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The Emergence of Digital Twins Technology in Urban Planning:
A study of Perceptions, Opportunities and Barriers

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Entrepreneurship and Innovation

Acknowledgements

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Sammendrag

Denne masteroppgaven undersøker digital tvilling-teknologi sin påvirkning på arealplanleggingsprosesser. Den undersøker også potensial og utfordringer ved implementasjon, med formål å skape et fundament for videre innovasjon innen arealplanlegging.

Studien er basert på en kvalitativ tilnærming og involverte en workshop i Stranda kommune i et fellesprosjekt mellom NTNU, NMBU og Augment City, der deltakerne navigerte i en digital tvilling verden og diskuterte den fremtidige utviklingen av verdensarvområdet rundt Geirangerfjorden. I tillegg inkluderte studien konsultasjoner med forskere innen byplanlegging og digital tvilling-teknologi og to separate fokusgrupper med arealplanleggere fra ulike kommuner.

Undersøkelsens funn avdekker en sterk entusiasme for teknologien blant arealplanleggere, spesielt med hensyn til dens visualiseringsevner, potensialet til å takle spesifikke urbane utfordringer, redusere avhengigheten av eksterne konsulenter, øke dynamikken i planleggingsprosessen, og dens prediktive kapabiliteter ble også sett på som betydelige fordeler. Imidlertid krever vellykket implementering, brukervennlig design, tilegnelse av ny ekspertise, sterk ledelsesstøtte og effektive samarbeidsstrategier. Resultatene antyder at digital tvilling-teknologi har potensial til å endre praksis innen byplanlegging, men adopsjon og effektiv bruk avhenger av å overvinne visse organisatoriske og institusjonelle utfordringer.

Studiets troverdighet er etablert gjennom triangulering av datakilder, ekspertinnspill og grundig dataanalyse. Etiske hensyn og sikker behandling av forskningsmateriale sikrer deltakernes personvern og konfidensialitet gjennom forskningsprosessen. Selv om studien er basert på et relativt lite utvalg av deltakere, gir den verdifull innsikt i brukerimplementerings-prosessen og bidrar til den voksende kunnskapsbasen innen bruk av digital tvilling-teknologi til arealplanlegging.

Samlet sett fremhever denne masteroppgaven behovet for ytterligere forskning for å kartlegge omfanget og sammenhengen mellom de ulike områdene som påvirker implementering av digital tvilling-teknologi i arealplanlegging, samt viktigheten av å fremme tverrfaglig samarbeid for å legge til rette for effektiv utnyttelse av denne fremvoksende teknologien.

Abstract

This master's thesis investigates the impact of digital twin technology in urban planning practice. It also investigates its potential and barriers for implementation, aiming to lay the groundwork for further innovation in urban planning.

Employing a qualitative approach, the research involved a workshop observation at Stranda municipality in a joint project between NTNU, NMBU, and Augmented City, where participants navigated a digital twin virtual world and discussed the development of the world heritage area around the Geiranger Fjord. Additionally, the study incorporated expert consultations and two separate focus group discussions with urban planners.

The findings reveal strong enthusiasm for the technology among urban planners, particularly for its visualization capabilities and potential to address context-specific urban challenges. The technology's capacity to reduce reliance on external consultants, increase dynamism in the planning process, and its predictive capabilities were also seen as significant benefits. However, successful implementation requires user-friendly design, acquisition of new expertise, strong management support, and effective collaborative strategies. The results suggest that digital twin technology holds great promise for transforming urban planning practices, but its adoption and effective use hinge on overcoming certain organizational and institutional challenges.

The study's credibility is established through the triangulation of data sources, expert input, and rigorous data analysis, while ethical considerations ensure that participants' privacy, confidentiality, and informed consent are protected throughout the research process. Although the study is based on a relatively small sample of participants, it provides valuable insights into the user implementation process of digital twin technology, contributing to the growing body of knowledge in the field of urban planning.

Overall, this master's thesis highlights the need for further research to explore the potential benefits and challenges of implementing digital twin technology in urban planning, as well as the importance of interdisciplinary collaboration to facilitate the successful adoption of this emerging technology.

List of figures

List of tables

Translations and abbreviations

English	**Norwegian**	**Abbreviation**
Digital twin	Digital tvilling	DT
Spatial planning	Arealplanlegging	SP
Urban planning	Byplanlegging	UP
Technology acceptance model	Teknologiaksept modellen	TAM
Building information modeling	Bygningsinformasjonsmodellering	BIM
Offshore simulation center	Offshore simulator senter	OSC
Geographic information systems	Geografisk informasjonssystem	GIS
Internet of things	Tingenes internett	IoT
Digital twin-technology	Digital tvilling-teknologi	DTT

Table of contents

Figure 1. Spatial planning illustration // Dall-E

Chapter 1: Introduction

1.1 Background

Spatial planning is a complex and challenging process that involves balancing competing priorities and interests in order to create livable, sustainable communities. Over the years, planners have relied on a range of tools and technologies to help them navigate these challenges, from zoning laws to participatory planning processes.

The work of urban planners involves various processes and tasks and often require the use of different software programs for spatial analysis, mapping, and simulation. This can lead to a time-consuming process, as planners need to learn and manage multiple tools, import and export data between programs, and ensure that the data remains accurate and up to date.

In recent years, a new technology has emerged in this field that has the potential to transform the way spatial planning is done: digital twin technology. In Spatial planning, digital twins can be used to create dynamic, realistic simulations of neighborhoods or communities, allowing planners to test different scenarios on the fly and make more informed decisions in collaboration with citizens and other departments.

However, the use of digital twin technology in spatial planning is not without controversy. Researchers have raised several concerns about using digital twin technology in urban planning, including data privacy and security, accuracy and reliability, ethical considerations, integration with existing systems, technical complexity, uncertainty in decision-making, and environmental impact. Besides these concerns, there is also confusion about what defines a digital twin, how it differs from the traditional tools of an urban planner, and how the technology should be developed and used by the planners to ease their workflow and collaboration with different stakeholders.

1.2 Problem statement

Innovative trends in urban planning, combined with the potential and complexity of digital twins has led to the following problem statement:

"What is the potential impact of digital twin technology on urban planning practice, and what are the perceived benefits, challenges, and requirements for its successful implementation?"

1.2.1 *Research objectives*

The primary objective of this research is to examine the potential of digital twin technology in transforming urban planning practices, focusing specifically on its perceived usefulness and ease of use among urban planners. Evaluating these two key factors helps in understanding the factors that influence technology acceptance, user motivation and expected behavior, which can then be used by organizations and developers to enhance the design, implementation, and adoption of this technology. Ultimately, this study aims to facilitate the innovation in spatial planning processes by exploring the potential of DTT and addressing the challenges and opportunities it presents.

1.3 Conceptual framework and approach for the thesis

The conceptual framework for this research is built upon the Technology Acceptance Model (TAM) as the foundation for understanding how digital twin technology is perceived by urban planners and how it can be used to innovate in the field of spatial planning. The TAM model has been widely applied in various domains to predict and explain users' acceptance and adoption of new technologies based on perceived usefulness and perceived ease of use

(Davis, 1989). By evaluating these two key factors, the framework aims to provide insights into the factors that influence technology acceptance, user motivation, and expected behavior in the context of DTT in urban planning.

Perceived usefulness refers to the degree to which users believe that a specific technology will enhance their job performance or improve their work processes (Davis, 1989). In this study, we will explore how urban planners perceive the usefulness of DTT in terms of its potential to facilitate communication and collaboration, provide better visualizations, enable more informed decision-making, and optimize spatial planning processes.

Perceived ease of use is the degree to which users believe that a specific technology is easy to learn and use, without requiring significant effort (Davis, 1989). In this context, we will investigate how urban planners perceive the ease of use of DTT, considering factors such as user interface, data integration, and software compatibility. By focusing on these two core dimensions of the TAM, the conceptual framework aims to provide a comprehensive understanding of the factors that influence implementation of DTT.

1.4 Method and analysis

A qualitative research approach was employed to gain a comprehensive understanding of how DTT was perceived by urban planners and its potential use in innovating the field of spatial planning. The approach was divided into four parts.

Participation in a workshop was undertaken in collaboration with the Twin Fjord project, observing how participants interacted with a prototype of Augment City's digital twin. Additionally, a visit was conducted to the OSC to gain first-hand experience with DTT in a large-scale simulation environment.

Throughout the study, consultations were held with expert researchers in the field to identify key factors that influenced technology acceptance and potential strategies for enhancing DTT's design, implementation, and adoption in urban planning.

Finally, two separate focus group sessions were conducted with urban planners, providing valuable insights into their perceptions and experiences in relation to DTT, as well as gathering feedback on its perceived usefulness and ease of use. Through these qualitative research methods, the data was thoroughly analyzed and interpreted, generating a comprehensive understanding of the factors influencing the acceptance and implementation of DTT by urban planners.

1.5 Structure

This master’s thesis is structured into five main chapters, each contributing to the overall understanding of implementation and use of digital twin technology and its potential to innovate the field of spatial planning. The article follows the IMRaD model, with some modifications.

Chapter one sets the context for the research by providing an overview of the problem statement, research objectives, and the conceptual framework. It also outlines the method and analysis approach and briefly describes the structure of the thesis.

Chapter two provides a literature review of evolution and use of digital twin technology, its applications and currency state of twins in urban planning. The chapter also discusses Technology Acceptance Model (TAM) and its relevance to digital twin implementation in spatial planning, including previous applications of TAM in related fields.

Chapter three details the research design and methods employed in this study, including workshop observation, expert consultation, simulator demonstration, and focus group discussions. It further elaborates on the credibility and ethical considerations of the research, ensuring the study's trustworthiness and adherence to ethical guidelines.

Chapter four presents the findings from the workshop observation, expert consultation, simulator demonstration, and focus group discussions.

Chapter five provides a comprehensive analysis of the data collected, addressing the research questions and objectives.

Chapter six synthesizes the research findings, exploring the potential implications of the study, addresses limitations in the study and provides recommendations for future research.

Each chapter of the thesis is designed to build upon the previous chapters, weaving together the various aspects of the research to create a cohesive and comprehensive exploration of the implementation process of DTT in urban planning, as well as a comfortable reading experience.

Chapter 2: Literature review

2.1 Purpose

The purpose of this literature review is to provide a comprehensive understanding of the development, current state, and potential future directions of digital twin technology within the context of urban planning. This review will examine the motivations behind the evolution of digital twin technology and explore its applications in spatial planning. By doing so, it will set the foundation for our study and contextualize our research objectives.

Our problem statement, *“What is the potential impact of digital twin technology on urban planning practice, and what are the perceived benefits, challenges, and requirements for its successful implementation?”* highlights the need for a deeper understanding of user perception and the factors influencing the adoption of this technology. This literature study also explores previous research on the development, use and implementation of digital twins in urban planning, as well as the role of TAM in technology adoption. This will uncover potential research gaps, discussions and provide a solid foundation for our research.

2.2 Origins and development of digital twin-technology

The concept of DTT has its roots in the early 2000s when it was first introduced by Dr. Michael Grieves at the University of Michigan (Grieves, 2016). Digital twins are virtual replicas of physical assets, processes, or systems, which are used to simulate, analyze, and optimize their real-world counterparts (Tao et al., 2018). The technology has evolved significantly over the past two decades, driven by advancements in data collection, computational power, and visualization techniques.

The initial motivation for developing digital twins was to improve the design and manufacturing processes within the aerospace and automotive industries (Grieves, 2016). By creating virtual models of complex products, engineers could better understand their performance, predict potential issues, and optimize their designs before physical prototypes were built (Rosen et al., 2015). This approach allowed for cost reductions, faster time-to-market, and increased product quality.

Over time, the applications of DTT have expanded beyond manufacturing and into a wide range of sectors, such as energy, healthcare, and urban planning (Tao et al., 2018). In the context of urban planning, digital twins offer the potential to simulate and analyze the performance of entire cities, enabling planners to make more informed decisions regarding infrastructure, resource management, and environmental sustainability (Batty, 2018). The integration of real-time data from various sources, such as IoT devices and social media, has further enhanced the capabilities of DTT, allowing for more accurate and dynamic representations of urban environments (Kitchin, 2014).

