3DxVERSE

# Work Package 8

## D8.5: Interoperability and Data Governance - First Report

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# TABLE OF CONTENTS

# LIST OF FIGURES



# LIST OF TABLES

## List of abbreviations and acronyms

| Abbreviation | Meaning |
|---|---|
| **ABAC** | Attribute-Based Access Control |
| **AI** | Artificial Intelligence |
| **AI Act** | The Artificial Intelligence Act (Regulation (EU) 2024/1689) |
| **DevSecOps** | Development Security Operations |
| **DGA** | Data Governance Act |
| **DPI** | Digital Public Infrastructure |
| **DSA** | Digital Services Act |
| **EC** | European Certification |
| **EDIC** | European Digital Infrastructure Consortium |
| **eIDAS** | European Identity, Authentication and trust Services |
| **EIF** | European Interoperability Framework |
| **EIRA** | European Interoperability Reference Architecture |
| **EU** | European Union |
| **FIDO** | Fast Identity Online |
| **G20** | Group of 20 (international forum for governments and central banks) |
| **GDPR** | General Data Protection Regulation |
| **IATA** | International Air Transport Association |
| **ICT** | Information and Communication Technology |
| **IDSA** | International Data Spaces Association |
| **IoT** | Internet of Things |
| **ISO** | International Organization for Standardization |
| **ITB** | Interoperability Testbed |
| **ITU** | International Telecommunication Union |
| **MIMs** | Minimum Interoperability Mechanisms |
| **NIS2** | Network and Information Security Directive 2 |
| **OASC** | Open and Agile Smart Cities |
| **OWASP** | The Open Worldwide Application Security Project |
| **RBAC** | Role-Based Access Control |
| **SD-JWT** | Selective Disclosure - JSON Web Token (A form of Verifiable Credential) |
| **SOTA** | State Of The Art |
| **TEE** | Trusted Execution Environment |
| **TF** | Trust Framework |
| **VC** | Verifiable Credential |

# EXECUTIVE SUMMARY

This deliverable, D8.5 – Interoperability and Data Governance – First Report, is prepared under Work Package 8 (WP8): Pilots and Citizen Engagement, and specifically focuses on Task 8.3: Interoperability and Data Governance. It aims to provide an implementation framework that translates conceptual and technical inputs from other work packages into practical guidance for the 3DxVERSE pilot implementations in Almelo (Netherlands), Aruba, Hamburg (Germany), and Timișoara (Romania).

**Chapter 1: Introduction**

Chapter 1 presents the overarching objectives of the 3DxVERSE project, which include creating interoperable, secure, and citizen-centric Local Digital Twins (LDTs) that support sustainable urban living and mobility. It elaborates on the intended audience, the document's public dissemination level, and the integration of workshops, stakeholder meetings, and prior deliverables in shaping this report.

**Chapter 2 – Conceptual Framework**

This chapter outlines the foundations of interoperability and data governance in the project. It describes the four-layer interoperability model from the European Interoperability Framework (EIF) and its application through the 3DxVERSE Interoperability Testbed and OASC MIMs+. The chapter includes the iSHARE Trust Framework, a federated identity and access system compatible with eIDAS 2.0 and W3C Verifiable Credentials. It also shows how security and privacy-by-design principles and socio-technical design approaches are embedded into governance structures via alignment with the Digital Commons Framework (DCF).

**Chapter 3 – Practical Aspects for Pilot Participants**

This chapter offers human-centric mechanisms to ensure inclusive and ethical pilot deployment. It introduces personas and story-driven design to engage diverse user types and identifies "bad-actor personas" to anticipate misuse. A storytelling-based co-creation method is used to improve accessibility and citizen engagement. The chapter discusses how community ownership of outcomes and metrics is operationalized using NEB principles, and how harm reduction techniques and “what could go wrong?” scenario planning are embedded into DevSecOps processes for resilience and security.

**Chapter 4 – Interoperability Implementation in Pilots**

This chapter describes how the theoretical models are being applied across the 3DxVERSE pilots. It focuses on semantic interoperability, such as using $CO_2e$ as a unified environmental metric to allow data comparisons between air and ground mobility. The chapter presents the concept of a $CO_2$ wallet, particularly for Aruba and Hamburg pilots, where transport emissions data is used to generate verifiable carbon credits. It explains how verifiable credentials and decentralized identifiers (DIDs) can link environmental impact data to digital identities securely. These implementations are technically aligned with ISO standards and contribute to energy savings and emissions transparency, reinforcing data exchange between systems in an interoperable format.

In the governance context, each pilot is advised to form an advisory group of stakeholders, aligned with the democratic governance philosophy of the DCF. Pilots are also encouraged to explore decentralized governance models, including experiments with Decentralized Autonomous Organizations (DAOs) to operationalize ethical rules through transparent, rule-based systems. This structure enables a shared data commons per pilot allowing standardized, federated data sharing that empowers communities while protecting sensitive data through access controls and trust frameworks.
In conclusion, D8.5 serves as the bridge between the conceptual and technical groundwork of earlier WPs and the real-world deployment of interoperable and ethically governed digital twins. The deliverable sets a clear foundation for implementing secure, inclusive, and scalable pilot systems that conform to European interoperability and data governance standards. It will evolve in future iterations based on feedback from implementation, stakeholder engagement, and pilot validation activities.

# 1. INTRODUCTION

## 1.1. Overview of 3DxVERSE

The 3DxVERSE project develops an interoperable and user-centric Local Digital Twins (LDTs) to support sustainable living and mobility. It demonstrates how digital twins can enhance sustainability, resilience, and social inclusion across airports, cities, and communities.

Grounded in European norms and the New European Bauhaus principles, 3DxVERSE combines Artificial Intelligence (AI), Extended and Virtual Reality (XR/VR), and Data Spaces to enable cross-domain collaboration between citizens, public administrations, and industry. It aligns with the G20 Framework for Digital Public Infrastructure and the EU Data Strategy, promoting transparency, accountability, and ethical use of data.

In partnership with leading initiatives such as CitiVerse Project, Open & Agile Smart Cities (OASC) working on the OASC Minimal Interoperability Mechanisms (MIMs), and European Digital Infrastructure Consortia (EDICs), the project strengthens Europe's capacity for trusted data exchange and interoperable governance of digital ecosystems.

By creating an open, interoperable, secure, trustworthy, fair, and inclusive reference implementation blueprint digital twin for EU citizens, businesses, and public administrations, this project strives to build a resilient, inclusive, and environmentally conscious digital economy and society.

Implementation takes place through a diverse network of pilot locations—Almelo (Netherlands), Hamburg (Germany), Timișoara (Romania), and Oranjestad (Aruba). Each pilot contributes unique environmental, regulatory, and social conditions, collectively demonstrating how interoperability and data governance can enhance scalable, human-centric digital twins across Europe and beyond.

