CORFU
FP7 Collaborative research on flood resilience in urban areas

FLOOD RISK MANAGEMENT IN BARCELONA (SPAIN)

This brief explains how the CORFU project (Collaborative research on flood resilience in urban areas) has influenced the flood risk management and planning policy in Barcelona city in Spain. The ideas behind the research have captured the interest of the Barcelona metropolitan area governments, whereas the technical and scientific advancements of the project have demonstrated how these policies can be implemented in their municipalities.

Introduction

Urban areas are, due to the concentration of population and economic activities, one of the most sensitive regions to natural hazards. Trends show that world's population is moving to cities: currently 50 % of the global population lives in urban areas, and by 2030 at least 61 % of the world's population will be living in cities (IBRD/WB, 2009). In Europe, such values present even more extreme situations: 83% of the population is expected to live in cities by 2050 (EC, 2010). The concentration of people in cities increases their opportunities as well as their vulnerabilities to natural hazards and climate change impacts (Djordjević et al., 2011). Consequently, flood risk management is an issue of high interest, specially taking the European Floods Directive (EC, 2007) into account.

Barcelona case study

Barcelona (Spain) is prone to flash flooding because of its climate and topography. It is not rare for 50% of the annual precipitation to fall in two or three events with high rainfall intensities. Steep mountains to the east mean that the catchment responds quickly, with little warning time. The Raval District is in a flat area of the city and is densely populated (Figure 1). This area particularly suffers from flooding problems when heavy storm events occur, due to excessive surface runoff and the poor capacity of the sewer system.

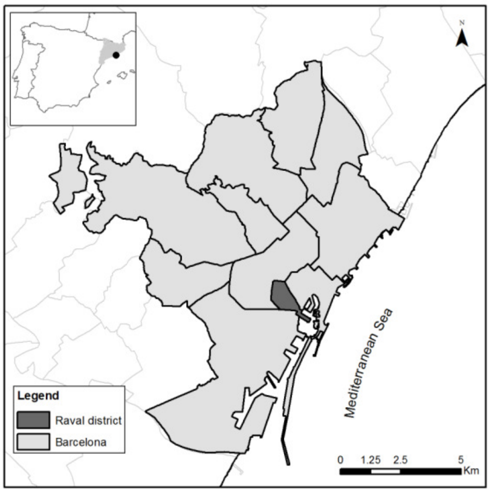

Figure 1. Administrative limits of Barcelona and the case study area, the Raval District

Technical and scientific advances

The challenges of flooding were addressed within the project, through several steps. The first crucial step is the accurate estimation of flood depths in the affected area. A detailed flood model that coupled the drainage and surface flows was developed, that take surface flows coming from upstream catchments into account. The detailed 1D/2D coupled model, simulating surface and sewer flows was developed using Infoworks ICM version 3.0 by Innovyze (2013).

Special attention was paid to the hydraulic characterization of the inlet systems (representing the interface between surface and subsurface flows) using experimental expressions obtained by the Technical University of Catalonia (Gómez and Russo, 2011). The sewer model was calibrated and validated (Figure 2) using data from four rainfall events which occurred in summer 2011. These results are described in Mark et al. (2014).

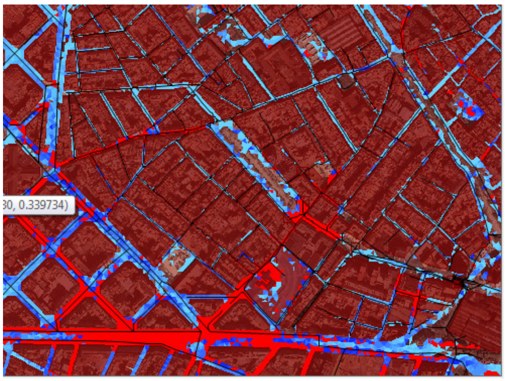

Figure 2. Validation results, presenting flow depths provided by the model for the event of 30 July 2011.

Flooding produces significant hazards for vehicles and pedestrian circulates, as well as producing economic damages. To estimate the risk to pedestrians and vehicles, research from previous studies was used to produce hazard, vulnerability, and risk maps (Russo et al., 2013; Shand et al., 2011).

