Gaia-X Voices:
Use-Case Testimonial

Digital Road Condition Monitoring – Predictive Infrastructure Maintenance

Gaia-X 4 Future Mobility

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1. Introduction

a. *Brief overview of organisation and Industry*

deltaDAO AG is a German ecosystem operating and software development company. As an accredited Gaia-X Digital Clearing House provider, and Gaia-X member, we provide data economy services across Gaia-X ecosystems, such as manufacturing, mobility, agriculture, aerospace, the public sector, energy, smart cities, and more. deltaDAO is the initiator of the Pontus-X ecosystem, the largest publicly available X-Ecosystem.

b. *Main stakeholders and the roles they play in designing the use-case*

This use case is part of the Gaia-X 4 Future Mobility family of projects, supported by the German Ministry for Economic Affairs and Climate Action (BMWk). Gaia-X 4 Future Mobility (GX4FM) is also considered a Gaia-X Lighthouse Project[1]. The digital road condition monitoring use case is part of the GX4FM moveID project 'Decentralized digital vehicle identities in the highly networked traffic environment' led by Robert Bosch GmbH, and the GX4FM AMS project 'Advanced Mobility services for autonomous driving'. The Digital Road Condition Case is relevant for both projects as GX4FM AMS deals with Operation Design Domains (ODDs), thus the condition of the infrastructure in which autonomous vehicles operate in. While moveID looks at Vehicle Data and Mobility Infrastructure Data Sharing where information about mobility infrastructures is collected and shared between participants. In this case, four main stakeholders are responsible for the use case and its successful implementation:

- Peregrine Technologies GmbH facilitated the collection of infrastructure condition data in cooperation with the City of Hamburg, and developed road damage detection software to analyse the collected data.
- The City of Hamburg also acts as the data consumer, aiming to improve their digital twin of the mobility infrastructure of Hamburg.
- deltaDAO AG also collects and provides infrastructure condition data and provides analysis software and compute infrastructure to detect and annotate infrastructure damages, in addition to operating the base service of the ecosystem.
- The enablers of this use case are the Pontus-X ecosystem operators or "federators", which provide the federated base service of the ecosystem to all participants. In this case the federators of the ecosystem are deltaDAO AG (Germany), PTW TU Darmstadt (Germany), Pilotfabrik TU Wien (Austria), WOBCOM GmbH (Germany), AIRBUS Defense and Space GmbH (Germany), and Neusta Aerospace GmbH (Germany).

1 Though technically a family of projects.

Role	Organization
Data Service Providers	City of Hamburg, deltaDAO AG, Peregrine Technologies GmbH
Software Service Providers	Peregrine Technologies, deltaDAO AG
Compute Service Providers	deltaDAO AG
Federation Service Providers	PTW TU Darmstadt, Pilotfabrik TU Wien, WOBCOM GmbH, AIRBUS Defense and Space GmbH, Neusta Aerospace GmbH, deltaDAO AG

2. Context & Challenge

a. *Brief description of the problem that the use-case addresses*

The mobility infrastructure is run-down and requires billions in annual investment. More and more German companies and citizens are complaining about the state of the roads and other mobility infrastructure. This causes economic damage and dangerous situations that could be avoided. Monitoring road conditions is currently a very costly and inefficient process. Data is collected by individual municipalities in isolated systems, and a digital twin of the infrastructure, along with seamless collaboration between stakeholders, is still far away.

3. Solution description

a. *Solution implemented to address the identified challenges*

The vehicle data collection and road condition monitoring use case leverages a scalable digital data services ecosystem, based on Pontus-X, where data providers, software providers, infrastructure providers and consumers efficiently work together to exchange and combine mobility infrastructure data, AI applications for analysis and infrastructure for calculations - from the cloud to edge and IoT solutions. Data can be collected and analysed directly on the edge, i.e., by fleet owners and data collection specialists, and the results can be offered as a service to the consumers (here smart mobility providers and municipalities) that must deal with the mobility infrastructure and its condition.

In this case the ecosystem and its operating organisations provide the federation services used by all participants, such as the market, catalogue, contracting, payment, logging services and the Gaia-X framework (operationalised by the GXDCH) is used for transparency, identity assurance and semantic interoperability, together with the Base-X framework designed for mobility and logistics services.