The project can scale to global collaboration with partner countries, including Africa, India, Singapore, South Korea, Japan, the UK, and Canada. Besides, the consortium is active in ISO TC-204-WG17 with active engagement of Australia and New Zealand.

## 1.2. Purpose of Deliverable D8.5

This deliverable, Interoperability and Data Governance for Pilots, is produced under Work Package 8 (Pilots and Citizen Engagement), specifically addressing Task 8.3 (Interoperability and Data Governance). Its purpose is to operationalize and validate the interoperability and governance frameworks established in the earlier technical and conceptual work packages WP3 (Interoperability Testbed and Reference Architecture), WP4 (Digital Commons Framework), and WP5 (Security & Privacy of Digital Twins).

D8.5 builds upon the principles and technical specifications defined in D1.1, D3.1, D4.1, D5.1, D6.1 and D6.3, D7.1 and D7.3, translating them into practical technicalities for interoperability and ethical data governance within the pilot environments. This deliverable ensures that the Local Digital Twins (LDTs) which are under construction in Almelo, Aruba, Hamburg, and Timișoara operate within a common interoperable framework while remaining compliant with European standards and regulatory requirements.

The document provides a comprehensive description of:

- The implementation of interoperability protocols and data exchange mechanisms that enable seamless integration between pilots.
- The governance structures and ethical oversight models ensuring data is handled in a trustworthy, transparent, and rights-preserving manner.

- The alignment of pilot data governance with the DT and the Trust Framework (TF) and all other workable frameworks that have been outlined in D5.1.
- The validation of multi-level interoperability, technical, semantic, legal, and organizational, across the pilots and their stakeholder ecosystems.

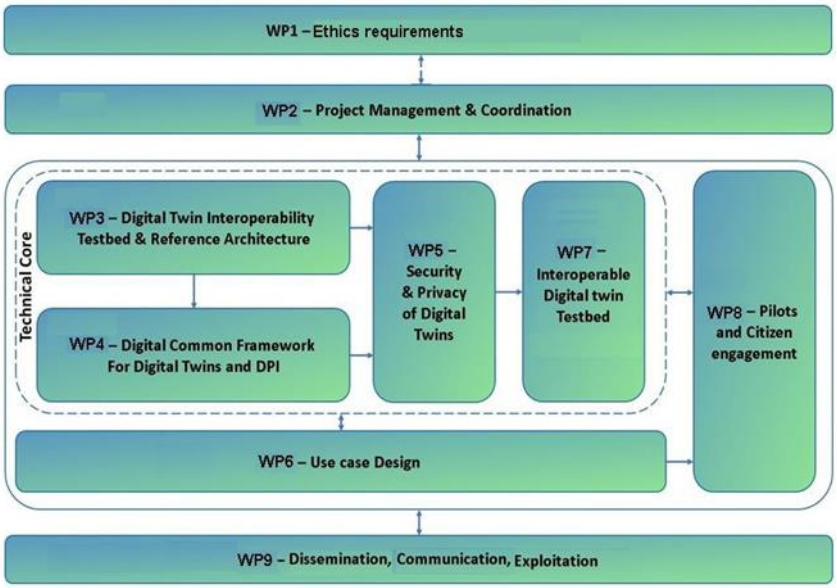


**Figure 1: Logical interdependency map of the work packages**

As shown in the logical interdependency map of the work packages (figure 1), D8.5 represents the up-to-date implementation layer where the trust, interoperability, and data governance frameworks converge in operational pilots. It provides a methodology for evaluating how interoperability standards and governance protocols function in pilot conditions, leading toward the D5.2 report.

By establishing clear rules for data lifecycle management, interoperability conformance, and ethical data use, this deliverable ensures that each pilot within 3DxVERSE contributes to a trusted, replicable, and sustainable European digital twin ecosystem.

## 1.3. Interdependencies with other WP's

Deliverable D8.5 provides the framework for pilot implementation, ensuring that interoperability and data governance principles are consistently applied across the Almelo, Aruba, Hamburg, and Timișoara pilots. It connects the conceptual and technical outputs from previous work packages with the operational activities of WP8, serving as the reference for how data should be exchanged, managed, and governed.

- WP1 – Ethics requirements: delivers an overarching framework of check-list for the technical implementation and all pilot activities with public engagement, defined in D1.1 followed by D2.3, D2.4 and D2.5 reporting the activities linked to ethics.
- WP3 – Interoperability Testbed & Reference Architecture: delivers the core architecture, standards, and APIs that define technical interoperability, which D8.5 contextualizes for pilot use.
- WP4 – Digital Commons Framework: establishes the policy and governance rules for ethical data exchange, adapted in D8.5 as operational governance guidance which has been articulated in the house of digital commons.
- WP5 – Security & Privacy of Digital Twins: provides the Trust Framework, DevSecOps, and Privacy-by-Design principles that underpin secure data management across pilots.

- WP6 – Use Case Design: defines the functional and data needs for each pilot, guiding the structure of D8.5's interoperability and governance framework.
- WP7 – Interoperable Digital Twin Testbed: offers the technical environment in which D8.5's governance and interoperability guidelines are validated and refined.

Together, these interlinked work packages ensure that D8.5 acts as a strategic bridge that translates technical and ethical frameworks into an operational governance model that assures the interoperable, secure, and trustworthy deployment and use of Local Digital Twins in the pilots.

## 1.4. Intended Audience and Dissemination Level

This deliverable is intended for a broad audience, including members of the 3DxVERSE consortium, the European Commission, and the wider community of policymakers, researchers, and practitioners involved in the development and governance of Local Digital Twins (LDTs) across Europe.

Deliverable D8.5 is classified as Public (PU), ensuring open access to its findings, methodologies, and framework recommendations.

By disseminating the results publicly, the deliverable supports knowledge sharing across European cities, research institutions, and private-sector partners working toward interoperable and trustworthy Digital Twin ecosystems.

## 1.5. Status of the deliverable

The information used in the deliverable is based on the deliverables of previous work packages, the periodic WP meetings, the workshops organized by the WP leaders such as Technical Deep Understandings in Enschede October/2025 and the workshop organized by the Hague University of Applied Sciences October 2025, and the meetings conducted at the Smart City Expo in Barcelona November/2025.

This deliverable is considered an implementation framework regarding data governance and interoperability for the pilots.

