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Introduction

Digital Twins in Infrastructure, Mobility and Cities

Potentials, Challenges & Enabling Factors across Europe

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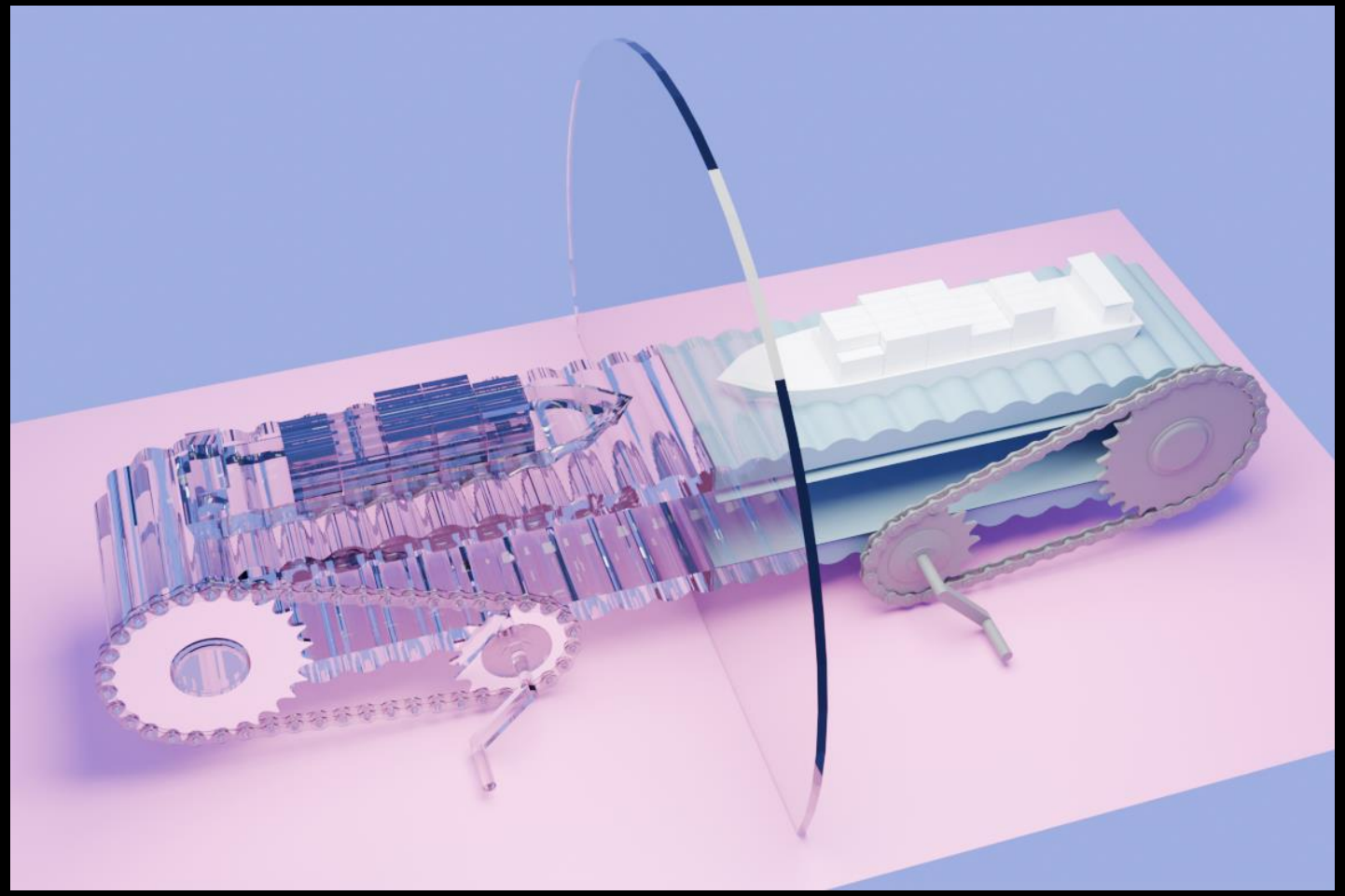
OpenTwin Research Project



- Duration: May 2025 – June 2026
- Funded by Federal Ministry of Transport within mFUND initiative
- Findings and analysis summarised in forthcoming research report

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The physical system crosses boundaries, so, the digital representation should follow.

- Within Europe, infrastructure, mobility, and energy systems extend across countries, sectors, and organisations. But Digital Twins applications remain limited to national, sectoral, or organisational contexts.
- Cross-Border Digital Twins can connect existing systems through federated, secure, and interoperable data exchange.
- This European perspective can reduce duplicated work, support common standards, enable reuse, and strengthen cooperation between local Digital Twins

Possible use case: Cross-border charging infrastructure

Combines traffic flows, charging-point availability, grid capacity, and spatial planning data to support coordinated investment and infrastructure deployment.

What is a Cross-border or “Transnational Digital Twin”?

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Working Definition of Transnational Digital Twins*

***T**ransnational Digital Twins can be understood **as decentralized, cross-border digital representations** of physical* objects*, processes, or systems that extend across **national and sectoral boundaries**. Transnational Digital Twins are typically designed as **federated systems** in which data remain within their original legal and organizational contexts while being exchanged in a sovereign, secure, and interoperable manner.*

* Proposed working definition, basis for discussion.

