Conférence Européenne des Directeurs des Routes

Conference of European Directors of Roads

Digital Road Operator Information and Data Strategy (DROIDS)

Data Strategy for the digital road operator

D5.1 Recommendations and Guidelines on Conceptual Data Strategy for Road Operators

4th of September 2025

Digital Road Operator Information and Data Strategy (DROIDS)

Recommendations and Guidelines on Conceptual Data Strategy for Road Operators

Due date of the deliverable: 30th of June 2025

Actual completion date of the deliverable: 4th of September 2025

Start date of project:
15th of September 2023

End date of project:
14th of September 2025

Author(s) of this deliverable:
Anthony Bokolo J, IFE
Petter Kvalvik, IFE
Jan Erik Farbrot, IFE
Ilkka Kotilainen, Traficon
Risto Kulmala, Traficon

Version: 1.0

Executive summary

This data strategy for European physical and digital road operators was part of the European road operators CEDR funded Call 2022 Data and its DROIDS (Digital Road Operator Information and Data Strategy) project. The data strategy summarises the CEDR Call 2022 Data results and recommendations for the digital road operators. The main results are divided into following two deliverables that are interrelated and therefore should be read together:

1. Recommendations and Guidelines on Conceptual Data Strategy for Road Operators (DROIDS Deliverable 5.1, i.e. this deliverable)
2. A roadmap for implementing the data strategy, DROIDS Deliverable 5.2 (DROIDS Deliverable 5.2, Kvalvik et al. 2025)

Methodology of the DROIDS project utilises the Digital Transformation Framework (DTF) and included, in addition to the digital road infrastructure, two other CEDR Call 2022 Data projects: PRESORT on third-party data and TIARA on trustworthy and secure data infrastructure. The data strategy builds on the results of the three mentioned projects. **The methods** used in the study included a literature review, collaboration with road operators and private industry experts, as well as a workshop.

The data strategy results included the following five recommendation categories based on the previously mentioned three CEDR funded DROIDS, PRESORT and TIARA projects, which are further shortly summarises in this executive summary. For more details about the recommendations can be found from the referred chapters where also references to their CEDR research study deliverables.

1. European data strategy and recommendations (Chapter 3)
2. Stakeholder roles and priority of use cases for road operators (Chapter 4)
3. Information life cycle, maintenance and regulations (Chapter 5)
4. Use of third-party data (Chapter 6)
5. Trust in data and service provision (Chapter 7)

A major conclusion is that the NRAs and other road operators benefit from digitalisation and the use of digital models, shadows and twins. The development, operation, maintenance and use of the digital representations are estimated to have high benefit to cost ratios in most use cases.

European data strategy recommendation topics based on European data strategy and related initiatives such as operationalization of dataspaces to ensure safe, reliable, and trustworthy data sharing for NRAs and other stakeholders, were as follow:

- Recommendations on data governance
- Recommendations for a sovereign data sharing approach
- Recommendations on trusted data sharing and exchange
- Recommendations from deployment methodology for dataspaces
- Implementing skills and training

A conclusion is that the in a multistakeholder European-wide digital ecosystem, liaison between stakeholders and data exchange according to the guidelines of the European mobility data space are essential for the NRAs and other road operators.

The role of the road operator for digital representations (model – shadow – twin) depends on the use case. It is important to bear in mind that the European NRAs have also other roles

than the road operator depending on the national road transport system governance models. Thereby, many road operators have also the role of traffic managers, while some also have the role of traffic information service provider or road transport authority.

Typically, the road operator assumes an active role in development, operation and maintenance of the use cases directly connected to the primary tasks of the road operator. In addition, road operators tend to be the users of the digital presentations available for all use cases as this likely increases the efficiency of the road operators' own processes.

The restrictions of public sector budgets in road infrastructure and its operations mean that the NRAs have to move towards digital road operation as all evidence supports the view that digitalisation makes also NRA operations more efficient with high benefit-cost estimates. At the same time the restricted budgets mean that digital representations cannot be realised for every use case. The conclusion thereby is that the NRAs need to focus on some use cases. The data strategy proposes the following overall priority order for digitalisation for the next years:

- asset management (digital model/shadow)
- electronic traffic regulations – speed limits (digital shadow)
- road works (digital model/shadow)
- incident detection (digital shadow)
- access control/ UVAR incl. road tolls (digital shadow)
- electronic traffic regulations – general regulations (digital model)
- CCAM – distributed ODD awareness (digital shadow)

Many of the use cases are expected be realised as digital shadows, i.e. the digital representation is automatically updated whenever the status of the physical counterpart is changing. For asset management and road works, however, the very likely 2030 situation will be digital models. For most critical parts of the infrastructure such as vulnerable bridges and tunnels, the asset management should likely be utilising digital shadows.

