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D6.6- Historical 'as-if' cash flow diagrams according to all strategies developed

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VERSION MANAGEMENT

Revision table			
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V 0.1	Simona Denaro (RED),	24/06/2024	First draft
V 0.2	Gianbattista Bussi (RED), Paola Ceresa (RED)	24/06/2024	Updated draft internally reviewed
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V 1.0	Iulia Anton (ATU), Salem Gharbia (ATU)	30/06/2024	Final version
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LIST OF ACRONYMS AND ABBREVIATIONS

Acronym / Abbreviation	Meaning / Full text
AAL	Average Annual Loss
AAP	Average Annual Affected Population
RAAL	Residual Average Annual Loss
CCLL	Coastal City Living Lab
EBA	Ecosystem-Based Approach
JRC	European Commission's Joint Research Centre
RCP	Representative Concentration Pathways
DSS	Decision Support System

BACKGROUND: ABOUT THE SCORE PROJECT

SCORE is a four-year EU-funded project aiming to increase climate resilience in European coastal cities.

The intensification of extreme weather events, coastal erosion and sea-level rise are major challenges to be urgently addressed by European coastal cities. The science behind these disruptive phenomena is complex, and advancing climate resilience requires progress in data acquisition, forecasting, and understanding of the potential risks and impacts for real-scenario interventions. The Ecosystem-Based Approach (EBA) supported by smart technologies has potential to increase climate resilience of European coastal cities; however, it is not yet adequately understood and coordinated at European level.

SCORE outlines a co-creation strategy, developed via a network of 10 coastal city 'living labs' (CCLLs), to rapidly, equitably and sustainably enhance coastal city climate resilience through EBAs and sophisticated digital technologies.

The 10 coastal city living labs involved in the project are: Sligo and Dublin, Ireland; Barcelona/Vilanova i la Geltrú, Benidorm and Basque Country, Spain; Oeiras, Portugal; Massa, Italy; Koper, Slovenia; Gdansk, Poland; Samsun, Turkey.

SCORE will establish an integrated coastal zone management framework for strengthening EBA and smart coastal city policies, creating European leadership in coastal city climate change adaptation in line with The Paris Agreement. It will provide innovative platforms to empower stakeholders' deployment of EBAs to increase climate resilience, business opportunities and financial sustainability of coastal cities.

The SCORE interdisciplinary team consists of 28 world-leading organisations from academia, local authorities, RPOs, and SMEs encompassing a wide range of skills including environmental science and policy, climate modelling, citizen and social science, data management, coastal management and engineering, security and technological aspects of smart sensing research.

EXECUTIVE SUMMARY

In the context of the project activities of WP6, entitled "Strategies to increase the financial resilience of coastal cities", this document briefly describes the contents of D6.6 "Historical 'as-if' cash flow diagrams according to all strategies developed". The data provided, in conjunction with the DSS tool (D6.7), serves decision makers in Massa, Vilanova i la Geltrú, and Oarsoaldea CCLLs by helping them evaluate and choose among different financial resilience strategies to manage flood related financial risk.

LINKS WITH OTHER PROJECT ACTIVITIES

The present Historical 'as-if' cash flow diagrams demonstrator (D6.6), together with the accompanying Decision Support System (DSS) tool (D6.7), were developed concurrently in the context of WP6's Task 6.4. Task 6.4 develops financial resilience strategies aimed at managing the financial risk related to floods (both fluvial and coastal) for the three frontrunner CCLLs (Massa, Vilanova i la Geltrú, and Oarsoaldea). This task will provide input to Task 6.5, which will produce a set of risk management decision support guidelines for policymakers. Task 6.4 is linked to the previous Task 6.3 and the results previously produced by WP6, namely the flood risk and residual flood risk profiles.

The flood risk model used to estimate both losses and residual losses, utilized initial information on the elements and exposure characteristics of the CCLL frontrunners provided by WP2 and derived from their "CCLL questionnaires". The hazard maps used to estimate losses were provided by WP3. Additionally, the development of the Ecosystem-Based Approaches (EBAs) was a collaborative effort involving the frontrunner CCLLs and WP7.

CONTENT OF DELIVERABLE D6.6

The files in this demonstrator compose D6.6 of the SCORE project, entitled "Historical 'as-if' cash flow diagrams according to all strategies developed". The D6.6 zip file is located on Zenodo, under, D6.6, SCORE community.

