RESCCUE – Lisbon research site

1. Context

The RESCCUE project (RESilience to cope with Climate Change in Urban arEas, www.resccue.eu) was born in May 2016. It was Europe's first large-scale innovation and urban resilience project, aimed at improving the capability of cities to anticipate, prepare for, respond to, and recover from significant multi-hazards.

The RESCCUE approach turned a new page by leaving sectorial approaches behind, and considering cities as networks of interdependent systems. The four-year project went beyond the conventional analysis of the impacts of climate change on single critical infrastructures, such as energy, water or transportation. RESCCUE's perspective is holistic, focusing on interconnections rather than on separate city units of the urban infrastructure networks.

The objective of RESCCUE was to produce a set of models and tools to analyse urban resilience based on a multisectoral approach, to overcome current difficulties related to lack of information integration of different urban services. To interconnect sectoral models, the project takes advantage of the RESCCUE tools and methodologies as the basis for further software developments able to support the assessment, management and planning of urban systems resilience in an integrated way.

The three cities included as pilot sites (Barcelona, Lisbon and Bristol) were the validation platforms of the RESCCUE tool, where integrated analyses of urban resilience were carried out during the project.

The resilience roadmap for these cities, in the form of a Resilience Action Plan (RAP), was one of the key results of the project. Produced at the very end, each presented the strategic lines on which the city must focus, considering also the concrete measures that will be applied to solve specific problems. Nonetheless, these results not only aim at providing an overview of the resilience building in Barcelona, Bristol and Lisbon, but are also intended to help many other cities around the world build their capacity to adapt to current and future shocks and stresses.

Taking advantage of the Clarity CSIS platform, some of the RESCCUE results can be seen in the following sections, presenting the main maps for Lisbon with regards to Hazard, Vulnerability and Risks in the city:

2. Lisbon research site

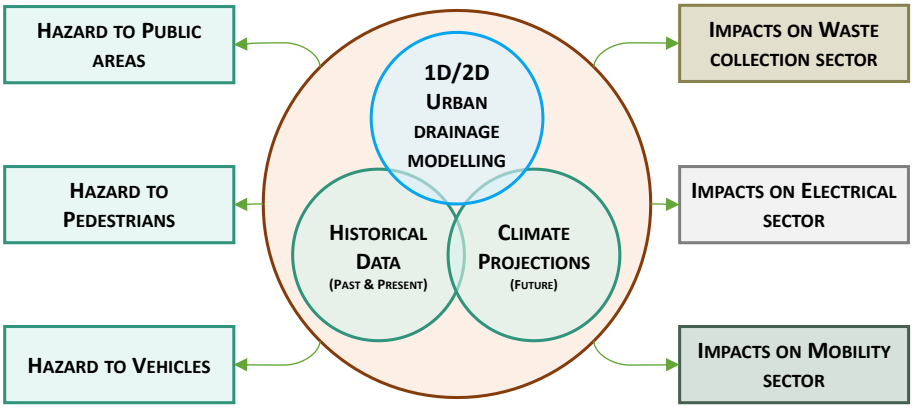
In the case of Lisbon, a comprehensive multi-hazard assessment was developed considering several sectors detailing the approach to hazards related to urban flooding. Risk identification and assessment in Lisbon included direct and indirect damages. Direct damages were estimated using the best data available using both qualitative and quantitative maps obtained by sectorial and integrated models. The information of this assessment was considered for the development of the Resilience Action Plan of Lisbon.

In this web-portal, hazard, vulnerability and risk maps for current (Baseline) and future (Business as Usual or BAU and Adaptation strategies) scenarios are presented. These

maps are related to sea level and rainfall induced flooding focused on the following potential hazards/ impacts/ city scale:

1 Hazards and impacts in public areas and to waste collection, electrical and mobility sectors (citywide)

2 Hazard to pedestrians and vehicles; hazards and impacts to waste collection, electrical and mobility sectors (downtown catchments)



1. **Hazards and impacts in public areas and to waste collection, electrical and mobility sectors (citywide)**

Context. General information on the objectives of the study, methodology adopted, geographical area of interest, participants, climate scenarios considered, impacts or risks of interest and possible target stakeholders.	
Objectives	The aim of this analysis is to define the flood risk areas, which could compromise people's safety and city functions continuity.
Geographical area of interest	Lisbon, Portugal
Climate scenarios	Current and future rainfall, estuary water level (sea level rise and storm surge)
Main participants	Maria do Céu Almeida, LNEC, Laboratório Nacional de Engenharia Civil Maria Adriana Cardoso, LNEC, Laboratório Nacional de Engenharia Civil Rita Salgado Brito, LNEC, Laboratório Nacional de Engenharia Civil Cristina Pereira, LNEC, Laboratório Nacional de Engenharia Civil Maria João Telhado, CML, Câmara Municipal de Lisboa Marco Morais, CML, Câmara Municipal de Lisboa João Barreiro, HIDRA, Hidráulica e Ambiente Ruth Lopes, HIDRA, Hidráulica e Ambiente
Impacts / Risks	Hazards and impacts for residents, buildings, road and rail network, transport hubs, wastes components and electricity infrastructure network.

