine Digital Elevation models (DEM) that are more comprehensive and larger scale. New inundation maps for a 100 year event within 6, 12, 24 hours have been created. The validation of the flood modelling has relied on people to confirm instances of flooding, but model validation still needs to be improved.

Regarding forecasting the impact of sea-level rise, it is difficult to forecast to 2050 and 2100 without knowing the drainage and sewage systems for these periods.

Monitoring, simulation, evacuation:
Models were used for integrated flood prevention strategy and the creation of an operational real-time early warning system. A GIS platform was used for integrated flood monitoring. This platform consists of a network of cameras showing flood levels which addresses citizens that may not react to real-time numeric updates on water levels.

As has been the case in most of the other PEARL case studies, information dissemination systems important for early warning and evacuation are key to reducing the impact of hazards. A digital application was developed for citizens of Tainan, which has been installed by more than 400 000 people. This app as well as TV-announcements are used to report flooding and share information about evacuation procedures. Community-based evacuation is also encouraged. Education and practice improves the effectiveness of community-based evacuation. Alarm-equipped sensors are also installed in low-lying areas, which relay a signal to police via the internet.

Q&A

Q: Are there any ideas to involve the people on the streets living in flood prone areas into the planning?
A: A meeting with the people is arranged to get their feedback. For the research, they will not do this because the feedback will be too diverse. For the flood inundation map, we discussed some data points with the local people, but they do not have a scientific background so you cannot guarantee that you get the right results.

1.3.4 Alessandra Marchese, GISG: Genova, Italy

Alessandra Marchese presents the Genova case study

Case study description:
Genoa (Genova) is a coastal city located in the northwest of Italy. The PEARL case study site is close to the RISC-KIT project area (another coastal resilience project funded by the EC). Genoa is prone to flooding from the Bisagno River due to extreme rainfall and storm events. This is largely due to the location of Genoa between mountains and the sea, which creates favourable conditions for extreme events, through the formation of V-shaped storms. The last few kilometres of the Bisagno are funnelled into culverts under the city. There are currently 2 large hydrological works that have started in Genoa working on expanding the capacity of the culvert section of the Bisagno and another to construct an underground channel to bring water from the upper catchment directly under the city to the sea.

Adapting the PEARL process to Genoa:
The PEARL project has developed simulations for rainfall events in 2011 and 2014 based on 1D modelling of the Bisagno River. Corresponding 2D flood maps for the city were also generated. A vulnerability assessment and risk assessment was conducted through stakeholder participation and mitigation measures have resulted from PEARL outputs in Genoa.

Key outcomes from PEARL methodology:
After the rainfall simulation and flood modelling of the Bisagno River was conducted, the vulnerability assessment was carried out. This was carried out by developing vulnerability indicators based on the 3 components of social vulnerability (susceptibility, lack of coping and lack of adaptation). A vulnerability map was generated for the year 2014. The results of this map were then combined with the results from a household survey. By combining the hazard and risk maps that were generated, 2 risk maps

were generated for the purposes of comparison. One risk map based on geo-spatial and census data and another enriched with field survey data. This demonstrates that social and scientific maps can differ quite significantly.

Next, a flood resilience index was calculated based on natural, social, economic, institutional and physical factors. The results of this exercise are available on a web-based tool developed for PEARL. Stakeholder consultations were also carried out with institutional and research stakeholders in November 2016.

Looking ahead, the PEARL tools and methodologies developed will help assess how the 2 major structural hydrological works that are underway will decrease flooding risk. Even with these interventions, the city will need to address the residual risk with the help of the PEARL outcomes and based on a holistic approach. Genoa is also part of the Climate Change Adaptation Partnership as part of the Urban Agenda, so they would like to use the PEARL outputs to support this role. The city of Genoa would also like to become a National Hub for Climate Change Adaptation, where PEARL outputs can support this effort. There has also been uptake from universities in Italy of PEARL tools and methodology into curriculum and further research.

