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JPI Urban Europe
Final Report for the General Public
Urban Transformation Capacities

1. KEY DATA OF THE PROJECT

SHORT TITLE	CREST
LONG TITLE	Climate resilient coastal urban infrastructures through digital twinning
PROJECT NUMBER	101003758
PROJECT PERIOD	01.04.2022 - 31.03.2025
PROJECT WEBSITE	www.crestproject.eu
KEYWORDS	Digital twins, climate change adaptation, urban infrastructure resilience, co-creation, participatory methodologies

2. EXECUTIVE SUMMARY

Climate change largely impacts urban life. Extreme temperatures have an impact on sea level rise and, subsequently, nefarious events such as floods, droughts and storms that have costly impacts on cities' basic services, infrastructure, housing, livelihoods and health. Cities are responsible for 75% of CO2 emissions, and so its stakeholders must come forward with out-of-the-box solutions to promote innovation and stimulate urban resilience by limiting the negative impacts of climate change. But for a problem to be addressed, it must first be seen and felt. Visualization is a potential way of increasing the engagement with climate change, and IT developments, such as Artificial Intelligence and Augmented Reality, provide significant advancements that can be transformative in engaging audiences with climate change issues. This is at the core of AugmentCity which developed a ground-breaking way to operate digital twins of cities, enabling data and "what-if" scenarios to be analysed and visualised in an interactive and immersive visualisation tool to be used by policy-makers, researchers, companies and citizens.

CREST built on AugmentCity and applied digital twins for demonstration, co-creation and mobilization of stakeholders for capacity-building and collective decision-making in 3 European urban areas for resilient urban infrastructure adaptation to climate change.

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3. PROJECT PARTNERS

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4. SUMMARY OF THE CONTEXT AND OVERALL OBJECTIVES OF THE PROJECT

Over the last years the planetary climate emergency has finally become socially widely admitted along with the urgency to adapt and react before the climate change effects have passed from being considered a scientific discussion to be a social priority with huge political implications. Following the previous declarations of several national and regional parliaments, the EU Parliament declared climate emergency in 2019. This stems from the sustained increase of the frequency of the climate-induced emergencies as floods, storms, wildfires, heatwaves and droughts in the last decades, particularly in coastal and statuary areas, resulting in numerous casualties and significant damages to communities in an unprecedented way. The problem has become more urging than ever being at the centre of the EU agenda and resulting in an agreement by EU leaders to reduce CO2 emissions by 55% until 2030, and the adoption of the EU's Climate Adaptation Strategy in 2021, which sets out a pathway toward a climate-resilient society by **strengthening preparedness and integrating climate risks into decision-making** processes.

This constitutes an ambitious objective that will not be possible to attain without innovation at both technical and governance levels, strong community and stakeholder engagement and regional leadership to trigger behavioural change and new ways of decision-making. Indeed, for a true change and appropriate urban transformation it is of critical importance that local and regional **sustainability and resilience strategies are**

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formulated with the involvement of all relevant stakeholders from across the public sector, private sector, academia and civil society (including concerned citizens) equipped with relevant knowledge and resources necessary to make the most fitting decisions for increased resilience. However, currently there is a **lack of sound methodologies for participatory planning** of sustainable and resilient city interventions, and **insufficient knowledge to unravel the growing complexity of cities or interpret big data** (a rising concern of city planners), indispensable for an impactful and well-grounded city planning. As also stated in the EC priorities (DestinE), it is of key relevance to give "access to high-quality information, models, scenarios, forecasts and visualizations" of the Earth to support sustainable development and environmental policy decisions.

The CREST project aimed to contribute to filling this gap by helping vulnerable urban areas to set-up and roll-out collaborative platforms supported by digital twinning (based on a breakthrough Augmented Reality – AR technology: AugmentCity) and co-creation approaches to support environmental decision making and innovative policy practices, enabling robust and resilient responses to climate change.