Digital Twins (derived from Blüml et al. 2025)

A virtual representation of a physical object, process, or system, linked to its real-world counterpart through continuous data exchange.

Transnational Dimension

Not only across countries, but also across administrative, legal, sectoral, organisational, and data-system boundaries.

Architectural Logic

Usually federated, connecting existing Twins, data platforms, sensors, models, interfaces, and analytical services rather than replacing them.

Added value: From local Digital Twins to a connected European ecosystem

Benefits and added value for existing Digital Twin initiatives

- Less duplicated work across cities, sectors, and countries.
- Reusable technical building blocks, data models, and standards.
- Shared learning on technical solutions and governance patterns.
- More scalable local and national Digital Twin projects.

Potential added value for future development

- Possibility to connect existing DTs across borders and sectors in the future.
- Allows digital representations to better reflect physical systems that already cross borders.
- Supports shared analytical layers for cross-border planning, simulation, monitoring, and decision-making.
- Strengthens European integration through compatible systems rather than isolated solutions.

Where Digital Twins across borders are emerging

Mobility & Transport Management
Rail, road, ports, waterways, multimodal transport.

Possible use case: cross-border rail operations and corridor management (e.g. MOTIONAL)

Environmental & Climate Research
Climate, weather, marine, and environmental systems.

Possible use case: large-scale climate and environmental simulations (e.g. Destination Earth).

Cities & Urban Governance
Urban planning, smart city services, mobility, and resilience.

Possible use case: Local Digital Twin Toolbox

Energy & Crisis Prevention
Energy networks, critical infrastructure, resilience, and maintenance.

Possible use case: grid planning and predictive maintenance (e.g. Begonia).

Border regions as empirical test fields
Practical spaces for cross-border data exchange and governance.

Possible use case: shared mobility, energy, and planning use cases in border regions.

Digital Twins across border become feasible when technical systems are matched with mature governance, legal clarity, and sustained cooperation structures.

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1 Foundation, Organisation & Governance

Shared vision, clear roles, multi-stakeholder coordination, address unequal starting conditions.

2 Data & Technical Infrastructure

Semantic interoperability, common standards, data spaces, federated architectures, and controlled access.

3 Institutional & Regulatory Framework

Long-term funding, regulatory clarity, national-European alignment, security and sovereignty.

⇨ The main barriers are currently less technical than organisational, institutional, legal, and regulatory.

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The more Digital Twins scale across systems and borders, the more coordination becomes the central implementation task.

Start with purpose

- Define the concrete problem and user need.
- Clarify whether a Digital Twin is the right tool.
- Agree on shared terms, scope of the use case, and define added value.
- Use limited pilots and success stories to build legitimacy.

Build the cooperation model

- Define roles, responsibilities, and decision rights.
- Align public, private, research, and administrative stakeholder.
- Combine vertical use cases with horizontal work strands.
- Use local counterparts to translate national and organisational requirements.
- Compensate for different levels of resources, maturity, and governance capacity.

Possible implementation pattern:
Vertical use cases, such as rail operations or charging infrastructure, combined with horizontal work packages, such as governance, technical architecture, data models, and long-term operation.

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Digital Twins can only scale when the necessary data can be found, understood, accessed, and exchanged securely.

Create interoperable data foundations

- Use common data models for objects, processes, and relationships.
- Harmonise metadata to improve data findability and reuse.
- Clarify who holds which data, under which access conditions.
- Use open data as an enabler, but plan for mixed data ecosystems.

Build reusable and federated infrastructure

- Use data spaces for controlled and sovereign data exchange.
- Combine open, partner-provided, operational, sensitive, and proprietary data.
- Use layered architectures so data can remain with the original owner.
- Apply identity management, authentication, and access control.
- Reuse reference architectures, and modular components.

Design data and technical infrastructure for reuse today, so Digital Twins can be connected across borders tomorrow.

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Digital Twins need stable framework conditions to move from pilots to reusable and connected systems.

Align rules and responsibilities

- Translate EU and national rules into a cross-border data governance model.
- Clarify data access, data protection, liability, and usage rights in practice.
- Align national implementation with European strategies and standards.
- Apply sector-specific governance, especially for critical infrastructure.

Move beyond pilot logic

- Secure long-term funding for operation, maintenance, and further development.
- Standardise technical and organisational structures for reuse.
- Build user communities and peer-to-peer exchange between cities, sectors, and countries.
- Use modular service catalogues, reference architectures, and governance models to replicate successful approaches.

Move from isolated pilots to durable governance, funding, and reuse structures.

Outlook: Towards a Connected European Digital Twin Ecosystem

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Cross-border Digital Twins are not a finished technology or product.
They are an emerging strategic approach to cross-border, data-driven infrastructure governance.

Main Value:
Their promise lies in enabling more integrated, cross-sector, and evidence-based decisions across Europe, connecting existing local or national Twins, data spaces, and platforms.

What this means today:
Digital Twins should be developed with a European perspective in mind considering interoperability, scalability, and possible future cross-border integration through federated, secure, and reusable digital infrastructure.

In the following workshops we want to discuss with you:

***W**hat is needed to make this vision practical in your sector, project, or organisation?*
What challenges occur, what are the next steps?