Q&A
Q: Did you simulate the hydrodynamic model with the new culvert and bypass?
A: No, there are too many people working on this and the final dimensions are not known. It will have to be run again once the data is available.

1.3.5 Jelena Batica, UNSA: Les Boucholeurs

This presentation was cancelled due to technical issues.

2 Case Session

2.1 Resilient Regions and Climate Change Adaptation

During this main session at AIWW, cases of adaptive, sociotechnical risk management measures were presented based on regional cases. There is the some overlap in content from the PEARL side event.

Case session: Resilient Regions and Climate Change Adaptation

2.1.1 Dr Lai, Director Water Resources Agency Taiwan: Introduction & case of Taiwan

Dr Lai giving his introductory address

Taiwan is a densely-populated island in typhoon-prone region. About 90 % of people live on the west side of the island. The mountain range (down the centre of the country) protects the Western side from the intensity of typhoons. The island suffers from multiple types of disasters (73% face 3 types of disasters, 90% face 2 types of disasters) – earthquakes, floods, etc.

When typhoon formation occurs, there are 2 days to prepare for the event. It is expected that it will take 7 hours for rain to come from mountains to the coast which is not a long time.

Due to high urbanisation on the West coast, this area is vulnerable and faces coastal erosion as well as rising sea levels. The coastal erosion on the Eastern coast is from strong waves from the Pacific Ocean

PEARL worked in Tainan city. The next step is to scale up the experience to the national level, for example developing inundation maps. In the past, there has been a strong focus on engineering management, but the new thinking is needed - move from top-down to public participation which includes non-structured thinking. The potential inundation map is a useful tool when talking with the public, and is a starting point for new methods for comprehensive river basin management, where floods are dispersed by the river and land.

Flood prevention technology includes monitoring, early warning, notification, response (including government and individual level). These are outlined below:

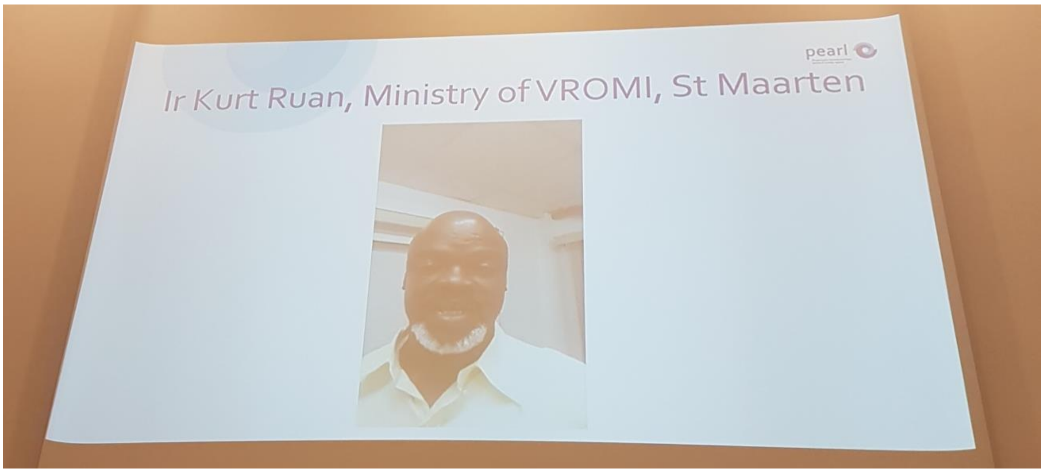
- Monitoring: Image recognition: Right now each station of the river have a camera to provide real-time images; Automated flood sensing technology system along the roads
- Warning: Forecasting rainfall data
- Notification: disseminate via cell phones and can collect information from smart appsResponse: Use multiple technologies to gather information from the people and with the people

Sensing devices and communication modules via IoT have been crucial for improved decision-making and will continue to be.

2.1.2 Zoran Vojinovic, IHE Delft Regional case: St. Maarten:

In the wake of Hurricane Irma, developing adaptive, sociotechnical risk management measures and strategies will become essential to rebuild a more resilient St Maarten.

