Appraisal of adaptation to river and coastal flood in Bilbao

Key Messages

- The study aims at the appraisal of an infrastructural measure of adaptation to river and coastal flood in Bilbao impacting a new urban development in Zorrotzaurre. The case study focuses on the analysis associated with the opening of the Deusto channel that has the potential to convert the area from a peninsula into an island.
- The methodology involves a full context analysis, followed by the hazard and impact assessment related to the measure, allowing for an economic assessment and finally the decision making process.
- The economic assessment used to integrate uncertainty combines three approaches: stochastic modelling, estimation of two risk measures (value at risk and expected shortfall) and real-option analysis.
- Each approach allows the integration of multiple sources of uncertainties in the economic assessment and provides different type of information on the risk of investing in particular infrastructures.

Context

Mainstreaming adaptation in infrastructure development is a crucial component of building resilience to climate change impacts. This Insight presents an appraisal of economic projects to support the assessment of adaptation options to river and coastal flooding in the city of Bilbao in Spain. The economic methodology to incorporate uncertainty into decision-making processes considers three approaches: 1) estimating the net present value of the expected damage using a stochastic model; 2) estimating two risk measures (value at risk, VaR, and expected shortfall, ES) which are robust indicators for assessing risk and provide key information in situations of uncertainty; 3) using a real options analysis framework, which can contribute to robustness offering flexibility in adaptation measures. Key to the assessment is to incorporate uncertainties in the economic appraisals. Addressing these uncertainties is a priority, and is discussed throughout the case study.

Policy and methodological developments

Context analysis

The Atlantic coast of the Basque Country is an area with high-risk, due to natural flood hazard (generated by high precipitation, strong slopes and steep valleys) but also with high vulnerability, with most of its low-lying areas densely urbanised (Ibisate et al., 2000). As other old industrial cities, the urban development in Bilbao has been shaped by the requirements of the manufacturing industry accompanied by a fast growing population (Rodríguez et al., 2001). Most of this urban expansion during the mid 20th century occurred in flood prone areas along the estuary, which increased the vulnerability of the city.

After the dramatic floods in 1983, several infrastructure measures were implemented, but the risk still remains. In 2012 a new urban development has been approved in a flood risk area within the estuary, on the peninsula of Zorrotzaurre. In a context of global climate change, with rising sea levels and increasing extreme events, this new development represents a perfect opportunity to analyse different adaptation measures that could be implemented in an urban context to reduce flood risk.

The institutional landscape is quite complex as the Basque region acts as an Autonomous Community approved by the Spanish Parliament. The urban transformation of Zorrotzaurre, because of its location on the Ibaizabal estuary, is affected by the concurrent competence of the regional and central governments. Competences on land and urban planning are exclusive of

Basque institutions, at different levels (regional, provincial and local). In the case of Zorrotzaurre, the Special Urban Development Plan to transform the area was finally approved by the Bilbao City Council in 2012, after a long period of different administrative procedures.

On the policy side, key documents include the EU Water Framework Directive and the EU Floods Directive, which are transposed at the national level through Basque water policy. There are also numerous strategic and planning documents identified at the local and national level. Two are the main policy areas related to the Zorrotzaurre case study. The first is related to flood risk prevention, for which the main stakeholder is the Basque Water Agency. The second policy area is at the local scale related to the urban design of Zorrotzaurre, with stakeholders being coordinated through the Management Commission for the Urban Development of Zorrotzaurre.

Hazard and Impact assessment

The Basque Water Agency (URA), in the context of the European Floods Directive 2007/60/CE, identified Bilbao as one of the main risk points in the Basque Country (URA, 2013). So far, in Basque hydrological assessments, URA has been using data from climate models that adopt the SRES climate change scenarios of the IPCC (IPCC, 2000). In this case study the aim was to show the implementation of the more recent RCP scenarios.

In order to produce the most reliable and updated output for the assessment, the study makes use of climate forcing data from the downscaling of a suite of state-of-the-art Regional Climate Models. As such, through collaboration with URA, new definitions of flood hazard probabilities were created under the new IPCC emission scenarios, RCPs 4.5 and 8.5 (Moss et al., 2010).

The simulated future climate regime under RCP4.5 and 8.5, considering changes in precipitation, temperature and sea level, was introduced into the TETIS v8.1 hydrologic model (Francés et al., 2007; Bussi et al., 2013, 2014), in order to obtain potential peak-discharges for different return periods. As a result, URA updated the flood risk maps for 10-, 100- and 500-year return periods, with hydraulic modelling being carried out using the HEC-RAS v4.1 model (Pappenberger et al., 2005).. An approximation to exposure was also developed based on the following factors: population, economic activity, and areas of environmental interest potentially affected. This analysis has included estimates of potential annual economic damages for each flood-risk area (URA, 2013).