As all of the use cases are relevant for the NRAs, the NRAs should at the minimum liaise or otherwise agree with the active stakeholders in a use case, where the NRA itself is not actively involved in except for its use and providing support to its maintenance by providing information to it. In addition, the NRA should liaise with other stakeholders operating similar digital representations as having an identical view of the physical aspects of the transport system is in every stakeholder's interest.

The road operators must standardise the information by adopting ISO 19650 and implementing an object type library from early phases of digital representation development in order to ensure interoperability. The road operators are recommended to pilot the usefulness of BIM and AIM information within HD maps in cooperation with HD map providers. At an early stage, road operators can focus on making sure that the information related to assets such as GIS information is organised, updated, and complete. It is questionable whether the HD maps would be NRAs core business even in the future, however.

Services and data that are typical and core business for an NRA as a road operator and often a traffic manager, and their operational services and common operational picture should be shared with the road traffic management ecosystem. These services and data can provide benefits for example on traffic safety and flow as well as reducing emissions. Important part of the benefits comes from OEMs and service providers who build their services by utilising the road operator and traffic manager data and services.

However, all data and services should not be shared. For example, data that has been bought

from third-party service providers and data that is under ecosystem agreement are outside of sharing scope. Furthermore, data that is shared should not cause harm or damage. The damage can involve for example security or privacy related issues. Therefore, a risk analysis is needed to evaluate any privacy, security or other risks that the data and services provided by the NRAs could include.

Information life cycle, maintenance and regulations included the following recommendations for the digital road operators on information maintenance and availability:

- Identify use cases and define the scope/purpose
- Invest in skills and education
- Adopt Open Data Standards
- Align with National Standards
- Prioritize Major Projects for Information Management Upgrades
- Move Towards Integrated Asset Management Systems
- Phased Implementation
- Change Management

BIM representation for full life cycle of road infrastructure included the following recommendations to maintain the BIM information throughout the lifecycle of road infrastructure:

- Implement ISO 19650
- BIM standards: Create or adapt existing BIM standards and guidelines
- Develop and implement OTL
- Establish collaboration and communication

In order to reap the benefits of standardisation emerging from OTL implementation and possible extension, road operators could consider the following key components:

- Data Dictionary Foundation: Build upon existing data dictionaries to establish standard definitions and meanings.
- Leverage Open Sources: Utilize open-source libraries like bSDD and Uniclass to establish a solid foundation and ensure continuous updates.
- Extend with New Attributes: Incorporate new attributes to accommodate dynamic information and future needs.
- Collaborative Development: Involve multiple stakeholders to ensure the OTL meets diverse needs and facilitates data exchange.
- Continuous Adaptation: Regularly review and update the OTL to adapt to evolving requirements and technologies.
- Standardization and Interoperability: Ensure the OTL is standardized and interoperable with other systems and platforms.
- ISO Standards Implementation: Adopt ISO 19650 to provide a framework for information management and exchange.
- Also, to improve the BIM information reuse, road operators should implement BIM standards within their organisation for information management and try implementing an OTL to provide structure to asset information.

Digital twin use cases – Digital transport regulations, opening new roads, automated lane level navigation, included the following recommendations:

1. Early engagement in standardization

2. Local perspective and requirement sharing
3. Phased digitalization of traffic rules
4. Development of a clear digitalization strategy
5. Uniform Traffic Regulation Order (TRO) processes
6. BIM standardisation
7. Ensuring high-quality infrastructure for Automated Driving Systems (ADS)

Third-party data usage recommendations for successful collaboration between NRAs and third-party data providers to fully utilise the potential of third-party data within NRAs were as follows:

- Establish a Shared Vision
- Invest in Staff Education
- Foster Collaboration and Innovation
- Prioritize Data Coverage:
- Adopt a Use-Case-Centred Approach
- Strategically Integrate AI and Sensors
- Address Data Quality Concerns
- Develop Standardized Frameworks and Agreements

Insights into the practical use of third-party data with in-depth overview of the outcomes and lessons learned by the selected NRAs in procuring, implementing, and utilising third-party data provided five main lessons learned included the following which are here summarised by main topic:

1. Pre-procurement phase
    a. Pre-studies
    b. Market consultation
2. Procurement phase
    a. Balancing quality and cost
    b. Setting minimum requirements and award criteria
3. Implementation phase
    a. Data integration: System operation and data extraction of procured data require ensuring compatibility with existing platforms and proper adaptation for smooth integration
    b. Understand the data that is procured
    c. Addressing data attributes
    d. Data access control for procured data and its derivatives must balance open access for public use and controlled distribution for private entities.
4. Maintenance and monitoring phase
    a. Ongoing data quality assurance and data understanding: Regular monitoring and validation of data quality are essential for maintaining effectiveness of third-party data.
    b. System flexibility: Adaptability in systems and data management processes is crucial for handling updates and changes in third-party data providers.
5. Overarching phase: Service Level Agreement (SLA), scalability, barriers/challenges, and risk
    a. SLA monitoring: third-party data providers meet the expected standards for data delivery and quality.
    b. Scalability challenges when aiming full-scale implementation with increased data coverage with accuracy and performance maintained.
    c. Risk mitigation

Improving the use of third-party data by NRAs provided step-by-step guidance for all phases of the process from pre-procurement studies to the actual procurement phase and follow-up activities during the contract period. Furthermore, Use Case Identification and Validation Framework provided NRAs guidance on how to assess the possibility of using 3rd party data as an input in their core business processes, before the actual decision has been made for proceeding to data procurement. Also, NRAs guidelines and decision-support how to successfully perform a 3rd party data acquisition process in each phase was presented with practical European case examples.

Trust in data and service provision recommendations included following, which start with an *overview of the ongoing roll-out of the C-ITS PKI* within the European NRAs, including overview of PKI roll-out, multiple PKIs and lessons from other sectors. Furthermore, *guidance on the implementation of the C-ITS PKI* include guidance on procurement and costs as well as a roadmap.

Review of legal and ethical ramifications for NRAs when making use of ITS and C-ITS data, and of how these change the role of the NRA, included responsibility of data accuracy, ethical use of data, inclusive communication and development of ITS and C-ITS services to road users. For the forementioned topics, the report provided the following seven recommendations for the NRAs:

1. The NRA should embed legal, contractual and ethical responsibilities for data accuracy in their operation
2. Identify the road users and involve them in communication and real-world development of the services
3. Understand and acquire expertise on C-ITS services, use cases and their limitations
4. Follow inclusive and transparent communication recommendations
5. Develop inclusive services by using the human-centred design principles
6. Apply basic principles and processes for ethical use of data
7. Carry out risk evaluation when communicating and developing ITS/C-ITS services

Connected vehicle deanonymisation research review and impact study provided knowledge on the privacy impacts of the processed road user location data, as well as recommendations to improve the location privacy-preservation.

Trusted service provision recommendations for road operators as related to *"Trust in the system"* included the following recommendations:

- R 4.1.1. - Reputation-based trust
- R 4.1.2. - Identify potential conflicts of interest with OEMs
- R 4.1.4. - Independent Third-Party Certification
- R 4.1.6. - Ensure Adherence to standards
- R 4.1.7. - Use of Standardised Data Formats
- R 4.1.8. - System auditing
- R 4.1.9. - Data Authentication
- R 4.1.10. - Maintain Access Control and Audit Trails
- R 4.1.14. - Data Redundancy and Cross-Verification

The recommendations for road operators as related to "*Trust with the system"* were as follows:

- R 4.2.1. - Transparency of Data Collection and Processing
- R 4.2.2. - Develop clear requirements for data provisioning

- R 4.2.4. - Assess risks associated with data
- R 4.2.5. - Document Assumptions and Use Constraints
- R 4.2.7. - Validate Data Against Ground Truth
- R 4.2.8. - Encourage Use of Complementary Data Sources
- R 4.2.9. – Define Baseline for Data Quality
- R 4.2.11. - Periodic Data Quality Assessments
- R 4.2.14. – Cross-NRA cooperation
- R 4.2.15. - Training and Capacity Building for NRAs

Validation of the proposed above recommendations in this study and a roadmap for them was done in the CEDR DROIDS project deliverable D5.2 Data strategy roadmap (Kvalvik et al. 2025). The mentioned validation and roadmap were completed by DROIDS work package leaders, road operators, and the DROIDS Advisory Group, which included public, private, and industry members.

DROIDS project description

DROIDS is a CEDR Transnational Road Research Programme Call 2022 project aiming to provide the road operators, including European National Road Authorities (NRAs), increased knowledge and support to reap optimal benefits from digitalisation as they evolve to become digital road operators operating the physical, operational and digital road infrastructures. As digital road operators, the road operators will provide better road user services while improving road transport's safety, efficiency and sustainability.

