DOCTORAL CONSORTIUM

SAFEGUARDING PUBLIC VALUES BY DESIGN: A SOCIO-TECHNICAL APPROACH TO DIGITAL TWINS IN REGIONAL SPATIAL PLANNING UNDER THE ENVIRONMENTAL PLANNING ACT

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In the context of climate change and housing challenges, Digital Twins (DTs) are a promising technology. However, there is little experience regarding good use of this technology. This research proposal explores how DTs can safeguard public values in spatial planning under the Environmental Planning Act (Omgevingswet). Combining a socio-technical perspective with Value-Sensitive Design (VSD), the study focuses on integrating values into DT technology. Expected studies include identifying key values, designing a normative framework, and measuring its impact. This contributes to improved decision-making and spatial planning by regional governments.

Keywords:
digital twins,
public values,
spatial planning,
provincial government,
environment act

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1 Introduction

The Netherlands is facing multiple societal challenges, such as climate change, requiring adaptation to risks like flooding and heat stress. The housing market is strained by the demand for affordable and sustainable homes. Moreover, the transition to renewable energy and reduction of CO_2-emissions marks a major energy shift (IPLO, 2024b).

To help tackle these challenges, the Environmental Planning Act (Omgevingswet), effective from January 1, 2024, was introduced (Rijksoverheid, 2024). This law simplifies and combines environmental regulations, making it easier to address complex issues (IPLO, 2024a). It promotes an integrated approach to national environmental policy, crucial for addressing issues like housing. Provinces play a key role in translating national policies into regional actions, empowered by the Act to develop tailored environmental visions and plans.

Supporting this, digital twins (DTs) are increasingly used at the provincial level for spatial planning, providing dynamic, (real-time) digital replicas of physical systems. These DTs, enhanced by the Internet of Things and AI, offer predictive capabilities. For instance, the Municipality of Almere and the Province of Flevoland are experimenting with DTs in various applications (GEONOVUM, 2024), while the Province of Utrecht and the Province of South Holland use DTs for urban development (Provincie Utrecht, 2024) and the "Samen fietsen" project (Provincie Zuid-Holland, 2024).

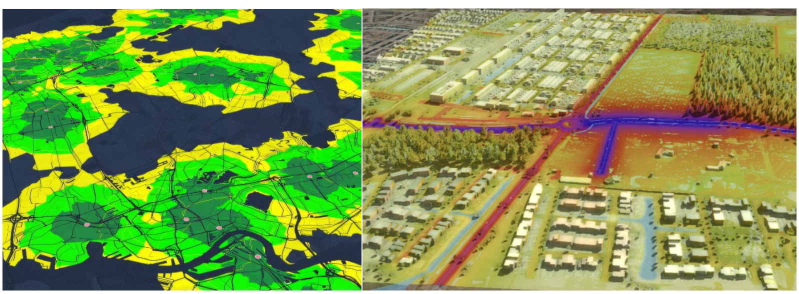

Figure 1: DT Example: Left: bike accessibility simulation, right: noise simulation

DTs also facilitate navigating the complexities of the Environmental Planning Act, modernizing the planning process through integrated decision-making and stakeholder collaboration (i.e., DTs can simulate policy impacts, helping policymakers make informed, balanced decisions). However, their deployment in complex environments poses challenges, particularly in aligning with public values (e.g., public safety). Misalignments can result in unfair outcomes, erode trust in decision-making, and provoke resistance to policy implementation. These risks highlight the need for a framework to align DTs with public values, preventing consequences like environmental damage, inequality, or inefficiency. (Friedman et al., 2013; Spiekermann, 2012).

Ignoring public values in spatial planning can have serious repercussions. A historical example is Robert Moses' parkway designs in New York, which restricted low-income and minority groups from accessing public beaches by designing low overpasses that buses couldn't pass through (Valentine, 2020). In the Netherlands, recent urban densification efforts aimed at accommodating population growth and maximizing land use have met resistance from residents (Claassens et al., 2020), who fear reduced public spaces, altered community dynamics, and deteriorating living conditions. This opposition underscores the challenge of aligning spatial development with community needs, highlighting the importance of incorporating public values into planning.