"A digital twin is a digital replica of a physical object, person, system, or process, contextualized in a digital version of its environment. Digital twins can help many kinds of organizations simulate real situations and their outcomes, ultimately allowing them to make better decisions"[1]. Digital twins can also be created from data from an entire city enabling users to visualise information at a city level or even at smaller geographical segments within a city.

CREST built on past experiences of partners and applied them in 3 urban areas particularly vulnerable to climate change, due to their coastal, or near coast location: Møre og Romsdal (Norway), Bordeaux metropolis (France) and Kołobrzeg (Poland). The urban areas share several commonalities, mainly due to their geographical positioning, while diverging in the specific challenges they face, deriving from their national/local political, economic, societal and scientific contexts. This exciting mix allowed the application of identical research methodologies in comparable urban settings, while obtaining diverse results and solutions with higher adaptability to further geographies across Europe. The short characterisation of these areas is presented below.

- **Møre og Romsdal** is a county on the west coast of Norway with over 9.000km of coastal line. Its topography and proximity to the ocean create challenges when it comes to infrastructure and climate change. Over the years, Møre og Romsdal has gained a lot of experience with serious events causing infrastructure damage (hurricanes, large landslides destroying infrastructure with subsequent tidal waves claiming many lives). The research in CREST focused on Kristiansund, a waterfront municipality with around 24,404 inhabitants located in the Møre og Romsdal county.

- **"Bordeaux Métropole"** is situated at the Gironde Estuary, 80 km upstream from the river mouth on the Atlantic. It is subject to a sea-river regime, undergoing both the influence of the rivers and the ocean. Its 18 municipalities are exposed to the risk of flooding. One third of the territory is located under the high waters of the Garonne and more than 40.000 people live in flood zones.

[1] https://www.mckinsey.com/featured-insights/mckinsey-explainers/what-is-digital-twin-technology

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- **Kołobrzeg** is a waterfront municipality located at the Baltic Sea, this region faces several climate risks. The Baltic Sea is rising 3-5 millimetres every year, which means it is expected that around the year of 2100 the sea level rise for the Polish coast is expected to be around 45-65 centimetres. This poses risks for the territory such as coastal erosion, floods, higher frequency and severity of storm floods conditions, among others. This increase has been noted since the 1970s, with tendency to celerity. It is also important to note that the consequences of sea level rise are not limited to coastal areas and can also cause flooding along the estuary zones dozens of kilometres inland.

To achieve the general project goals, CREST set the following specific aims:

- Develop and implement a monitoring and impact assessment framework to support the urban areas in assessing their sustainability and climate resilience performance
- Create graphical digital twins, giving users access to high-quality information, services, models, scenarios, forecasts and visualizations (e.g. in climate modelling) related to their urban areas, serving also as a tool for engaging local communities into co-creation activities and support their capacity building, deliberation and decision-making for more robust urban infrastructure capable of resisting climate threats/challenges
- Promote capacity building and co-creation for greater resilience of urban infrastructure, mobilizing and engaging local communities - decision makers, stakeholders, researchers/technologists, civil society and concerned citizens –from the 3 urban areas into a collective deliberation experiment to promote capacity-building and co-creation of solutions for strengthening urban resilience to climate change threats/challenges
- Develop pathways for the future uptake and replication of CREST results supporting the long-term sustainability and the future use of CREST solutions
- Broad citizen and stakeholder engagement for greater resilience and adaptation to climate change, increasing visibility and enhancing the capacity of communities related to climate change impacts, the importance of sustainability and resilience, and citizens and stakeholders´ role in these.