Dr Vojinovic began the case presentation of St Maarten with a video recording from Ir. Kurt Ruan from the Ministry of VROMI in St. Maarten.



Video recording from Kurt Ruan describing the impact of Hurricane Irma in St. Maarten

Mr Ruan began by describing how the island of St. Maarten/St. Martin is located in the Eastern Caribbean in an active hurricane belt. The recent hurricane Irma dislocated 5000 families on the island. At the height of its strength, Hurricane Irma surpassed the highest categorisation of hurricanes. With winds beyond 250 kilometeres per hour, Irma was more like a Category 7 hurricane. In the space of 6-9 hours, the families affected would have lost almost everything. It is the Government of St. Maarten's intention to improve monitoring and projection of monster hurricanes so that they can rebuild more resilient infrastructure. Hurricane Irma devastated airports, harbours, electricity grids, water, jails, police stations. In order to do this, the Government of St. Maarten has officially requested the assistance of PEARL for modelling future events. The Government also recognised the need to inform the general public about the impacts of climate change. Dealing with intense pluvial flooding has historically been an issue in St .Maarten. For example, in 2005, 6-8 inches of rain in 2-2.5 hours resulted in 2 deaths. This simply does not compare to the devastation of Hurricane Irma.

A pre-recorded video call form Paul Martens, Head of Disaster Management, St. Maarten was followed. Mr. Martens emphasized again the scale of the devastation caused by Irma. St. Maarten has enormous coastal areas, which are vulnerable to extreme weather events. At the time of the video recording in St. Maarten, the emergency phase following Irma was just coming to a close and the island was looking to move into the recovery and reconstruction phase. The Government has learned from previous extreme hurricanes, such as hurricane Louis in 1995, but more work is needed. Most buildings were slightly to completely damaged. PEARL will help model impacts of storm surges and other storm events. St. Maarten will need this and a great deal of help from the international community to help build back St. Maarten in a better way. Resilience needs to be fostered in the population, but there is a need for more information, which can be provided through PEARL.

Video recording from Paul Martens addressing the need for improved resilience

Zoran Vojinovic from IHE Delft concluded the presentation of the St. Maarten case. He described again that St. Maarten suffers a lot from flash floods and storm surges due to the hilly terrain in the middle of the island. The reason Hurricane Irma caused such devastation was due to the eye of the hurricane passing over the island while categorized as more than Category 5. Following Irma, PEARL has been working with the Red Cross to assess the damage to houses/buildings. The models developed in the PEARL project could be very helpful during future hurricane events. The models can be run on the same day of a potential hurricane to model storm surges. Agent based models were also created for the case of St. Maarten. Based on the different tools developed, different grey and green infrastructural measures can be evaluated. PEARL also developed various applications, such as a flood warning system to enable greater proactivity for dealing with extreme events, like Hurricane Irma.

2.1.3 Dr. Sutat Weesakul, Director Hydro and Agro Informatics Institute (HAII) in the Ministry of Science and Technology, Thailand: Regional Case: Thailand – what did PEARL do?

The PEARL project helped to conduct a flood risk assessment in cultural heritage in Ayutthaya. The perception of risk includes local and cultural contexts. This is important in the case of Ayutthaya, as 1/3 of the Ayutthaya is a UNESCO World Heritage Site. For the risk assessment in Ayutthaya, a multi-hazard and multi-vulnerability approach was taken to include social, cultural, physical and economic aspects of vulnerability. To better understand the social vulnerability component, questionnaires were used to gather survey data and the results showed that most people would like to have flood preparedness and prevention. Physical vulnerability is complex is Ayutthaya, as different buildings have higher or lower vulnerabilities. Economic vulnerabilities are where floods cause interruptions of business. Cultural vulnerability, which is the most important aspect to consider in this case, is a function of the level of property significance and sensitivity to flooding. People can contribute to this assessment. The risk map is the product of the hazard and vulnerability maps. People were asked to describe their perception of risk and this was compared to the calculated risk. The results of this comparison showed that social, cultural, economic aspects of vulnerability are less than physical vulnerability. This is likely because physical vulnerability has a longer memory time. PEARL in this case has shown the complementariness of the traditional and risk perception approach.