The evolution of DTT has been driven by several key factors, including the increasing availability of large datasets, advances in computing and simulation technologies, and the growing need for more efficient and sustainable urban planning solutions (Gartner, 2017). These developments have contributed to the rapid growth of the digital twin market, which is expected to reach $73,5 billion by 2025, according to a report by MarketsandMarkets (2022). The evolution and development of DTT have been motivated by the desire to improve design and decision-making processes across various industries. From its initial applications in manufacturing to its current potential in urban planning, DTT has continued to expand and innovate, driven by advancements in data collection, computation, and visualization.

2.3 Digital twin implementation and use in Norway

DTT has been gaining momentum in the field of urban and spatial planning worldwide, and Norway is no exception. With an emphasis on sustainable development, smart cities, and cutting-edge technology, Norway has been a keen adopter and developer of DTT. Norwegian researchers and companies were among the first to understand the potential of digital twins in urban planning. The concept was first introduced in Norway around the mid-2010s, spearheaded by companies like DNV GL and the Norwegian University of Science and Technology (NTNU), along with various start-ups like Augmented City. These pioneers saw the potential for a more integrative, real-time approach to managing urban spaces, and thus, digital twins became a focal point of their research and development (R&D) efforts.

Digital twins have been made for several of the biggest cities in Norway, as parts of development and research projects to advance the use of technology. One of these collaborative projects is Smartbyene (smart cities), where the different cities are test pilots for the implementation and testing of various smart solutions in urban planning. Smart city initiatives in Norway have been exploring the potential of DTT, piloting various projects to better manage and plan urban spaces. These pilot projects encompass a wide range of applications, from pollution measurement, natural disaster management, climate change analysis, traffic management, critical infrastructure monitoring, business park development, parking data analysis, future public infrastructure needs assessment, to neighborhood alerts, and more. For example, the City of Stavanger, part of the Norwegian Smart City Network, has been an active participant in these initiatives, deploying a digital twin as part of a pilot project to monitor and manage their urban environment (Norwegian Smart City Network, 2021). This involved the use of IoT sensors and data analytics to monitor various factors such as air quality, noise pollution, traffic conditions, and more.

However, it is important to note that these digital twins often focus on specific aspects or contained areas of the city, rather than offering a comprehensive digital replica of the entire urban space. This selective focus is due to the vast amount of data required to create a complete digital twin and the complexity of integrating various data sources and systems. As the use of DTT in urban planning continues to evolve, further research is needed to address these challenges and maximize the potential benefits of digital twins for smart cities in Norway.

2.4 Is digital twin-technology state of the art in urban planning?

Urban planning tools have experienced significant advancements in recent years, driven by the rapid development of technology and the increasing demand for more efficient, sustainable, and participatory planning processes. Traditionally, urban planning relied heavily on manual methods such as hand-drawn maps and physical models (Hall, 2002). These rudimentary tools required considerable time and effort to create and revise, limiting the scope of planning exercises and the level of public engagement. The advent of digital technology revolutionized urban planning. Computer-Aided Design (CAD) systems emerged in the late 1960s, and offered new possibilities for designing and visualizing urban spaces (Eastman et. al. 2008). CAD systems enabled urban planners to create detailed 2D and 3D models of urban areas, enhancing the precision and efficiency of planning processes.

In the 1990s, Geographic Information Systems (GIS) were introduced, providing a powerful tool for managing and analyzing spatial data (Longley et al. 2015). GIS has been used to support various urban planning tasks, such as land use planning, transportation planning, and environmental impact assessment. It has also facilitated public participation in planning processes by making spatial data more accessible and understandable to non-experts (Brown & Kyttä, 2018).

In the 21st century, the emergence of Building Information Modeling (BIM) has further advanced urban planning. BIM provides a multi-dimensional digital representation of physical and functional characteristics of places, integrating various data types into a single model (Azhar, 2011). BIM has been used in various urban planning scenarios, such as infrastructure development and sustainability assessment, enhancing collaboration among different stakeholders and improving decision-making (Patacas et al., 2015).

Recently, the concept of digital twin has emerged as a cutting-edge technology in urban planning. A digital twin is a dynamic virtual replica of a physical object or system, updated in real-time with data from its physical counterpart (Tao et al., 2018). In the context of urban planning, a digital twin of a city can provide a comprehensive, up-to-date, and interactive model of the city's physical infrastructure, environmental conditions, and social dynamics (White et al., 2021). This technology has the potential to further enhance visualization, simulation, and public participation in urban planning, while also offering new capabilities such as predictive modeling and real-time monitoring (Jiang et al., 2020). Based on current developments and trends, DTT can be considered state of the art in urban planning. However, its adoption and effective use hinge on overcoming certain technical, organizational, and societal challenges, which necessitates further research and innovation (Bosche et al., 2019).

2.5 Impact of digital twin-technology on urban planning practice

The advent of DTT has marked a significant shift in the landscape of urban planning. This innovative tool, through its ability to create digital replicas of physical entities, offers a new paradigm for understanding and managing the complexities inherent in urban environments. While this technology has demonstrated potential in enhancing the efficacy of urban planning practices, it also brings a set of unique challenges that necessitate careful consideration. Through an analysis of existing research, we aim to provide a comprehensive overview of the transformative potential of this technology and the issues that must be navigated to harness its benefits effectively.

2.5.1 Decision-Making and Efficiency

While the potential for DTT to enhance decision-making and efficiency in urban planning is widely recognized, perspectives within the scientific community vary, particularly in terms of the extent, feasibility, and conditions under which these benefits can be realized.

Many researchers highlight the significant potential of digital twins to improve decision-making and efficiency. For instance, Grieves and Vickers (2017) argue that DTT can enable more informed, accurate, and efficient planning decisions due to its predictive modeling capabilities. This perspective asserts that the ability of digital twins to simulate various scenarios allows urban planners to anticipate potential outcomes and make better-informed decisions.

Yet, not all researchers share this unreservedly positive view. Ham, Y., & Kim, J. (2020) acknowledge the potential benefits of DTT but caution that these benefits can only be realized under certain conditions. According to them, the effectiveness of digital twins in enhancing decision-making is contingent upon the accuracy of the data and models used, the complexity of the system being modeled, and the technical capacity of the planners utilizing the technology.

A more critical perspective is offered by Kitchin (2014), who questions the extent to which DTT can enhance efficiency in urban planning. While not denying the potential benefits, Kitchin argues that the implementation of digital twins can be a complex and resource-intensive process. He points out that the time and resources required to develop and maintain accurate digital twins may offset the efficiency gains.

2.5.2 Public engagement

Digital twin technology's role in facilitating public engagement in urban planning is a promising yet contested topic within the scientific community. Perspectives diverge, particularly in terms of accessibility, comprehensibility, and the potential to bridge the gap between urban planning professionals and the public.

Several researchers, such as Allam and Newman (2018), are optimistic about the potential of digital twins to enhance public engagement. They argue that the immersive, 3D visualization capabilities of digital twins can provide community members with a more tangible understanding of proposed changes. This visualization can lead to more informed input and increased participation from the public, enhancing the democratic aspect of urban planning.

However, others adopt a more realistic view. While acknowledging the potential of digital twins for public engagement, Biljecki et al. (2020) emphasize that the complexity of DTT may limit its accessibility for the general public. They suggest that the successful use of digital twins for public engagement hinges on the design of user-friendly interfaces and effective communication strategies that can bridge the gap between the complexity of the technology and the comprehension of the public.

A more skeptical perspective is offered by Kitchin (2014), who warns of the digital divide that could be exacerbated by the introduction of DTT. He posits that, while digital twins can potentially enhance public engagement, they may also inadvertently exclude those who lack digital literacy or access to the necessary technology, thereby reinforcing existing inequities. As DTT continues to advance, further research is needed to maximize its benefits for public engagement while mitigating potential drawbacks.

2.5.3 Sustainability and Resilience

DTT's impact on sustainability and resilience in urban planning is a subject of ongoing debate within the scientific community. Perspectives diverge, particularly in terms of predictive capabilities, long-term benefits, and potential pitfalls.

Many researchers, such as Batty (2018), emphasize the significant potential of digital twins to enhance sustainability and resilience in urban planning. They argue that the predictive capabilities of digital twins can simulate the impacts of climate change and other environmental factors, thereby guiding the development of adaptive strategies and infrastructure. This could lead to more sustainable and resilient urban systems.

However, some researchers adopt a more pragmatic stance. While acknowledging the potential of digital twins, researchers like Liu et. al. (2021) stress that the benefits for sustainability and resilience are dependent on various factors, including the accuracy of data, complexity of the models, and the expertise of the users. They suggest that to effectively leverage DTT for sustainability and resilience, urban planners must be adequately trained, and the data and models used must be of high quality.

A more cautionary perspective is represented by Kitchin (2014), who warns of the risk of over-reliance on DTT for sustainability and resilience planning. He suggests that while digital twins can provide valuable insights, they cannot replace the need for traditional methods of urban planning and decision-making. This perspective emphasizes the importance of a balanced approach that combines DTT with traditional urban planning methods.

2.5.4 Data privacy

The impact of DTT on data privacy in urban planning is a complex and contentious issue within the scientific community. Perspectives diverge, especially when considering the tension between the potential benefits of data use and the need to protect privacy.

Some researchers, such as Habibzadeh (2019), downplay the privacy concerns associated with DTT. They argue that with robust cybersecurity measures and clear data governance protocols, the privacy risks associated with digital twins can be mitigated. This perspective emphasizes the need for proper management and security measures to ensure data privacy. On the other hand, researchers like Liu et. al. (2021) adopt a more balanced view. While they acknowledge the potential of digital twins for urban planning, they also recognize the serious data privacy concerns this technology raises. They advocate for a balanced approach that leverages the benefits of DTT while implementing strict measures to ensure data privacy.

A more critical perspective is offered by Kitchin (2014), who argues that the extensive data requirements of DTT present significant privacy risks. He asserts that the detailed nature of the data involved, especially when linked to specific individuals or households, could lead to serious privacy infringements if misused or accessed without authorization. Kitchin urges caution and strong regulatory measures to protect privacy. The varying perspectives within the scientific community highlight the delicate balance between leveraging the benefits of DTT for urban planning and protecting data privacy. As this technology continues to evolve, careful consideration of data privacy issues will be essential to maintain public trust and ensure ethical use.

2.5.5 Cost and complexity

The impact of DTT on the cost and complexity of urban planning is a subject of ongoing debate within the scientific community. Perspectives diverge, particularly when considering the initial investment and maintenance costs, as well as the potential for increased efficiency and long-term savings. Some researchers, such as Grieves and Vickers (2017), contend that digital twins, while requiring an initial investment, can significantly enhance efficiency and result in long-term cost savings. They argue that the predictive modeling capabilities of digital twins can help anticipate and mitigate potential problems, thereby reducing the costs associated with trial-and-error approaches and reactive problem-solving in urban planning.

However, a more pragmatic perspective is offered by researchers like Botín-Sanabria et. al. (2022), who acknowledge the potential benefits of DTT but caution about the significant costs and complexity associated with its implementation. They suggest that the development, maintenance, and operation of digital twins require substantial resources, both in terms of financial costs and technical expertise.

A more critical perspective is provided by Kitchin (2014), who warns that the increased complexity introduced by DTT can potentially outweigh its benefits. He suggests that the technical skills required to utilize DTT effectively are often underestimated, leading to unexpected costs and delays. Moreover, the complexity of the models used can make them difficult to understand and use effectively, thereby limiting their potential benefits. Further research is needed to fully understand its cost implications and how to manage its complexity effectively.

2.5.6 Technological dependency

The impact of DTT on technological dependency in urban planning is a topic of ongoing debate within the scientific community. Perspectives diverge, particularly when considering the balance between leveraging technological advantages and the risk of over-reliance.

Researchers like Tao et al. (2018) emphasize the benefits that digital twins can bring to urban planning. They argue that DTT's predictive capabilities can lead to more informed decision-making and enhanced efficiency, making a strong case for embracing this technology despite the increased dependency.

However, some researchers strike a more balanced tone. Lehtola et. al (2022) acknowledge the potential of digital twins but warn of the risks of over-reliance on technology. They argue that while DTT can provide valuable insights and capabilities, it should complement rather than replace traditional urban planning methods.