5. WORK PERFORMED AND MAIN RESULTS ACHIEVED

For proposing a **framework for monitoring sustainability and climate resilience** across the 3 urban areas, the initial research concentrated on identifying suitable sustainability and climate resilience key performance indicators (KPIs), which involved an extensive review of relevant grey and scientific literature. As a result, the United for Smart Sustainable Cities (U4SCC) evaluation framework, complemented by selected indicators from ISO DIS 37123, was deemed the most appropriate for the project's objectives. The selected indicators were compiled into data requirement tables to guide the verification and gathering of data availability in the project urban areas. Following the data collection, a **comprehensive visualization dashboard** using the U4SCC methodology was developed for each of these areas in a lollipop chart format to display the sustainability and resilience performance of each urban area according to the established KPIs. KPIs were converted into percentages of target achievement to better allow the performance visualisation, categorized by performance thresholds (33%, 66%, and 95%), and aggregated to generate scores at the category, sub-

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dimension, and dimension levels. Figure 1-3 illustrate the lollipops for each urban area. More information is on this available at: https://crest.pages.mia.inra.fr/dashboard/

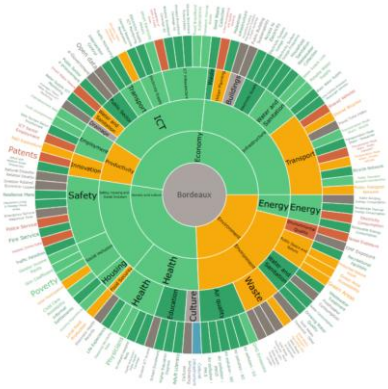

Figure 1: Bordeaux Métropole KPIs lollipop

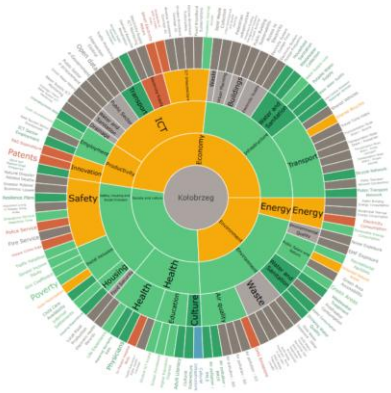

Figure 2: Kołobrzeg KPIs lollipop

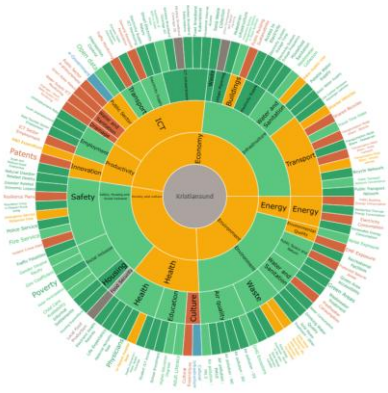

Figure 3: Kristiansund KPIs lollipop

Additional climate resilience KPIs that were deemed more specific /tailored to the local contexts of each of the 3 urban areas were also conceived later in the project. These KPIs are related to different themes and dimensions, such as mobility and transport (e.g. percentage of streets closed in case of flooding), infrastructure (e.g. storm sewer capacity per capita in flood-prone areas), building viability (e.g. percentage of ground floor apartments in flood-prone areas), emergency preparedness (e.g. average time of receiving notification from the public transport sector), and social resilience (e.g. percentage of buildings insured in case of flood in flood-prone areas).

In parallel to the sustainability and climate resilience assessment work, the **digital twins for the 3 urban areas were built** to be tested and validated in local settings in deliberation and co creation workshops. The research was driven by questions such as how the digital twins can aid /contribute to urban decision making related to climate change resilience and to what extent their use can result in different / better decisions than other / non digital tools (such as maps). The digital twin development started with the creation of the alpha versions of the 3 tools. This was a version with initial data on the 3 urban areas that laid the groundwork for later visualizing real-world challenges in a 3D interactive space. This alpha version advanced then into a beta stage (more advanced stage visualising more data) for each urban area, supported by additional data collection in the urban areas. Additional **data was collected via desk research and a citizen survey combined with a focus group session organised in each urban area.** The desk research first helped explore the state-of-the-art in regard to international, national and regional/local climate strategies and policy instruments to give an overview of the existing policy measures on climate mitigation, climate adaptation and related matters, as well as to identify concrete climate threats/challenges in the 3 urban areas and potential use cases that could serve as topics of debate at the future deliberation and co-creation workshops. Use cases were then specified and selected with the support of local citizens and professionals/stakeholders following a common participative methodology designed for the purpose, incorporating the online citizen survey (250 answers were received in the three cities) whose results were then consolidated in the 3 focus groups (1 in each city).