2.1.4 Natasa Manojlovic, TUHH: Case of Hamburg

Hamburg is located close to the Elbe Estuary, which is a flood prone area, making Hamburg and the surrounding area very vulnerable to floods. In 1962, a disastrous event destroyed large parts of Hamburg – this was the start of the development of adaption and protection measures. The Elbe area is protected by strong dykes to protect against flooding – riverine flooding and from storms from the North Sea. Along the Elbe River, 3 federal states are included in the planning process, which makes risk governance a challenge. The PEARL project first drew a roadmap for flood risk governance to better understand risk by linking stakeholders, response, adaptation and governance measures. It is important to note that intense stakeholder interaction process created the basis for PEARL to get to know the stakeholders. With the PERAL project, intense communication with selected key stakeholders led to the identification of a key contact person for direct communication. Together with the stakeholders, it was important to determine open questions and the necessary tools for understanding and assessing hazards; early warning systems; analysis of risk; adaptation; risk management and evacuation.

The early warning system is currently based on gauges along the Elbe River, which give real time data to allow for real time forecasting and can allow for 6 hour lay time. This system has been tested with a recent flooding event, where the model and real event matched up. PEARL helped to conduct temporal and spatial modelling of breach of dykes. Impact and risk assessments were conducted for several areas and for several direct and indirect damages. The PEARL tools showed that urban development brought a 15-20% increase in risk to one area of Hamburg.

To demonstrate the value of PEARL in Hamburg, a video recording was played from Dr. Gabriel Gonnert who works with roads and bridges in Hamburg and is a key stakeholder in the PEARL project. She stated that the added value of PEARL was the modelling of the Elbe River and the result of the multiple hazard assessment. This information is necessary for the building program to strengthen coastal stability; for the future development and protection of the city of Hamburg. The outcomes of the PEARL project will be used for the reinforcement of the city of Hamburg.

2.1.5 Janilo E. Ruubiato, General Manager, Atty., Environmental Management Department Philippine Reclamation Authority, Philippines: case of the Philippines

The last extreme typhoon that devastated the Philippines was Yolanda in 2013. Yolanda produced 7m of storm surge which submerged the city. The site of this case study is in Tacloban city and Palo, Province of Leyte, Philippines. The Dutch government has helped asses risk in both areas, with special emphasis given to building with nature, mangroves, evacuation measures and partnerships between the public and private sector. The coastal protection strategy was initially focused on reconstruction, but the Dutch team helped assess risk and address resilience. Coastal protection strategies were developed for 3 different areas – according to 3 levels of response. Today, the local

level governments have adopted level 2 and 3 of the response because these are less expensive. Zoning policies were also developed, which outline no build zones and no dwelling zones. The Filipino government is looking for more funding and collaboration to expand on this successful project.

Q&A

Q: With regards to the use of Mangroves in the case of the Philippines, how is this being scaled up with other nature based solutions?

A: It is a small project where several agencies undertake the mangrove replanting. Everyone has their own process. The project with the support of the Netherlands is being done in a very scientific way: planting and natural regeneration. They are hoping it will become a project for scaling-up. The granter is looking into the application of mangrove restoration – it could be a positive case for scaling-up in other cases.

2.1.6 *Louwrens op de Beek, Senior Business Development Manager, Royal IHC, Netherlands – Reviving dam ecosystems with positive impact on sediment reuse, rural economies and (agricultural) communities*

This case presentation aimed to extend the knowledge of dredging and reuse of sediment. As sediment builds up behind dams, the capacity to absorb floods in reservoirs declines. Siltation, longer periods of drought and climate change are increasing flood risk near dams. Royal IHC, Netherlands have built dredging technologies to be combined with other measures to improve flood control. Sediments that are removed from reservoirs can be put back into the river; can be used to produce different materials and products like bricks and dykes (dependent on local materials and based on circular economy thinking); or the sediment can revitalize near-by agricultural land.