A more skeptical perspective is provided by Kitchin (2014), who warns of the potential pitfalls of increased technological dependency. He argues that an over-reliance on DTT could lead to a devaluation of traditional planning expertise and a lack of resilience in the face of technological failures or disruptions.

2.6 Benefits and key challenges to digital twin implementation

DTT has emerged as a promising approach to addressing complex challenges in urban planning, offering real-time data, visualization, and simulation capabilities that can enhance decision-making processes (Batty, 2018). However, despite its potential, the adoption and implementation of DTT in urban planning are still in the early stages, with several obstacles to overcome (Kitchin, 2014).

Several examples of successful implementations of DTT in urban planning can be found around the world. The City of Singapore's Virtual Singapore project is a comprehensive digital twin that integrates 3D models, real-time data, and advanced analytics to support urban planning and management (Batty, 2018). In Europe, the City of Helsinki has developed a digital twin to facilitate its efforts to achieve carbon neutrality by 2035. These examples demonstrate the transformative potential of DTT in urban planning and its ability to contribute to more sustainable and resilient cities.

The implementation of urban digital twins, when done correctly, provides significant benefits to various stakeholders in a city, including the public administration, citizens, asset managers, owners, and researchers (Ferré-Bigorra et al., 2022). They serve as a comprehensive tool for urban management, enabling more informed decision-making and promoting a sustainable city ecosystem. For example, digital twins can be used to model and predict the impact of proposed changes and interventions on transportation networks, energy consumption, and greenhouse gas emissions (Onile et al., 2021). This enables urban planners to evaluate different planning scenarios and select the most sustainable and resilient solutions.These systems can process and integrate vast arrays of data, facilitating efficient city planning and control, thus enhancing public participation and engagement in urban planning (Hämäläinen, 2021; White et al., 2021).

Despite these benefits, the development and implementation of digital twins come with significant challenges. The high costs and technical complexity necessitate skilled workers for their design, installation, and maintenance (Batty, 2018). Also, the extensive and complex data required for these models pose a significant challenge, demanding high computational resources (Shahat et al., 2021). Concerns over data quality, accuracy, and distribution also limit the effectiveness of digital twins (Kim et al., 2019; Nochta et al., 2021).

By providing an intuitive and interactive platform, digital twins can help stakeholders visualize and understand the implications of planning proposals, thereby enhancing stakeholder engagement, collaboration and communication between decision-makers, experts, and the public (Biljecki et al., 2020), while others argue that it may exacerbate existing inequalities, as not all stakeholders have the same access to digital resources or the ability to interpret complex information (Tzachor et al., 2022). Cybersecurity also emerges as a critical concern, as cyber-attacks on urban digital twins can lead to severe consequences on vital urban infrastructures and potentially breach sensitive data (Lee et al., 2019).

A comprehensive study of 22 existing urban digital twins, conducted by Ferré-Bigorra et al., (2022) discovered that urban infrastructure models for roads, water supply, sewage, electrical power distribution etc. were typically developed separately as they had a completely different background and used different methods. The same study also claims that by the many digital twins in use, each implementation has been different and there is no clear picture of what an urban digital twin is and what systems should model. These digital twins model a diverse array of systems which necessitate integration into a single tool. Given that this subject is still in its nascent stage, there's an evident need to enhance and provide clarity on their definitions and concepts. Additionally, a comprehensive mapping of their current development status and the identification of future challenges is also a prerequisite.

The role of DTT in the urban planning toolkit is still evolving, and with this follows the need for systematic and in-depth research to explore its potential benefits and limitations, as well as strategies to address these challenges. By understanding and addressing these conflicting perspectives, planners and decision-makers can work towards harnessing the power of digital twins to drive innovation and improve urban planning outcomes. The current literature suggests the need for widely accepted standards to simplify the development and implementation of city models, aiming to reap benefits such as cost and error reduction (Shahat et al., 2021).

In conclusion, while urban digital twins offer promising benefits for city management, significant challenges and open issues need addressing, including their high development costs, technical complexity, data quality concerns, and cybersecurity vulnerabilities. The pursuit of standardization and the continued evolution of these models are crucial steps towards a more comprehensive and effective implementation of DTT in urban planning.

2.7 Technology Acceptance Model (TAM) and relevance to digital twin implementation

2.7.1 Explanation of the TAM model

The Technology Acceptance Model (TAM) is a widely used framework for understanding and predicting user acceptance and adoption of new technologies (Davis, 1989). Developed by Fred Davis, the model is based on the premise that an individual's intention to use a technology is determined by two primary factors: perceived usefulness and perceived ease of use. This chapter will introduce the primary components of TAM and discuss its relevance to the implementation of DTT in spatial planning.

Perceived usefulness refers to the extent to which a user believes that using a particular technology will enhance their job performance (Davis, 1989). In the context of DTT, perceived usefulness might encompass aspects such as the ability to improve decision-making processes, facilitate collaboration, and support sustainable urban development. If users perceive digital twins as useful tools for achieving their goals in spatial planning, they are more likely to adopt the technology.

Perceived ease of use, on the other hand, refers to the degree to which a user believes that using a technology will be free of effort (Davis, 1989). In the case of digital twins, perceived ease of use could include factors such as the intuitiveness of the interface, the availability of training and support, and the level of technical expertise required to operate the system. Users are more likely to adopt a technology if they perceive it as easy to use, as this reduces the barriers to adoption and increases the likelihood of successful implementation.

Jens Kaasbøll offered a simplified explanation of this model, and created the illustration below. Based on the work done by Venkatesh et al., (2003), he pointed out that Perceived usefulness is the biggest driving factor to achieve actual system use.

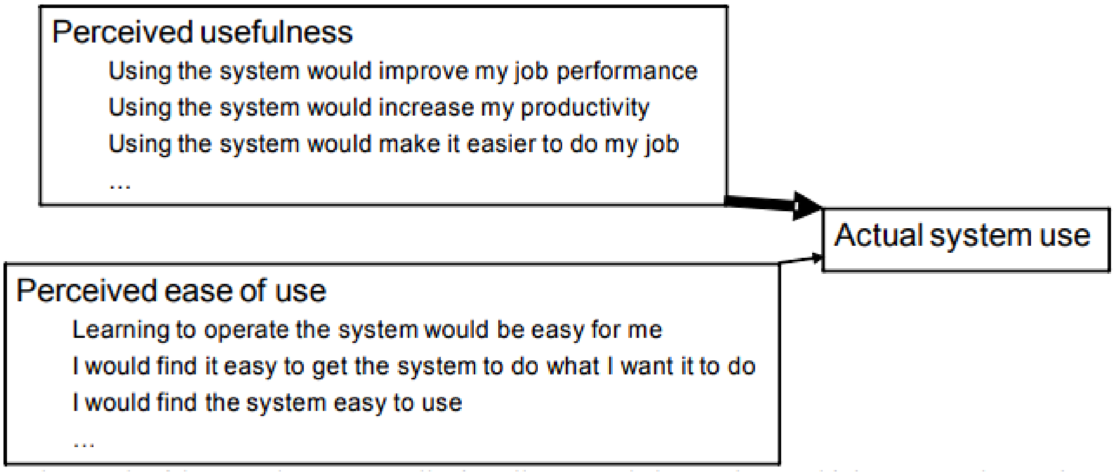

Figure 2. Simplification of the TAM model. Kaasbøll, J (2009)

The TAM has been applied extensively across various domains, including information systems, healthcare, and education, to predict and explain technology adoption (Venkatesh et al., 2003). In the context of urban planning and related fields, TAM can provide valuable insights into the factors that influence the acceptance and adoption of DTT, helping organizations and developers understand user perceptions and motivations.

By applying the TAM to the implementation of DTT in spatial planning, it is possible to identify the key factors that contribute to the perceived usefulness and ease of use of the technology. This understanding can then be used to design and develop digital twin solutions that address user needs and expectations, ultimately accelerating the adoption and integration of the technology into urban planning processes.

2.7.2 How TAM research can accelerate successful implementation

The Technology Acceptance Model (TAM) can be applied to the context of DTT in spatial planning to better understand user perceptions and motivations, ultimately accelerating its implementation. By focusing on the key determinants of perceived usefulness and perceived ease of use, TAM can offer insights into the factors that drive user acceptance and adoption of DTT in urban planning.

By identifying and addressing the factors that contribute to the perceived usefulness of digital twins, developers and organizations can improve the technology's design and functionality, making it more appealing to urban planners. For example, integrating features that facilitate collaboration, data visualization, and scenario testing can increase the perceived usefulness of digital twins in the planning process (Biljecki et al., 2020).

On the other hand, ensuring the user-friendliness of digital twins is essential for promoting adoption, as complex or unintuitive interfaces may deter potential users. Providing training and support for users, simplifying the user interface, and offering clear documentation can all enhance the perceived ease of use of DTT in spatial planning (Kwok et al., 2021).

By examining the perceived usefulness and ease of use of these technologies, researchers and practitioners can gain valuable insights into the factors that drive user acceptance and adoption, informing the design and implementation of new technologies in spatial planning.

2.7.3 TAM Applications in urban planning and related fields

The Technology Acceptance Model (TAM) has been applied to various fields related to urban planning, providing insights into the factors that influence the acceptance and adoption of new technologies in these domains. This section will discuss some examples of TAM applications in urban planning and related fields.

One study employed TAM to investigate the acceptance of web-based Geographic Information Systems (GIS) by urban planners (Jankowski et al., 2006). The results indicated that perceived usefulness and perceived ease of use significantly influenced the adoption of web-based GIS in urban planning practice. The study suggested that training and support could enhance the perceived ease of use, ultimately promoting the adoption of GIS tools in urban planning.

Another research focused on the adoption of Building Information Modeling (BIM) in the construction industry, which has implications for urban planning (Howard et al., 2009). The study found that perceived usefulness and perceived ease of use were significant determinants of BIM adoption, and that users were more likely to adopt BIM if they believed it would improve their job performance and was relatively easy to learn and use.

TAM has also been applied to study the acceptance of smart city technologies, such as the Internet of Things (IoT), which are increasingly being integrated into urban planning processes (Zanella et al., 2014). The research identified perceived usefulness, perceived ease of use, and trust as key factors that influenced the adoption of IoT solutions in smart city contexts.

A recent study published in mid-march 2023, titled "Factors Influencing Adoption of Digital Twin Advanced Technologies for Smart City Development: Evidence from Malaysia," offers insightful observations on the implementation barriers of DTT in the context of developing countries, with a specific focus on Malaysia (Waqar et al., 2023). This research provides a valuable contribution to our understanding of the challenges faced by developing nations in adopting advanced urban planning technologies like DTT.

The study employs a mixed-methods research design, combining interviews, a pilot survey, and a main survey, to identify and refine the barriers to DTT implementation in smart city development. The research concludes that out of the 15 barriers initially investigated, 13 were found to significantly affect the implementation of DTT in smart city development projects in Malaysia (Waqar et al., 2023)

The barriers identified in the research were divided into four main categories: personalization, knowledge, standardization, and operations. Among these, personalization barriers, primarily privacy issues, were found to be the most significant impediment to DTT implementation. The research also pointed out the existence of a knowledge gap and the lack of standardization as influential factors in DTT adoption. Interestingly, operational barriers were deemed as less impactful on the application process of DTT (Waqar et al., 2023)

The study's findings shed light on the specific challenges faced in implementing DTT in smart city development, particularly in the context of a developing nation like Malaysia. The research highlights the need for future research to focus on the identified barriers and develop effective mitigation strategies to facilitate the adoption of DTT in smart city development (Waqar et al., 2023) These insights are crucial for understanding the potential obstacles in the adoption of DTT in urban planning, particularly in developing regions, and the research emphasizes the need to address and overcome these barriers to fully harness the potential of DTT for smart city development.

2.7.4 Summary

This literature review provides a comprehensive overview of digital twin technology in the context of urban planning. It explores the development, current state, and potential future directions of digital twins, as well as their impact on decision-making, public engagement, sustainability, data privacy, cost and complexity, technological dependency, and standardization.

The review highlights the potential of digital twins to enhance decision-making processes in urban planning by providing predictive modeling capabilities and facilitating more informed choices. Factors such as improved collaboration, data visualization, and scenario testing contribute to the perceived usefulness of digital twins among urban planners (Biljecki et al., 2020; Batty, 2018).