Through the above methods, 3 use cases were derived to be discussed at the subsequent deliberation and co-creation workshops:

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- For Poland, the use case encompassed flooding and how it would affect local allotments, issues related to social resilience, and green-blue infrastructure development to help resist to potential flooding;
- For Norway, it concerned Kristiansund and the problem of losing connection to the mainland due to extreme weather events;
- In the case of France, the use case was linked to river flooding and its impacts on the city of Bordeaux.

The use cases allowed the CREST team to create **scenarios** around which the discussions would be structured at the deliberation and co-creation workshops. Figure 4 present images of the beta version of the digital twin used at the Kristiansund workshop. The first image indicates the scenarios that were discussed and served as a basis for co-creating solutions.

Figure 4. Kristiansund digital twin images

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For implementing the workshops, the design thinking method was applied (The Charrette method), with a subdivision of a "digital group" and a "control group". This meant that in each city 2 deliberation and co-creation workshops were organised, one supported by the digital twins and a control workshop supported by non-digital tools, such as maps. Both workshops discussed the same use cases and related scenarios. Establishing two types of groups was critical in comparing the results of the two groups and deriving conclusions on the use of the digital twins in comparison with other tools. 6 workshops were organised in total. Figure 5 and 6 present images from both workshops in Bordeaux, France.

Figure 5. Digital workshop in Bordeaux

Figure 6. Control workshop in Bordeaux

Based on the results of the deliberation and co-creation experiments, a **citizen science for urban resilience guidebook** was also elaborated providing a **universal model (MOST model) for the cooperation between urban stakeholders on climate resilience issues supported by digital tools.**

Several improvements were made in the digital twins during the course of CREST resulting in the final versions of these tools. Ones of these is accessibility of the digital twins via a web-based interface (SaaS), eliminating the need for local installation and enabling easier access even on devices with restrictive IT policies or limited hardware. All three city-specific digital twins and their climate risk datasets are now available through this platform successfully used in the deliberation and co-creation workshops with participant feedback informing future improvements.

CREST project and its results were presented in a range of events (e.g. Smart Cities Expo 2025, Urban Lunch Talk #38, Smart Sustainable Cities 2025: Pioneering Novel Frontiers For Green Urban Living Conference, CREST webinar…), in regular posts released on social media and other web platforms, and in other local communication channels (e.g. local newspaper), reaching around 50.000 citizens from accross Europe. CREST results´ future use was discussed and summarised in a sustainability plan.

The summary of CREST´s key results, accessible also via www.cresproject.eu, includes:

- A monitoring and impact assessment framework for sustainability and climate resilience based on 87 United for Smart Sustainable Cities (U4SSC) indicators combined elements from the ISO DIS 37123 framework.

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- U4SSC's sustainability and climate resilience KPIs and further additional climate resilience indicators developed for the 3 urban areas involved in the project
- A digital dashboard (lollipop) developed to visulise data collected according to the U4SCC framework helping CREST cities assess their performance in terms of sustainability and smart development
- Digital twins (alpha, beta and videos of the digital twin final versions) developed for and experimented and validated in the 3 urban areas involved in CREST
- A citizen science for urban resilience guidebook proposing a universal model of cooperation between various urban stakeholders, supported by digital tools to increase cities´ resilience to climate challenges

6. PROGRESS BEYOND THE STATE OF THE ART AND EXPECTED POTENTIAL IMPACT

The CREST project significantly advanced the state of the art in digital twin applications for urban sustainability and climate resilience by combining technical innovation with participatory processes. It introduced a fully **web-based digital twin platform** (SaaS), removing the need for local software installation and enabling broad access across devices with restrictive IT policies or limited hardware capabilities. This shift to cloud-based deployment, along with a new **Web User Interface** built from user feedback, allowed for intuitive management and sharing of datasets, scenes, and 3D assets, overcoming previous limitations in version control and collaboration. Functionality improvements—such as orbit mode stability, integrated timeline tools, enhanced camera and navigation controls, and unified scene and dataset management—greatly enhanced the user experience and responsiveness of the platform. These innovations were instrumental during the co-creation workshops, where stakeholders navigated realistic climate scenarios within the digital twins of the three cities. The CREST digital twin tools thus not only became more robust and scalable but also more effective as a medium for stakeholder engagement, scenario testing, and collaborative urban resilience planning.