Adaptation measures

The adaptation measure assessed in the case study consists in the opening of the Deusto channel that will convert the Zorrotzaurre area from a peninsula into an island, which will alter the hydrodynamics of the river trait thus lowering the height of flooding. The opening will be about 75 m wide, it should reduce the water depth in the event of extreme flooding (500-year) by on average 0.87 m. Works for the realization are planned to be completed by the end of 2016. Plans for Zorrotzaurre include the elevation of the urbanization level in certain areas or the construction of two storm tanks, but the impact of these measures has not been analysed in this appraisal context.

The new urban development in Zorrotzaurre will need to consider mainly the risk of tidal and river flooding, but both impacts imply a great degree of uncertainty regarding their timing (when will it occur) and extent. In this context of high uncertainty, deterministic approaches to define adaptation options at the local level might have strong limitations (Dobes, 2008). For example, the construction of a sea wall as a response to sea-level rise could be too low or to high or its construction might happen too early or too late; and this situation could derive in high social, environmental and economic costs.

Economic assessment

A previous study commissioned by the Bilbao City Council estimated the economic benefits of the opening of the Deusto channel in terms of avoided damages under present-day climate (Osés Eraso et al., 2012). The results obtained show a significant reduction of damages in the adaptation scenario. Floods of 10-year return period would not cause any damage, while they decrease by 67.4% for 100-year floods. For 500-year floods, damages are reduced by 30.7%. These damage data were used in the economic modelling in this particular case study.

Using the damage data of Osés Eraso et al. (2012), a new methodology enables the calculation of the expected average damages at a given time, with and without adaptation, applying a new stochastic function:

$$E(D_i^{0,\infty}) = \int_0^\infty d_i \lambda_i e^{(\mu-\rho)t} dt = \frac{d_i \lambda_i}{\rho - \mu}$$

In summary, the stochastic damage function defined by the equation above enables the calculation of flooding damages for any given time, depending on the difference between the increase of damages due to climate change and to economic growth and the discount rate. Using the data on benefits, in terms of avoided damages, as input, we can measure stochastically the damages related to flood of different return periods, but we can also estimate the benefits of adaptation, in terms of avoided impacts.

In situations in which uncertainty needs to be accounted for, risk measures have proven to be very useful tools. This is a quite novel approach in economics of adaptation, even though it has been frequently used, for example, to consider price uncertainties (Abadie and Chamorro, 2013).

There are two main risk measures that can be used for this purpose. The first, Value-at-Risk (VaR), is the most standard measurement and well recognised by international financial regulatory bodies. The VaR(α) at the confidence level α is the value at which the probability of obtaining higher values is 1-α. In the Bilbao case study, the VaR of damage resulting from river flooding in the case study area expresses the losses that could occur with a given confidence level α of 95%, for a time interval of 85 years.

The second risk measure is Expected Shortfall, ES, which in this case represents the average damage of the 5% worst cases. ES is, therefore, a better measure of risk for low probability but high damage events. Both measures of risk were estimated for the Bilbao case study, with a range of 266-330 M€ for VaR(95%) and 371-445 M€ for ES(95%) in the baseline.

The opening of the canal is expected to reduce not only the expected damage but also the level of risk, that is, the damages that would occur in the worst 5% of the cases. Average expected damages would be reduced by 41 to 58 M€, while ES decreases with the opening of the canal by 174-205 M€ during the period under assessment.

Decision making

A Real Options Analysis (ROA) was used to assess the investment risk under uncertainty due to climate change and socio-economic development. The ROA shows how uncertainty, flexibility and time can be incorporated into a climate-related investment decision and it enables the estimation of a "wait-invest" boundary. In the case of the opening of the Deusto channel, the infrastructure would fall within the investment region. Nevertheless, there are various parameters that influence the maximum cost that can be accepted for making investment immediately. For example, volatility can change the boundary of the wait-investment regions. The greater the volatility, the lower the investment-wait boundary. In other words, greater volatility makes potential investors more demanding and they invest only when the cost is lower. More detail on the application of the real-option analysis is provided here.

Main implications and recommendations

The study illustrates three economic measures of uncertainty in infrastructure investments: expected damages through stochastic modelling, value at risk and expected shortfall and real-option analysis. Each provides different types of information to decision-making. The main advantage of the methodologies presented is the capacity to consider and integrate multiple sources of uncertainties in the assessment. The table below presents how uncertainties were integrated in the assessment.

Table 1. Integration of uncertainties in the assessment.