The marketplaces or portals, create user interfaces that serve as participant agents for consumers and service providers. Some examples are https://portal.pontus-x.eu/ and https://portal.moveid.eu/ through which services can be published, managed, discovered, and consumed.

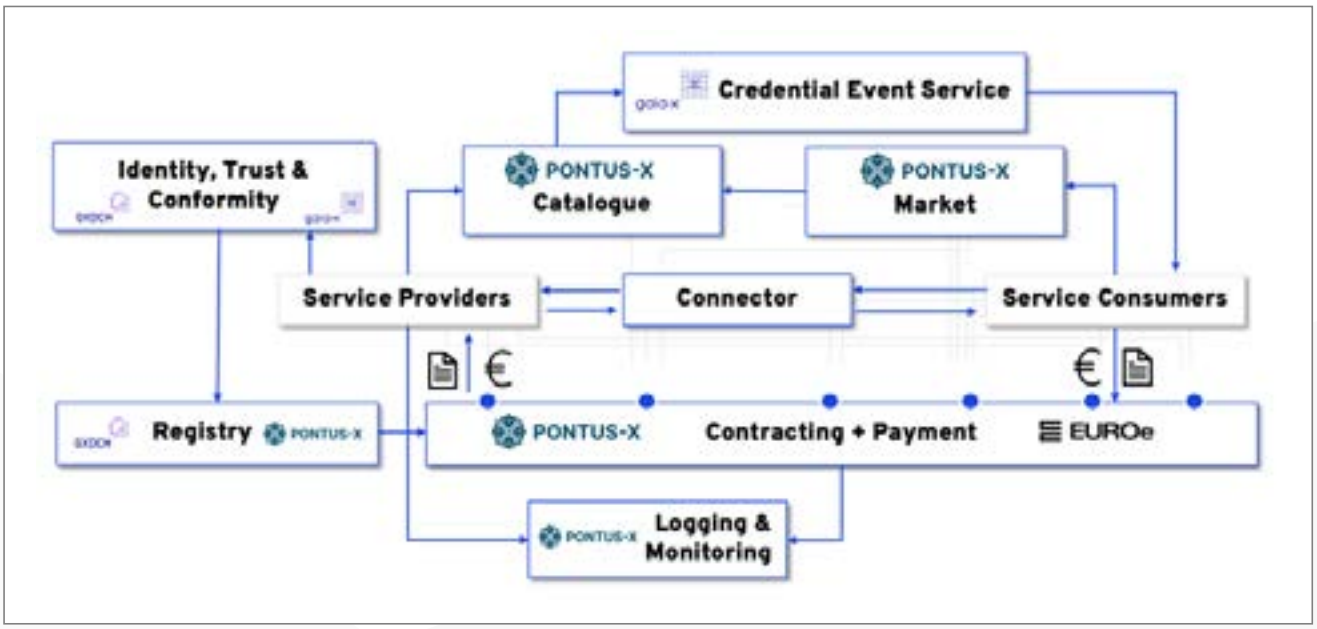
The catalogue service stores all the information about the services offered by the different services providers and is stored in a distributed manner. All marketplaces and portals can query the same public catalogue and also additional private catalogues to discover data, software, and other services and their service credentials.