# 2. CONCEPTUAL FRAMEWORK

## 2.1. Interoperability in the 3DxVERSE Ecosystem

Interoperability in 3DxVERSE refers to the seamless cooperation of digital twin systems, stakeholders, and data sources across different domains and locations. In the New European Interoperability Framework (EIF), interoperability is defined as the ability of organisations to interact towards mutually beneficial goals, involving the sharing of information and knowledge between these organisations, through the exchange of data between their ICT systems (European Commission, 2017). For more information: New European Interoperability Framework.

In practice, this means a Local Digital Twin in one city or use-case can readily exchange and understand data with another, using common standards and interfaces. The 3DxVERSE project places strong emphasis on European and global interoperability by design, aligning its reference architecture with EU guidelines. 3DxVERSE leverages the EIF and the European Interoperability Reference Architecture (EIRA) to design solutions that can interact efficiently in a digital ecosystem and work across borders. For more information: Interoperability Architecture Solutions.

By adopting shared architecture tools and interoperability testbeds, the ecosystem ensures that pilot implementations are built on compatible building blocks. This approach is also reinforced by EU policy, for example, the Interoperable Europe Act mandates such common frameworks for digital public services. In summary, interoperability in 3DxVERSE means all components (data, models, algorithms, services) can connect, interact or transact reliably across organizational and technical boundaries, providing a cohesive and future-proof digital twin environment.

Following the European Interoperability Framework (EIF) (European Commission, 2017), interoperability in 3DxVERSE operates across four layers: legal (policy coherence and alignment), organizational (business process alignment), semantic (what is sent is what is understood), and technical (conformance with technical specifications), and is realized through the 3DxVERSE's Interoperability Testbed and the OASC Minimal Interoperability Mechanisms (MIMs Plus).


**Figure 2: Interoperability Model in 3DxVERSE - Source: (European Commission, 2017)**

## 2.2. Data Governance for Local Digital Twins (LDTs)

Data Governance which is a core component of a Trust Framework (TF) in the context of 3DxVERSE, and as per D5.1, refers to the structured set of rules, policies, processes and standards, that enables

parties to confidently share and rely on identity, data or services in a consistent, secure, and interoperable way. It aims also to ensure data within LDT's is handled responsibly, securely, and in line with both project goals, legal compliance and ethical norms.

Each LDT must manage who can access or modify its data, under what conditions, and how data is shared or retained. The 3DxVERSE AI and Digital Twin Trust Framework provides the foundation for LDT data governance. This TF is conceived as a "structured model of rules, roles, and processes" to govern data and identity exchanges in the ecosystem. It is multi-layered by design:

- a policy layer defines the rules, agreements, and ethical guidelines for data use (anchored in EU regulations like GDPR and AI Act);
- a technical layer embeds these rules into the system architecture and standards (ensuring that enforcement is machine-enforceable and consistent across platforms);
- and an access control layer regulates permissions to data and services (using mechanisms such as role-based and attribute-based access control to ensure only authorized entities access sensitive information).

This mirrors the "twin stack" model, which has been discovered in D5.1, where governance sits alongside technology in equal measure (see figure 3). For example, before an LDT in a pilot shares data with another service, the TF requires that parties be onboarded with defined roles and that data exchange follows predefined policies and consent rules. Technical measures (like metadata standards, secure APIs, and audit trails) support these policies, while identity and credential management (e.g. issuance of verifiable credentials to data providers/consumers) enforce the access rights. By covering the full lifecycle, from participant onboarding and provisioning of data to continuous monitoring and off-boarding, the TF ensures that data governance is continuous and adaptive. For more information about the five life stages of 3DxVERSE participants see D5.1.

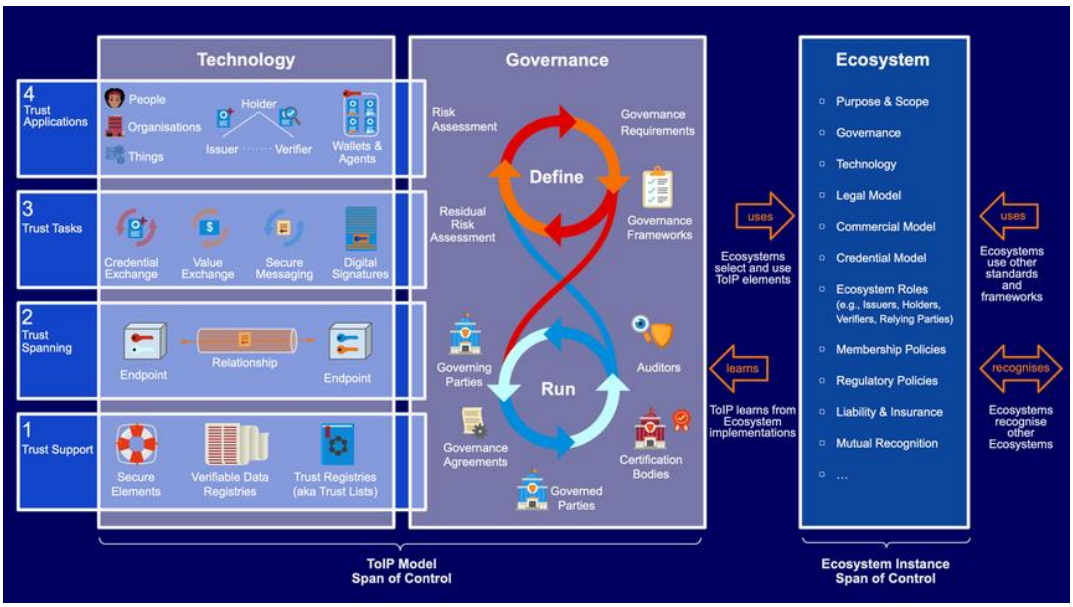


**Figure 3: The Trust over IP Model (Source: Trust over IP Foundation)**

In pilot implementation, this means each LDT operates under a clear governance scheme: data is shared for a specific purpose, on a need-to-know and agreed basis, usage is transparent and auditable, and governance rules can be updated as risks or requirements evolve.

This governance model is not static. It emphasizes dynamic, participatory, and iterative control, allowing local authorities and stakeholders in the pilots to refine policies as lessons are learned (consistent with the Digital Commons approach in D4.1).

Overall, the goal of data governance in 3DxVERSE's pilots is to balance innovation with accountability, ensuring data is used in innovative ways for sustainability and smart solutions, while maintaining trust, privacy, and compliance across all LDTs. By using the common trust framework, the project's pilots can enforce governance in a standardized way, making the ecosystem trustworthy and scalable.

## 2.3. iSHARE Trust Framework

Specifically, the 3DxVERSE TF conforms with roles and rules for data exchange within iSHARE Trust Framework, which is a governance scheme and technical architecture that enables federated trust for data sharing across ecosystems. It is maintained by the iSHARE Foundation (the scheme owner), which provides legal agreements and oversight of the framework. iSHARE enables organizations to verify identities, authenticate users, and enforce coarse and fine-grained data access policies using standardized roles. A key feature is its delegation mechanism, which allows data owners to issue dynamic, revocable permissions to others via structured licenses. This ensures that data sovereignty is preserved even in multi-party data flows. For more information: iSHARE Trust Framework.

