Coping with Uncertainty: A Data-Driven Approach for Adaptive Decision-making
The Copenhagen Cloudburst Strategy, and the Flood Hazards

Abstract (< 4000)

Urban planning is increasingly required to operate within contexts characterised by rapid, multiscale, and multidimensional transformations, intensified by the accelerating impacts of climate change. Cities are embedded in highly interconnected social, environmental, technological, and institutional systems, where climate-related hazards, particularly extreme precipitation events, introduce significant uncertainty into decision-making processes, demanding continuous reassessment of planning assumptions, tools, and governance mechanisms. In this context, traditional planning approaches struggle to adequately address risk, vulnerability, and long-term adaptation, highlighting the need for more adaptive, data-driven, and interdisciplinary frameworks capable of navigating uncertainty while ensuring equitable outcomes. This thesis investigates these challenges through an empirical focus on urban flash flooding in Copenhagen, a city that has developed one of the most advanced climate adaptation strategies in Europe. The research aims to develop a comprehensive adaptive planning framework capable of assessing, prioritising, and sequencing flood adaptation measures under varying future climate scenarios. The central research question addresses how emerging modeling technologies and risk-based methodologies can support the evaluation of adaptation strategies while accounting for uncertainty, resource constraints, and socio-environmental equity. Methodologically, the study integrates climate science, advanced flood risk modeling, and spatial analysis within a multisectoral planning approach. A detailed review of contemporary sewer-related flood risk assessment models establishes the state of the art and informs the development of a hydrodynamic and GIS-based simulation tool. This model evaluates localised flood risk by incorporating critical variables such as sewer network performance, land cover, soil absorption capacity, surface morphology, and the vulnerability of exposed urban assets. By explicitly accounting for infrastructure performance and spatial heterogeneity, the framework enables a more precise assessment of risk than conventional basin or regional-scale analyses. The framework is applied to a detailed case study of Copenhagen's Cloudburst Adaptation Strategy, including a comparative assessment of its preliminary and subsequent revisions. Simulation results demonstrate that inaccuracies in sewer capacity assumptions and insufficient monitoring can significantly undermine adaptation effectiveness, leading to inefficient allocation of economic resources. The analysis reveals that earlier strategy configurations outperformed later updates in terms of cost-benefit efficiency and risk reduction, underscoring the importance of robust modeling and continuous performance evaluation. Beyond technical assessment, the research situates adaptation as a spatial and institutional process shaped by governance structures, historical planning legacies, and equity considerations. Green and open spaces are examined not as isolated ecological elements but as integrated infrastructural systems capable of reducing vulnerability, particularly along mobility corridors. Throughout the analysis, equality and equity emerge as guiding principles, ensuring that adaptation benefits are distributed fairly across vulnerable populations. The proposed adaptive framework reframes uncertainty not as a limitation but as a generative condition for innovation. By embedding modularity, scenario-based decision-making, and continuous monitoring, the framework enables gradual, resource-aware implementation while remaining responsive to evolving climatic and urban conditions. Ultimately, this thesis contributes a replicable, data-driven approach to climate-adaptive urban planning, positioning adaptation as a dynamic, strategic process essential to resilient, and sustainable urban governance.