URBAN AND REGIONAL DEVELOPMENT

FULL - Urban digital twin and scenario planning. Challenges and paths for exploration

Funded By	Centro Interdipartimentale FULL

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Context of the research activity	The research focused on the development of an Urban Digital Twin at the intersection of Urban Studies and Advanced Urban Energy Modelling. This interdisciplinary project aims to explore the current state of the art about the creation and application of digital models for sustainable urban environments, exploring how advanced modelling techniques can allow the simulation of complex urban phenomena, ranging from energy consumption patterns to climate resilience and spatial transformation. It investigates the technical dimensions of a digital twin, focusing on the interconnection between digital lakes, data extrapolation, and scenario simulation in a gaming-like setting to explore what-if scenarios for urban futures. The phd fellowship is based on the partnership between the Future Urban Legacy Lab and the Energy Security Transition Lab.
	The Urban Digital Twin is an advanced, virtual modelling of an urban system —an innovative framework designed to integrate a city's physical and digital infrastructures into a comprehensive model that can be simulated, analyzed, and modified in real-time. As cities continue to grow and evolve in complexity, the ability to predict, manage, and optimize urban systems becomes increasingly vital. The integration of real-world data with digital models offers an unprecedented opportunity to understand urban environments better, enabling city planners, decision-makers, and stakeholders to visualize and anticipate the impacts of urban interventions before they are implemented. This PhD fellowship will explore the operational challenges of an Urban Digital Twin (UDT) and the path for research development in several disciplines, focusing on advanced modeling, data extrapolation, and scenario simulation in a gaming-like setting. This project lies at the intersection of Urban Studies, Sustainability and Technological Advancements, offering an interdisciplinary approach that integrates the study of sustainable transition scenarios in urban spaces with cutting-edge digital tools. The fellowship will explore how the UDT addresses critical issues such as urban sustainability, resilience, infrastructure management, and climate change adaptation through the application of what-if scenarios that model potential futures for urban landscapes. This research will reflect on the role of digital lakes—large repositories of real-

Objectives	time urban data that are continuously updated and analyzed, to extrapolate trends, predict future conditions, and simulate possible scenarios to guide urban decision-making. The research explores how advanced modeling techniques can allow the simulation of complex urban phenomena, ranging from building energy use and distributed renewable energy production patterns to climate resilience and social interactions. By leveraging scenario simulations in a gaming-like setting, researchers will explore how to model alternative urban futures, through potential outcomes under different policy, environmental, and technological scenarios—allowing city planners to test the effectiveness of their decisions before making any actual changes to the physical environment. The overarching goal of this PhD project is to investigate how digital modeling can tackle real-world urban challenges by integrating scientific research with practical applications. The candidate will help create tools that enable stakeholders to visualize the potential impacts of decisions on urban systems, providing a way to enhance the sustainability and resilience of cities while improving their functionality and livability. The PhD candidate will be responsible for designing and developing the Urban Digital Twin models, integrating multiple types of urban data and creating sophisticated simulation tools that can be used to evaluate urban interventions. This includes: 1. Designing and Developing Digital Twin Models: o This will involve the integration of data from various sources, including geospatial data, sensor networks, and city databases. By blending these sources into a unified digital platform, the candidate will create a dynamic, real-time model capable of simulating different urban processes and systems, such as traffic flows, energy consumption, water management, and waste systems. 2. Collaborating with Experts from Multiple Disciplines: o The fellowship involves close collaboration with experts from urban studies, building physics and energy systems and networks, data science, environmental science. The candidate will work within a multidisciplinary team to explore the application of digital twin technologies for urban sustainability and resilience. Collaboration will also extend to understanding the broader implications of urban interventions and how digital modeling can help optimize resource usage and improve the quality of life in cities. 3. Applying What-If Scenario Simulations: o A key responsibility will be to develop and implement what-if scenario simulations to explore alternative futures for cities. This will include the application of digital twin models to assess the potential outcomes of various urban interventions, such as changes in land use, mobility systems, green infrastructure, or climate resilience measures. By simulating different urban futures, the candidate will help stakeholders understand the trade-offs and long-term impacts of different policy and planning decisions. 4. Engaging with Real-World Urban Challenges: o The research will address critical urban challenges such as climate change, sustainable urban mobility, and energy efficiency. By simulating future urban environments, the candidate will help to identify the most effective strategies for improving urban sustainability and resilience. This includes exploring how cities can adapt to rapidly changing environmental conditions, manage growing populations, and improve the efficiency of urban systems. 5. Contributing to Dissemination Activities: o As part of the fellowship, the candidate will contribute to the dissemination of research findings through academic publications, conference

	presentations, and other scholarly activities. Additionally, (s)he will collaborate on the development of tools and platforms that can be shared with practitioners in urban planning and policy-making. By developing and applying these digital models, the PhD candidate will play a crucial role in transforming the way urban environments are understood, planned, and managed, offering powerful tools to enhance the sustainability, resilience, and livability of cities worldwide.
Skills and competencies for the development of the activity	Urban Studies & Planning Knowledge, in particular, understanding of urban systems, sustainability and transition studies. Any sort of knowledge or experience in energy-related issues and implications for urban systems is not mandatory but will be considered with particular attention. Advanced Modeling & Simulation Skills, i.e. attitude in digital twin technology studies (spatial modeling, dynamic systems, agent-based models), and interest in what-if scenarios. Data Analysis & Integration, i.e. expertise in data management and integration, working with diverse datasets, and data visualization. Technological & Computational Proficiency, i.e. programming skills (e.g., Python, R, ..) and experience with simulation software. Knowledge or experience in the use of AI-based tools for data mining and data-driven model development is not mandatory but will be considered with particular attention. Interdisciplinary Collaboration & Communication, fast learning capabilities and strong analytical and critical thinking skills.