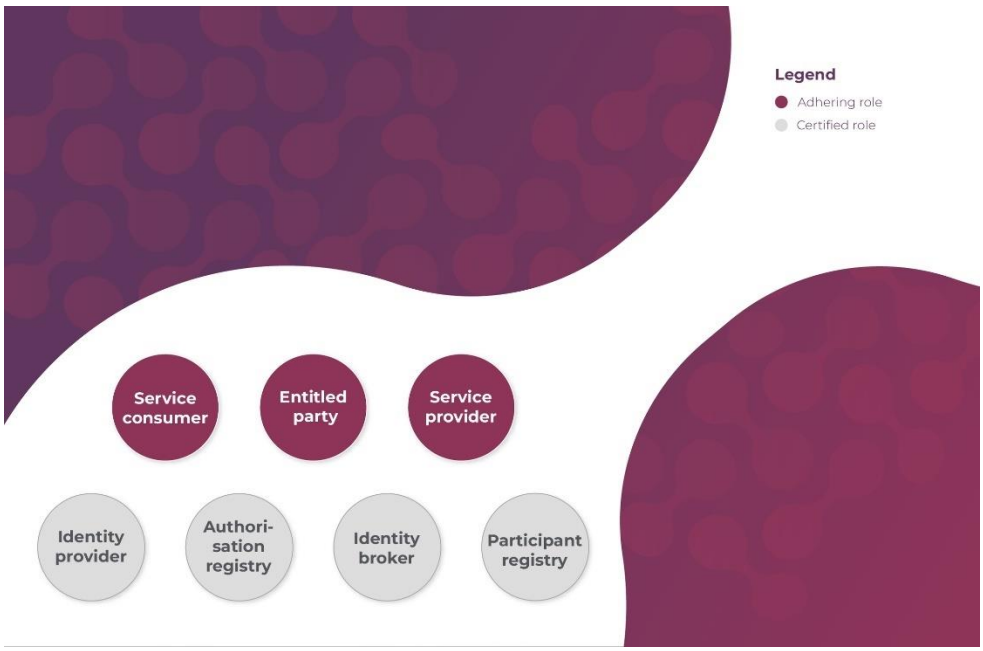


**Figure 4: Roles of iSHARE Trust Framework, Source: iSHARE Trust Framework**

A 3DxVERSE workshop has been held in October/2025 and found that iSHARE is highly relevant for implementing cross-domain trust and interoperability in pilots involving carbon footprint tracking. For instance, in a carbon footprint wallet use case, a citizen's travel and mobility data can be aggregated securely using iSHARE-based authorizations. Data providers only release information when a verifiable delegation exists, for example: the citizen authorizes a wallet service to access their travel logs for emission calculations. These authorizations are validated against a shared Authorization Registry, and all identities are verified through iSHARE's federated identity system, which is compatible with eIDAS 2.0 credentials, W3C Verifiable Credentials and other identity and data sharing standards as specified in D5.1.

By using widely adopted open standards, the pilot implementations ensure that solutions are built on interoperable, standardized foundations that can integrate with other city systems and be scaled or replicated across different locations.

## 2.4. Integration with the 3DxVERSE's Digital Commons Framework

The Digital Commons Framework (DCF) developed in D4.1 provides the blueprint for how 3DxVERSE pilots are implemented and managed. In essence, the pilots are designed not as isolated technical projects, but as community-governed digital commons and digital twin platforms that are co-created, shared, and governed by their stakeholders (cities, citizens, companies) rather than owned by a single vendor. D4.1's principles of democratic governance, open-source, and inclusion directly inform the pilots' design and operations. See figure 5 for more insights about the WP4 house of digital commons.

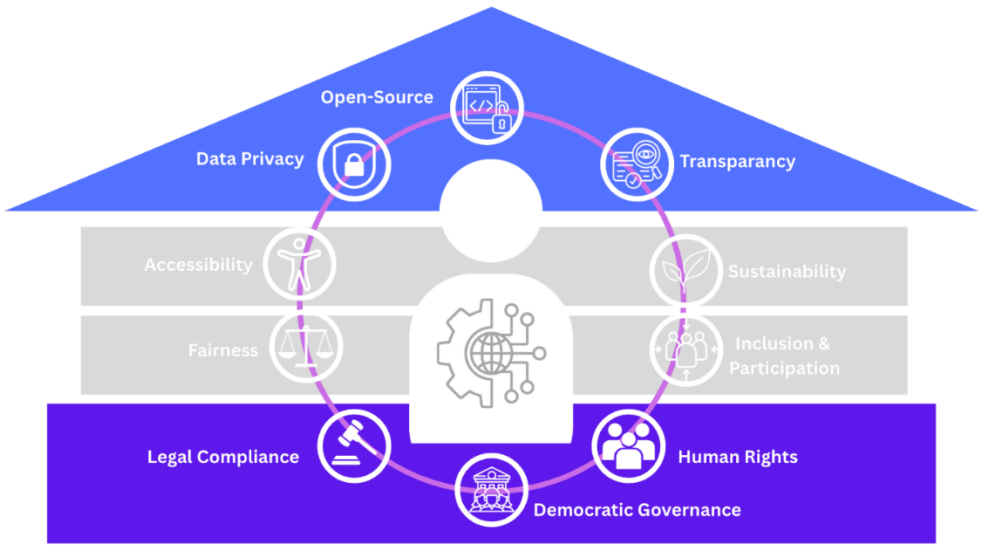


**Figure 5: The house of digital commons**

In the WP8 pilots, those principles have been translated into concrete practices, such as involving end-users (city officials, mobility authorities, energy companies, airport authorities, residents) in co-design workshops and feedback loops, transparently communicating policies about how data is used, what are the "what-if" scenarios, how to get the benefit of LDT, or how the predictive models in the digital twin assist in making decisions.

Each pilot should have an advisory group including community representatives as a direct reflection of WP4's democratic governance for digital commons. By adopting this approach, the LDT will not be top-down but bottom-up and involve the community.

Pilots will experiment with decentralized governance mechanisms as provided by D4.1. This deliverable proposes to test the viability of decentralized governance through practical experiments, including the use of Decentralized Autonomous Organizations (DAOs), to operationalize ethics through technical infrastructure. By evaluating such a DAO prototype within the safe environment of the pilot, we can assess its ability to enforce rules transparently and distribute power among stakeholders. Early insights from these experiments will flow back into the final Digital Commons Framework (D4.2), creating a feedback loop between pilot implementation and the project's conceptual governance model.