Perceived ease of use is another important aspect influencing the adoption of digital twins in urban planning. Factors such as intuitive interfaces, training and support, and technical expertise required to operate the system impact the ease of use. Simplifying the user interface and providing adequate training and support can enhance the perceived ease of use, promoting the adoption of digital twins (Kwok et al., 2021).

Organizational and institutional factors play a crucial role in the implementation of digital twins in urban planning. The development, maintenance, and operation of digital twins require significant resources, both in terms of financial costs and technical expertise. Challenges related to data quality, accuracy, distribution, and cybersecurity must also be addressed to ensure successful implementation (Kitchin, 2014; Shahat et al., 2021).

The impact of digital twin technology on public participation in urban planning is another important aspect explored in this review. Digital twins have the potential to enhance public engagement by providing immersive and interactive platforms that enable stakeholders to visualize and understand planning proposals. However, concerns related to digital divide, accessibility, and comprehension must be addressed to ensure equitable participation (Allam & Newman, 2018; Biljecki et al., 2020).

Based on the findings of the literature review, four research questions are proposed:

1. Which possibilities with digital twin technology contribute to perceived usefulness among urban planners?
2. Which factors impact the perceived ease of use of digital twins in urban planning, and how?
3. What are the perceived organizational and institutional factors that impact digital twin implementation in urban planning?
4. What is the perceived impact of digital twin technology on public participation?

These research questions are highly relevant to further explore the potential benefits, challenges, and implications of digital twin implementations in urban planning. By addressing these questions, researchers can deepen our understanding of digital twins and help guide the development and implementation of this technology in urban planning practice.

Chapter 3: Method

3.1 Research design and methods

A qualitative research approach was used, employing a combination of observations, expert consultations, elements from design thinking and focus group discussions to gather data and insights. The methodology consisted of four main steps; Workshop observation, expert consultation, simulator demonstration and focus groups with urban planners from Norway.

Table 1. Data collection methods

Activity	Data collection
Workshop	Observations
Expert consultation (digital twin developers)	Experience user perspectives
Focus groups	Interviews
Expert consultations (Urban planners)	Discussions and reflections

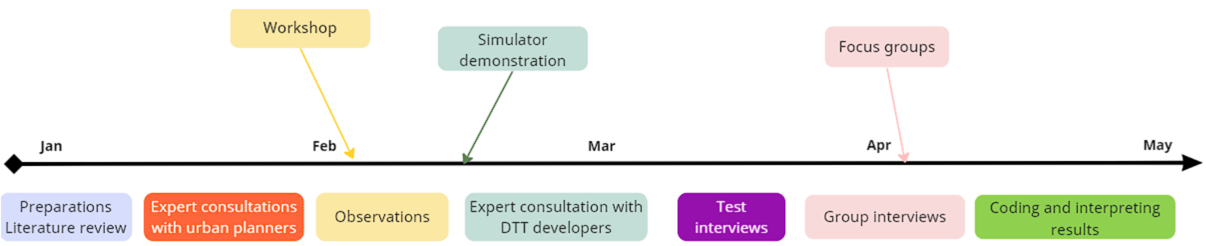

Figure 5. Timeline and research activities

3.1.1 Workshop Observation

The research team attended a workshop in Stranda municipality, arranged by the Twin Fjord project. This project is a joint effort and research project between NTNU, NMBU and Augment city. The project features a cross-sectoral, interdisciplinary collaborative and knowledge building project that aims to develop a participatory planning support system for co-creative and sustainable land management using DTT.

Figure 4. Workshop with Twin Fjord. Photo // Anders Bolstad Eri

Approximately 25 participants attended the workshop, both from the public and private sector. Their common ground is that they all had stakes in the future development of the Geiranger world heritage fjord.

A trained "digital twin operator" from Augment city navigated the virtual world at the request of the participants, while they discussed different infrastructure and plans. The process was observed, and participants' reactions and interactions with the DTT was recorded in writing according to a premade observation guide[1] that guided the research.

[1] Appendix 4

3.1.2 Expert Consultations

The researchers attended the planning and review of the Twin Fjord workshop. Together with the project manager, digital twin developers and urban planning experts, they discussed the observations and evaluated use of DTT during the event.

The discussions focused on understanding how users made use of the digital twin during the workshop and exploring ways to develop the program to enhance its perceived ease of use and usefulness. As researchers for the thesis, notes were taken to gain insights into the perspectives and experiences of various stakeholders involved in the development and implementation of DTT. This helps to identify potential challenges and opportunities in its adoption within spatial planning. Second, the input from these experts can contribute to a more robust understanding of the technology's strengths and weaknesses, enabling us to better evaluate its potential impact on urban planning practices. Lastly, engaging with these experts provides an opportunity to establish relationships and collaborate with professionals who have a deep understanding of the technology, ultimately enriching our research and its relevance to the field.

3.1.3 Simulator demonstration

The researchers conducted a visit to the Offshore Simulation Centre (OSC), which houses one of the world's largest simulators. The purpose of this visit was to gain firsthand experience and understanding of the practical applications and potential benefits of DTT in a large-scale, immersive simulation environment. The insights gathered from this visit helped inform our research on how DTT is perceived by urban planners and how it can be used to innovate in the field of spatial planning.

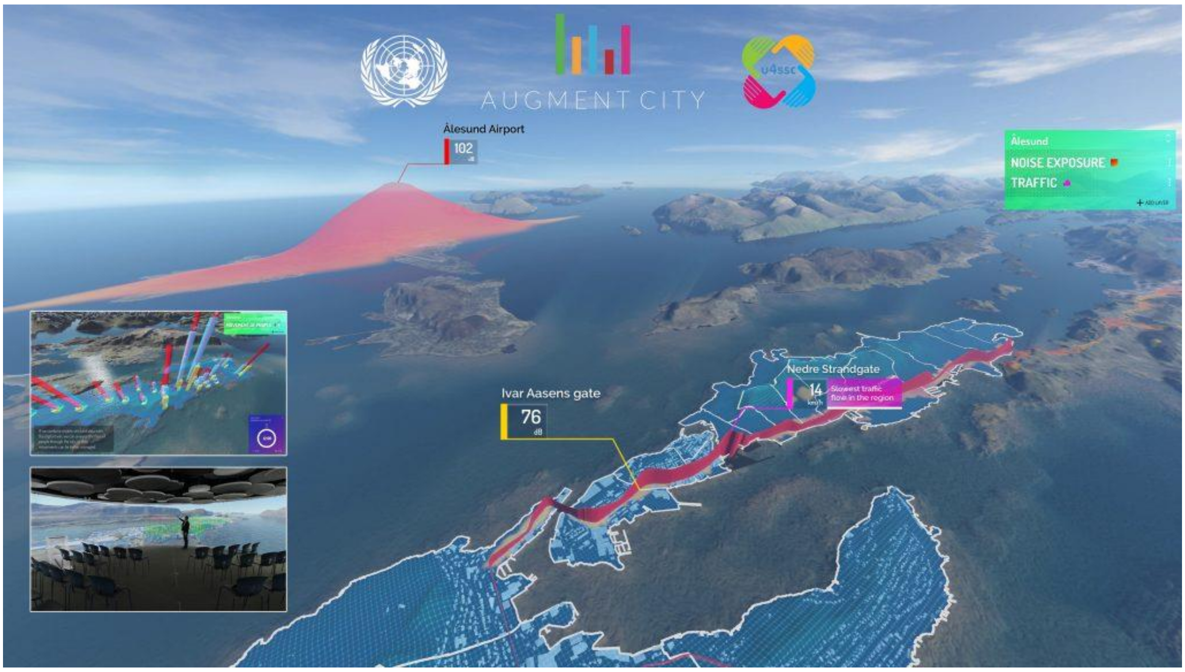

Figure 5. The digital twin showing the city of Ålesund. Photo: Augment city

During the visit, we were given a guided tour of the simulation facilities by an expert in DTT who demonstrated the various functionalities and capabilities of the digital twin within the simulator. This allowed us to observe the intricacies of the technology, as well as the challenges and opportunities it presents for urban planning and other industries.

In addition to the guided tour, we were able to interact with the DTT in the simulator, providing us with valuable hands-on experience. This enabled us to better understand the potential ease of use, user interface, data integration, and software compatibility aspects that urban planners may encounter when adopting DTT in their work.

The insights and experiences gained from the visit to the Offshore Simulation Centre were instrumental in enriching our understanding of DTT and its potential applications in urban planning. By incorporating these observations into our research, we were better equipped to analyze and interpret the perceptions and experiences of urban planners in relation to DTT. Furthermore, the visit allowed us to identify areas where the technology could be improved or adapted to better meet the needs and expectations of urban planners.

3.1.4 Focus Group sessions

Over 50 municipalities were proactively reached out via email, which included detailed information and an invitation[2] to participate in the study. The recommended sample size for qualitative interviews, according to Taylor et al. (2021) is 10-20 participants. Duch-zebrowska and Zielonko-jung (2021) on the other hand proposes a range of five to fifty experts. However, due to various factors such as holidays and time constraints, only seven urban planners were able to participate. Two separate focus groups were held, involving a total of seven urban planners (three in the first group and four in the second group). The group was split because of the potential implications with bigger groups on video calls, as well as to avoid the potential echo effect from bigger groups.

Initially, the researchers collected participants' personal information and their current habits related to technology and urban planning tools. Next, a minimum viable product[3] (MVP) demonstration of the possibilities offered by DTT was provided to the focus group participants. This MVP was not an interactable program, but rather a powerpoint guiding the users through different scenarios that can occur in the twin. The participants then engaged in discussions, sharing their thoughts, concerns, and intentions regarding the use of DTT in their professional contexts.

The interviews followed a semi-structured guide[4] and gathered quantitative data on stakeholders' perceptions of the digital twin, its effectiveness in improving spatial planning and cooperation, and any changes in spatial planning outcomes from a potential implementation of a digital twin. Both focus groups were recorded and automatically transcribed by the software. A final cleanup of the transcripts was done manually while watching the recording, to ensure every detail was correct.

3.1.5 Focus group participant demographics

The focus group participants were selected to represent a diverse range of backgrounds, experiences, and roles within the urban planning field. This section provides an overview of each participant's demographic information, educational background, and work experience.

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[2] Appendix 2
[3] Appendix 3
[4] Appendix 1

Focus Group 1 consisted of four participants with diverse backgrounds in urban planning. The group included both male and female participants, ranging from recent graduates to mid-career professionals. Their educational backgrounds were primarily Master' or Bachelor' degrees in urban planning, as well as further studies in geomatics and GIS. One of the participants held a Masters' degree in construction. Collectively, their work experience spanned small to large municipalities, with responsibilities in areas such as processing of applications, plans for land use, detailed zoning plans, cultural heritage, land division and innovation support for urban planning and digitalization.

Focus Group 2 consisted of three participants with a mix of genders, representing different stages of their careers in urban planning. The participants held master's degrees in urban planning and political science. Their professional experiences encompassed working in small and medium-sized municipalities, for the Ministry of Climate and Environment and the UN's environmental program. The group's work tasks included processing of applications, plans for land use, detailed zoning plans, the social element of the municipal master plan, dispensation cases for wild animals, sustainability and environmental considerations in spatial planning.

3.1.5 Analysis

The data for this study were collected from a combination of workshop observation, expert consultations, and focus group discussions. This provided a broad, multifaceted perspective on the research problem and allowed for a rich understanding of the topic.

Upon completion of the data collection phase, the transcripts were thoroughly examined and coded inductively in a suitable computer software. An inductive approach to coding allows for the data to guide the creation of codes, rather than relying on pre-existing theoretical frameworks. This method was chosen to ensure that all potential themes could surface organically from the data, and no preconceived notions would limit the scope of analysis. This process resulted in a total of 160 distinct codes[5] from the focus groups alone.

Following the coding process, these codes were reviewed to identify patterns. This pattern recognition was guided not only by the emergent trends within the data but also by the Technology Acceptance Model (TAM) framework and a contextual understanding of urban planning. The TAM framework, with its emphasis on perceived ease of use and perceived

[5] Appendix 5

usefulness, provided a useful lens through which to interpret these patterns, especially given the focus on the implementation of a new technology in an urban planning context.