The background of the research is the ongoing transformation of the road operators to digital road operators responsible for operating both the physical and digital road infrastructure. Some road operators have already developed their processes and services accordingly, while some are still reflecting on the developments and discussing the transformation.

First the project will look at the evolving roles of the road operators as they transform themselves into digital road operators. Special focus is given to new roles brought by digital road operation while changes foreseen about the existing roles are addressed. DROIDS pays specific attention to the role evolution in different CEDR member countries with currently varying roles and digital maturity.

Secondly, the project studies the evolution of digital twins from road data banks to comprehensive real-time digital twins of the road transport system, including the infrastructures, traffic, land use, road environment etc. Here, the integration of the digital twins with the processes in the road operator's core business and tasks is assessed in a thorough manner.

Thirdly, trust has been identified as the key attribute for road operator originated data/information concerning its use by private sector stakeholders such as vehicle manufacturers and service providers. Thereby DROIDS also highlights the issues related to ensuring trust and security in the maintenance, sharing, and use of the digital road infrastructure.

Finally, the work of DROIDS concludes in the production of an overarching data strategy for the physical and digital road operators taking on board the results from DROIDS and other ongoing projects (such as CEDR Data Call 2022 PRESORT and TIARA projects).

Expected achievements and benefits to road operators:

- DROIDS offers road operators a clearer understanding of the prerequisites and roles associated with becoming a digital road operator, vital for road operators considering this transition.
- It emphasizes the crucial step for road operators: adapting processes to maximize benefits from digital tools.
- While DROIDS provides insights for process adaptation, the actual implementation must align with each road operator’s unique digital and organizational maturity.
- The project results will outline specific recommendations regarding actions and roles tied to HD maps, electronic traffic, and transport regulations, aiding road operators in decision-making

Glossary

ADS	Automated Driving Systems
AIM	Asset Information Modelling
BIM	Building Information Modelling
C-ITS	Cooperative Intelligent Transport Systems
CCAM	Cooperative Connected and Automated Mobility
CEDR	Conference of European Directors of Roads
DIM	Deconstruction information model
DROIDS	Digital Road Operator Information and Data Strategy project funded by CEDR.
DT	Digital Twin
EC	European Commission
EU	European Union
GNSS	Global Navigation Satellite System
IoT	Internet of Things
NAP	National Access Point
NRA	National Road Authority. NRA is often used in Europe. This study uses a term “road operator” that also includes NRAs.
ODD	Operational Design Domain
OTL	Object Type Libraries
PIARC	World Road Association
PIM	Project Information Model
SOTA	State-of-the-Art
TRL	Technology Readiness Levels

Content

Tables

Figures

1 Introduction

In the mobility domain, strengthening public and shared transportation as a backbone for sustainable mobility in Europe depends on the availability and linkage of large datasets. For example, mobility data can provide valuable insights regarding movement patterns that can help address questions in the public interest, including sustainable urban planning and the provision of public services. Also, in the mobility domain data exchange enables increased efficiency of solutions and offers prospect for new business models and services. Presently, Road operators, including the National Road Authorities (NRAs) in Europe, are pursuing benefits from digitalisation as they evolve to become digital road operators with responsibilities, amongst others, to operate the physical, operational and digital road infrastructures. As digital road operators, road operators should be able to provide better road user services while improving road transport's safety, efficiency and sustainability. To do so, increased knowledge and experience are necessary among the full spectrum of digital possibilities.

The concept of a digital twin is closely linked to the use of data as a resource to create digital representation of physical entities, phenomena, etc. Currently, many Data Exchanges or Data Centers have been set up. However, it is challenging to govern the circulation of data: difficult to confirm rights, difficult to price, lack of protection technology, difficult to comply with rules and supervision, and insufficient relevant protection laws. As a result, the willingness of data owners to participate in sharing data is low, which leads to difficulties in data circulation, and the digital ecosystem is facing a crisis.

However, data can only enable road infrastructure planning, operation, and maintenance (assets), digital road infrastructure operation, traffic management and monitoring, and sustainable transport, if there is trust in the data and if the data that is being produced, processed, shared, and stored has the appropriate safety measure. Additionally, to pursue digital twins as a tool for digital road operations and simulation, one must understand which phenomena are relevant to safe, efficient, and sustainable road operations to be represented digitally. These representations require relevant models and access to high-quality data provided by different providers. This document provides an overview of the required constitutes enabling digital twins and a draft strategy and roadmap for deploying digital twins for road operations in Europe.