D4.1's model of data sharing pushes the pilots toward a data commons approach rather than closed data silos. In practical terms, this means the pilots implement a "shared data commons" for each use case domain (airport data commons, mobility data commons, and energy data commons). As described in D6.2, a data commons is a "shared digital infrastructure that facilitates collaborative data access and utilization, often within a community or for a specific purpose". For the energy, airport and mobility pilots, this translates to a decentralized, federated data platform where multiple stakeholders contribute data that is standardized and made interoperable for the common good. The data commons allows

information (such as energy usage, LCMM data, public transport status, flight data) to be securely shared and pooled, enabling a holistic view that no single party would have on their own.

Adopting the DCF requires strong governance to balance openness with privacy/security. D4.1's guidance on ethical data governance is applied by implementing access control and data protection mechanisms within the commons. Practically, each data source in the pilot should be accompanied by metadata and policies specifying who can access it and for what purpose. The TF is used to enforce these policies. For example, only authorized services can query certain sensitive data (like passenger flows), and even then, only aggregated anonymised forms to protect privacy. This should be applied also to the LCMM data from mobility use-cases according to the Ethical Framework defined in D1.1, also see References.

## 2.5. Security and Privacy by Design Principles

The project iterations will be applied to each use-case across three workstreams: Social Design, Governance (Trust Framework) and Technology.

Citizen engagement will be encouraged into the 3DxVERSE pilots through the project's NEB Toolkit aligned social design process, security and privacy are embedded by design into the 3DxVERSE pilots through the project's Trust Framework and DevSecOps Framework (as described in D5.1). Below some key principles (which are consistent across the Digital Commons Framework and Trust Framework), will be summarised that guide pilot implementation:

Privacy & Data Protection by Design: using techniques like data minimization, encryption of data in transit and at rest, anonymization/pseudonymization of personal data, and obtaining informed user consent as defaults Pilots should implement this via secure APIs, user dashboards for consent management, and applying privacy filters to data before it's shared on the commons (e.g. aggregating or blurring location data to protect individual identities, or using timestamped aggregated data instead of individual data for LCMM data).

Pilots should adopt strong authentication and authorization measures such as multi-factor methods or using eIDAS-compliant digital IDs. Role-based access control (RBAC) is enforced for data and functionalities.

## 2.6. Socio-Technical and User-Centric Design

3DxVERSE follows socio-technical design and "privacy, security and value creation by design" principles to ensure the pilots meet human and societal needs. In practice, this involves actively engaging users and stakeholders in the design process. As noted in D5.1, the project merges agile development with New European Bauhaus (NEB) participatory methods, "rooting technology development in citizen needs and social equity".

For pilots, this means features that impact end users, for example a dashboard showing $CO_2$ footprint, or a feature to submit community reports to the DT.

Iterative co-creation workshops could be conducted to test the usability and for major decision. This helps baking inclusiveness and trust into each release cycle.

Socio-technical design also means addressing social risks. For example, digital exclusion or potential misuse of digital twin data, alongside technical risks.

# 3. PRACTICAL ASPECTS FOR PILOTS' PARTICIPANTS

Building on the 3DxVERSE Trust Framework (Deliverable D5.1) and industry best practices, the following recommendations offer practical, operational guidance for teams in WP6 (Use Case Design) and WP8 (Pilots & Citizen Engagement). These guidelines align with the Trust over IP Foundation's "Practical Steps for Overcoming Human Harm Challenges in Digital Identity Ecosystems" and aim to embed trust, inclusion, and safety into pilot implementation. The focus is on inclusive design, community ownership, harm reduction, and a "what could go wrong?" mindset throughout development and deployment.

## 3.1. Personas and Storytelling for Inclusive Co-Creation

Design with people has a high priority in 3DxVERSE. Participatory design can be challenging, but it's essential for inclusive, user-centric outcomes. A proven technique is to use personas and storytelling in the design process as have been recommended by WP5. By incorporating these persona-driven stories, WP8 can more effectively communicate and co-create with pilot participants. In fact, 3DxVERSE has committed to AI-driven personas and citizen co-creation workshops to surface edge-case harms early. This proactive, narrative approach enhance inclusion into each iteration of design.

### 3.1.1. Diverse Personas

Personas must be created representing not only average users, but also edge-case or extreme users that have unique needs or in atypical contexts. This ensures your use-cases consider a broad range of real-life scenarios from the start. For example, consider users of LDT with limited digital literacy, or those in low-connectivity environments. Designing for these "extreme" personas helps uncover usability issues that mainstream scenarios might miss. The Edge Cases that Break Hearts (And Products).

WP8 will start from the detailed roles and responsibilities in 3DxVERSE which has been developed in D5.1 and then update the list by each pilot leader with different roles as below:

1- **Providers:**

**Table 1: Provider Roles and Responsibilities**

| Role | Relevant EU Frameworks | Key Responsibilities |
|---|---|---|
| **Data Service Provider** | GDPR, DGA, Data Act | Ensure lawful data collection, privacy, consent, and access conditions; may need to register as data holder under DGA. |
| **Algorithm / Model Provider** | AI Act, GDPR, Cybersecurity Act | Must classify and ensure conformity of high-risk AI systems; transparency, human oversight, fairness, explainability. |
| **Infrastructure Provider** | Cybersecurity Act, DSA, EIF | Must provide secure, trusted, and interoperable platforms; possible obligations under critical infrastructure rules. |

| | | |
|---|---|---|
| **Intermediary or Support Service Provider** | DSA, GDPR | Responsible for content moderation, user access services; may be treated as intermediaries under DSA. |
| **Orchestrator / Integrator** | EIF, AI Act, DGA | Ensure semantic and technical interoperability, risk mitigation, standard adoption; enable cross-border services. |

### 2- Consumers

**Table 2: Consumer Roles and Responsibilities**

| Role | Relevant EU Frameworks | Key Responsibilities / Rights |
|---|---|---|
| **Institutional / Professional User** | AI Act, DGA, GDPR | Must understand and validate outputs from AI systems; benefit from data-sharing obligations under DGA. |
| **Citizen / Community User** | GDPR, DSA, AI Act | Have rights to data protection, explanation of AI decisions, access to digital public services. |
| **Intermediary or Service Consumer** | GDPR, DSA | If repackaging or re-using data/services, must comply with re-use conditions and user protections. |
| **Innovators / Entrepreneurs** | Open Data Directive, DGA, AI Act | May access high-value datasets and twin APIs; must follow AI development standards, especially for high-risk systems. |

### 3- Observers

**Table 3: Observer Roles and Responsibilities**

| Role | Relevant EU Frameworks | Key Responsibilities |
|---|---|---|
| **Data Steward / Ethics & Compliance Authority** | GDPR, DGA, AI Act | Ensure data minimization, lawful purpose, and explainable AI; liaise with Data Protection Officers and AI conformity assessors. |
| **Observer (Regulators, CSOs, Auditors)** | GDPR, AI Act, DSA, DGA | Monitor algorithmic fairness, privacy, access equity; ensure ecosystem transparency and citizen protections. |

After formulating the roles and responsibilities list, the participants user stories shall be developed and addressed according to the personas as per the demonstration of D5.1.

