Integrating Nature-Based Solutions for Climate Adaptation: Lessons from Dutch Case Studies on Urban Transitions

Intégrer des solutions fondées sur la nature pour l'adaptation au changement climatique : enseignements tirés d'études de cas néerlandaises sur les transitions urbaines

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RÉSUMÉ

Les solutions fondées sur la nature sont de plus en plus reconnues pour leurs avantages dans de nombreuses transitions urbaines, notamment en matière d'adaptation au changement climatique, et sont rigoureusement intégrées aux politiques nationales et locales. Cependant, la coexistence de différentes transitions urbaines au sein d'un même environnement urbain engendre inévitablement des interactions entre les secteurs urbains, ce qui conduit à des compromis et des synergies à prendre en compte tout au long du processus de planification. Il est donc nécessaire d'intégrer les infrastructures bleues et vertes d'adaptation au changement climatique aux autres transitions urbaines, telles que l'énergie, la mobilité et l'économie circulaire. Si les objectifs et les politiques témoignent d'intentions claires, la mise en œuvre des mesures d'adaptation au changement climatique reste souvent limitée dans la pratique. Des recherches récentes menées à l'Université de technologie de Delft (TU Delft) ont identifié des facteurs contribuant à ce problème, en particulier la concurrence pour l'espace et le manque de collaboration intersectorielle. S'appuyant sur les enseignements de ces projets de recherche, cette étude vise à comprendre les conflits techniques et les lacunes organisationnelles qui jalonnent les processus de transition.

ABSTRACT

Nature-based solutions are increasingly being recognised for their benefits in numerous urban transitions, particularly climate adaptation, being rigorously incorporated into national and local policy. But as different urban transitions occur simultaneously in the same urban environment, interactions between urban sectors become inevitable, resulting in trade-offs and synergies to be addressed throughout the planning process. This calls for the integration of climate adaptive blue-green infrastructure with other urban transitions, such as energy, mobility, and circular economy. While targets and policies present clear intentions, the implementation of climate adaptation measures is often limited in practice. Recent research at the Technische Universiteit Delft (TU Delft) identified factors contributing to this issue, particularly competition for space and poor cross-sectoral collaboration. Drawing on knowledge from these research projects, this study aims to understand the technical conflicts and organisational shortcomings throughout the transition processes.

KEYWORDS

blue-green infrastructure, climate adaptation, integration, nature-based solutions, urban transitions

1 INTRODUCTION

1.1 Frontiers in Integrated Climate Adaptation

There is a paradigm shift in motion in urban planning towards cross-sectoral integration and nature-based solutions for more effective urban climate adaptation. Conventional planning approaches with siloed sectoral governance are no longer suited to handle the complexity required to retrofit interconnected urban infrastructures for climate resilience (Kuitert et al., 2024). Energy, mobility, circularity, and blue-green infrastructure (BGI) transitions are complex and intertwined processes requiring new alternative planning practices (Newton & Frantzeskaki, 2021). Recent research explored various strategies to facilitate this transition from urban design and research-through-design approaches to digital and technological tools and facilitating collaboration and public participation. The increasing need for integrating nature into urban environments prompted alternative strategies to create room for BGI via other urban transitions, particularly through reduced car dependency in urban mobility (Torkfar & Russo, 2023). Such approaches could help improve urban living, contribute to reaching climate goals, and make more effective use of available space.

