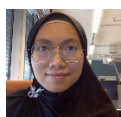


What are “Usable” Digital Twins? Learning from Existing Digital Twins for Transport Planning



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INTRODUCTION

Imagine being able to simulate and visualise the impacts of a new parking policy in a city. Are parking areas still being used as they were before? Who uses these spaces? Do citizens switch to using other modes of transport because they find the parking fees too high? How is public transport utilised because of these changes? Practitioners and planners frequently ask these types of questions during and after the implementation of new transport plans or policies. Digital Twins (DTs) show great promise in answering these questions with ease, which has garnered the attention of urban planners and city authorities.

However, DTs are not cheap! For example, Singapore’s DTs initiative reportedly cost \$73 million (Johnson, 2022). Given the scale of substantial investment, not only for infrastructure development but also operations and maintenance, it is crucial to ensure that DTs are “usable” and tailored to real planning needs. This study explores the existing DTs in transport planning to synthesize key considerations for conceptualizing usable DTs in transport planning.

About DTs and their features

DTs are digital representations of physical systems that maintain continuous data and information exchange between the two entities (Grieves, 2015). DTs consist of three core components: (1) the physical system, (2) the virtual representation, and (3) the bidirectional data exchange that keeps both updated (VanDerHorn & Mahadevan, 2021). A newer definition envisions five components—physical, digital, data model, service and connections (Grübel et al., 2022). The data model component utilizes advanced data analytics (real-time data modelling, simulation, etc.) to generate actionable insights for the service components (visualization, scenario development, etc.). Naturally, service is the crucial component that can help describe usable DTs in practice.

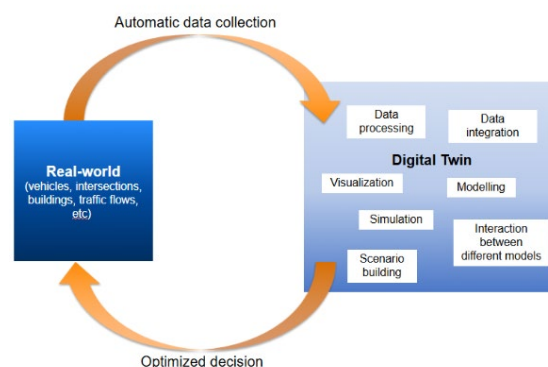


Figure 1: Illustrations of Digital Twin



METHOD

This article reports a systematic literature review of 136 DTs in transport studies published between 2000 and 2024, and investigates the components above and their relationships. Furthermore, stakeholders involved in a cross-sectoral climate resilience initiative in Kristiansund, Norway, were interviewed regarding the use of DTs, particularly focusing on transport.



RESULT

Not all DTs are Digital Twin

The systematic review showed that only one study demonstrated a “true” DT, where components interacted with each other through automatic and bidirectional information exchange. In contrast, the remaining 47% and 51% of the studies were categorized as ‘Digital Model’ and ‘Digital Shadow’, respectively (Nag et al., 2025). Digital Models involve manual data transfer between physical and digital components, similar to conventional modelling tools, while Digital Shadows automate unidirectional data flow between them (Kritzing et al., 2018).

Many cases labelled as DTs were in fact Digital Models, justified by features such as 3D visualization, realistic digital replicas, new data types, or virtual testing environments. This highlights the early misuse of “Digital Twin” as a buzzword, often adopted without a clear definition in its initial adoption.

Automation in DTs is Associated with Reduced Spatial and Temporal Coverage

The systematic review indicates that DTs in the transport sector mainly focus on small-scale areas and short-term predictions, making them more suitable for operational monitoring than long-term strategic planning. City-wide applications with medium- to long-term forecasting were more commonly found in studies classified as Digital Models. This suggests that applying fully automated DTs at broader scales remains challenging. Urban transport systems involve complex human behaviors that are difficult to

model. Developing reliable DTs, therefore, requires rigorous validation of underlying models and assumptions before scaling to city-wide applications.

DTs Visualization for Engagement and Participatory Planning

An interview conducted with the project lead of CREST¹ highlighted that the most valuable DT features were visualisation capabilities, as they function as a tool for stakeholder engagement. The CREST DT itself included a 3D digital replica of the built environment, which acted as a visualisation dashboard integrating manually input data and pre-defined scenarios co-created in workshops. This served as a scenario simulator to initiate focus group discussions with stakeholders and the public.

Implications

Re-thinking Usability: Key Considerations

Among the key features, 3D visualization has shown value in engaging citizens through participatory planning processes. Besides, it is suggested that DTs are currently more suited to operational monitoring rather than long-term strategic transport planning, which will require high development and operational costs. For instance, could a simple 3D animation video (based on results from Digital Model or Shadow) effectively engage politicians instead of a full-scale DT platform?

Identifying Planning Needs and Bottom-up Design

Moving beyond the technical allure of DTs, it is important to define the planning questions being addressed clearly. Are we aiming to understand shifts in travel behavior due to a policy intervention, or to support citizen engagement in evaluating alternatives? Do we want to forecast modal shifts at the city level or detect vehicle crashes at a single intersection? These distinctions determine the data, models, and functionality required of any planning tool. Currently, few studies systematically identify the needs of stakeholders in transport planning tools. A

bottom-up, need-driven approach, starting from planning objectives rather than technological ambition, can guide the development of more usable and purpose-fit DTs.



CONCLUSION

This study conducted a systematic literature review of existing Digital Twin applications in transport planning. The findings reveal that most DTs are limited in both spatial and temporal scope, with very few addressing long-term travel demand scenarios. Their most applied feature is enhanced visualization, often used to engage the public. However, the limited integration of bidirectional data flow and planning-relevant modelling raises questions about the suitability of current DT implementations for long-term strategic planning. Given the high cost of DT development, it is essential to assess planning needs first and ensure that DTs are designed to be "usable" - aligned with specific goals, stakeholder requirements, and context-specific decision-making processes.

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