### 3.1.2. Bad-Actor Personas

In addition to understanding and designing for benevolent users, it's crucial to explicitly consider "villain" personas who may misuse the system or engage in malicious behavior. For every new service or feature developed, designers should ask the critical question: How might someone intentionally misuse this?

By creating user stories from the perspective of a bad actor, designers can proactively identify potential security vulnerabilities and implement safeguards from the outset. This approach has proven essential in various projects. Including villainous personas can significantly enhance the success of an application by preventing fraud and abuse before it even launches. Villainous Personas – Anticipating the Users You Don't Want.

In summary, integrating an understanding of malicious users into the design process is a vital strategy for creating secure and resilient systems. For that reason, WP8 will create user stories of bad actors and perform a comparison analysis with the real participants user stories to determine those actors and create the required countermeasures.

### 3.1.3. Story-Driven Design

Storytelling must be used to make complex technology concepts accessible to diverse stakeholders. WP8 along with pilot leaders should craft simple narratives (user journeys) for each persona including edge and adversarial personas, to illustrate how the system should (or should not) serve them.

Storytelling engages community leaders and members and creates a shared understanding of goals and pain points. It also supports co-creative workshops where citizens and any other relevant user can give feedback on whether these stories resonate with their lived experiences.

iLabs will offer a 3-hour persona and storytelling work-based learning workshop to 3DxVERSE community leaders and team members to support common understanding and techniques, developing a library of persona with their user stories that enable diverse, secure and inclusive development of the 3DxVERSE. We will also explore the technique of training an AI agent to act as a persona for user testing.

## 3.2. Community Ownership of Outcomes and Metrics

One of the main principles of the DCF and trust framework is the ownership of the outcomes. This principle was inspired by the New European Bauhaus principles NEB: New European Bauhaus. This means that the communities and users affected by 3DxVERSE should have an influence on defining success. Some principles were provided to operationalize this:

- **Stakeholder-Defined Metrics:** Pilot leaders must invite citizens, users and stakeholders to define the metrics that matter to them for each pilot or use-case. WP8 and pilot leaders should facilitate workshops where participants articulate what delivers value in their context rather than imposing top-down KPIs.

- **Shared Accountability:** Citizens and users can feel greater ownership when they set their own success criteria, including metrics and targets. This enhances trust as participants see the LDT is accountable to their needs.

- **Trust Metrics and Governance:** Stakeholder metrics should be integrated into the project's trust framework and DevSecOps monitoring. D5.1 highlights "value-centric KPIs" like stakeholder participation rates, trust incidents, and reach as key performance measures. In practice, WP8 can continually gather data on how citizens are using (or struggling with) the pilots and feed those insights back to WP6/WP7. For instance, a "trust incident" (e.g., a security scare or a user expressing discomfort) should be logged and treated as a metric, just as

important as uptime or latency. This will help ensuring that system's value is measured in human-centric terms, not just technical success.

## 3.3. Harm Reduction Techniques and Failure Scenario Mapping

According to D5.1, even with the best design, "nothing can ever be 100% de-risked" in digital systems. Rather than chasing an impossible zero-risk ideal, WP8 and pilot leaders should focus on harm reduction and proactively minimizing the likelihood and impact of the risks. The Trust over IP Foundation outlines seven practical steps that ecosystem participants can implement today to mitigate human harms Practical Steps for Overcoming Human Harm Challenges In Digital Identity Ecosystems. Below explanation is inspired by the article of Trust over IP foundation.

1. Define the business case for harm reduction:
    a. Make safety and harm mitigation an explicit goal of your use case.
    b. Clearly articulate why preventing harm matters.
    c. This ensures leadership buy-in and resource allocation for trust and safety work.
2. Train your team in ethics:
    a. Ensure that all team members (designers, developers, community managers) receive training or orientation on digital ethics and human harms.
    b. Consider dedicated workshops on ethics and harms reduction techniques.
    c. iLabs offers a 1-hour training on applying the Trust over IP harms framework.
3. Recognize vulnerabilities:
    a. Proactively identify where users or communities might be vulnerable or at risk (e.g. children, elderly users, those with disabilities, or anyone who might be disproportionately harmed if something goes wrong.
    b. Pilot and community leaders to surface these vulnerabilities early.
    c. Recognizing vulnerability also means anticipating misuse by malicious actors targeting the vulnerable.
4. Promote human agency:
    a. Design features that empower users with control and choices.
    b. Human agency reduces harm by preventing powerlessness (e.g. giving users clear privacy settings, consent options, and the ability to easily opt out).
    c. Emphasize self-sovereign approaches where possible (letting users own their data and credentials).
5. Balance power between parties:
    a. Establish governance processes that distribute power and decision-making across stakeholders.
    b. Involve citizen representatives in pilot governance boards.
    c. Create community feedback loops that have real influence.
6. Reinforce collective resiliency:
    a. harms can be contagious – issues often span beyond one system.
    b. Build resiliency not just within 3DxVERSE, but with adjacent ecosystems through cooperation.
    c. Plan incident response scenarios that involve multiple stakeholders.
    d. A resilient ecosystem can predict, detect, recover, and prevent harm through joint efforts.
7. Keep Asking "What Could Possibly Go Wrong?":
    a. In pilots, explicitly brainstorm failure modes and negative outcomes.
    b. Conduct "pre-mortem" sessions.
    c. Use failure scenario mapping to complement your user story mapping.
    d. Document these scenarios and potential harms in the project's Risk Log.
    e. consider different categories of harm: direct harms (immediate effects like fraud or identity theft), indirect harms (secondary effects like algorithmic bias or misinformation spread), contingent harms (long-term or system-wide impacts, e.g. a feature that inadvertently enables environmental damage), and felt harms (emotional or psychological impacts on individuals).

## 3.4. Embedding “What Could Go Wrong?” into DevSecOps

The DevSecOps pipeline must continuously address the question “what could go wrong?” throughout development and deployment and this will help to sustain trust beyond initial design. In practice, this means tightly integrating the risk-thinking and stakeholder input from the pilots into the agile development cycle.