Source of uncertainty	**Degree of Uncertainty**	**How it was addressed**
Future emissions	Medium	Use of two RCPs: RCP 4.5; RCP 8.5
Regional climate	High	Use of 11 climate simulations from several RCMs for precipitation and temperature; for sea level rise a regionalization of IPCC mean global sea level change
Hydrological modelling		Not addressed
Socio-economic developments	High	Results are provided for a range of values of increase in damage, also reflecting socioeconomic development
Damage calculation	Medium/High	1. Damages were modelled stochastically 2. Risk measures were estimated (VaR and ES)
Costs of adaptation	Medium	Results of the decision-making process are provided for a range of values of investment costs
Method of EAD calculation	Low	Estimation of likelihood of occurrence of stochastic events of three return periods with Poisson process
Discounting approach	Medium	Results are shown for a vast range of discounting values
Discount rate	Medium	Results are shown for a vast range of discounting values

There are a few limitations arising from this methodology that are worth highlighting. While on the one hand sea-level rise will surely increase the damages of floods, it is not clear whether changes in precipitation and temperature will impact the damages in a positive or negative fashion. The economic risk modelling and the resulting decision-making rules do nevertheless explicitly include the effects of climate change in their assessment, at least in a conceptual manner. With regards to the temperature and precipitation data developed by the Basque Water Agency, a compromise of the method of processing projections is that inter-model uncertainties, and therefore the subsequent calculation of extremes in peak discharge, especially for the winter months, could have been underestimated.

Bibliography

Abadie, L.M., Chamorro, J.M. (2013), Investment in energy assets under uncertainty: Numerical methods in theory and practice, 1st ed. Springer, London.

Bussi, G., Francés, F., Montoya, J.J., Julien, P.Y. (2014), Distributed sediment yield modelling: Importance of initial sediment conditions. Environ. Model. Softw. 58, 58–70, *http://dx.doi.org/10.1016/j.envsoft.2014.04.010*.

Bussi, G., Rodríguez-Lloveras, X., Francés, F., Benito, G., Sánchez-Moya, Y., Sopeña, A. (2013), Sediment yield model implementation based on check dam infill stratigraphy in a semiarid

Mediterranean catchment. Hydrol. Earth Syst. Sci. 17, 3339–3354. *http://dx.doi.org/10.5194/hess-17-3339-2013*.

Dobes, L. (2008). Getting real about adapting to climate change: using'real options' to address the uncertainties. Agenda J. Policy Anal. Reform 15, 55.

Directorate General Regional Policy (2006), Strategic evaluation on environment and risk prevention under structural and cohesion funds for the period 2007-2013. Contract No. 2005.CE.16.0.AT.016.

Fernández Gómez, M. (1993), Inundaciones en el País Vasco. Obras Públicas 1, 26–35.

Francés, F., Vélez, J.I., Vélez, J.J. (2007), Split-parameter structure for the automatic calibration of distributed hydrological models. J. Hydrol. 332, 226–240, *http://dx.doi.org/10.1016/j.jhydrol.2006.06.032*.

Ibisate, A., Ollero, A., Ormaetxea, O. (2000), Las inundaciones en la vertiente cantábrica del País Vasco en los últimos veinte años: principales eventos, consecuencias territoriales y sistemas de prevención. Ser. Geográfica 9, 177–186.

IPCC (2000), Nakićenović, N., Swart, R., ed., Special Report on Emissions Scenarios: A special report of Working Group III of the Intergovernmental Panel on Climate Change (book), Cambridge University Press, ISBN 0-521-80081-1, 978-052180081-5 (pb: 0-521-80493-0, 978-052180493-6).

Moss, R. H., et al. (2010), The next generation of scenarios for climate change research and assessment, Nature, 463(7282), 747-756.

Osés Eraso, N., Foudi, S., Galarraga, I. (2012), Análisis del impacto socio económico del daño por inundación en la Ría de Nervión: un cambio de escenario ante la apertura del Canal de Deusto. Informe de Avance del Proyecto. BC3 Basque Centre for Climate Change, Bilbao.

Pappenberger, F., Beven, K., Horritt, M., Blazkova, S. (2005), Uncertainty in the calibration of effective roughness parameters in HEC-RAS using inundation and downstream level observations. J. Hydrol. 302, 46–69, *http://dx.doi.org/10.1016/j.jhydrol.2004.06.036*.

Rodríguez, A., Martínez, E., Guenaga, G. (2001), Uneven Redevelopment New Urban Policies and Socio-Spatial Fragmentation in Metropolitan Bilbao. Eur. Urban Reg. Stud. 8, 161–178, *http://dx.doi.org/10.1177/096977640100800206*.

Further Information
Policy and decision context of case studies
Description of adaptation options and their costs and benefits
Description of uncertainties associated with planned investments and incorporation in decision rules
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