Multi-hazard flexible climate change adaptation for port infrastructures

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INTRODUCTION

Ports are essential nodes for coastal and maritime transportation, being a key source of income and economic activities of coastal zones. This significance, jointly with their location in coastal areas, prone to climate-driven impacts, makes them highly susceptible to Climate Change (CC) and Sea Level Rise (SLR) effects. Therefore, consideration of CC induced variability is necessary within adaptation assessment frameworks, which evaluate the performance of both port services and assets under the affection of interacting climatic drivers.

However, although CC affection to port infrastructures is virtually certain, there are clear uncertainties on those changes' rates (Christensen et al., 2010) and the derived CC-impacts. New adaptation methodologies ought to be developed to hamper the effects of future's unpredictability. Including flexibility (Wilby & Dessai, 2010) within adaptation strategies is emerging as an effective solution, as they allow to stablish a portfolio of diverse adaptation measures (Haasnoot et al., 2012) that might be applied only when and where necessary. These approaches combine a full probabilistic CC risk assessment with the characterization of a portfolio of adaptation measures, alongside with the definition of a coherent monitoring strategy of the climate drivers and derived impacts that may pose the highest threats to the evaluated infrastructures. Thus, a robust tool for port planners and decision makers is developed to define which climate variables ought to be followed and which set of actions may be performed to guarantee the infrastructure's performance in an uncertain future climate.

METHODOLOGIES AND STUDY CASE

Against this backdrop, the authors propose a new methodological framework of climate change adaptation for port infrastructures. Firstly, it develops a multi-hazard CC risk assessment (following IPCC, 2022 risk framework and considering waves, sea level and currents as the main climatic hazards) that accounts for climate compound effects. Criticality of port infrastructures is modelled in a full probabilistic framework (characterizing CC and SLR following two different RCP scenarios and several RCM models and SLR levels) considering impacts on protecting and berthing structures, port equipment and the harbored services. Then, it defines a portfolio of feasible, flexible and cost-effective measures combinations (adaptation options), characterizing their effectivity in reducing CC derived impacts. The proposed methodology is applied in four cases in the north coast of Spain, as depicted in Figure 1 for Ribadesella port (Spanish North coast): an urban port lodging a riverine channel, a marina area; and a fishing area along the urban promenade with port equipment such as a dry dock, a crane and several buildings and warehouses.

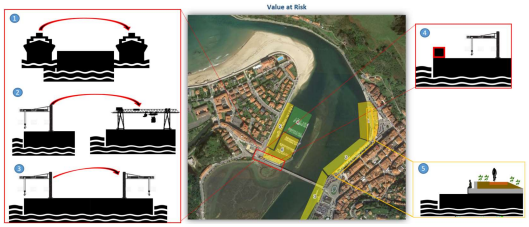

Figure 1 – CC-risk assessment and adaptation options portfolio for the Port of Ribadesella (Spanish north coast)

Finally, a series of climate drivers (wave heights, sea level values and wind gusts) are evaluated to characterize CC-derived impacts evolution (via driver-to-impact stress tests), setting a number of *thresholds for adaptation* (via an early-signal probabilistic analysis), allowing to act before it is too late. The result of the methodology is a flexible adaptation strategy plan (as shown in Figure 2 for the case study): a powerful tool for stakeholders and policy makers that provides them with the climate variables to monitor in the coming years. It is developed in combination with a flexible plan that allows managing and allocating reserves for future actions. The plan is designed to be updated regularly in the future according a monitoring plan, which reports the trend of the climatic drivers variation or the maladaptation of the designed and implemented measures.

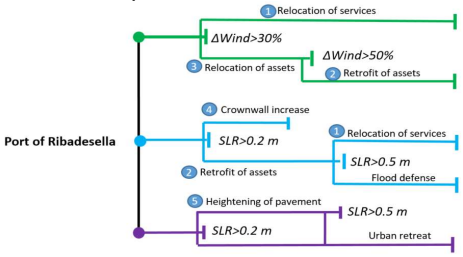

Figure 2 – Flexible adaptation strategy for the study case

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