Past studies identified various factors limiting the effective implementation of nature-based climate adaptation strategies. These factors can relate to tangible or intangible aspects of urban functioning, as described by Sádaba et al. (2025). Major limitations arise from the fragmentation of urban sectors, which fail to adequately cooperate on the intersections of their domains or avoid interaction with other sectors altogether to reduce complexity in their work (Newton & Frantzeskaki, 2021; Nieuwenhuis, 2023; van Alten, 2025). This siloed behaviour impairs climate adaptation at several stages of the planning and implementation process (Newton & Frantzeskaki, 2021), ultimately hindering effective integration. Kreijen (2023) attribute the absence of cross-sectoral collaboration in part to a "lack of uniform and integrated climate policy." Newton & Frantzeskaki (2021) stress the need for a unified platform facilitating collaboration between sectors and stakeholder engagement in a user friendly and timely manner. On the more tangible side, particularly in dense urban areas where available space is scarce, the effective implementation of nature-based solutions requires multifunctional and adaptable designs (Sádaba et al., 2024). Sádaba et al. (2025) bring attention to the inflexibility of urban infrastructures resulting from rigid planning solutions left over from a "pre-climate change era." They argue that conventional systems fail to encourage collaboration, struggle to respond to changes quick enough, and do not consider long-term adaptation. Further research was recently suggested on exploring the implications of integrating urban transitions through diverse sustainability projects at various spatial scales, particularly investigating the interaction of nature-based solutions with mobility, energy, and climate adaptation strategies (Kuitert et al., 2024; Torkfar & Russo, 2023). Addressing the above-described context, this research explores the question: *How can nature-based solutions for climate adaptation be integrated with other urban transitions?*

2 PRELIMINARY RESULTS

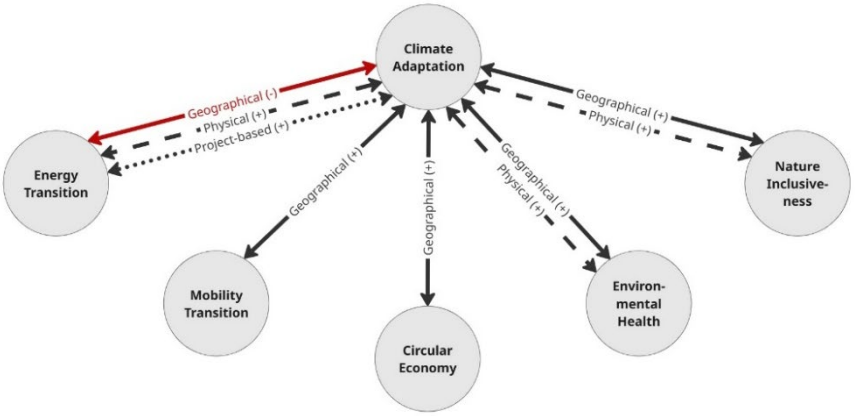
2.1 Research Projects at TU Delft

Following international climate agreements, the Dutch government has put in place national policies to guide municipal urban transition efforts concerning climate adaptation, energy and heat systems, mobility and transportation, environmental health, and nature inclusive planning (van Alten, 2025). Although overarching policies and visions set clear goals for municipal climate adaptation, the success of such projects varies significantly among Dutch cities, facing various challenges from planning to implementation (Hartog, 2023). As part of a longer running research theme at TU Delft, previous projects focused on urban transition interactions from perspectives relating to space use and planning process. Four master's thesis projects aggregated in this study include: *"Exploring possibilities for climate adaptation in context of the ongoing energy transition"* by Anke Merkx (2020), *"Climate Adaptation: Relating Policy, Tools, and Measures for the Public and Private Sectors"* by Noa Hartog (2023), *"Creating space for climate adaptation through shifting to green mobility"* by Kaj Kreijen (2023), and *"Navigating Climate Adaptation Through Cities in Transition"* by Marijn van Alten (2025).

2.1.1 Urban Transition Interactions

Research at TU Delft has explored interactions between urban infrastructures, aiming to understand the patterns, challenges, and opportunities that emerge during the integration of climate adaptation in cities working simultaneously on various urban transition processes. Van Alten (2025) examined in great detail (Figure 1) how

climate adaptation interacts with other urban transitions, highlighting key processes, trade-offs (-), and synergies (+) to be considered in project implementation. Positive geographical and physical relations (synergies) were found between climate adaptation and mobility transition, circular economy, environmental health, and nature inclusiveness based on mutually beneficial space or resource use and overlapping interests (van Alten, 2025). A complex relationship involving both trade-offs and synergies was identified between climate adaptation and energy transition due to mutually beneficial physical processes and the possibility of simultaneous



implementation, but with considerable competition for space (van Alten, 2025; Merkx, 2020).