This research advocates operationalizing a socio-technical perspective (i.e., considers the interaction between people, technology, and the social environment) through Value Sensitive Design (VSD) to address these risks. VSD incorporates human values into technology development across conceptual, empirical, and technical investigations, ensuring ethical and societal considerations are integrated into technology design and usage (Friedman et al., 2013). This approach aims to create a normative framework that upholds public values in DT applications, promoting responsible technology adoption. Collaborations are arranged with partners, including the Province of Utrecht, Vereniging van Nederlandse Gemeenten (VNG), Data- en Kennishub Gezond Stedelijk Leven (DKH-GSL), and Netherlands 3D.

MRQ: What conditions are necessary for Digital Twins to safeguard public values by design in regional spatial planning under the Environmental Planning Act?

Sub-questions:

1. What public values emerge and how are they prioritized in regional spatial planning under the Environmental Planning Act? (**RQ1**)
2. What is the state-of-the-art in applying Digital Twins from a socio-technical perspective in regional spatial planning under the Environmental Planning Act? (**RQ2**)
3. How can a normative framework be designed to safeguard public values in the use of Digital Twins in regional spatial planning under the Environmental Planning Act? (**RQ3**)
4. How can this normative framework be implemented in regional spatial planning under the Environmental Planning Act? (**RQ4**)
5. How can the impact of the normative framework be measured and what effects does it have in regional spatial planning under the Environmental Planning Act? (**RQ5**)

3 Methodology and Expected results

The research has five studies: RQ1 explores public values, RQ2 reviews state-of-the-art DT, RQ3 designs a normative framework, RQ4 develops a code of conduct and prototype to operationalize the framework, and RQ5 tests its impact and effect, see the following figure:

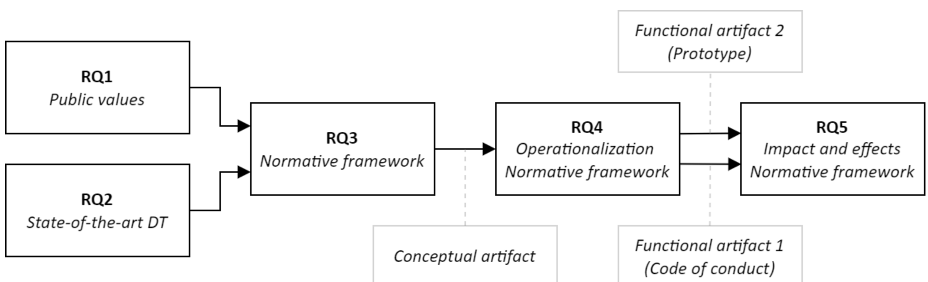

Figure 3: Research overview

Study 1 (RQ1): What public values emerge and how are they prioritized in regional spatial planning under the Environmental Planning Act?

The first study identifies and prioritizes public values (Bozeman, 2019; Jørgensen & Bozeman, 2007).

The identification of public values will use two methods. The first is a scoping review, following the framework outlined by Paré (2015), which will survey literature from the Netherlands and countries with similar (cultural) contexts at both conceptual and empirical levels. This phase aligns with VSD's *conceptual investigation*, uncovering stakeholders' values

Subsequent focus groups (Morgan, 1996) will include diverse stakeholders—civilians, policymakers, council members, and data scientists—who will first be asked to identify what they consider to be public values and elaborate on their meaning. To facilitate this discussion, we will use value scenarios, a proven VSD-technique (Friedman & Hendry, 2019). Participants will then prioritize public values using Q-methodology (Brown, 1996), a tool for collecting subjective data to capture diverse perspectives. This empirical phase will continue until data saturation is achieved, with findings validated by multiple senior researchers, aligning with the *empirical investigation* of VSD. This structured approach ensures a comprehensive understanding of public values into spatial planning initiatives.

Study 2 (RQ2): What is the state-of-the-art in applying Digital Twins from a socio-technical perspective in regional spatial planning under the Environmental Planning Act?

NASA coined DT technology in the 1960s, and it has advanced since (El-Agamy et al., 2024). Understanding the current state-of-the-art in DT technology and its application within this study's context is crucial. To achieve this, two methods will be used. First, a qualitative systematic review following Paré's (2015) methodology will be conducted. This approach will consult empirical sources and provide a narrative synthesis, examining DTs through a socio-technical lens to understand both technical and social dimensions.

Second, a survey based on Krosnick's methodology (Krosnick, 1999) will be administered to stakeholders to explore how DT technology is currently used. This survey will leverage the extensive network of the supervision team (DKH-GSL, VNG, Netherlands 3D, Province of Utrecht, and others) to ensure a broad and representative sample. The survey will gather data on current practices, challenges, and perceptions regarding DTs in regional spatial planning.