Moreover, CREST's participatory approach—linking digital twin visualizations with co-creation workshops—pushed the boundaries of **how digital tools support stakeholder engagement and informed decision-making**. The combination of scalable technology, data-driven methodologies, and inclusive processes positions CREST as a reference model for future digital twin applications in urban governance and climate adaptation.

CREST has achieved and is expected to achieve **several impacts on a short term**. Following the deliberation and co-creation workshops, 14 in-depth interviews were conducted with stakeholders (professionals and citizens that participated in project activities) in Norway, Poland in France to receive their feedback on these events and on impacts that CREST generated on them as individuals and on their institutions. A major impact reported by the respondents was linked to **capacity increase**. In particular, respondents from all sites noticed a significant increase in the technical capabilities after taking part in the conducted activities, including the raising of awareness in the field of new technologies (in workshops in which digital twins were used). Respondents also reported that they strengthened their technical skills related to the interpretation of more complex visualisation models and achieved a better understanding of complex urban issues through the co-creation activities and the use of digital twins. The digital twin technology emerged as a versatile tool with

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wide-ranging applications, particularly valued for its ability to visualize complex information and scenarios. Respondents consistently noted the value of visualization in making complex data more accessible and understandable to diverse stakeholders. This ability of the digital twins is of key importance especially to urban authorities that got empowered though the use of these digital tools to visualize intricate scenarios, refine strategic urban planning, and ultimately support resilient infrastructure development.

In fact, the **digital twin technology was well-received across all sites**, with respondents seeing potential applications in various areas such as **urban planning and development, crisis management and emergency preparedness, healthcare planning and service optimization, energy management and sustainability planning, and citizen engagement & communication.**

Responses from stakeholders also demonstrated that the co-creation experiments not only **enhanced critical thinking** but also increased the ability of participants to **analyse multi-dimensional challenges** by incorporating multiple stakeholder perspectives. Respondents from Poland, France, and Norway reported appreciable improvements in understanding local flood risks, coastal challenges, and broader climate change impacts, as well as potential adaptation strategies.

Professionals & policymakers from all sites mentioned intentions to **apply approaches / insights from the deliberation and co-creation activities in their future work.** Apart from incorporating visual tools in communication and engagement projects and using the digital twin technology for scenario planning and decision-making processes in various sectors, these plans also included applying co-creation methods in citizen engagement initiatives. One manifestation of the project´s immediate impacts was an application filed by Norwegian stakeholders for research funding to visualize sea-beds and coastal areas using digital twin technology, with plans already in motion to extend these methods to tackle biodiversity and other environmental challenges.

Regarding involvement in policymaking and trust in decisions, there was a general trend across all sites that **stakeholders felt more involved in the policymaking process** after taking part in the deliberation and co-creation activities. However, the degree of involvement varied. In Poland for instance, stakeholders reported feeling more engaged and confident in their ability to contribute to local decision-making processes. In France, on the other hand, some respondents felt they were already involved before, but the activities reinforced their engagement. Regarding trust in decisions, most respondents across all sites reported an increase achieved through deliberation and co-creation processes, viewing them as more transparent and inclusive. Overall, **the co-creation activities fostered a sense of engagement and trust among the participants**, although the extent of involvement varied based on individual circumstances and prior experiences.