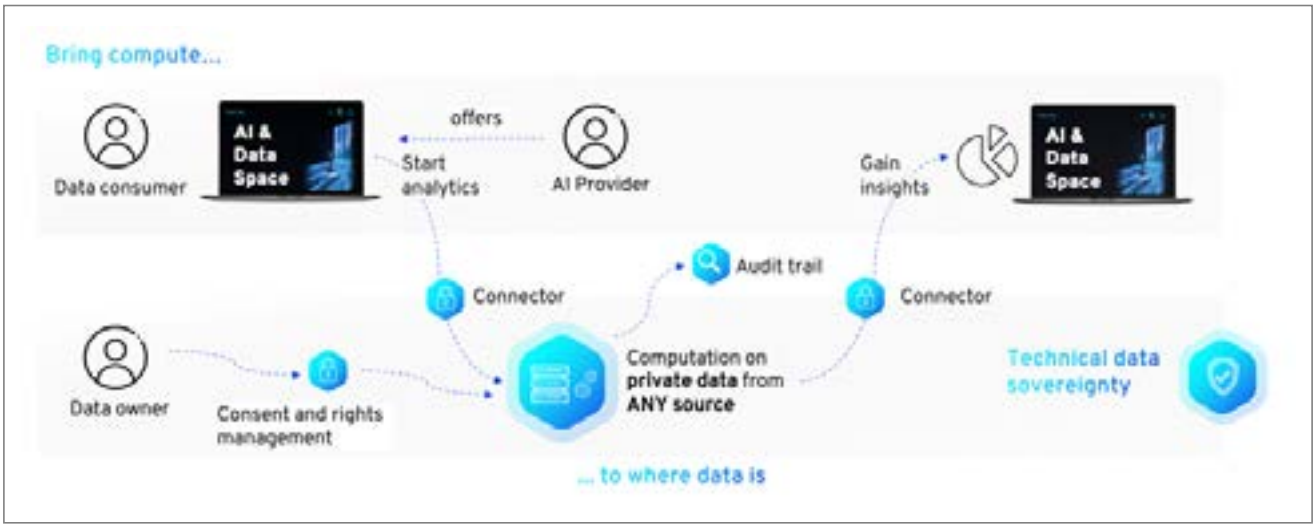
The contracting service is performed through the terms and conditions of the individual service providers and a smart contract functionality in Pontus-X that allows the timestamped logging of agreements and payments. Contracting can include the prerequisite of payment, which is also executed directly between participants using European e-money, a digital EURO. Other currencies, such as USD can also be supported for international trade outside of Europe.

The payment service is by default based on smart contracts and enables real-time settlement between participants and ecosystem operators.

Logging services are performed by the underlying smart contracts of the ecosystem and supported by private logs in the participant agent components of the ecosystem. Each interaction and immutable log entry is written and stored in a distributed database shared with all participants. Due to the usage of Trusted Execution Environments and Smart Privacy features in the Pontus-X ecosystem, these logs can also be private and only shared with the interacting participants.

Consumers can directly leverage the GXDCH to verify the claims of service providers via the marketplaces / portals in the Pontus-X ecosystem. Unique in this context is the utilization of Compute-to-Data on the service provider side, to allow analysis of the data without the need to transfer or copy it, thereby technically enforcing usage policies. The Pontus-X ecosystem is based on Ocean Enterprise and Oasis free open-source software components. The payment service is based on the digital EUROe, a modern European 'stable coin' issued by Membrane Finance used in a smart contract-based payment and contracting service.





b. *Role of technology in the development and deployment of the solution*

The new federated digital service ecosystem capabilities of Pontus-X and its federated services, as a Gaia-X ecosystem, enabled this implementation and its unique features, in combination with Compute-to-Data and digital payments. It was possible for the first time to create an open ecosystem controlled by all participants and not depend on a centralised platform provider. Furthermore, the computation and analysis of the sensitive data happens in an IP- and privacy-preserving manner, breaking down barriers to collaboration. The seamless integration of IoT and payment services completes the continuum and aligns incentives across stakeholders, while scalability, compliance, identity assurance and trust are supported through the SSI integration and Gaia-X Framework.

4. Implementation

a. *How the solution was integrated into the use-case organisation's existing systems or processes*

Integration has been very easy. Service provider and consumer are able to use the participant agents in the form of the Pontus-X marketplaces and nautilus agent to publish, manage, discover, and consume services. Here only front-end and middleware components are added, with no deeper integration necessary. The only major integration is the installation of the Ocean Enterprise Provider / Connector and the associated Compute-to-Data environment in the managed Kubernetes infrastructure of the service provider, which also does not affect pre-existing infrastructure and services, on the edge or in the cloud controlled by the service provider.

These components ensure technical data sovereignty by technically enforcing access policies for data transfer and data usage, i.e., regulating which software can be used on said data. It is important to note that in this case, only the data provider needs a “connector”, while any consumer only uses a participant agent (which can be offered by the service provider) and simply brings his own identity through a wallet. The last necessary integration is a simple web-hosting service which directly relates to Gaia-X Compliance and requires the service provider to provide the artifacts for compliance checks against the GXDCH. The

service provider will need to expose the X.509 certificate, issued by a Gaia-X accredited Trust Service Provider, the Gaia-X Participant Credentials, a DID:WEB, and the Gaia-X Service and Resource Credentials.