Target Stakeholder	Lisbon City Council: used and considered in the development of the in the Resilience Action Plan of Lisbon. Local stakeholders, namely on services providers on electricity, transports and mobility, wastes, civil protection, urban planning, environment, among others.

Hazard. Climate variables and hazards considered in the study. As first step the relevant climate variables are selected and serve as a base to derive climate indices necessary for the hazard analysis. For each climate-related hazard one or more relevant indices, such as probability of occurrence, exceedances over threshold values, are identified. The indices are calculated for a defined climatic period and climate variables can be combined with other parameters to evaluate characteristics of more complex natural hazards, such as landslides or floods. Given a defined hazard scale, the hazard conditions in the project area can be quantified.	
Description of variables and indices.	Historical records and simulation results for used sewer capacity (simplified modelling approach).
Data sources	Data from Lisbon GIS database and drainage masterplan (Lisbon city council)
Scale of work or resolution	City scale, Lisbon, Portugal
Methodology	1D GIS model
Uncertainty	-
Maps description	Hazards maps representing proxies of levels of likelihood.
Projection and reference system	GCS: PT-TM06 / ETRS 89
Type	Licensed
License	Proprietary
Data set (Raster/shp)	Georeferenced raster format (set 1, see excel file)

Vulnerability. Vulnerability refers to the propensity of exposed elements (such as human beings, their livelihoods and assets) to suffer adverse effects when impacted by hazard events. Refers to the inventory (and values) of elements that are present in areas in which hazardous events (floods in our case) may occur and can be adversely affected (potentially damaged or disrupted) by those events. These values depend on the presence of people, livelihoods, species or ecosystems, environmental services and resources, infrastructure, or economic, social, cultural assets in places that could be adversely affected (IPCC, 2013). On the other hand, susceptibility (or sensitivity) is the degree to which the system is affected, depending on the own intrinsic characteristics of its exposed elements within the area in which hazardous events may occur, while the adaptive capacity of a system is its ability to endure any perturbation, like floods maintaining significant levels of efficiency in its social, economic, environmental and physical component.

Description of vulnerable elements.	Residents, buildings, road and rail network, transport hubs, wastes components and electricity infrastructure network. Deliverables: D2.4 (Russo, B., Sunyer, D., Locatelli, L., Yubero, D., Vela, S., Martínez, E., Martínez, G., Palau, A., De Prada, M., Dominguéz, G., Almeida, M.C., Telhado, M., Morais, M., Coelho, L., Severino, M., Muñoz, M., Pimentel, N., Lourinho Alves, R., Cândido Silva, I., Alberto, P., Duarte, N., Louro, M., Carvalho, D., Rodrigues, B., Saldanha Matos, J., Ferreira, F., Lopes, R., Barreiro, J., Morgado, P., Dominguéz, J.L., Pardo, M., Duarte, M., Evans, B., Stevens, J., Chen, A., Djordjevic, S., Goodey, P., Jennings-Howe, A., Henderson, R. (2018). Multi-hazards assessment related to water cycle extreme events for current scenario (Public summary). D2.4 RESCCUE project (Public), 2018. D2.5 (Russo, B., Sunyer, D., Locatelli, L., Martínez, E., Almeida, M.C., David, L. M., Telhado, M., Morais, M., Duarte, N., Lopes, R., Barreiro, J., Simões, J., Dominguéz, J.L., Sánchez, D., Pardo, M., Evans, B., Stevens, J., Goodey, P., Henderson, R. (2020). Multi-hazards assessment related to water cycle extreme events for future scenarios (With adaptation strategies). D2.5 RESCCUE project (Public), 2020.
Data sources	Data from Lisbon GIS database and drainage masterplan (Lisbon city council)
Projection and reference system	GCS: PT-TM06 / ETRS 89
Scale of work or resolution	City scale; resolution is a function of base maps
Relationships	-
Functions / Tables	The classification scales adopted are explained in the maps and in D2.4 and D2.5.
Maps description	Maps representing vulnerability/exposure. Explained in each map provided and in D2.4 and D2.5.
Type	Licensed
License	Proprietary
Data set (Raster/shp)	Georeferenced raster format (set 1, see excel file)