CREST is also expected to **influence not only urban decision-making processes** but also the contents of urban policies. **CREST has produced policy recommendations specifically addressing the Kristiansund municipality in Norway**. The recommendations were developed by the Møre og Romsdal Fylkeskommune, authority for the region where Kristiansund is located. It discusses the importance of a comprehensive communication plan that ensures citizens receive timely alerts and have clear guidelines on what actions to take before a crisis occurs. It also contains some further recommendations for the content of this plan regarding leveraging on Digital Twin (DT) technology for forecasts and scenario planning; establishing emergency hubs across the islands and key points in Kristiansund; and promoting local volunteer networks that assist vulnerable populations, among others. It is expected that some of these recommendations will

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be incorporated shortly in policy documents.

Long-term, CREST's outputs are expected to yield significant societal, economic, and environmental impacts.

- **Environmental impacts**: As urban authorities continue to leverage insights gained from co-creation activities and DT applications, they will enhance their ability to address long-term climate challenges, such as flooding, coastal erosion, and biodiversity loss. The integration of these technologies into urban planning processes will result in better adaptation measures for environmental hazards, contributing to more resilient urban ecosystems. For instance, public authorities in Gmina Kołobrzeg (Poland) and Kristiansund (Norway) have secured licences to continue utilizing DT platforms, thereby ensuring that the digital transformation of urban planning persists beyond the project's lifecycle and that these can contribute to conceiving more tailored climate adaptation responses at city levels.
- **Social impacts:** The co-creation activities facilitated by CREST have fostered greater civic participation, with citizens from all sites reporting increased involvement and trust in local policymaking. In the long term, this will lead to more inclusive and participatory governance, where citizens are actively involved in shaping their communities' futures. The uptake of the MOST model - A Hybrid Model for Building Urban Resilience created by CREST based on its experience gained through the project – will assist this process acting as a tool in enhancing public authorities´ capacities for engaging citizens in digitally enhanced decision-making processes, a development that underscores the project's legacy in participatory governance.
  Additionally, CREST and its policy recommendations will contribute to enhancing social resilience in the long term. Communities will be better equipped to respond to crises and disasters and vulnerable populations will be better assisted during emergencies.
- **Economic impacts**: The application of DT technology in areas such as urban development, energy management, and healthcare planning will stimulate innovation in various sectors. As stakeholders in Poland, Norway, and France apply these technologies to urban policymaking, they will unlock new economic opportunities, fostering the development of tech-driven industries and supporting the growth of smart city economies. In addition, the adoption of digital twin technology for urban planning, crisis management, and sustainability efforts will enable cities to optimize their operations, leading to cost savings over time. By reducing inefficiencies, managing resources more effectively, and preventing costly disasters through proactive scenario planning, municipalities will experience long-term economic benefits, including lower infrastructure and maintenance costs.

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7. OUTLOOK

The CREST project has laid a solid foundation for integrating digital twins into urban climate resilience planning. With the development of a fully web-based, user-friendly platform, the digital twin technology is now more scalable, accessible, and aligned with the needs of diverse stakeholders—from local authorities to citizens. The project has also demonstrated the value of combining technical modelling with participatory co-creation processes, bridging the gap between data-driven tools and human-centered decision-making. Moving forward, the outlook is promising for upscaling the approach to new cities and regions, refining indicators based on contextual needs, and embedding digital twins into real-time urban governance frameworks. There is also potential to integrate live data streams and AI-powered analytics for dynamic monitoring and forecasting.

Despite major progress, several questions remain open and present opportunities for further research and development:

- Data availability and harmonization: How can urban areas with limited or fragmented datasets be better supported in implementing sustainability and climate resilience monitoring?
- Proxy indicators and comparability: To what extent can the use of proxy indicators affect comparability across cities, and how can these proxies be validated?
- Sustainability of the digital twin platform: Who will maintain and update the digital twins post-project, and how can long-term funding and governance be ensured?
- Stakeholder engagement and impact: How do digital twin visualizations concretely influence public understanding and policy decisions in the long term?
- Institutional integration: How can the digital twin tool be effectively integrated into municipal workflows and decision-making processes?

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