To enable interoperability at the use case and application layer, and between the systems of the participants in the digital service ecosystem, this use case leverages the Base-X semantics. Regardless of the service provider, the results follow the same schemata and can be processed by any party using the Base-X semantics.

b. *Significant milestones or challenges during the implementation phase*

Stakeholder	Description of challenge	Dimensions					Level of difficulty experienced (Low, Medium, High)
		Design of the use-case	Governance of participants	Development of elements & apps	Integration of systems & participants	Using the use -case	
Service Provider	Design Business Case	✓	✓		✓		Low
	Onboarding		✓			✓	Low
Service Provider & Service Consumer	Define Data Schema	✓	✓	✓	✓		Low
Service Provider	Ensure Data Sovereignty	✓	✓	✓	✓		Low
	Enhance Services			✓	✓		Low
	Deploy Infrastructure			✓	✓		Low
	Gaia-X Compliance		✓	✓	✓	✓	Medium
	Create Contracts		✓			✓	High
	Adapt Services to Gaia-X			✓	✓	✓	Low
Service Consumer	Gaia-X Compliance		✓	✓	✓	✓	Medium
	Onboarding		✓			✓	Low
Operators	Onboarding		✓		✓		Medium
	Base Services Provisioning				✓	✓	Medium

5. Benefits & Impact

a. *Measurable use-case implementers' benefits observed since implementation*

Description of benefit	Role this benefit applies to	Dimensions			
		Technological	Operational	Functional & participant-related	Governance & legal
Data availability increased	Service Provider & Service Consumer	✓	✓	✓	
Software availability increased	Service Provider & Service Consumer	✓	✓	✓	
Compute availability increased	Service Provider & Service Consumer	✓	✓	✓	
Interoperability	Service Provider & Service Consumer		✓	✓	
Business Model Enabled	All Participants		✓	✓	
Resilience increased	All Participants	✓	✓		✓
Speed increased	Service Consumer			✓	
Cost reduced	All Participants		✓		
Gaia-X Trust Framework enablement	All Participants	✓			✓
Scalability	All Participants	✓	✓		✓
Compliance supported	All Participants			✓	✓

b. *Benefits for the end-users*

- Authorities or road construction companies can focus on the most urgent road sections and assess and repair damage before it leads to high costs.
- The data can be shared with other vehicles and mobility service providers to identify potential hazards, optimise routing, and avoid unfavorable routes.
- The largest economic gain will be achieved through the economics of scale and the creation of an open ecosystem for all stakeholders under free competition. This leads to significant investments and the development of more efficient software solutions in a competitive market. Prices for data acquisition and analysis can be reduced while software developers and solution providers can address a more frictionless market.
- Overall, the solution significantly reduces the costs of collecting, providing, finding, and analysing mobility data. As a result, more of the available resources can be allocated to maintaining and improving the existing infrastructure.
- The open identity ecosystem of Gaia-X enables the reusability of identities. As Pontus-X uses the Gaia-X identities for onboarding, the onboard-once approach and acceptance of previous identifications by Gaia-X accredited Trust Service Providers makes it easier for customers to join X-ecosystems. There is no need to establish a new identity with each X-ecosystem a customer joins, but the identity can be used across all X-ecosystems.
- The standardised semantics of Gaia-X and Base-X enable more interoperable applications.
- Data, software, and cloud resources can be used without the need to deploy complex infrastructure on an ad-hoc basis.
- Compute-to-Data protects valuable and sensitive information.
- Digital Twins of mobility structure are enabled and can be fed with data from decentralised sources, while creating audit trails and compliance logs.

6. Added Value through Gaia-X

a. *Alignment with the Gaia-X vision*

The use case takes full advantage of the Gaia-X architecture and its Trust Framework, and implements the vision of an open identity and digital service ecosystem that enables the orchestration of data, software, and cloud resources in an environment that benefits from transparency, standardised services, and open-source software without any lock-in to specific cloud services or platforms.

b. *Alignment of current architecture and technology stack with the Gaia-X technology model, and any convergence needs*

The current architecture makes use of all Gaia-X federation services and the Trust Framework 22.10. Marketplaces / Participant Agents, a federated catalogue, contracting and payment services, logging services, usage of the open identity ecosystem and the shared operation of these services. By not being bound to a centralised service provider, it enables free competition and collaboration.

The main and remaining convergence need is for the Gaia-X credential issuance, verification, and exchange mechanisms which shall be based on OpenID4VCI and OpenID4VP to be interoperable and reusable across all X-ecosystems. Additionally, the Gaia-X Trust Framework in the future accepts Elliptic Curves, and keys other than RSA key, as the basis for identities and for signing credentials to allow current battle-tested and widely used methods in the market.