The process of thematic analysis[6] was then applied to the coded data. This involved the integration of the recognized patterns into broader themes, providing an overall interpretation of the data. Thematic analysis was particularly useful for this study, given its exploratory nature. Through the analysis, patterns and trends were identified within the data. These trends highlighted the participants' views on the opportunities and barriers associated with the implementation of DTT in urban planning, and its perceived usefulness and ease of use.

3.2 Credibility

The credibility of this study is reinforced by several factors that contribute to the robustness and trustworthiness of the findings. By employing a well-structured methodology that triangulates multiple data sources, such as workshop observations, expert consultations, and focus group discussions, the research design allows for the cross-validation of findings and the development of a more comprehensive understanding of the research problem.

Expert input from consultations during the evaluation of the workshop provides valuable insights into the use of DTT in urban planning, ensuring that the analysis and interpretation of the data are grounded in current knowledge and understanding of the field. The in-depth qualitative approach used in the study enables the collection of rich and detailed data on users' experiences and perspectives regarding DTT, while the systematic and transparent data analysis process, which includes the use of coding and categorization techniques, ensures that the findings are based on a thorough examination of the data.Throughout the research process, the researchers engaged in reflexivity, critically examining their own assumptions, biases, and preconceptions in relation to the study, thereby mitigating some of the potential researcher bias and enhancing the credibility of the research findings. However, it is essential to acknowledge that the research is based on a relatively small sample of participants and that the workshop was focused on a specific urban planning context. As such, the findings may not be generalizable to all urban planning scenarios involving DTT.

Further research involving a more extensive and diverse sample of participants and contexts is recommended to validate and expand upon the findings of this study.

[6] Appendix 5

3.3 Ethics

In conducting this research, the researchers adhered to ethical principles and guidelines to ensure the protection of participants' privacy. Prior to their involvement in the study, participants in the focus group discussions were provided with a consent form outlining the purpose of the research, the nature of their participation, and any potential risks or benefits associated with their involvement. This form allowed participants to make an informed decision about whether to participate in the study, ensuring that their participation was voluntary and based on a clear understanding of the research process.

The researchers took measures to protect participants' anonymity and maintain the confidentiality of the data collected during the study. During the workshop observation, no personal information was gathered. In the focus group discussions, while personal information was collected, the data was anonymized in the transcripts to protect participants' identities.

The video recordings of the focus group sessions are deleted shortly after the completion of the study to further ensure the confidentiality of the participants. In compliance with the National Information Act, the research project was planned and approved to ensure that the collection, storage, and use of data adhered to relevant data protection regulations and guidelines. Personal information gathered during the study was stored securely, and access to the data was restricted to authorized members of the research team.

Throughout the research process, the researchers demonstrated respect for the participants by valuing their time, opinions, and contributions. The research team was mindful of participants' comfort and well-being during the workshop and focus group discussions and took steps to create an inclusive and supportive environment for open dialogue.

The researchers maintained transparency and openness in their communication with participants and other stakeholders, providing clear information about the purpose of the study, the methods used, and the intended use of the findings. This transparency helped to establish trust between the researchers and participants, contributing to the overall ethical conduct of the study.

By addressing these ethical considerations, the researchers sought to ensure that the study was conducted with integrity and respect for the rights and well-being of the participants. In doing so, they contributed to the credibility and trustworthiness of the research findings while adhering to the ethical principles and guidelines that govern research in the field of urban planning.

Chapter 4: Results

4.1 Introduction

This research aimed to explore the implementation process of digital twin-technology based on its perceived usefulness and perceived ease of use among urban planners in Norway, with the following problem statement: *"What is the potential impact of digital twin technology on urban planning practice, and what are the perceived benefits, challenges, and requirements for its successful implementation?"* The purpose is also to investigate which factors that led to these perceptions, which can then be used by organizations and developers to enhance the design, implementation, and adoption of this technology. Ultimately, this study facilitates the innovation of spatial planning processes by addressing the perceived challenges and opportunities it presents. The findings are presented in sections related to each research question identified in the literature study.

Table 2: Correlation between research questions and findings

Research question	**Related findings**
Which possibilities with DTT contribute to perceived usefulness among urban planners?	**Perceived usefulness** Visualization Context specific benefits Use of external consultants
Which factors impact the perceived ease of use of digital twins in urban planning, and how?	**Perceived ease of use** User interface and interaction Technical competence Learning requirements Knowledge transfer and role of superusers

What are the perceived organizational and institutional factors that impact DTT implementation?	**Organizational and institutional factors** Organizational adaptation and management support Regional collaboration Interdisciplinary collaboration
What is the perceived impact of DTT on public participation?	**Public participation** Facilitating public feedback Improved public understanding The importance of physical interaction Inclusivity and accessibility Informing public decisions

4.2 Perceived Usefulness

The perceived usefulness of the DTT in urban planning was apparent from the participants' responses. Many participants were enthusiastic about the technology's potential. For example, one participant said, "*I can absolutely see the value of the technology. It is really cool that it can predict the future, but I also see value towards public participation.*" This illustrates the recognition of the technology as not just a tool for professional use, but also as a means of engaging the public in the planning process. Another participant further elaborated on its potential by highlighting the time-saving aspect of the technology, "*I believe the program can help a lot, and would save us time, not only for my own work, but for the entire planning process.*"

4.2.1 Visualization

Many participants found the technology's ability to visualize the most beneficial. A quote that encapsulates this sentiment is, *"I see the greatest benefit in relation to visualization, and especially in relation to residents.*" Also, another participant stated, "*I think that visualizing and communicating it is the most important feature of this program.*"

The ability to visualize projects was recognized as a powerful tool for saving time and improving understanding both internally and externally. A participant elaborated on the benefits of visualizing in 3D by explaining, “*There is much that can be misunderstood in 2D maps, for example the terrain. Internally, we spend a lot of time discussing, and sometimes we don’t even know what we really are talking about.*” Furthermore, a participant who experienced that new plans often received a lot of adversity initially stated, "*Visualizing projects, and already from the very beginning, will save the planners a lot of time. It saves a lot of planning work, and probably a lot of meeting activities.*"

4.2.2 Context-Specific Benefits

Another significant theme that emerged from the focus group discussions was the context-specific utility of DTT. Participants highlighted the technology's usefulness differently depending on the specific challenges faced by their respective municipalities.

One participant from the Norwegian West Coast noted, "*I know that natural hazards are very relevant where I work, so stormwater, floods, and landslides would have been very useful.*" Another participant mentioned the importance of simulating technical infrastructure capacity, such as water and sewage, and public services such as schools and kindergartens, while a participant facing mobility challenges considered that as the most critical area for digital twin application.

These statements show the potential of DTT to address a wide range of urban planning issues, demonstrating its versatility and adaptability to different contexts. However, they also indicate that the perceived usefulness of the technology is dependent on the specific needs and priorities of each municipality, suggesting the need for flexibility and customization in the design and implementation of digital twin systems.

4.2.3 The Impact on the Use of External Consultants

The implementation of DTT in urban planning could significantly reduce the municipality's dependency on consultants, making the process more dynamic, less time-consuming, and cost-effective. Participants provided several insights into how digital twins could transform the traditional process of engaging consultants in planning processes.

A recurrent theme in the focus group discussions was the frustration with the existing dependence on external consultants. One participant stated, "*For now, we are somewhat at the mercy of what the consultants have done, and it is taken for granted that the traffic flow* *analysis, for example, is correct.*" This situation is perceived as problematic, particularly when it comes to verifying the quality of the work delivered by consultants. As another participant explained, "*It would have been appropriate if the municipality could do the calculations themselves. Because then it is also easier to ensure the quality.*"

One of the main challenges identified by participants is the static nature of the consulting service. A participant explained, "*For example, if we consider traffic flow as a consulting service for a thematic plan. Then we order a consultant service at the start, then we get the result. And then we find out that perhaps we should have had some other analyses in addition, but it is too late by then.*" This highlights a key issue where the iterative nature of planning often leads to additional requirements emerging later in the process when it's too late or expensive to modify the consultant's scope of work.

The participants reflected on the common delays and inflexibility in the current planning process involving consultants. One participant noted, "*It often takes a long time between each meeting that we have with consultants, so here you could work much more dynamically.*" With a digital twin, the urban planning process could become more interactive and responsive, allowing for immediate changes and instant visualization. This would replace the current process where it could be several weeks between meetings and updates, resulting in a more efficient and dynamic workflow.

Finally, by enabling municipalities to carry out complex tasks like 3D modeling, traffic-forecasting, and environmental simulation in-house, DTT could lead to substantial cost savings. One participant remarked, "*It's great that you can simulate things like solar access and wind direction. These are usually mappings that we spend a lot of money on through consulting firms.*" This demonstrates that the DTT will not only reduce the financial burden on municipalities, but also allows them to reallocate resources to other pressing urban planning issues.

4.2.4 The Power of Predicting the Future

One of the most intriguing capabilities of DTT, according to the participants, is its ability to predict the future. This ability is not merely an impressive technological feat but offers practical solutions to complex problems in urban planning.

The power of prediction is seen as highly relevant to long-term planning by the participants, particularly in relation to infrastructure. A participant noted, "*In relation to the municipality's Master plan, for the revision of the social and land-use element for its long-term planning, I* *think that the possibility to predict future scenarios is very important. But especially in relation to the planning of future infrastructure.*" This comment highlights the potential of DTT to make informed decisions on infrastructure development, with benefits such as enhanced efficiency and effectiveness.

While many elements of future prediction already exist, the integration of these into a digital twin platform could significantly enhance their value. As one participant noted, "*We already have a lot of information on the future. For example, the traffic planners are projecting their figures with a percentage value of expected growth.*" This suggests that the ability to predict the future using DTT could enhance the utility of existing data and help translate it into actionable insights.

4.3 Perceived Ease of Use

This section presents the findings from the focus groups concerning the perceived usefulness of the DTT, specifically focusing on user interface, interaction, technical competence, and learning requirements.

4.3.1 User Interface and Interaction

It is worth noting that the participants' impressions are based on viewing a minimum viable product (MVP) of the DTT, including pictures and video from various sources. As one participant pointed out, "*It seems very intuitive, but it's hard to say really.*" This indicates that although the technology appeared user-friendly, a comprehensive evaluation was not possible without hands-on experience.

Participants emphasized the importance of the user-friendliness of the technology. One participant expressed concern over potential issues, stating, "*I'm thinking about user-friendliness, you get a lot of information, but it's important that it's user-friendly is good. Because sometimes technology can make things a little more difficult, and systems can crash.*" Another participant echoed this sentiment, adding, "*I think that I would manage the program, but it is important that it is made as simple as possible to understand.*"

4.3.2 Technical Competence

The participants rated their technical competence as medium and were familiar with a variety of software in their professional work. This includes Norkart's map solutions with GISLINE, OpenCities Planner, and ArcGis.

Despite their technical background, some participants felt that adopting the DTT might require new expertise within the organization. One participant stated, "*I think that if the municipality is going to start using that type of tool, then we will have to bring in a different type of expertise in the organization. In public administration, many people have backgrounds as sociologists and social scientists, and not the technological expertise.*"

4.3.3 Learning Requirements

Most participants believed that an intensive course over a day or two would be sufficient to learn the new program, with some suggesting an online course as a viable option. One participant stated, "*I think one or two days with an intensive course would be sufficient, and then I would require to use the program continuously afterwards.*" The idea of 'learning by doing' was also endorsed, with participants asserting that a lot of the learning would come from exploring the program through trial and error.

4.3.4 Knowledge Transfer and Role of Super Users

The focus group participants, who were based in larger municipalities with more workers, pointed out the existence of knowledge transfer mechanisms within their organizations. A common approach was to train certain individuals to a higher level who could then act as in-house 'super users'. As one participant put it, "*I think that some resource persons in the organization must be trained to a higher level, who can somehow take it further as super users.*"

However, it is important to note that the majority of participants viewed themselves as users rather than modelers of the technology. Several participants stated that they had used similar programs for specific tasks but had not been involved in creating 3D models. Moreover, they emphasized that more technically demanding tasks were usually handled by other staff members within their organizations.

4.4 Organizational and Institutional Factors

The implementation of new technology such as a digital twin in a municipal context is influenced by a range of organizational and institutional factors. These factors emerged as significant themes in the focus group discussions and provide a contextual understanding of how DTT might be integrated and utilized.