1.1. INTRODUCTION

All climate and temporal scenarios considered in the development of the risk profiles were described and presented in D6.4 "Residual risk assessment report for the frontrunner CCLLs ", and D6.5 "Risk profiles for the frontrunner CCLLs" both delivered in June 2024. A more comprehensive description of the methods and results obtained in Task 6.4 will be provided in Report D6.8 Financial strategy and guidelines for CCLLs, due M44.

In this context, the present document, entitled "Historical 'as-if' cash flow diagrams according to all strategies developed", briefly describes the datasets included in this demonstrator and their potential use for decision support. Task 6.4 involved the development of layered financial risk management strategies. These strategies comprise of risk retention mechanisms, such as a reserve fund for high-frequency, low-impact risks, and risk transfer mechanisms, such as insurance or parametric insurance, for low-frequency, high-impact losses.

Several parameters define these strategies. For instance, determining the optimal size of the reserve fund is essential to ensure it effectively covers high-frequency losses while remaining economically viable. Additionally, decisions regarding the extent of insurance coverage, which involves determining how much risk to transfer to an insurance company, are crucial. This process is complex, considering both monetary costs and socio-economic impacts. For instance, the unavailability of critical infrastructure after a flood event can significantly disrupt economic activities and social well-being. Ensuring financial coverage for prompt repairs and assistance extends beyond financial considerations, having substantial implications for the city's resilience and functionality. Therefore, considering the socio-economic and political dimensions is crucial for city officials when selecting the most appropriate strategy. For this reason, the strategies were designed to optimize two different objectives: minimizing the total cost of the strategy and minimizing the Residual (uncovered) Average Annual Losses (RAAL). The result is a set of Pareto optimal alternatives. In this context, a Pareto optimal solution refers to a scenario where no objective can be improved without worsening another. The following section illustrates the methodology that was implemented to design the optimal strategies.

1.2. METHODOLOGY

To derive a set of Pareto optimal alternatives, we conducted a simulation-based Multi-Objective (MO) optimization using a 20,000-year Monte Carlo simulation. This method employs random sampling to model and analyze the impact of uncertainty across different scenarios, allowing for a thorough evaluation of each strategy's performance. In this context, the Monte Carlo simulation helps identify the best strategies by simulating thousands of potential outcomes and balancing multiple objectives. The process was organized as follows:

1.2.1. Dataset Preparation:

We generated a Monte Carlo dataset, comprising 20,000 years of stochastically independent and identically distributed realizations.

The first step involved fitting the simulated loss data points, which delineate the risk curve from Task 6.3, to an appropriate distribution. Several potential distributions were tested (see Figure 1), and the best-performing one, the Piecewise Cubic Hermite Interpolating Polynomial (PCHIP), was selected. Using this distribution, we generated 20,000 years of synthetic data to ensure a comprehensive and robust dataset for the Monte Carlo simulation.

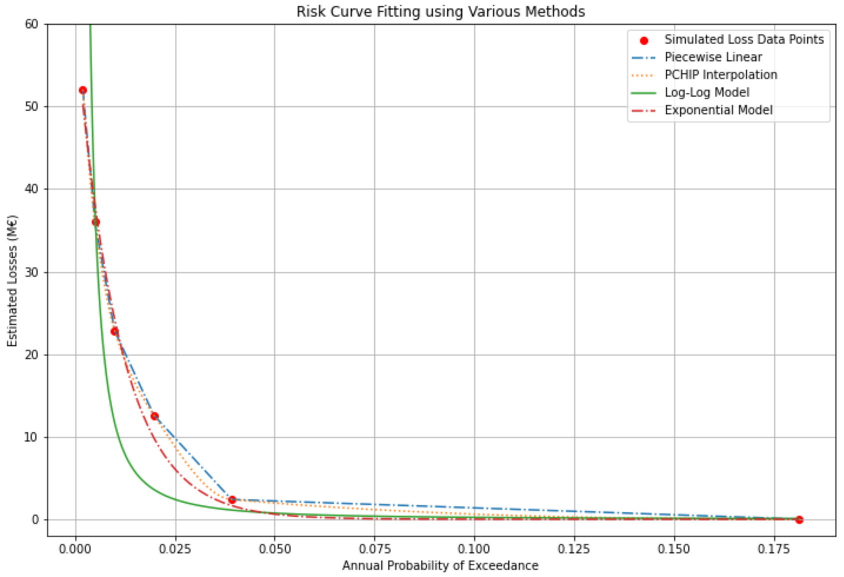

Figure 1. Risk Curve Fitting

This dataset is the historical as-if cash flow data from the "business as usual" scenario (scenario before the implementation of any financial strategy) and it provides the baseline financial losses that the strategies are intended to manage.