These methods offer a holistic view of DT technology and its socio-technical implications. The results will inform the design of a normative framework in subsequent research.

Study 3 (RQ3): How can a normative framework be designed to safeguard public values in the use of Digital Twins in regional spatial planning under the Environmental Planning Act?

The results of studies one and two will be integrated to develop a normative framework (we define a normative framework as the standards and criteria to which a technology must adhere), working from both a scientific knowledge base and a practical perspective, as outlined in Hevner's (2004) Design Science Research (DSR) model. Leveraging Peffers' (2007) interpretation of DSR, along with the results from studies one and two, the development process of the normative framework will start from the design and development-centered approach step.

Three methods will be employed: a scoping review, in-depth interviews, and focus groups. The scoping review will identify and analyse methods for building a normative framework. This review, part of the *conceptual investigation* phase of VSD, will draw from the academic and practical knowledge base to pinpoint successful principles and methodologies.

In-depth interviews with technical-ethical experts will explore how public values relate to the components of digital twins and how these values can be effectively incorporated into the normative framework. This step falls under the *empirical investigation* phase, focusing on understanding the value-technology relationship through empirical data.

Finally, focus groups with stakeholders will refine the initial draft of the normative framework. These groups will assess the alignment of design choices with the target audience and ensure the language used is clear and consistently interpreted. This phase aligns with the *technical investigation* phase of VSD.

This study will construct and refine the normative framework (conceptual artifact).

Study 4 (RQ4): How can this normative framework be implemented in regional spatial planning under the Environmental Planning Act?

Study four explores the operationalization of the normative framework developed in Study three, specifically for regional spatial planning under the Environmental Planning Act. The study focuses on advancing the normative framework into a code of conduct (functional artifact 1) and creating a prototype (functional artifact 2) for semi-automatically validating DTs. These developments occur within the Develop/Build phase as described by Hevner et al. (2004) and the Design & Development phase by Peffers (2007), in alignment with VSD principles.

The study consists of two main phases. The first uses focus groups Morgan (1996) to explore the application of the normative framework in regional spatial planning. Participants, including citizens, policymakers, and council members, will discuss how the framework can guide the manual validation of DTs, focusing on technology, process, and people. This socio-technical approach ensures a holistic examination of the framework's practical application, culminating in the creation of a code of conduct.

The second phase is the development of a prototype (functional artifact 2) for the semi-automatic validation of DTs, aimed at assessing their compliance with public values. Building on previous studies, the prototype will be developed in accordance with the phases outlined by Hevner et al. (2004) and Peffers (2007), this aligns with the *technical investigation* of VSD.

The goal is to produce both a code of conduct and a prototype for DT validation, both grounded in the normative framework established in previous studies.

Study 5 (RQ5): How can the impact of the normative framework be measured and what effects does it have in regional spatial planning under the Environmental Planning Act?

In this study, case studies and/or projects will be selected to implement the developed code of conduct (functional artifact 1) and prototype software (functional artifact 2). Various regional projects in the Netherlands, such as the Geodan project in North Brabant (*Provincie Noord-Brabant*, 2023), the optimal climate-proof design by RIVM and Tygron (RIVM, 2021), and Dutch Metropolitan Innovations (DMI) in Flevoland (Mureau, 2023), provide potential case study sites. The specific cases will be selected from one of our partners mentioned earlier.

A case study offers a unique opportunity to examine the prototype within its natural context, capturing the dynamics and complexities that experimental settings often lack. It allows for multiple perspectives, offering a deep understanding of real-world phenomena (Runeson & Höst, 2009).

This research adopts an exploratory approach to understand the effects and implications of both artifacts. Qualitative methods (interviews with direct and indirect stakeholders, including policymakers and community representatives) and quantitative methods (metrics comparing previously developed digital twins with those developed using the prototype) will be used. Information will be collected before and after the prototype's application to enable accurate comparisons. These methods align with the *technical investigation* of VSD, examining how technology safeguards public values from a socio-technical perspective.

This study will enhance our understanding of how the code of conduct and the prototype functions within regional spatial planning and the Environmental Planning Act, providing insights into their impact and effectiveness.