Q&A

Q: Are you also looking at the CO_2 footprint from moving the sediment around from dams?

A: We are looking at the surrounding areas, then create a recipe and use it for key roles and other applications

Also, for example in Malawi, the power produced by the dam is used to power the machines for dredging.

Depends on what type of soil there is.

2.1.7 *Ellen Tromp, Deltares / TU Delft, Netherlands – Deltares*

The Netherlands has a strong focus on prevention and the legal standard for acceptable flood risk increased to 1 in 100 000 in any given year. 60% of the Netherlands is flood-prone. The purpose of this case is to compare the case of flood prevention in Sheffield, UK with that of the Netherlands.

Sheffield had significant flooding in 2007, where 500 businesses were at risk. This prompted local businesses and the chamber of commerce to come together to improve flood protection. They managed to increase flood protection to a 1 in 100 year standard. This approach is very business focused and shows a new mechanism being created: a Business Improvement District as the basis for public/private partnerships to improve flood prevention.

GoWA (one of the Dutch Water Authorities) operates 23 km of dykes in the Netherlands. The GoWA deals with 3 municipalities, 2 provinces, central government when addressing flood protection. The organisation sought to involve public participation where groups were asked to develop ideas and visions for 5 areas and designers were asked to incorporate this into their designs, keeping in mind flood prevention.

The comparison of the case of Sheffield and GoWA is a comparison of a business centred and a public participation centred approach to flood prevention. The Dutch case is an example of the ladder of participation, which describes the rungs of a ladder as different degrees of participation, where, for example, consultation is on a lower rung than decision making. It is a challenge to intensify the power

of the citizen in developing resiliency against flooding. Securing private financing is also a challenge, but there is growing interest in this.

3 Concluding remarks

Over the course of AIWW 2017, PEARL brought together project partners and AIWW participants. Each case study that was presented demonstrated different responses to extreme events and climate change and offered different roadmaps for implementing adaptation measures. The following key points formed the red thread that connected the different cases studies:

- There is no one way to apply any one methodology or tool in a given context. Further, in areas where traditional data are not available (e.g. fine scale satellite data, data from sensor networks), more progress needs to be made in developing hydrometeorological models based on novel data points.
- Coastal cities located in typhoon and hurricane prone regions are areas where innovation in risk and vulnerability mapping are occurring. However, as urban populations in coastal areas continue to grow, the impacts of these events will also continue to grow, prompting a critical need to address risk in coastal areas. These areas will require help to improve disaster preparedness, response and recovery.
- 2D/1D mesh models are giving finer grain risk modelling and forecasting capacity of storm surges and urban flooding under different adaptation measures and development scenarios.
- By combining calculated risk with socially or culturally defined risk, different adaptation measures can be identified. Both the calculated and new method for risk calculation are valuable.
- A key element to responding to coastal risk from extreme hydrometeorological events is public participation. Public participation is at the heart of the human centred approach to assessing vulnerability, mapping risk and identifying adaptation measures.
- While public participation is essential to fully understand the complex nature of vulnerability and risk, public participation is always challenging, especially in areas where there is no history of frequent public consultation. However, too much public participation can lead to fatigue.
- Each context will need to develop a tailored approach to public engagement and will need to adapt methodologies to appropriately engage citizens in risk assessments; identifying adaptation measures and preparing, responding and rebuilding after disaster strikes.