4.4.1 Organizational Adaptation and Management Support

The introduction of new technology within a municipal context typically involves a gradual process of adoption and adaptation. As one participant observed, "*The introduction of new things in the municipality usually takes some time, but then the employees get used to it eventually*." This suggests a level of organizational resilience and adaptability, though the pace of change may be slower than in other contexts.

A crucial factor in successful implementation is management support, with one participant noting, "*To implement this, you really have to have talked your way through all levels up to management, so that everyone can understand it in order to use it effectively*." This highlights the need for clear communication and understanding at all levels within the organization for the technology to be utilized effectively. One participant suggested a potential strategy, stating, "*We may have to say that this will be the main program we use, otherwise there is a risk that there will only be a small number of people who are very passionate about it, but difficult to get everyone on board.*"

4.3.2 Regional Collaboration

For smaller municipalities, collaboration across regions and with other municipalities was suggested as a potential strategy for overcoming resource constraints. A participant from a smaller municipality suggested, "*We have a regional collaboration across several municipalities, and we have talked about being able to coordinate a kind of active participation. This is where I can think the digital twin could be relevant, but I think it must be as a collaboration with several municipalities. Since we do not have the time or the expertise to implement this ourselves.*"

4.3.3 Interdisciplinary Collaboration

The use of DTT in urban planning implies a shift from traditional planning tools and may require a level of interdisciplinary collaboration that is not commonly practiced within municipalities. One participant noted, "*When we have looked at other planning tools, we have struggled implementing other tools than purely GIS. We are in a way going outside the traditional field of planning, and that will require a collaboration that may not be there.*"

Participants noted that a municipality is not a monolithic entity but is divided into many specialist areas, each with its own interests and concerns. For instance, one participant said, "*When creating such systems, it is easy to see the municipality as one thing, but we are, after all, divided into many specialist areas. For example, water and sewage have had very little to do with construction. And then you could say that we should have been better at working cross-functionally, it really should have been completely natural to work cross-functionally with water and sewage, property and construction matters. We struggle with that in my municipality. This tool actually reveals this weakness in us.*"

Another participant emphasized the need for diverse expertise in implementing a tool like the digital twin, stating, "These programs bring together many different types of subjects. GIS is a field in itself, and it is only a small part of this here. Traffic flow and movement is again a completely different field that requires quite a long education to be able to analyze results and give the right input. So that means that you have to bring in expertise that you don't have in-house in order to get sufficient expertise."

4.4 Public Participation

Public participation is a crucial aspect of urban planning, and DTT presents new opportunities for enhancing and expanding public involvement in planning processes. The focus group discussions revealed several potential benefits and challenges related to using digital twins for public participation.

4.4.1 Facilitating Public Feedback

The prospect of a more interactive map where residents can provide feedback and proposals was met with enthusiasm by the focus group participants. They saw potential for the digital twin to facilitate an active role for the public in spatial planning. One participant said, "*I can* *imagine that the program will be very relevant in relation to getting public input. If they can click around to leave comments.*" Furthermore, participants felt that the digital twin could simplify and enhance the participatory process in spatial planning. As one planner stated, "*Much of the process in spatial planning involves facilitating involvement and participation and anchoring the plans both politically and to the citizens. So, simplifying this with the program, and making it more accessible will certainly help us a lot.*"

4.4.2 Improved Public Understanding

The digital twin could also improve public understanding of plans and processes. Participants noted that current planning methods could be confusing for laypeople, and the digital twin's ability to visualize information could help clarify these processes. As one participant remarked, "*Today's methods and plans are not very easy to understand for the common man. In relation to the process, there is much that is not obvious and logical. I see that this tool could help to visualize and inform to a greater extent.*"

4.4.3 The Importance of Physical Interaction

While the potential benefits of digital participation were recognized, participants also emphasized the continued importance of physical meetings and interactions. One participant warned, "*I think one should be careful not to become dependent on digital tools in relation to public meetings. Because humans need physical interactions.*"

Through the workshop observation, remarkable benefits were witnessed when the participants engaged in physical interaction while utilizing digital twin technology. This powerful combination did show the ability to enhance collaboration and learning, as individuals can manipulate virtual representations of objects and environments in real-time.

4.4.4 Inclusivity and Accessibility

Concerns were raised about the potential for digital tools to exclude individuals who are not comfortable with technology. One participant said, "*People who cannot use such digital tools won't get access to this information, meaning there will be some people who are left out.*" However, others saw potential for digital tools to engage new audiences, particularly younger people who may not typically participate in traditional public meetings. As one participant noted, "*We could reach other groups, such as more young people who traditionally may not be involved in these types of processes. If the program discriminated against the elderly, the opposite would happen at an open meeting set in the morning.*"

4.4.5 Informing Public Decisions

Finally, participants saw the digital twin as a tool for providing public access to information and helping to make informed decisions. They envisaged a scenario where the municipality, consultants, and residents all interact within the digital twin, leading to more dynamic planning processes. As one participant noted, "*Perhaps we could get a little more dynamism in it if, for example, a politician could play with a traffic model, and get a better understanding of how things work in one system. That is the potential, but it is also demanding to get there. It would also become a bit more dynamic in that case, because now the process is very static and linear. Planning is not linear, but one assumes it is.*"

4.5 Summary of findings

The findings revealed several compelling insights into the perceptions and requirements surrounding the implementation of DTT in urban planning. Participants clearly saw the potential of digital twins, not only as a tool for reducing reliance on external consultants and consequently saving costs, but also as a means to simulate and test different scenarios in real time. They particularly appreciated the predictive capabilities of the technology which would allow them to anticipate future scenarios and make more informed decisions about infrastructure and environmental impacts.

Participants valued the enhanced visualization capabilities of the digital twin. They believed that this would improve understanding and communication, both within their organizations and with the public, and save considerable time in planning and meetings.

However, these potential benefits were closely tied to the user interface and interaction of the technology. While participants acknowledged the importance of user-friendly design, they were confident in their ability to adapt to the new tool. Their past experiences with other software tools played a significant role in this confidence. Despite this, they anticipated the need for initial intensive training, but believed that through continued use and internal knowledge sharing, they could fully master the tool.

At an organizational level, the participants underlined the importance of full buy-in at all stages of the hierarchy to ensure successful implementation of the digital twin. They were aware of potential challenges such as the need for new types of expertise within their organizations, and suggested potential collaborations with other municipalities, especially for smaller entities.

The discussions also brought to light the potential of the digital twin to facilitate interdisciplinary collaboration within municipalities. By breaking down existing silos and integrating different fields of expertise, the technology could potentially revolutionize the way these entities' function. Nevertheless, they also recognized this as a challenge, as it necessitated a level of collaboration that might not currently exist in some organizations.

Lastly, public participation emerged as a key theme during the discussions. The digital twin was seen as a powerful tool that could make urban planning more accessible and understandable to the public, thereby enabling a wider range of community members to engage in the planning process. Despite the enthusiasm for this potential, participants also expressed concerns about the risk of digital exclusion and emphasized the importance of maintaining traditional forms of engagement.

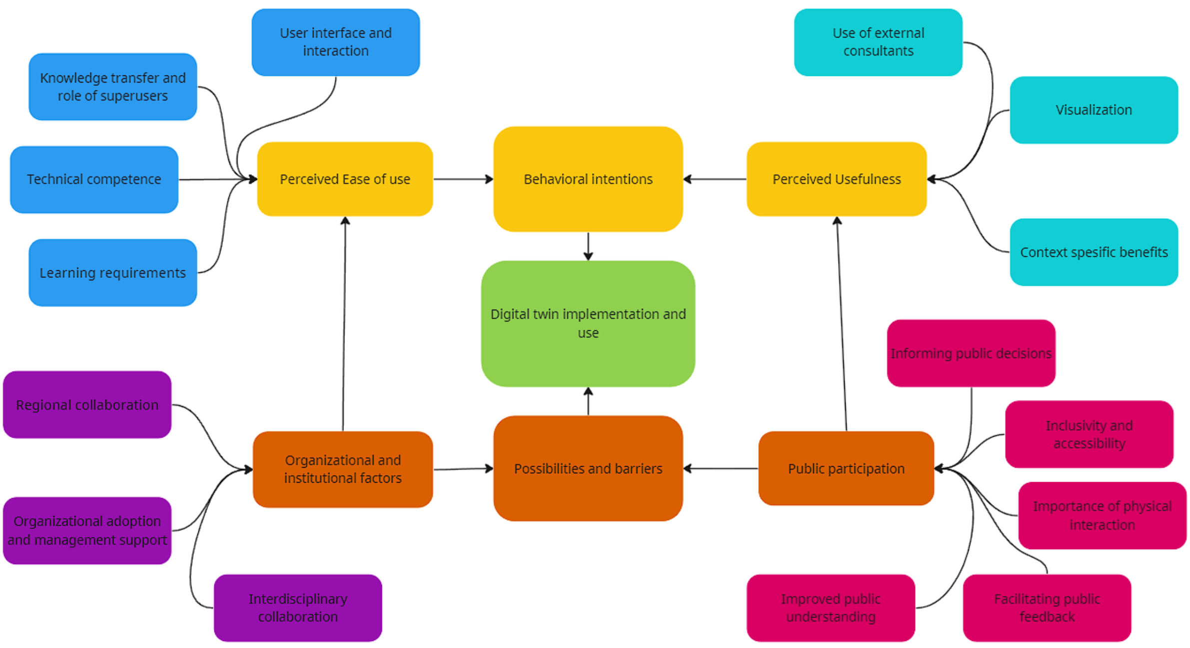

Figure 6: Factors identified to be influencing digital twin implementation and use

Chapter 5: Discussion

5.1 Interpretation of findings and correlation with literature

The discussion chapter aims to analyze and interpret the findings of this study by examining the similarities and differences between the current research and previous studies from the literature review. It also highlights the relevance of the research and explores the practical implications of the findings.

The findings of this study revealed that participants recognized the usefulness of digital twin technology (DTT) in urban planning. The ability of DTT to visualize projects and improve decision-making processes was seen as a significant benefit. The participants appreciated the potential of DTT to save time, enhance collaboration, and engage the public in the planning process. Furthermore, the study identified the factors influencing the perceived ease of use of DTT in urban planning. Participants expressed the need for user-friendly interfaces, adequate training, and technical competence to ensure the smooth adoption and implementation of DTT. Similar findings have been reported in previous studies where ease of use and technical skills have been identified as critical factors affecting technology acceptance (Davis, 1989; Venkatesh et al., 2003).

The research also explored the perceived organizational and institutional factors that impact the implementation of DTT in urban planning. The findings highlighted the importance of organizational adaptation, management support, and regional collaboration in successfully integrating DTT into planning processes. These factors align with previous research that has emphasized the role of organizational support and collaboration in implementation of digital twin technology (Jankowski et al., 2006). The study further emphasized the need for interdisciplinary collaboration within municipalities to leverage the full potential of DTT, which is an unexplored field in the academic world.

The study also explored the perceived impact of DTT on public participation in urban planning. Participants identified the potential of DTT to facilitate public feedback, improve public understanding and increase transparency and accessibility in the planning process. These findings align with previous research that has emphasized the role of technology in enhancing public participation and engagement (Zanella et al., 2014). The study highlighted the need to balance digital tools with traditional forms of engagement to ensure inclusivity and accessibility which is corresponding to previous research that has emphasized the importance of hybrid approaches to public participation (Zanella et al., 2014).

The findings of this study demonstrate several similarities with previous research on technology acceptance. The importance of organizational adaptation, management support, and collaboration resonates with studies exploring the adoption of technology in different contexts (Jankowski et al., 2006). However, this study also brings forth some differences compared to previous research. The focus on the perceived impact on public participation, as well as the role of DTT in reducing dependence on external consultants, enhancing transparency, and improving decision-making processes provides unique insights that add to the existing body of knowledge,

The relevance of this research lies in its contribution to the understanding of DTT implementation in the context of urban planning. By investigating the perceived usefulness, perceived ease of use, organizational factors, and impact on public participation, this study provides valuable insights for organizations and developers seeking to enhance the design, implementation, and adoption of DTT in urban planning processes.

The findings have several practical implications for the field of urban planning. First, the recognition of the perceived usefulness of DTT highlights the need for incorporating visualization capabilities, time-saving features, and context-specific functionalities into digital twin systems. Developers and organizations can leverage these insights to design and develop DTT solutions that align with the specific needs and priorities of urban planners.