Impact / Risk. The risk and impact assessment1 process work through taking into account the magnitudes and likelihoods of the impacts associated with the hazards identified previously. Evaluate exposure to climate hazards and assessing the significance of the assessed risks to the success of the project.	
Impact analysis	-
Risk Assessment	-
Uncertainty	-
Maps description	-
Projection and reference system	-
Type	-
License	-
Data set (Raster/shp)	-

Business as Usual (BAU) and adaptation options	
Business as usual scenario	Climate change scenarios were obtained by means of statistical spatial and temporal downscaling techniques on 20 future pluviometric series provided by 10 general atmospheric circulation models, forced by RCPs 4.5 and 8.5 scenarios, and previously validated for an historical control period (1976- 2005).
Adaptation options considered	CAS1: Adaptation of green infrastructure CAS2: Peak flow attenuation by construction of retention basins CAS3: Construction of new components in drainage system
Economical appraisal	A cost-benefit analysis has been conducted in the prioritization process for the adaptation scenarios.
Maps description	Current situation as baseline. The hazard and vulnerability/exposure maps, related to current situation and climate change scenarios, indicate potential increase of flood hazards (BAU) and localized reduction for each adaptation scenario.
Projection and reference system	GCS: PT-TM06 / ETRS 89
Type	Licensed
License	Proprietary
Data set (Raster/shp)	Georeferenced raster format (set 1, see excel file)

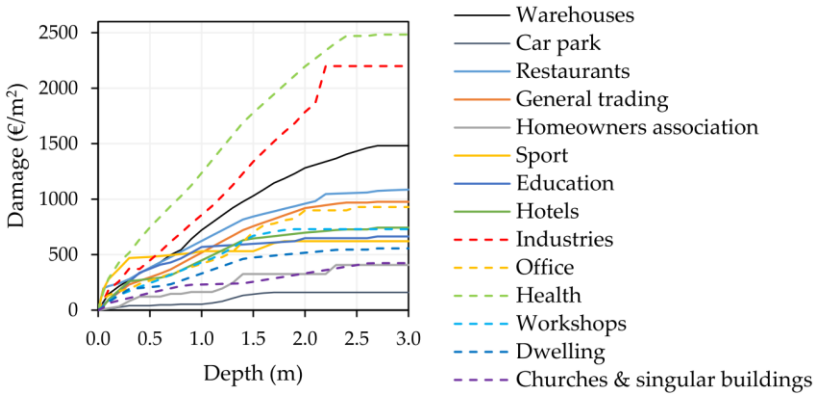
2. Hazard to pedestrians and vehicles; hazards and impacts to waste collection, electrical and mobility sectors (downtown catchments)

Context. General information on the objectives of the study, methodology followed, geographical area of interest, participants, climate scenarios considered, impacts or risks of interest and possible target stakeholders.	
Objectives	The aim of this analysis is to define the flood risk areas, which could compromise people's safety and city functions and services continuity, detailing for two Lisbon downtown catchments.
Geographical area of interest	Lisbon downtown catchments, Lisbon, Portugal.
Climate scenarios	Current and future rainfall and estuary water level conditions
Main participants	Maria do Céu Almeida, LNEC, Laboratório Nacional de Engenharia Civil Maria Adriana Cardoso, LNEC, Laboratório Nacional de Engenharia Civil Rita Salgado Brito, LNEC, Laboratório Nacional de Engenharia Civil Cristina Pereira, LNEC, Laboratório Nacional de Engenharia Civil Maria João Telhado, CML, Câmara Municipal de Lisboa Marco Morais, CML, Câmara Municipal de Lisboa

	João Barreiro, HIDRA, Hidráulica e Ambiente Ruth Lopes, HIDRA, Hidráulica e Ambiente
Impacts / Risks	Hazards and impacts for residents, pedestrians, buildings, road and rail network, vehicles, transport hubs, wastes components and electricity infrastructure network.
Target Stakeholders	Lisbon City Council: used and considered in the development of the in the Resilience Action Plan of Lisbon. Local stakeholders, namely on services providers on electricity, transports and mobility, wastes, civil protection, urban planning, environment, among others.