Annex 1

PEARL side event

Responding to risks of extreme events to advance climate change adaptation

Monday, 30 October 2017 | 09:00-15:45
Room: G106

The EC funded PEARL project (http://www.pearl-fp7.eu/) demonstrates solutions to government's and water practitioners on adaptive risk management measures for coastal cities against extreme hydro-meteorological events (with the focus on floods and storm surges). In this event the science behind the PEARL framework and its application in case study cities across Europe, Asia and the Caribbean will be presented. Bridging the science to practice will be demonstrated in the form of roadmaps where presenters will discuss the way forward to building resilience and adapting to climate change in cities such as Hamburg, Genova, Rethymno, Greve, Les Boucholeurs, Marbella, the Islands of St. Maarten and St. Lucia, Ayuthaya and Bangkok in Thailand and Tainan in Taiwan.

Session 1 – 09:00-10:45

Time	Item	
Introducing PEARL *Opening and plenary with moderated panel discussion* *Room set up: Theatre style*		
09:00-09:15	Welcome and Opening address	Welcome address: IHE Delft Programme overview: *Zoran Vojinovic, IHE Delft* • Introduction to PEARL • Structure of event
09:15-10:00	PEARL presentation Science behind PEARL framework • What is innovative in the subject area • How is the related work undertaken in PEARL contributing to the cities	Chair: *Christos Makropoulos, NTUA* 3 presentations (15 minutes each): • Social innovation (*Mark Pelling, KCL*) • Hazard modelling innovation (*Caroline Baugh/Chris Pain, ICL*) • Risk assessment innovation (*Zoran Vojinovic, IHE Delft*)
10:00-10:15	Synergies with other EC projects • General presentation and synergies with PEARL	RESCCUE *Marc Velasco*
10:15-10:40	Open panel discussion Scientific research applied in case study areas	Moderator: *Pritha Hariram, IWA* Panel members will include the presenters, and other partners (RESCUE).
10:40-10:45	Wrap up	*Zoran Vojinovic, IHE Delft*
10:45-11:00	*Coffee break and networking*	

Session 2 – 11:00-12:40

Time	Item	
Science to practice: Creating Roadmaps A *Room set up: Theatre style*		
11:00-12:35	Plenary Science to practice *Format of presentations:* • *Case study description* • *Solutions (Roadmaps)* • *Tools* *What has PEARL done in these cities and where are we going (roadmaps) in the case study locations*	Chair: *Christos Makropoulos, NTUA* Presentations (15 minutes presentation + 5 minutes Q/A each): PEARL partners and stakeholders • Thailand (Sutat Weesakul, HAII) • Crete (Archontia Lykou, NTUA) • Hamburg (Peter Fröhle, TUHH) • Greve (Nina Domingo, DHI) • St. Lucia (Nina Domingo, DHI)
12:35-12:40	Wrap up	*Zoran Vojinovic, IHE Delft*
12:40-14:00	*Lunch and networking*	

Session 3 – 14:00-15:45

Time	Item	
Science to practice: Creating Roadmaps B *Room set up: Theatre style*		
14:00-15:35	Plenary Science to practice *Format of presentations:* • *Case study description* • *Solutions (Roadmaps)* • *Tools* *What has PEARL done in these cities and where are we going (roadmaps) in the case study locations*	Chair: *Natasa Manojlovic, TUHH* Presentations (15 minutes presentation + 5 minutes Q/A each): PEARL partners and stakeholders • St. Maarten (Zoran Vojinovic, IHE Delft) • Marbella (Eduardo Marrtinez Gomariz, CETAQUA) • Taiwan (Dong-Jiing Doong,) • Genoa (Alessandra Machese, GISIG) • Les Boucholeurs (Jelena Batica,)
15:35-15:45	Wrap up/Closing *Promote case session and lunch meeting (on Wednesday)*	*Zoran Vojinovic, IHE Delft*

Annex 2

Case session

Resilient Regions and Climate Change Adaptation

Wednesday November 1st 11.00-12.30
Room: D203/D204

Various regions worldwide face severe social, economic and environmental impacts due to climate change events. This case session focusses on the regions Europe, Caribbean and Asia with examples of cases on how to develop adaptive, sociotechnical measures and strategies to cope with these climate change events. Solutions are being incorporated in the session to indicate other possible contributions. This session is being led by the PEARL consortium.