Second, the findings emphasize the importance of user-friendly interfaces, adequate training, and technical competence in ensuring the ease of use of DTT. Organizations should invest in comprehensive training programs and support systems to enable urban planners to effectively utilize the technology. Moreover, the identification of organizational and institutional factors underscores the need for management support, collaboration, and adaptation to facilitate the successful implementation of DTT.

Third, the study highlights the potential of DTT to enhance public participation in urban planning. The ability of DTT to facilitate public feedback, improve understanding, and increase transparency can foster meaningful engagement between planners and the community. However, it is crucial to ensure inclusivity and accessibility by maintaining traditional forms of engagement alongside digital tools.

Chapter 6: Conclusion

6.1 Summary and implications

This master's thesis aimed to explore the potential impact of digital twin technology on urban planning practice, as well as identify the perceived benefits, challenges, and requirements for its successful implementation. Through a comprehensive literature review and quantitative research involving focus group discussions with urban planners in Norway and several other methods, valuable insights have been gained that contribute to the understanding of digital twin technology in the context of urban planning.

The findings of this research indicate that digital twin technology holds significant potential for enhancing urban planning practice. Urban planners perceive the technology as useful in various ways, such as improving decision-making processes, facilitating visualization, and engaging the public in the planning process. The ability of digital twins to predict future scenarios and simulate different planning scenarios are also valued characteristics.

The study identified several factors and underlying explanations that impact the implementation of digital twin technology and shed light on the potential impact of digital twin technology on public participation in urban planning. Digital twin technology has the potential to significantly enhance urban planning practice by improving decision-making processes, facilitating visualization, reducing dependence on external consultants, and fostering public participation. The perceived benefits include timesaving, improved understanding, and enhanced collaboration. However, challenges such as user interface design, technical competence, and organizational factors need to be addressed for successful implementation. In terms of new knowledge contributed, this thesis provides insights into the specific context of digital twin technology in urban planning in Norway. The empirical research conducted with urban planners offers valuable perspectives and firsthand experiences, enriching the understanding of the implementation process.

Overall, this thesis has contributed to the knowledge and understanding of digital twin technology in urban planning practice. It has provided insights into its potential impact, perceived benefits, challenges, and requirements for successful implementation. By addressing the research question and making recommendations for future work, this research can guide further advancements and foster the innovation of spatial planning processes in the era of digital transformation.

6.2 Limitations and weaknesses

While our research provides valuable insights into the implementation process of digital twins in urban planning, it is important to acknowledge the limitations that were encountered during the study. These limitations, inherent to any research process, pertain to the formulation of research objectives, data collection methods, sample size, scope of discussions, and analysis. Understanding these limitations can guide future research efforts and enhance the interpretation of our findings.

Geographical context: The geographical context of the study is limited to Norway. As such, the findings and implications are particularly relevant to the Norwegian urban planning context and may not directly apply to different cultural, economic, or regulatory environments in other countries. It's worth noting that urban planning practices, acceptance of new technologies, and institutional structures can vary significantly across different geographical contexts.

Limited research foundation: The field of digital twins in urban planning is relatively new, and there is little existing research to build upon. For example, the similar, although more empirical work done by Waqar et al., (2023) was published at the time this research was almost completed, which limited the ability to contextualize our findings within a broader theoretical framework and may affect the robustness of our conclusions.

Small sample size: Our study relied on a relatively small sample of urban planners. While this allowed for in-depth interviews and qualitative analysis, it might limit the generalizability of our findings. The perspectives of our participants might not fully represent the range of views and experiences of urban planners across different regions and contexts.

Exclusive focus on urban planners: Secondly, the study exclusively interviewed urban planners who work in municipalities. While their insights are valuable, the views of other key stakeholders such as developers, architects, policymakers, and citizens are not represented in this thesis. Different stakeholders may have different perspectives and experiences with digital twin technology that could further enrich the understanding of its potential and challenges in urban planning.

Participants not experienced with digital twins: The urban planners who participated in this study had little to no experience with actual digital twins, but some with similar tools. Consequently, their perceptions and attitudes are largely based on their understanding and expectations of the technology, rather than on direct personal experience. This lack of experience might have influenced their responses and views on the potential and challenges of digital twin technology in urban planning.

Absence of quantitative data: The study adopted a purely qualitative research approach. While this approach allows for an in-depth exploration of the perceptions and experiences of the participants, it does not provide quantitative data that could be used to measure and compare the relative importance of different factors influencing the acceptance and use of digital twin technology.

Limited use of TAM: The use of the Technology Acceptance Model (TAM) was restricted to its most basic constructs: "perceived ease of use" and "perceived usefulness". Although these constructs are fundamental to technology acceptance, the TAM model includes other factors and connections that were not investigated due to the lack of a larger sample size and the research methods selected.

Despite these limitations, our research contributes to the nascent field of digital twins in urban planning by providing an initial exploration of its potential benefits and challenges from the perspective of urban planners. It also provides a foundation for future research to build upon, and the identified limitations can serve as starting points for this future work. It is our hope that subsequent studies will overcome these limitations and continue to enrich the understanding of the role of digital twins in urban planning.

6.3 Recommendations for future research

This research has provided insight into the establishment and perception of digital twins in urban planning. However, it has also uncovered new questions and potential avenues for further exploration. The following areas are suggested for future research endeavors.

Inter-departmental Collaboration in Digital Twins: Our study alluded to the importance of collaboration between different departments in creating and utilizing a shared digital twin. However, the mechanics, challenges, and benefits of such cross-departmental collaboration remain largely unexplored. Future research could aim to understand how different departments can work together more effectively within the digital twin framework, examining best practices, potential pitfalls, and strategies for overcoming barriers to collaboration.

Citizen and Developer Interaction: It is clear that active engagement of citizens and developers is crucial for the success of digital twins in urban planning. Future studies could probe deeper into how these groups interact with existing web portals that allow input and suggestions of plans, identifying opportunities for improving user experience, engagement, and the quality of input provided.

Cost-Benefit Analysis of Digital Twins: As digital twins become more prevalent in urban planning, it is important to understand the economic implications of their development and maintenance. Future research should delve into a comprehensive cost-benefit analysis of digital twins, considering not only the financial aspects but also the social, environmental, and long-term strategic benefits.

Standardizing the Norwegian Digital Twin: What should a 'base' digital twin for Norwegian cities and rural municipalities include, and what additional modules can generate further value? Future research could focus on developing a standardized framework for digital twins in the Norwegian context and investigating how to create value through the integration of additional modules.

Changes in Education for Digital Twin Operation and Maintenance: The advent of digital twins necessitates changes in the education and training of professionals who will be tasked with operating and maintaining these systems. Future research could explore the educational requirements and skill sets necessary for this new era of urban planning.

Impact of Digital Twins on Development Projects: An important area for future research is to understand the effect of using digital twins on the time and quality of development projects. This includes studying how digital twins can streamline processes, improve decision-making, and enhance the overall quality of urban development projects.

Technical aspects: Future studies can delve into the technical aspects of digital twin implementation, such as data integration, interoperability, and the development of standardized frameworks. The exploration of new visualization techniques and interactive features that enhance user experience and engagement can also be a fruitful avenue for future research.

Quality of Predictions and Simulations: The accuracy and reliability of predictions and simulations generated by digital twins are crucial for their success. Future studies should aim to understand the balance between input quality and output in relation to time and cost, finding the 'sweet spot' for optimal performance of digital twins.

Qualitative TAM study: A quantitative study examining the factors influencing the adoption of DTT technology in Norway, similar to the recent study done by Waqar et al., (2023) could be interesting to compare regional and cultural differences, based on empirical evidence such as survey-based data and Structural Equation Modeling (SEM) analysis. This would help to quantify the relative importance of different factors influencing technology adoption and provide a more comprehensive understanding of the barriers and facilitators of digital twin technology implementation in the Norwegian urban planning context.

To sum it up, our study has laid the groundwork for understanding the application of digital twins in urban planning, but there is much left to explore. The future of digital twin research is ripe with opportunities for further investigation and discovery.

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Appendices

Appendix 1. Interview guide

Intervjuguide

Samtykke

- Repetere hva vi forsker på

Vi forsker på hvordan en interaktiv 3D verden kan tilrettelegge for kommunikasjon mellom innbyggere, eiendomsutviklere og det offentlige (kommunen).

Hensikten med intervjuet er å samle informasjon som kan brukes til å evaluere dagens teknologi og faktorer som påvirker adopsjon og bruk av en eventuell ny modell. Intervjuet er forventet å ta ca. 30 minutter.

- Spørre om samtykke til å ta opp video og transkribere
- Forklare hvordan persondata behandles (sikkert, anonymiseres, lagres lokalt på enhet og slettes ved prosjektets slutt)

Grunnleggende informasjon

1. Alder
2. Kjønn
3. Utdanning (relatert)
4. Yrke og arbeidserfaring

Erfaring med teknologi

1. Har du smarttelefon? På hvilken måte benyttes denne? ringe/sosiale media/spill
2. Har du erfaring med tredimensjonale spill på datamaskin eller konsoll?
3. Hvilke programmer har du erfaring med fra utviklingsprosjekter? Antall år brukt.
4. Beskriv din nåværende erfaring når det gjelder kommunikasjon mellom eiendomsutviklere, innbyggere og planleggere. Initiativ, typer kommunikasjon, felles forståelse, prosessflyt, involverte parter. Åpen diskusjon.

Minimal Viable Product Idea

Presentere MVP powerpoint.

Forventninger til DT/Spillmotorbasert samarbeidsplattform

1. Hvor motivert er du for å lære og bruke dette?
2. Hvor mye, og hvilken form for opplæring tror du kreves?
3. Hvor brukervennlig du dette?
4. Hvor relevant er verktøyet for jobben du skal gjøre?
5. På hvilken måte kan det påvirke arbeidshverdagen og resultater?
6. Beskriv din tidligere erfaring med liknende teknologi
7. Hvor viktig oppfatter du at det er å bruke teknologien? Rollemodeller (Prosjekter eller personer/firmaer som har benyttet DT)
8. Hvordan tror du teknologien kan påvirke samarbeid/kommunikasjon?
9. Hvilke muligheter ser man ved å benytte denne teknologien til arealplanlegging?
10. Hvilken sanntidsdata ser du viktigheten av å ha integrert i programmet?
11. Hvilke funksjoner synes du en slik plattform burde ha for å bidra til forbedret informasjonsflyt?
12. Har du noen bekymringer eller protester mot å bruke et slikt verktøy?

Konklusjon

Er det noe mer du har lyst til å legge til, eller spørsmål du har til oss?

Takk for deltagelsen

Appendix 2. Information and consent form

Information sheet sent out to all respondents prior to interviews.

The information sheet is approved by NSD.

Mal for informert samtykke

Vil du delta i forskningsprosjektet

Digital tvilling som samskapingsverktøy

Dette er et spørsmål til deg om å delta i et forskningsprosjekt hvor formålet er å undersøke potensialet for samskaping med digital tvilling i arealplanlegging. I dette skrivet gir vi deg informasjon om målene for prosjektet og hva deltakelse vil innebære for deg.

Formål

Forskningen er en del av en masteravhandling ved Handelshøyskolen på NMBU. Prosjektet har som mål å undersøke faktorer som spiller en rolle for teknologiimplementering og samle innsikter og erfaringer fra erfarne arealplanleggere og studenter innenfor dette fagfeltet.

Hvem er ansvarlig for forskningsprosjektet?

Handelshøyskolen ved Norges miljø- og biovitenskapelige universitet (NMBU) er ansvarlig for prosjektet.

Hvorfor får du spørsmål om å delta?

Personer som er spurt om å delta i denne forskningen er et tilfeldig utvalg av arealplanleggere fra kommuner over hele Norge, samt siste års studenter innenfor fagfeltet ved NMBU. Kontaktinformasjonen er funnet gjennom kommunens og universitetets egne nettsider

Hva innebærer det for deg å delta?

Forskningen vil basere seg på fokusgrupper med inntil en times varighet der det vil bli spurt om grunnleggende personopplysninger, erfaringer fra arbeid og teknologi. Møtet vil bli tatt opp (videoopptak).