This dataset serves as input to the optimization and was organized into 1,000 realizations, each spanning 20 years, enabling us to assess the performance of strategies over short to medium-term horizons.

1.2.2. Optimization Objectives:

The optimization aimed to minimize two primary objectives:

1. **Total Financial Strategy Cost**: This includes the insurance loading (the actual cost of insurance policies) and the opportunity cost of the strategy. Opportunity cost refers to the value of the best alternative use of resources, such as investments, that are forgone by allocating liquidity to the reserve fund and/or insurance premiums.
2. **Average Annual Residual Loss (AARL)**: This measures the losses that remain uncovered after the implementation of the strategy, which has significant socio-economic and political implications. Minimizing AARL is crucial to ensuring the strategy effectively mitigates residual risks.

1.2.3. Optimization Variables:

The key decision variables optimized in this process included:

1. The allocation of the yearly budget between reserve fund intake and insurance premiums.
2. The percentage of risk transferred to a third party through insurance (insurance ceding).
3. The thresholds such as insurance deductibles and exhaustion points. These variables define the layered financial risk management strategy, determining the balance between immediate liquidity and long-term financial stability.

1.2.4. Constraints:

The optimization was constrained by the total yearly budget allocated for the strategy. This constraint ensures that the strategies are financially feasible within the available resources.

1.2.5. Optimization:

The simulation based multi-objective optimization (MO) problem was solved using an evolutionary algorithm (NSGAII). In solving MO problems, evolutionary algorithms are highly effective, drawing inspiration from natural evolution processes like selection, crossover, and mutation. These algorithms begin with a diverse set of potential solutions, each representing different combinations of decision variables such as budget allocation between reserve funds and insurance premiums.

To assess each solution, the algorithm evaluates its performance 1,000 times across a 20-year horizon, focusing on minimizing the total financial strategy cost and the Average Annual Residual Loss (AARL) in each scenario. The best-performing solutions are selected to form the next generation, mimicking natural selection. Through crossover, parts of selected solutions are combined to create new ones, mixing and matching traits to potentially produce better outcomes. Mutation introduces small random changes to maintain diversity and explore new areas in the solution space.

This process of selection, crossover, and mutation is repeated over many generations, with the population of solutions gradually improving. The algorithm converges towards the Pareto front, representing a set of optimal solutions where no single objective can be improved without worsening the other. For our problem, this means finding the best trade-offs between minimizing financial costs and residual losses.

Evolutionary algorithms excel in handling complex, nonlinear relationships between variables and provide a diverse set of high-quality solutions. This allows us to identify the most effective financial risk management strategies, making informed, robust decisions in the face of uncertain future scenarios.

1.2.6. Pareto Optimal Solutions:

Solutions on the Pareto front (see Figure 2) represent optimal trade-offs between minimizing the total strategy costs and AARL. Ideally, the most favourable solutions are positioned in the lower-left corner of the Pareto front, indicating strategies with both low insurance costs and minimal residual losses. Solutions above the Pareto front are considered suboptimal within our defined criteria, while those below are deemed unfeasible or beyond computational limits or the problem definition. A number of solutions (20) were homogeneously sampled from the optimal front for further analysis and comparison. Cashflow diagrams and attributes/parameters of each sampled strategy are included in the deliverables and can be interactively explored via the DSS tool (D6.7).