Hazard. Climate variables and hazards considered in the study. As first step the relevant climate variables are selected and serve as a base to derive climate indices necessary for the hazard analysis. For each climate-related hazard one or more relevant indices, such as probability of occurrence, exceedances over threshold values, are identified. The indices are calculated for a defined climatic period and climate variables can be combined with other parameters to evaluate characteristics of more complex natural hazards, such as landslides or floods. Given a defined hazard scale, the hazard conditions in the project area can be quantified.	
Description of variables and indices.	Flood water depth and overland flow velocity.
Data sources	Flood maps obtained from 1D/2D hydrodynamic model; Data from Lisbon GIS database and drainage masterplan (Lisbon city council)
Projection and reference system	GCS: PT-TM06 / ETRS 89
Scale of work or resolution	Downtown catchments J&L
Methodology	Simulation of scenarios with 1D/2D hydrodynamic model Pedestrian hazard rating: HR=d ×(v+0.5)+DF (d - water depth (m), v - overland flow velocity (m/s), DF - debris factor (Defra and EA, 2005), 4 classes, low C ≤ 0.75, moderate 0.75 < C ≤ 1.25, high 1.25 < C ≤ 2, very high C > 2; Vehicle hazard classes: F(flow depth D, flow velocity $\|\vec{v}\|$) (Martinez et al, 2017), 3 classes, low D ≤ 0.28 and $D \times \|v\| \leq 0.40$, moderate D ≤ 0.28 and 0.40 < $D \times \|v\| \leq 0.55$, high D > 0.28 or $D \times \|v\| > 0.55$ Other: overland flow level classes Department for Environment, Food and Rural Areas (DEFRA) (2005). Flood Risk Assessment Guidance for New Development. Phase 2 Framework and Guidance for Assessing and Managing Flood Risk for New Development – Full Documentation and Tools. Defra and Environment Agency. London: Defra - Flood Management Division. Martínez E., Gómez M., Russo B., Djordjevíc S. (2017). A new experiments-based methodology to define the stability threshold for any vehicle

	exposed to flooding. Urban Water Journal. Taylor & Francis. Vol. 14, No. 9, 930-939. DOI: 10.1080/1573062X.2017.1301501.
Uncertainty	-
Maps description	The hazard and vulnerability/exposure maps, related to current situation and climate change scenarios, indicate potential increase of flood hazards (BAU) and localized reduction for each adaptation scenario.
Projection and reference system	GCS: PT-TM06 / ETRS 89
Type	Public
License	Freeware
Data set (Raster/shp)	Georeferenced raster format (set 2, see excel file)

Vulnerability. Vulnerability refers to the propensity of exposed elements (such as human beings, their livelihoods and assets) to suffer adverse effects when impacted by hazard events. Refers to the inventory (and values) of elements that are present in areas in which hazardous events (floods in our case) may occur and can be adversely affected (potentially damaged or disrupted) by those events. These values depend on the presence of people, livelihoods, species or ecosystems, environmental services and resources, infrastructure, or economic, social, cultural assets in places that could be adversely affected (IPCC, 2013). On the other hand, susceptibility (or sensitivity) is the degree to which the system is affected, depending on the own intrinsic characteristics of its exposed elements within the area in which hazardous events may occur, while the adaptive capacity of a system is its ability to endure any perturbation, like floods maintaining significant levels of efficiency in its social, economic, environmental and physical component.	
Description of vulnerable elements. Vulnerability classes for all relevant element at risk types.	Elements at risk are people, buildings, transport infrastructures, wastes components. Depth-damage curves developed for Barcelona were used (See: Martínez-Gomariz, E., Forero-Ortiz, E., Guerrero-Hidalga, M., Castán, S., Gómez, M., 2020. Flood Depth–Damage Curves for Spanish Urban Areas. Sustainability 12, 2666. https://doi.org/10.3390/su12072666)
Data sources	Flood maps obtained from 1D/2D hydrodynamic model; Data from Lisbon GIS database and drainage masterplan (Lisbon city council)
Scale of work or resolution	Catchment scale; resolution is a function of base maps
Functions / Tables	

Maps description	Maps representing vulnerability/exposure. Explained in each map provided and in D2.4 and D2.5.
Projection and reference system	GCS: PT-TM06 / ETRS 89
Type	Licensed
License	Proprietary
Data set (Raster/shp)	Georeferenced raster format (set 2, see excel file)

Impact / Risk. The risk and impact assessment1 process work through taking into account the magnitudes and likelihoods of the impacts associated with the hazards identified previously. Evaluate exposure to climate hazards and assessing the significance of the assessed risks to the success of the project.	
Impact analysis	-
Risk Assessment	-
Uncertainty	-
Maps description	-
Projection and reference system	-
Type	-
License	-
Data set (Raster/shp)	-

Business as Usual (BAU) and adaptation options	
Business as usual scenario	Climate change scenarios were obtained by means of statistical spatial and temporal downscaling techniques on 20 future pluviometric series provided by 10 general atmospheric circulation models, forced by RCPs 4.5 and 8.5 scenarios, and previously validated for an historical control period (1976- 2005).
Adaptation options considered	CAS3: Construction of new components in drainage system
Economical appraisal	-
Maps description	Current situation as baseline. The hazard and vulnerability/exposure maps, related to current situation and climate change scenarios, indicate potential increase of flood hazards (BAU) and localized reduction for each adaptation scenario.
Projection and reference system	GCS: PT-TM06 / ETRS 89
Type	Public
License	Freeware
Data set (Raster/shp)	Georeferenced raster format (set 2, see excel file)