Damage to buildings was estimated using depth-damage functions. New depth-damage functions for six different land-use types were developed in this study, using a synthetic 'what-if' analysis and using flood expertise acquired from past flood events (Velasco et al., 2013).

One of the main goals of the study was to assess the current and future flood risk, and then propose several adaptation strategies to cope with future impacts. In order to evaluate this, a long-term cost-benefit analysis of several resilience strategies using a combination of different future scenarios of climate, adaptive capacity and socioeconomic aspects was developed. These future scenarios are centred on 2050.

There were two Business-as-Usual (BAU) scenarios, in which no adaptation strategies were implemented, but had two different climate scenarios. The other future scenarios covered several plausible futures implying different levels of adaptive capacity (Table 1) and climate futures. Of course, these scenarios were related and compared to the current situation or baseline scenario, which represented the nowadays flood risk situation in the Raval district.

Adaptations 1 to 3 represent low, medium and high adaptive capacity respectively, under pessimistic climate scenarios. Adaptations 4 to 6 represent low, medium and high adaptive capacity respectively under optimistic climate scenarios. Low adaptive capacity includes the use of non-structural measures including the use of sand bags and flood boards and the implementation of early warning systems. Medium adaptive capacity corresponds to the implementation of SuDS, and green roofs in particular. High adaptive capacity corresponds to structural measures which include new drainage pipes, and the installation of large underground storage tanks.

The damage estimates for scenarios and rainfall events with different return periods were obtained. By calculating the costs for different return periods, the expected annual damage (EAD) of the area was calculated (Figure 3). This figure shows Adaptation 1.4 which is a variation of Adaptation 1, where 100% of properties adopt non-structural measures such as flood boards.

A cost-benefit analysis of the different adaptation measures was conducted considering the scenarios from Table 1. Results from this cost-benefit analysis provide insights on the economic efficiency of the different adaptation measures. Within the scope of this analysis, benefits are defined as the reduction in the EAD to buildings and their contents that presumably is going to be achieved by implementing the considered adaptation measures. Costs were analysed by taking into account the initial cost of setting up or constructing the respective measure, and any costs that are required to operate and maintain the adaptation measure.

Table 1. Combinations of the scenarios used for the Raval district.

Scenario ID	Climate Scenario	Socioeconomic Scenario	Adaptive Capacity	Adaptive Measures
BAU1	Pessimistic	Medium	None	-
Adaptation 1	Pessimistic	Medium	Low	Non-structural measures
Adaptation 2	Pessimistic	Medium	Medium	SuDS (green roofs)
Adaptation 3	Pessimistic	Medium	High	Structural measures
BAU 2	Optimistic	Medium	None	-
Adaptation 4	Optimistic	Medium	Low	Non-structural measures
Adaptation 5	Optimistic	Medium	Medium	SuDS (green roofs)
Adaptation 6	Optimistic	Medium	High	Structural measures

When calculating the benefits, the BAU scenarios are compared to the different adaptation scenarios with equal scenario parameters except for the adaptive capacity. The cost benefit analysis highlights that in general, strategies that imply lower investments lead to higher net benefits. In addition, the benefits are only focused in Raval District while in some cases they have a wider extension (for Adaptation 3 and 6 scenarios). Therefore, although the structural strategies have smaller benefits, including all these factors would lead to best results. These results are presented in detail in Hammond et al. (2014).

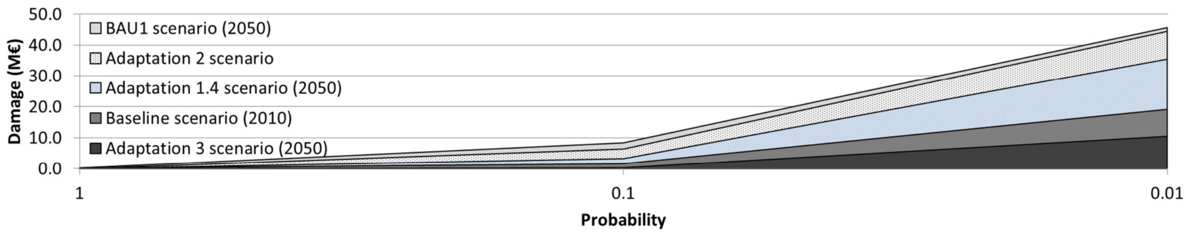

Figure 3. Damage-probability curves for the whole Raval district and the pessimistic climate change scenarios. The area under these curves expresses the EAD of the region. The probabilities 1, 0.1 and 0.01 represent the events of 1, 10 and 100 years of return period, respectively