Overall coordinator: Xander de Bruine
11:00-11:05 | Moderator: Professor Zoran Vojinovic, Urban Water Systems, IHE-Delft
11:05-11:20 | Key Note: Dr. Chien-Hsin Lai, Director General, Water Resources Agency, Ministry of Economic Affairs, Taiwan

Cases

Case Adaptive, sociotechnical risk management measures and strategies for coastal communities. Regional cases highlighted:

Time	Item	Presenter
11:20-11:30	Regional case St. Maarten	• Stakeholder video (Kurt Ruan, Department Head of New Projects, Ministry of VROMI, St. Maarten) • Zoran Vojinovic, IHE Delft
11:30-11:40	Regional case Thailand	Dr. Sutat Weesakul, Director Hydro and Agro Informatics Institute (HAII) in the Ministry of Science and Technology, Thailand
11:40-11:50	Hamburg	• Stakeholder video • Natasa Manojlovic, TUHH
11:50-12:00	Coastal Protection Strategy: Nature-Based and Infrastructural Solutions to Protect the Region from Future Floods in Tacloban and Palo	Janilo E. Ruubiato, General Manager, Atty., Environmental Management Department Philippine Reclamation Authority, Philippines
12:00-12:10	'Reviving dam ecosystems with positive impact on sediment reuse, rural economies and (agricultural) communities'	Louwrens op de Beek, Senior Business Development Manager, Royal IHC, Netherlands

Solutions

Time	Item	Presenter
12:10-12:15	IWA 9154: Spatially integrated and socially accepted flood defences, designed by stakeholder engagement, Dutch Flood Protection Programme	Ellen Tromp, Deltares / TU Delft, Netherlands
12:15-12:30	Question & Answers	

Annex 3

An informal lunch event was organised to get delegates discussing with PEARL case study areas. Tables were set up to represent the regions (Asia, Caribbean and Europe). The purpose of the lunch event was to establish an informal platform for participants to engage and discuss roadmaps for the development of adaptive~~,~~ sociotechnical measures and strategies.

PEARL lunch event

Roadmaps towards climate change adaptation

Wednesday, 1 November 2017 **|** *12:30-14:00*
Room: G001-002

The world is changing, becoming increasingly complex. Climate change is the environmental problem of the 21st century contributing to the complexity, and introducing unpredictable changes with potentially harmful consequences to growing urban settings. Following the case session “Resilient Regions and Climate Change adaptation” (Wednesday, 1 November 2017, 11:00-12:30), case study representatives will be taken into a-world-café-style roundtable discussions delving into actions towards climate change adaptation for their respective cities. The session provides participants with an interactive space to probe further into roadmaps for the development of adaptive, sociotechnical measures and strategies. Join Dr. Sutat Weesakul, Director of the Hydro and Agro Informatics Institute, Dr. Lai, Director General, Water Resources Agency, Ministry of Economic Affairs and other partners and local stakeholders from the Caribbean and Europe, as we respond to the realities of today, the uncertainties of the future and seek to become more climate resilient.

Time	Item	
Roadmaps towards climate change adaptation *Room set up: Round table*		
12:30-13:55	Rotational World Cafe style*	• Table 1 (Asia): ○ Thailand; Dr. Sutat Weesakul, HAII ○ Taiwan; Dr. Lai, Director General, Water Resources Agency, Ministry of Economic Affairs ○ Taiwan; Dong-Jiing Doong, NCKU • Table 2 (Caribbean): ○ St. Maarten; Kurt Ruan, VROMI ○ Zoran Vojinovic, IHE Delft ○ Ole Mark, DHI • Table 3 (Europe): ○ Crete; Archontia Lykou, NTUA ○ Crete; Christos Makropoulos, NTUA ○ Hamburg; Peter Fröhle, TUHH ○ Hamburg; Angelika Gruhn, TUHH
13:55-14:00	Wrap up	Zoran Vojinovic, IHE Delft