Figure 1. Visual adaptation of the findings of van Alten (2025) based of the integration framework of Nieuwenhuis (2023).

2.1.2 Factors of Integrated Urban Climate Adaptation

The implementation of nature-based climate adaptation measures faces various challenges arising from the interactions of different urban functions and infrastructures sharing the same space. Space was identified by several studies as a major limiting factor for climate adaptation and BGI. Trade-offs between different urban transitions present a considerable challenge for implementation (Merkx, 2020). Such spatial interactions can occur both above-ground, such as between green space and car parking, and below-ground, such as between underground waste storage and various pipes and cables, shown in Figure 2 by Merkx (2020). Energy transition appears to compete the most with climate adaptation for space, requiring a careful assessment of risks and benefits during implementation (van Alten, 2025). Unique opportunities were also highlighted for the resourceful reallocation of space between urban sectors, particularly via mobility transition (Kreijen, 2023; van Alten, 2025).

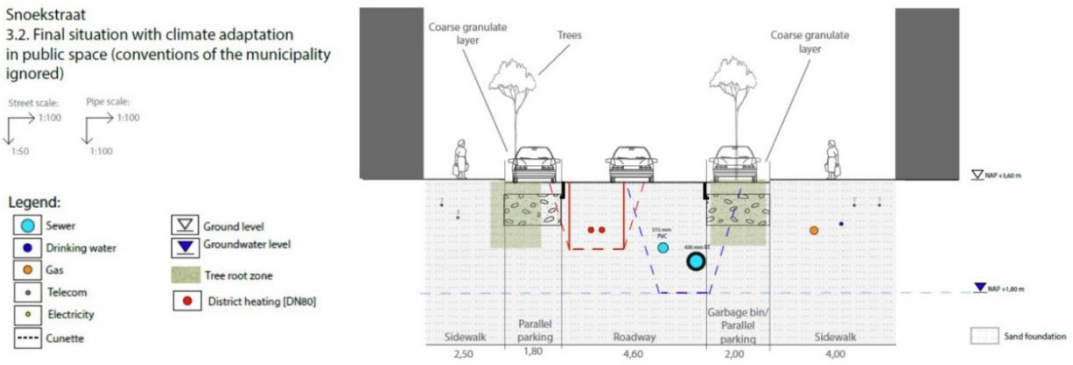


Figure 2. "Cross-sectional view of the Snoekstraat – Situation 3: final situation with possible climate adaptation measures in public space, conventions of Rotterdam ignored" (Merkx, 2020, p. 89.)

Further challenges discussed by previous literature relate to the inadequate or completely lacking cooperation of relevant actors. The effective integration of climate adaptation into urban infrastructures requires a comprehensive framework established via stakeholder collaboration enabling the simultaneous implementation of various urban transition goals (Merkx, 2020). Through analysing and modelling multiple study sites in Rotterdam, Merkx (2020) found that due to emerging trade-offs and increasing climate pressure, the integrated implementation of climate adaptation and energy transition goals was sometimes only possible through public-private collaboration or a break from planning conventions. However, van Alten (2025) highlights that actors needed to be involved in such collaborations sometimes specifically avoid interaction, hoping to maintain

simplicity, which significantly hinders integration. The complexities arising from newly formed interactions between urban infrastructures due to integration indeed create challenges for stakeholders working with distinct frameworks (Nieuwenhuis, 2023). Clearer governance and cross-sectoral collaboration are thus pivotal for the success of integrated climate adaptation.