The following figure outlines the CEDR DROIDS project Data strategy and roadmap deliverables, i.e. including this deliverable, overview and content. The content is further explained in the following paragraphs.

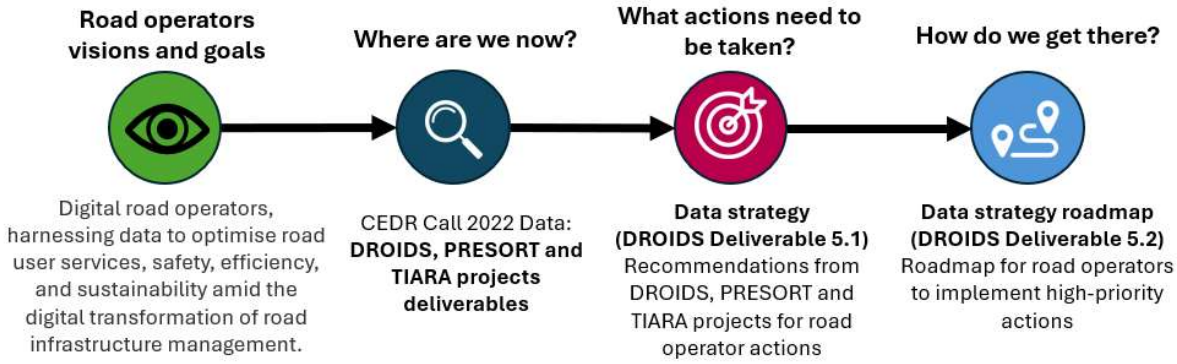

Figure 1 CEDR DROIDS project Data strategy and roadmap deliverables overview and content.

The background of the CEDR-funded DROIDS project research was the ongoing transformation of the road operators, including National Road Authorities (NRAs) and road

managers, to digital road operators responsible for operating both the physical and digital road infrastructure.

CEDR undertook and funded in CEDR 2022 Research call on Data three projects to research how road operators can maintain and share the digital road infrastructure data and improve the use of third-party data. The three project topics are listed below and illustrated in Figure 1.

a) Maintaining and sharing the digital road infrastructure (DROIDS project)
b) Improving the use of third-party data by NRAs (PRESORT project)
c) Integrity, Authenticity and Non-Repudiation (e.g. proof of the origin, authenticity and integrity of data) integrated in Trust Models for C-ITS applications (TIARA project)