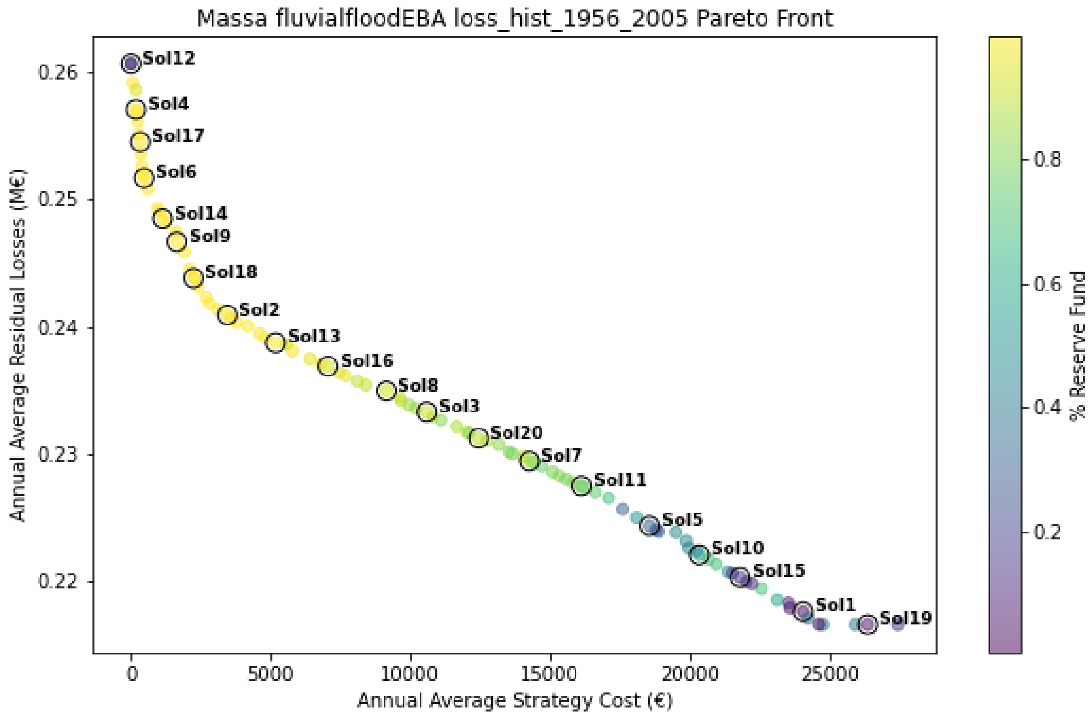

Figure 2. Example of Pareto Front and sampled solutions

1.3. CASH FLOW DIAGRAMS

The cash flow diagrams, therefore, include 20,000 years of data for both the baseline "business-as-usual" and each optimal strategy on the Pareto front identified under a certain scenario. The cash flow data is organized in 20-year segments. These diagrams report simulated losses, residual losses (post-strategy implementation), and strategy costs.

Specifically, the delivered folder contains the baseline option cashflow for all cities and climatic and temporal scenarios and all sampled optimal strategies on the Pareto front in the fluvial flood EBA scenario. For each combination of city and scenario, the cashflow data is organized as follow:

- 20,000 years of simulated losses for the baseline option of no financial strategy (organized in 1000 20 years scenarios)
- 20,000 years of annual residual losses for each sampled optimal strategy (organized in 1000 20 years scenarios)
- 20,000 years of yearly financial strategy costs for each sampled optimal strategy (organized in 1000 20 years scenarios).

These values determine the objective metrics of each strategy and their position along the Pareto front, allowing for further evaluation of each approach. The DSS tool (D6.7) indicates the location of the cash flow diagram for each selected strategy, facilitating detailed analysis and decision-making.

1.3.1. Contents of the deliverable folder

The D6.6 folder contains the following subfolders:

Baseline_losses

- **Description:** This subfolder contains .csv files with 20,000 stochastically independent and identically distributed loss realizations.
- **Purpose:** It represents historical cash flow data from the "business as usual" scenario, before any financial strategy was implemented. This dataset provides baseline financial losses that the strategies aim to manage.
- **Structure:** The data is organized into 1,000 realizations, each covering a span of 20 years, allowing for the assessment of strategy performance over medium to long-term horizons.

Strategies_Cashflow

- **Description:** This subfolder contains subfolders for each combination of city and climate/temporal scenario for the peril fluvial flood EBA.
- **Content:** Each subfolder includes an .xlsx file corresponding to each relevant optimal solution.
- **Details:** The .xlsx files display each strategy's "annual residual loss" and "annual cost" across 1,000 simulation scenarios, each lasting 20 years.

curve_fitting_figs

- **Description:** This subfolder contains .png files that show the curve fitting of loss data points to the distribution used for generating the baseline loss realizations.
- **Purpose:** These images visualize how the loss data points were fitted to a distribution, providing insight into the baseline losses.