Functional artifact 1 (code of conduct) can be used in both the design and operation phases of a DT, while functional artifact 2 (prototype) is used once a DT is in operation. These artifacts create the conditions to safeguard public values in DTs by design, see the following figure:

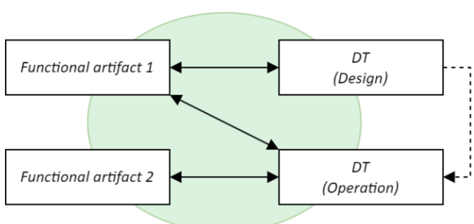

Figure 3 - Functional artifact 1 (code of conduct) and functional artifact 2 (prototype)

4 Scientific and social impact

The primary scientific contribution lies in the development (RQ1, RQ2, RQ3), operationalization (RQ4), and validation (RQ5) of a normative framework with a socio-technical perspective through VSD. This interdisciplinary approach addresses a crucial gap in existing literature, where socio-technical approaches often fail to adequately safeguard public values (Abbas & Michael, 2023; Baxter & Sommerville, 2011). Recent studies have emphasized the urgency of integrating public values systematically into socio-technical designs to address societal challenges and ethical concerns (Royakkers et al., 2018; Sattlegger, 2024). By systematically incorporating values into the design and implementation of DTs, this research advances the fields of socio-technical systems, VSD and DTs. The integration of VSD with a socio-technical perspective offers a novel theoretical contribution. VSD's emphasis on values throughout the design process aligns well with the complex and dynamic nature of regional policy making, thereby enhancing the theoretical understanding of how values can be systematically integrated into digital technologies. This theoretical advancement has broader implications for the field of information systems, particularly in terms of ethical considerations and the societal impact of digital innovations.

Moreover, the research provides a comprehensive analysis of the state-of-the-art of DTs, revealing their current applications and limitations within regional-level spatial planning. This detailed overview contributes to the academic discussion by highlighting the technological and methodological advancements required for the effective deployment of DTs in complex policy environments (Yao et al., 2023).

The iterative design methodology employed in this research, encompassing conceptual, empirical, and technical investigations (VSD (Friedman et al., 2013)) as well as a DSR approach, demonstrates a rigorous scientific approach. This methodology not only contributes to the robustness of the normative framework but also facilitates its empirical validation within the context of the Environmental Planning Act. The scientific relevance of this research lies in the development of the first scientifically validated and operationalized framework for DTs, which accounts for diverse stakeholders, societal challenges, and values, specifically tailored for use by a regional governmental agency.

The societal impact of this research is significant, given the complexity and challenges faced by regional governments in managing spatial planning. The implementation of DTs, guided by a normative framework that safeguards public values, can enhance the decision-making process in regional policy making. By simulating the potential consequences of policy decisions, DTs enable policymakers to make more informed, transparent, and equitable choices, improving the quality of life for citizens.

One of the key societal benefits of this research is its potential to foster social cohesion and equity. By ensuring that diverse public values are considered in spatial planning, the research promotes inclusive and participatory governance. This is particularly important in addressing the needs of various demographic groups, thereby reducing inequalities in access to resources and opportunities. The emphasis on public trust and transparency in the decision-making process further enhances civic engagement and support for policy initiatives.

Environmental sustainability is another aspect of the societal impact. The integration of environmental considerations into spatial planning ensures that DTs help promote sustainable development practices, mitigate environmental degradation, and protect natural resources for future generations. By enabling policymakers to assess the environmental impact of their decisions, DTs can contribute to more sustainable and responsible governance.

The research also addresses practical challenges such as infrastructure overload, resource shortages, and affordable housing. By providing functional artifact 1 and 2 for validation and optimizing policy solutions, DTs help regional governments devise innovative strategies to, e.g., manage urban growth, improve transportation systems, and promote affordable housing options. This capability is particularly valuable in rapidly expanding cities, where effective spatial planning is crucial for maintaining the quality of life.

In the context of the Environmental Planning Act, the research supports the legislation's goal of integrated and collaborative decision-making among stakeholders. By visualizing differing interests and perspectives, DTs facilitate a more comprehensive understanding of stakeholder needs, thereby enhancing the legitimacy and acceptance of policy decisions.

This research not only advances scientific knowledge in the field of DTs, VSD and socio-technical systems but also delivers tangible social benefits by enhancing the effectiveness, transparency, and inclusivity of regional policy making. By addressing technical and social dimensions, the research ensures that the deployment of DTs in spatial planning aligns with public values, contributing to more sustainable and equitable urban development.

5 Future development

This chapter is not yet applicable, as I have only recently started my PhD research. At this stage, I am not yet able to provide an answer to this chapter.

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