Det er frivillig å delta

Det er frivillig å delta i prosjektet. Hvis du velger å delta, kan du når som helst trekke samtykket tilbake uten å oppgi noen grunn. Alle dine personopplysninger vil da bli slettet. Det vil ikke ha noen negative konsekvenser for deg hvis du ikke vil delta eller senere velger å trekke deg.

Ditt personvern – hvordan vi oppbevarer og bruker dine opplysninger

Vi vil bare bruke opplysningene om deg til formålene vi har fortalt om i dette skrivet. Vi behandler opplysningene konfidensielt og i samsvar med personvernregelverket.

Opplysninger og eventuelle video/lydopptak vil kun være tilgjengelig for de to i prosjektgruppen og veilederen. Alle persondata vil under prosjektet lagres lokalt på en passordbeskyttet harddisk. Intervjuer vil bli transkribert ved hjelp av innebygget funksjon i Microsoft Word.

Informasjon som publiseres i avhandlingen vil ikke kunne knyttes direkte eller indirekte til enkeltpersoner. Kun bearbeidet informasjon vil bli publisert.

Hva skjer med personopplysningene dine når forskningsprosjektet avsluttes?

Prosjektet vil etter planen avsluttes 16. mai 2023. Etter prosjektslutt vil video og lydopptak slettes. Transkriberte data og andre notater vil anonymiseres ved at alle identifiserbare faktorer som navn og liknende slettes. Anonymisert data lagres i tre år for etterprøvbarhet og eventuell videre bruk i forskningsformål ved NMBU. Dette lagres lokalt på privat enhet og/eller på universitetets server.

Hva gir oss rett til å behandle personopplysninger om deg?

Vi behandler opplysninger om deg basert på ditt samtykke. På oppdrag fra Handelshøyskolen ved NMBU har Sikt – Kunnskapssektorens tjenesteleverandør vurdert at behandlingen av personopplysninger i dette prosjektet er i samsvar med personvernregelverket.

Dine rettigheter

Så lenge du kan identifiseres i datamaterialet, har du rett til:

- Innsyn i hvilke opplysninger vi behandler om deg, og å få utlevert en kopi av opplysningene

- å få rettet opplysninger om deg som er feil eller misvisende
- å få slettet personopplysninger om deg
- å sende klage til Datatilsynet om behandlingen av dine personopplysninger

Hvis du har spørsmål til studien, eller ønsker å vite mer om eller benytte deg av dine rettigheter, ta kontakt med:

Handelshøyskolen NMBU
Elin Kubberød.
Mobil: 41042435
E-post: Elin.kubberod@nmbu.no

Vårt personvernombud:
Hanne Pernille Gulbrandsen
Mobil: 402 81 558
E-post: personvernombud@nmbu.no

Hvis du har spørsmål knyttet til vurderingen som er gjort av personverntjenestene fra Sikt, kan du ta kontakt via:

- Epost: personverntjenester@sikt.no eller telefon: 73 98 40 40.

Med vennlig hilsen

Prosjektansvarlig | *Studenter*

Elin Kubberød | Ivar Anders Elnæs, Anders Bolstad Eri

Samtykkeerklæring

Jeg har mottatt og forstått informasjon om prosjektet *Digital tvilling som samskapingsverktøy* og har fått anledning til å stille spørsmål. Jeg samtykker til:

- ☐ å delta i *intervju*

Jeg samtykker til at mine opplysninger behandles frem til prosjektet er avsluttet

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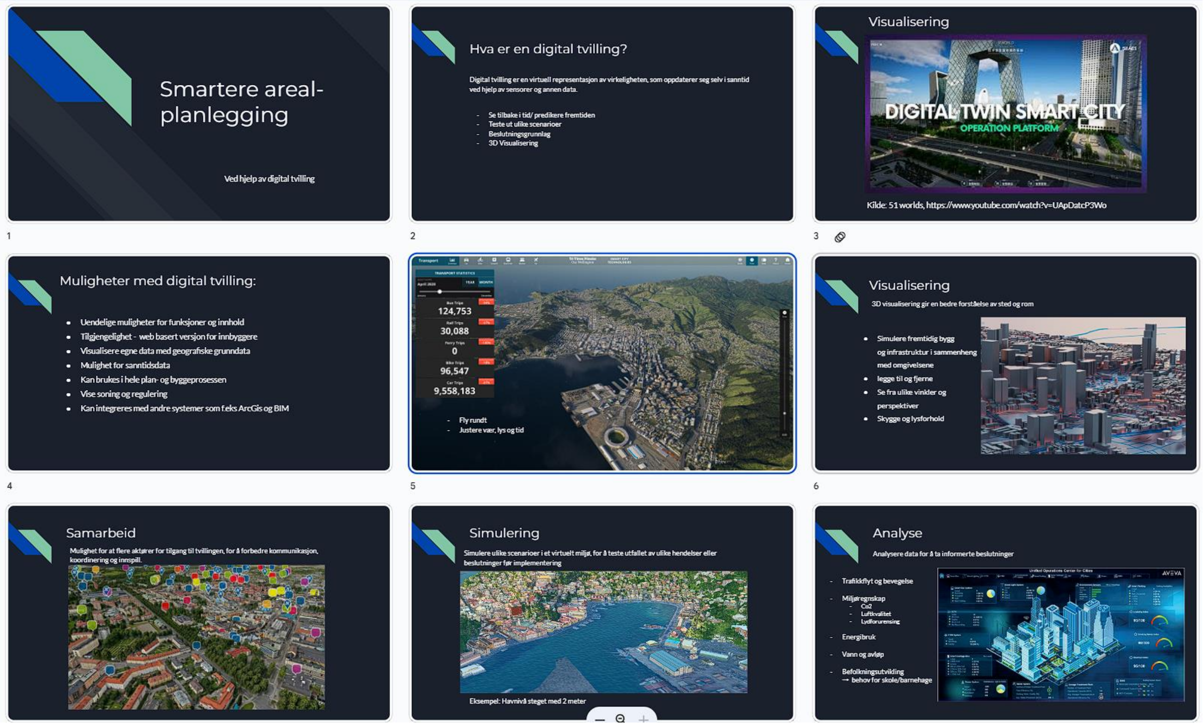
(Signert av prosjektdeltaker, dato)

Appendix 3. Focus group MVP



Appendix 4. Observation guide

Observasjonsguide

Hensikt: Gjennomføre en systematisk observasjon.

Observasjonen skal være passiv og åpen

Kvantitativ data vi kan samle inn:

- Hvor mange ganger spør deltakerne om hjelp?
- Hvem spør mest om hjelp (og deres bakgrunn)?

Fasilitering:

- Spørsmål som ble stilt
- Ordstyring
- introduksjon

Brukervennlighet:

- Hvor sømløs er teknologien?
- Hvor mye tid går til teknisk?
- Hvor mange utfordringer dukker opp ved bruk av tvillingen?
- Kan deltakerne intuitivt forstå programmet, eller kreves det mye opplæring?

Nytte:

- Blir deltakerne sine meninger ivaretatt?
- Blir data som samles inn på seminaret (i forhold til arealplanleggings-prosessen) ivaretatt for senere bruk?

Interaksjon:

- Bruker deltakerne den digitale tvillingen, eller bruker de alternativer som f.eks penn og papir?
- Hvem holder ordet mest? Kommer alle deltakerne sine meninger frem?
- Hvordan forholder deltakerne seg til hverandre
- Enighet vs. uenigheter

Appendix 5. Coding sheet

Theme:	Mentions:
Perceived usefulness	42
Important features	14
Visualization	12
Climate and sustainability	4
Simulation and prediction	7
Consultant work	9
Communication	17
Collaboration	4
Perceived Ease of Use	37
Interface and interaction	7
Relevant experience	17
Education and background	13
Learning the program	8
Similar programs	16
Required competence	8
Expected behavior	6
Organizational factors	7
Legal and regulatory framework	5
Public participation	17
Benefits and opportunities	18
Challenges and obstacles	8

Name	Grounded
konsulent	9
e-post	9
trafikkflyt	7
tverrfaglig samarbeid	7
Tilsvarende programmer	7
Arbeidserfaring	6
medvirkning	5
Visualisering	5
inkludering	5
Utdanning	5
telefon	4
predikere	4
kurs	4
matte	4
Programmer	4
simulering	3
lover og regulering	3
Acos	3
Krever høy kompetanse	3
arbeidsoppgaver	3
norkart	3
konsulent pains	3
Work tasks	3
ArcGis	3
førsteinntrykket er positivt	3
fagområder	3
ekstern kompetanse	3
solforhold	2
dokumentering	2
nettkurs	2
dagens programmer	2
learning by doing	2
dynamisk prosess	2
intuitiv løsning	2
superbruker	2
Miljøregnskap	2
Dårlig kapasitet	2
Scenario testing	2
pains	2
User of the software	2
Positiv	2
3D	2
Langsiktige planer	2
Overflødig	2
lysforhold	1
Potentialet er stort	1
visualisering er den viktigste effekten	1
funksjoner	1
aktiv medvirkning	1
energi	1
belyser ting godt	1
høyde	1
bruker mye 3D modellering i dag	1
frykt for at brukervennligheten ikke er god	1
postmottak	1
Essensen av plan er å involvere og medvirke	1
En standard for alle kommuner	1
mobilitet og infrastruktur	1
Det eneste programmet	1
Lite dynamisk prosess	1
frykt for at programmet blir konsulent- mat	1
erfaring med 3D	1
krevende prosess	1
generere ting	1
samle alt i en modell	1
Bruker av programmene	1
Veldig relevant for arbeidhverdagen	1
Utfordringer med 2D Kart	1
kontinuerlig bruk for å lære programmet	1
komplekst	1
Liten kommune	1
informasjonspunkter	1
støy	1
pålitelighet	1
frykt for diskriminering	1
Avansert teknologi	1
Større byer	1
kunstig inteligens	1
brukervennlighet	1
Naturfare på vestlandet	1
Altinn	1
frykt for at det blir ett dyrt verktøy	1
visualisere innledningsvis	1
Usefullness	1
OpenCity Planner	1
planprosess	1
vanskeling å tilnærme seg ny teknologi	1
konsulent som utarbeider solforhold	1
parametere for utbygging	1
stort engasjament rund åpen innspillsmodell	1
Alle nivåer opp til ledere	1
Tro på at dette er framtiden	1
møter	1
Ser at det er mye potentialle	1
Tradisjonelle kanaler	1
Spare tid	1
Dagens 3D modeller er ofte enkle	1
Se helheten	1
nye virkeligheten vi må forholde oss til	1
ambita infoland	1
integrert i arbeidsmetodene	1
gjøre beregninger selv	1
se sammenheng	1
svar med en gang	1
spare tid på å visualisere	1
trenger de fysiske møtene	1
hjemmeside	1
puplic participation	1
byggesøknad i modellen	1
vanskelig å si om en sparer arbeidstid	1
Overflatevann	1
transparent	1
implementering av verktøy	1
kapasitet på skole og barnehage	1
ArcGis storymaps	1
ArcGis storymaps til å presentere planer	1
legge inn kommentarer	1
frykt for at det er alt for avansert	1
Dagens 3D modeller er sjeldent klikkbare	1
Kommunens arealdel	1
vindretning	1
money talks	1
Veibygging bruker mye 3D	1
byggesaker har ofte mye kritikk innledningsvis	1
største fordel er visualisering	1
Planlegging er ikke linært	1
superbrukere i organisasjonen	1
folk flokket mot rommene med 3D	1
knagger	1
viktig å kunne måle avstander, høyde og arealer	1
sanntidsdata	1
Bruker 3D til å lese terreng og se volum	1
fantastisk med simulering i sanntid	1
interkommunalt sammarbeid	1
virker intuitivt	1
digital synsfaring	1
quotes	1
alt på ett sted	1
belyse ting bedre	1
forutsetter høy kunnskap	1
viktig både med skriflige og visuelle inspill	1
eksterne utviklere	1
politisk ønske	1
krever ny kompetanse	1
viktig å kunne skissere i modellen	1
bevegelsemønster	1
Ting tar tid	1
klima	1
tidsbesparende for hele arbeidsprosessen	1
ser for seg geodata på den tekniske kompetansen	1
ulike interesser	1
interaktivt kart for innbyggere	1
inhouse	1
web3 utviklingen	1
bruker 3D i strandsonen i dag	1
visuelt	1
frykt for at ikke alle blir med	1

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