7. Use-case scaling

a. *Requirements and steps for a new member (user, provider, or service providers) to join use-case*

Adherence to the Gaia-X Trust Framework and the Terms and Conditions of the ecosystem. If a Gaia-X-compliant identity can be provided, every legal person (organisation or company) is invited to participate and be onboarded into the ecosystem.

b. *Other sectors that could benefit by making use of the resources in this usecase*

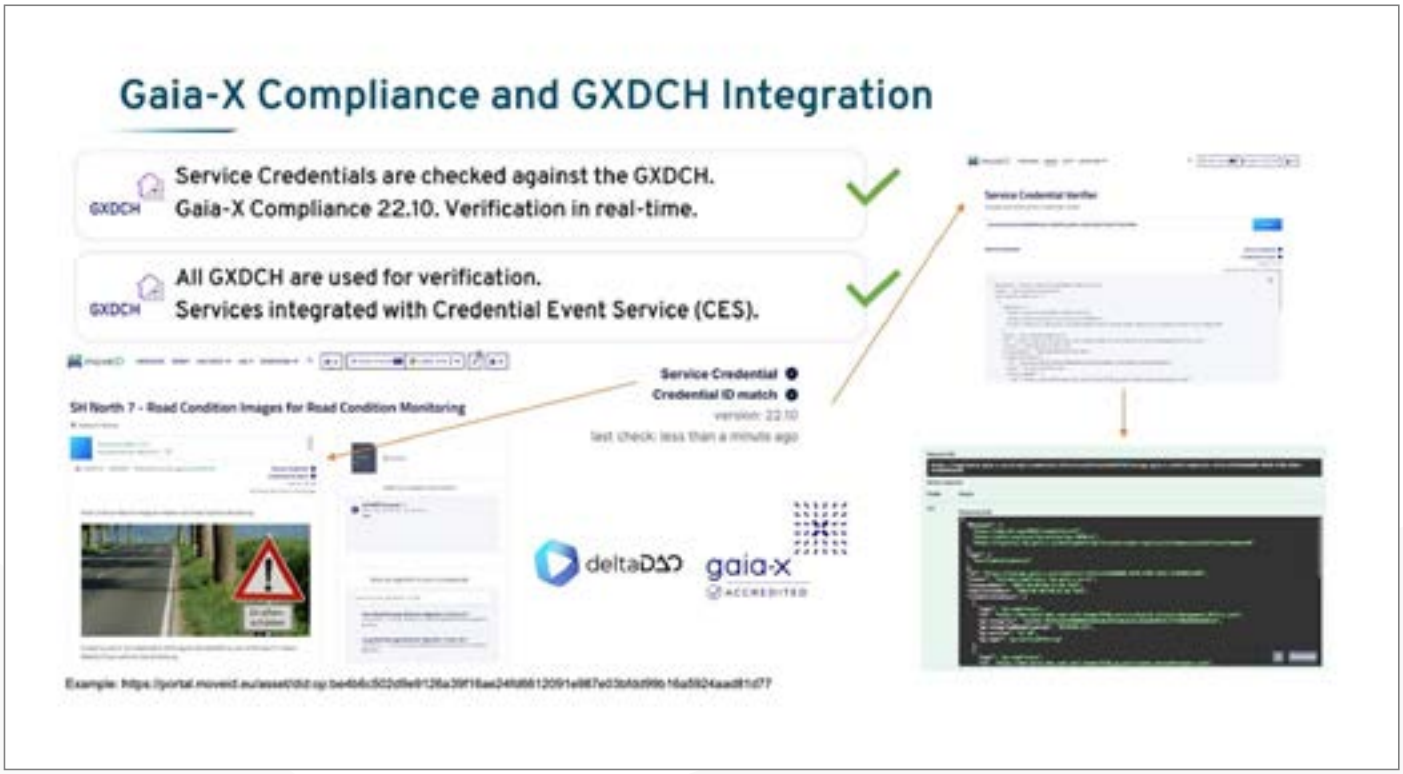
The resources are also very useful in logistics, maritime traffic and more generally in tourism, agriculture, smart cities and more. The applied technologies and software components, as reference implementations, are mostly sector agnostic and can be adapted to other use cases and domains.