**Risk Log:** The scenarios and harms identified (from the steps above) should feed into a live Risk Log, which is reviewed in every sprint/release. Use this log to drive security testing, QA, and monitoring priorities. For example, if a failure scenario is “bad actor tries to spoof a digital identity,” ensure the DevSecOps plan includes penetration tests or red-team exercises for that scenario. D5.1 calls this “differential risk management” – addressing stakeholder-specific risks continuously in the pipeline.

**Continuous Monitoring and Feedback:** Once pilots are running, channels should be set up to continuously monitor for harm signals. This could include community hotlines, in-app feedback, or periodic user surveys asking if anything made them feel unsafe or disempowered. Feed these signals back into DevSecOps: treat them as incidents or at least as important as technical bugs. As D5.1 mentioned, track and respond to trust and harm metrics with the same rigor as uptime and errors.

**Emergency Response Drills:** Drills could be incorporated in the DevSecOps schedule where the team practices responding to something going wrong. Simulate a data breach in a test environment, or a scenario where a user is harmed (e.g. a privacy leak), and walk through the response. This keeps the team ready and verifies that mitigations work as expected. It also reinforces the culture that everyone is responsible for user safety, not just the security officer.

# 4. INTEROPERABILITY IMPLEMENTATION IN PILOTS

Interoperability is a cornerstone of the 3DxVERSE pilots, ensuring that diverse data streams from energy, mobility, and airport domains can work together seamlessly.

## 4.1. Overview of Pilots

**Almelo (Netherlands) - Sustainable Living Community & Energy Pilot:**
Almelo's pilot centers on energy transition and digital commons for a living community. It creates a common energy data platform that models and visualizes renewable energy deployment using digital twin technology. Almelo demonstrates how digital twins can optimize energy use (e.g. grid performance, renewables integration, PED) in a community, supporting EU Green Deal goals.

This pilot emphasizes open data-sharing and cross-sector collaboration among utilities, government, and tech providers to enable innovative energy solutions. Ultimately, Almelo aims for an energy- self-sufficient community, showcasing how citizen-centric digital twins can drive the energy transition. For more information: 3DxVERSE website.

**Aruba - Airport & Mobility Pilot:**
The Aruba pilot focuses on the airport ecosystem, integrating mobility and environmental data in a local digital twin of Aruba Airport. This pilot is developing an operational airport digital twin that streams real-time environmental, energy, and operational data. A key goal is to support Airport Carbon Accreditation (ACA) targets by tracking and visualizing carbon emissions from flights and ground operations.

Each flight's data is used to compute its emissions and noise contribution, updating the airport's carbon baseline and informing nearby communities of noise exposure.

Furthermore, Aruba is implementing the Low Carbon Mobility Management (LCMM) smartphone app for airport ground transport. Given Aruba's smaller vehicle pool, Aruba pilot leader is recruiting participants (taxi drivers, etc.) to use the app, so that their GNSS speed profiles and other data are submitted to the platform. These data help analyze traffic bottlenecks and emissions on airport access roads similar to larger pilots.

Aruba pilot is highly interoperable as it merges flight data, road mobility data, environmental data, and even digital identity (via AHOP) into one framework. For more information: 3DxVERSE website.

**Hamburg (Germany) – City Mobility & ITS Pilot:**
The Hamburg pilot addresses urban mobility and intelligent transport systems (ITS) in a large city context. This pilot feeds extensive LCMM App data, Floating Car Data, traffic sensor streams and construction-sites data into a city digital twin to monitor and reduce transport emissions and enhance the traffic flow. For more information: ERTICO website & 5G-LOGINNOV Project

The LCMM smartphone is key here. In Hamburg, the LCMM app data (from professional taxi fleets and private drivers). For more information: LCMM App & LCMM App 2. Additionally, Hamburg's pilot incorporates Co-operative, Connected and Automated Mobility (CCAM) data streams. All these feeds could be integrated via open standards into the Hamburg digital twin.

**Timișoara (Romania) – Emerging Urban Mobility Pilot:**
Timișoara's pilot is in a preparatory stage (planned for future implementation), focusing on urban mobility patterns in a medium-sized city. It will leverage the LCMM app and other data sources similarly to Hamburg and Aruba. A local partner will help gather driving data using the LCMM app. Additionally, the pilot intends to integrate data from ride-sharing services (Uber) and public transit or other urban mobility platforms, to get a holistic view of how people move around Timișoara.

## 4.2. Semantic Interoperability across Use-cases

3DxVERSE could address this by adopting common standards, units, and ontologies that link energy, mobility, environmental, and airport information across the pilots. Key examples of this include:

**Energy and mobility:**

A unifying metric between energy and mobility is energy consumption (kWh). The project leverages the concept of energy labels and consumption values in both use-cases. For instance, building performance in Almelo is measured in kWh/m² and given an energy label (A, B, …), and similarly, vehicle trips or road segments in Hamburg are assessed in terms of kWh/km and labeled green/yellow/red per ISO 23795-1. By converting vehicular fuel use into kWh, the twin can directly compare the energy a car fleet uses in a day with the energy a neighborhood uses in a day. This semantic alignment allows a mutual understanding as the mobility data speaks the energy use-case's language. A concrete showcase is the labeling of Hamburg's taxi routes with an efficiency color that is complementary to the building energy labels in Almelo. In practice, this means if a certain street is marked red (inefficient) due to traffic emissions, it can be correlated with the energy-inefficient buildings on the same street.

**Mobility and environment:**

Mobility data is intrinsically linked to environmental impact. The pilots should ensure semantic consistency by using common environmental metrics. All transport emissions are ultimately expressed as $CO_2$ equivalents (kg $CO_2e$) in the system, whether they come from road vehicles or aircraft. This common unit means the carbon footprint of a flight to Aruba can be added to that of a taxi ride in Aruba and be presented in a unified way. This method could be applied to Hamburg to link between the port and roads carbon emissions.

In 3DxVerse, it is planned to link the existing carbon wallets, in test phase for ARUBA tourists and travelers, with pioneering Corporate Emission Trading Systems. The data flow principle is depicted in Figure 6. For combustion engines, one liter of diesel equals 2,6 kg $CO_2e$. Saving one liter of diesel by eco-routing or eco-driving making use of Newtonian Physics of Driving principles, then, has the well-defined value of 14 cents at Emission Trading Systems (ETS-2) Market places based on the EU-ETS-Price of 75-80 € per ton. Meanwhile, eco-drive is standardized, see ISO-23795-1 reference, and the potential of carbon saving is documented as 9%. Worldwide thus sums up to 500 million tons of carbon reduction with an EU-ETS market volume of 38 billion-€. For a truck with a mileage of 3000 km and 15 liters per 100 km of diesel consumption, fuel savings would sum up to €81 of the €900 total costs – assuming the 9% savings published by UNFCCC. Additionally, the truck could generate €8.43 cents per month as carbon credits in his digital wallet. Giving this simultaneous income by

A) saving fuel/energy costs and

B) generating carbon credits,

will stimulate a new market with worldwide ISO-Standards for users as trusted calculation methodology.