The discrepancy between policy and implementation is another major obstacle for nature-based solutions and climate adaptation projects. Kreijen (2023) draws attention to a "lack of uniform and integrated climate policy" which hinders both cross-sectoral collaboration and the implementation of nature-based solutions. Recent studies identified various factors influencing the translation of policies into effective climate adaptation, including financial constraints, public-private divisions, understanding of climate impacts, and the incorporation of climate and biodiversity goals in public space policy (Hartog, 2023; van Alten, 2025). It is clear from these past studies that there are complex interactions between urban transitions, some setting obstacles, others presenting opportunities. Progressing from theoretically sound policies to successful implementation is hindered by various tangible (e.g., spatial limitations) and intangible interactions (e.g., shortcomings in cooperation). When bridging these gaps, interactions, impacts, goals, and responsibilities are important influencing factors to address.

3 CONCLUSION AND OUTLOOK

As nature-based solutions are recognised in planning practice and climate adaptation is incorporated into policy, cities begin transition processes requiring additional considerations for implementation. Multiple urban transitions occurring simultaneously can result in both supporting and conflicting goals between transitions. Recent research at TU Delft found climate adaptation having synergistic effects with most other urban transitions, with considerable opportunities regarding mobility transition, but substantial competition for space with energy transition efforts. While targets and policies are clear, shortcomings of cross-sectoral collaboration and implementation of climate adaptation measures hinder integration. Various aspects of long-term climate adaptability require further research, including the maintenance of BGI (Kreijen, 2023; Hartog, 2023), planning processes focused on adaptability (Nieuwenhuis, 2023), and evaluating and improving the performance of interventions (van Alten, 2025). The quantification of interactions between climate adaptation and other urban transitions and a tool focused on modelling them has yet to be developed (Merkx, 2020; Kreijen, 2023). The next stage of this research further investigates urban transition interactions from a blue-green infrastructure perspective, delving into the identified challenges and determining factors of effective integration.

LIST OF REFERENCES

Hartog, N. M. (2023). *Climate Adaptation: Relating Policy, Tools, and Measures for the Public and Private Sectors. A case study of six municipalities in the Netherlands*.

Kreijen, K. J. F. (2023). *Creating space for climate adaptation through shifting to green mobility*. https://resolver.tudelft.nl/uuid:15b36993-5ac9-4feb-99bc-5771fce704d8

Kuitert, L., Willems, J., & Volker, L. (2024). Value integration in multi-functional urban projects: a value driven perspective on sustainability transitions. *Construction Management and Economics*, *42*(2), 184–200. https://doi.org/10.1080/01446193.2023.2264969

Merkx, A. (2020). *Exploring possibilities for climate adaptation in context of the ongoing energy transition. A case-study of Rotterdam*. https://resolver.tudelft.nl/uuid:6b2b80bd-1566-475c-8ffa-09725db42300

Newton, P., & Frantzeskaki, N. (2021). Creating a national urban research and development platform for advancing urban experimentation. *Sustainability (Switzerland)*, *13*(2), 1–18. https://doi.org/10.3390/su13020530

Nieuwenhuis, E. M. (2023). *The end of the sectoral approach? Understanding the role of integration in urban water management*. https://doi.org/10.4233/uuid:4dbd0b57-c40c-4cc2-84a7-e47e000f1437

Sádaba, J., Alonso, Y., Latasa, I., & Luzarraga, A. (2024). Towards Resilient and Inclusive Cities: A Framework for Sustainable Street-Level Urban Design. *Urban Science*, *8*(4). https://doi.org/10.3390/urbansci8040264

Sádaba, J., Luzarraga, A., & Lenzi, S. (2025). Designing for Climate Adaptation: A Case Study Integrating Nature-Based Solutions with Urban Infrastructure. *Urban Science*, *9*(3). https://doi.org/10.3390/urbansci9030074

Torkfar, P., & Russo, A. (2023). Assessing the Benefits of Climate-Sensitive Design with Nature-Based Solutions for Climate Change Adaptation in Urban Regeneration: A Case Study in Cheltenham, UK. *Sustainability (Switzerland)*, *15*(22). https://doi.org/10.3390/su152215855

van Alten, M. (2025). *Navigating Climate Adaptation Through Cities in Transition. A Case Study of the Municipalities Almere, Lelystad, and Urk*. https://resolver.tudelft.nl/uuid:7a137042-c863-4b3c-9353-258f065d59aa