8. Next steps

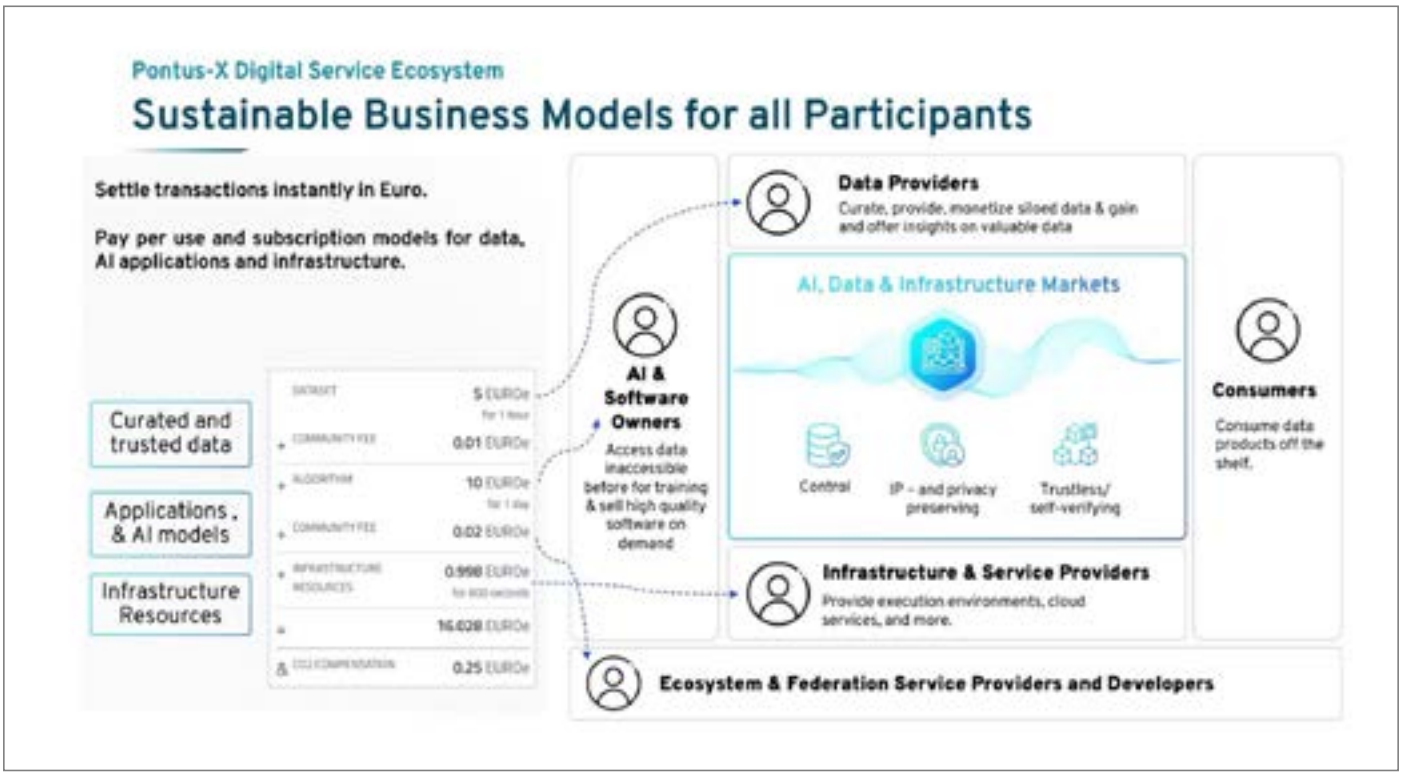
a. *What are the next steps of your project functionally-speaking?*

The next step will be the transition to the production infrastructure and the transition to the Loire (Gaia-X v2) GXDCH release. We also aim to enable additional analysis software for different use cases and improve the quality of the services. Furthermore, the transparency, especially in terms of the Gaia-X Trust Framework and service composition, shall be extended. To facilitate the implementation for service providers, the open-source software stack will be further developed in the next release of Ocean Enterprise and the integration with Gaia-X specifications will be deepened.

Digital Road Condition Monitoring with data collected by Peregrine in the City of Hamburg



Integration of Gaia-X Digital Clearing Houses in the Market and real-time verification of service credentials



Support for business models and a fair pay-per-use mechanism for all participants

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