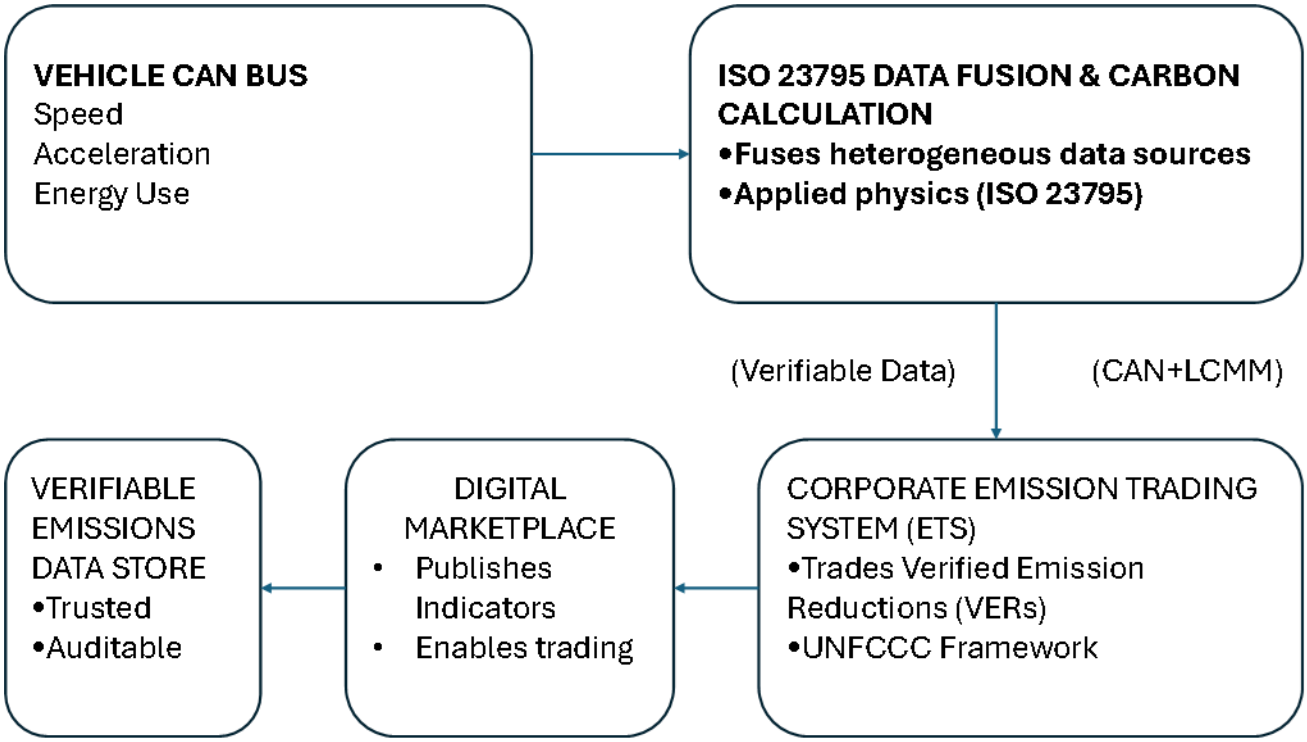


**Figure 6: $CO_2$ wallet planned to give Verified Carbon Credits to Eco-Driver**

Moreover, the concept of a $CO_2$ wallet is used in both mobility and environment contexts. In Aruba, flight and ground transport data feed into $CO_2$ calculations for the airport, and simultaneously into a traveler's $CO_2$ wallet.

**Environment and identity:**

The project also bridges environmental data with digital identity through the use of Verifiable Credentials (VCs) and personal data wallets. In Aruba's AHOP platform, a traveler's digital identity can be linked with their travel-related emissions. For example, after a trip, a traveler receives a $CO_2e$ certificate in their AHOP app – effectively a verifiable credential that states how much $CO_2e$ their journey caused.

This requires semantic alignment between environmental data ($CO_2e$ amounts, trip details) and identity records (personal DID, travel credentials). The project achieves this by structuring the $CO_2e$ data in a standardized schema (e.g. W3C Verifiable Credential format with claims about emissions) so that it can be bound to an identity wallet in an interoperable way.

# CONCLUSIONS

Deliverable D8.5 has laid the groundwork for the pilot implementations in 3DxVERSE by defining how data will be shared and governed across diverse environments. The key outcome of this report is a dual framework addressing both technical interoperability and data governance. On the technical side, we have identified and adopted common standards that enable different digital twin pilots to exchange data seamlessly. This interoperability framework mitigates the risk of siloed development and ensures that insights and services developed in one pilot can be leveraged in others, and that all pilot systems speak a common language. On the governance side, we have defined clear policies and structures to manage data responsibly. By integrating legal requirements and ethical principles from the project's Digital Commons approach, the pilots are set to operate under a transparent and trust-centric system. This means citizen data and other sensitive information will be handled with care, security, and respect for privacy, thereby fostering trust among participants and stakeholders.

In practical terms, the pilots apply these frameworks through use-case-aligned solutions. For example, a carbon wallet for Aruba first then could be applied in other pilots, decentralized governance structures, semantic alignment around environmental indicators (like $CO_2e$), and the integration of the Trust Framework that is aligned with the iSHARE methodology for secure data sharing. The combination of these elements ensures that data is shared across platforms in a secure, scalable, and privacy-respected manner.

The report shows that interoperability and governance are not treated as separate layers, but rather as interdependent capabilities. Interoperable systems require governance, and governance must be technically enforced. The pilot sites already reflect this mutual dependency and flexibility, each adapting the framework to local context while maintaining a shared architecture.

A central contribution of this deliverable is the integration of citizen engagement through persona-based co-creation. By designing pilots around diverse user personas (citizens, authorities, operators, and vulnerable groups), the project ensures inclusivity, accessibility, and ethical integrity. Storytelling methods, harm-reduction scenarios, and "bad actor personas" are used to anticipate risks and strengthen trust. This approach transforms citizens from data subjects into active participants in shaping Local Digital Twins, aligning with the New European Bauhaus principles and reinforcing the human-centric dimension of the 3DxVERSE ecosystem.

This first report provides groundwork for pilot execution. It will be refined in D8.6 based on field experiences, stakeholder feedback, and evolving policy landscapes that support a trustworthy, citizen-centered, and standards-aligned Local Digital Twin ecosystem.

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