Policy Impact of CORFU

CORFU project has improved the flood risk management and sewer planning policy of the city of Barcelona in two main aspects:

- By improving the hydraulic modelling with a detailed 1D/2D coupled model simulating surface and sewer flows.
- By developing hazard and risk maps and cost-benefit analysis to justify the implementation of the most efficient measures to reduce flood risk.

These project results have also captured the interest of flood managers who are interested in transferring them to their own municipalities in the same region. Over eighty people attended the final stakeholder workshop, with people from industry and municipalities, and even intergovernmental organisations (Barcelona is home to the UN-Habitat's Resilient Cities Programme).

Further Information on the CORFU Project

Start / End Date of Project:

1st April 2010 to 30th June 2104

Participating institutions

University of Exeter, UK (Coordinator)

Hamburg University of Technology, Germany

DHI, Denmark

University of Nice - Sophia Antipolis, France

Indian Institute of Technology in Bombay, India

AREP Group, France

Institute of Water Modelling, Bangladesh

Beijing University of Technology, China

China Academy of Urban Planning Design, China

Beijing Municipal Institute of City Planning and Design, China

CETaqua, Spain

Hydrometeorological Innovative Solutions, Spain

Cranfield University, UK

Dura Vermeer Business Development, Netherlands

Hamburg Institute of International Economics, Germany

Programme:

The CORFU project received funding from the European Union through the 7th Framework Programme, Grant Agreement Number 244047.

Web-link:

www.corfu7.eu

Master Drainage Plans which will be developed by members of the project team using the technical and scientific improvements. At the same time an important CORFU results dissemination process through the AEAS (Spanish association of water supply and urban drainage service operators) has been developed and several Spanish municipalities have shown their interest in these advanced solutions to solve their flooding problems.

REFERENCES

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

EC, European Commission (2007) *EU Directive of the European Parliament and of the European Council on the estimation and management of flood risks.* 2007/60/EC. Brussels.

EC, European Commission. (2010). *World and European Sustainable Cities*, Ref: EUR 24353, Brussels.

Gómez, M. and Russo, B. (2011) Methodology to estimate hydraulic efficiency of drain inlets. *Proceedings of the ICE - Water Management,* 164 (2), 81-90. DOI: 10.1680/wama.900070.

Hammond, M. et al., (2014) Report on assessment of cost-effectiveness of flood resilience measures. CORFU Deliverable D3.9, 124pp.

IBRD/WB (2009) *Climate Resilient Cities.* International Bank for Reconstruction and Development/The World Bank, Washington.

Innovyze (2013) *InfoWorks ICM (Integrated Catchment Modeling) v.3.0.* User manual references.

Mark, O. et al., (2014). *Future impacts of urban growth and climate change on flood probability.* CORFU Deliverable D2.4, 144pp.

Russo B., Gómez M. and Macchione F. (2013) Pedestrian hazard criteria for flooded urban areas. *Natural Hazards.* Springer. 63(11), 2666-2673. DOI: 10.1007/s11069-013-0702-2.

Shand, T. D., Cox, R. C., Blacka, M. J. and Smith, G. B. (2011) *Appropriate Safety Criteria for Vehicles. Literature Review.* Stage 2 Report, Australian rainfall and runoff Project 10. Engineering Australia, Water Engineering.

Velasco, M., Cabello, A., Russo, B. and Kersting, T., (2013) Flood vulnerability assessment considering climate change impacts: Application to Barcelona case study using relative depth-damage curves. *International Conference on Flood Resilience: Experiences in Asia and Europe, Exeter, United Kingdom, 5-7 September 2013*.