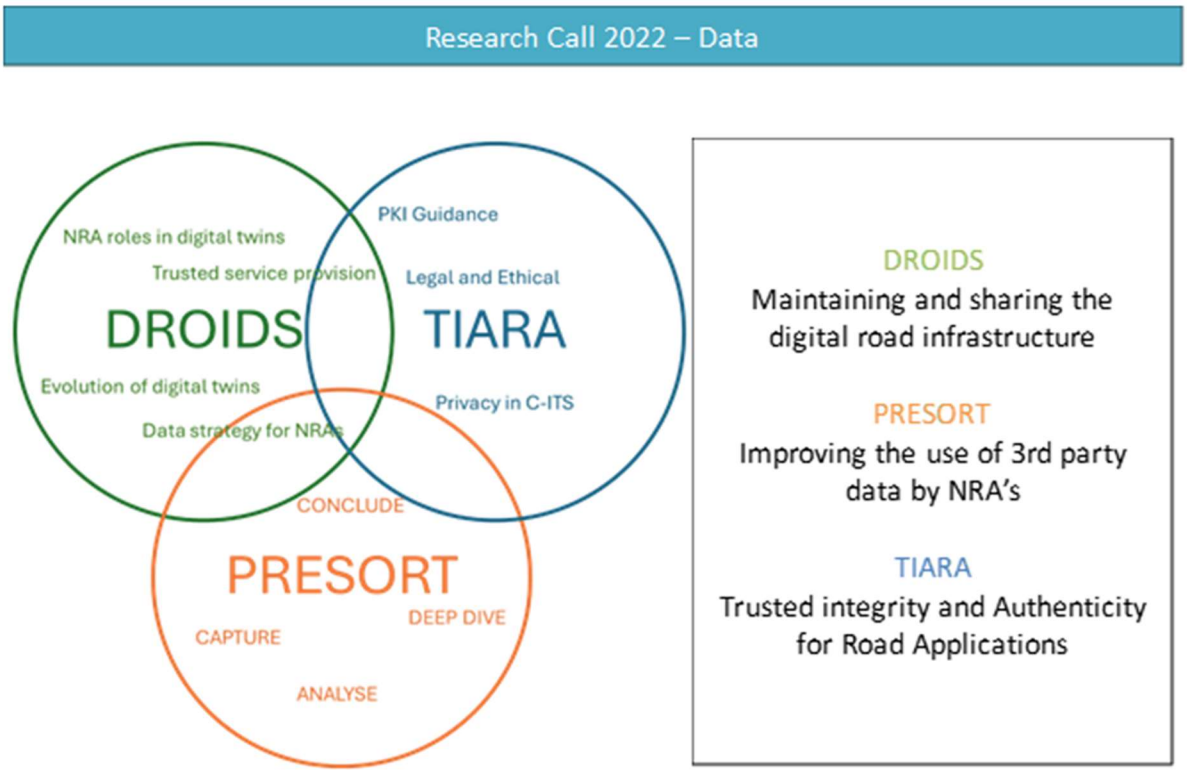

Figure 2: High-level topics researched across the three CEDR research projects

The three projects of the CEDR Call 2022 Data program, related to digital road infrastructure (DROIDS), third-party data (PRESORT), and trustworthy and secure data infrastructure (TIARA), provided insights into different perspectives, initiatives, and technologies driving the digital transition of road operations.

The Scope of this research deliverable is to present a data strategy for road operators. Therefore, this study effectively summarises the project's previous research questions and results, as well as the aforementioned CEDR Call 2022 Data projects PRESORT and TIARA results, as presented in the table below.

Table 1 DROIDS project Work Package 5 and the scope of its deliverables, including this data strategy deliverable 5.1.

DROIDS WP5 Data strategy deliverable (D)	Description of deliverable content	Expected end result
D5.0 Background report for data strategy (07/2025)	Presents key findings from the research results of digital blueprint, data governance models and data sovereignty.	A background study for the data strategy.
D5.1 A data strategy for digital road operators (07/2025) ***(this deliverable)***	**Respond and refer to previous results on all research questions on the strategic level in form of a digital road operator data strategy by utilising the results from DROIDS project work packages and CEDR Call 2022 Data PRESORT and TIARA projects.**	**ER2 An overarching European data strategy for the role of physical and digital road operator**
D5.2 A proposed roadmap for implementing the data strategy	Proposed roadmap for the road operators to implement the data strategy.	Proposed roadmap for implementing the data strategy.

The conceptual data strategy aims to outline the evolving role of road operators and recommendations indicating how to achieve this. Data serves as the essential resource for the digital transformation, but exchanging this new raw material faces several challenges, such as privacy, ownership, quality, security, trust, and valuation. The data strategy chapters cover the following topics:

- **Methodology and methods** used to build the data strategy (Chapter 2)
- **Data space is the backbone for digital road operations**. (Chapter 3)
- **Role of road operators**. Development, operation, maintenance and use of the digital representations, including the use of digital twin technology supporting asset management, electronic traffic regulations – speed limits, road works, incident detection, access control/ UVAR incl. road tolls, electronic traffic regulations – general regulations, CCAM – distributed ODD awareness. (Chapter 4)
- **Providing new digital services and information life cycle**. Provide BIM and AIM for HD Maps, sharing of the operational picture with the wider road traffic management ecosystem. (Chapter 5)
- **Use of third**-party data in digital road operation. (Chapter 6)
- **Secure and trusted exchange of data** in a multi-actor environment. (Chapter 7)

2 Methodology and methods

2.1 Methodology of the DROIDS project

The DROIDS project utilises the Digital Transformation Framework (DTF) structured approach that supports the design, development, planning and management of necessary organisational transitions. The DTF adopted for the DROIDS project is illustrated in Figure 3. Within the DTF, it is important to ensure vertical and horizontal alignment between the different columns and layers.

Vertical Alignment: This refers to the strategic alignment between requirements, gaps, and actions to fill these gaps, which form the three phases of the project. It follows a top-to-bottom approach, translating overall goals into relevant business cases and roadmaps. The information gained in one layer supports the content creation in the layer below, ensuring a consistent way of achieving the business cases, overarching strategy, and implementation roadmap.

Horizontal Alignment: This ensures completeness by not focusing only on technology or stakeholders but also considering other important organizational factors. It ensures alignment between stakeholders, core business, internal processes, and IT for an organization. This alignment produces the expected outputs holistically and is taken into account in the individual work packages. It pays special attention to alignment with key stakeholders.

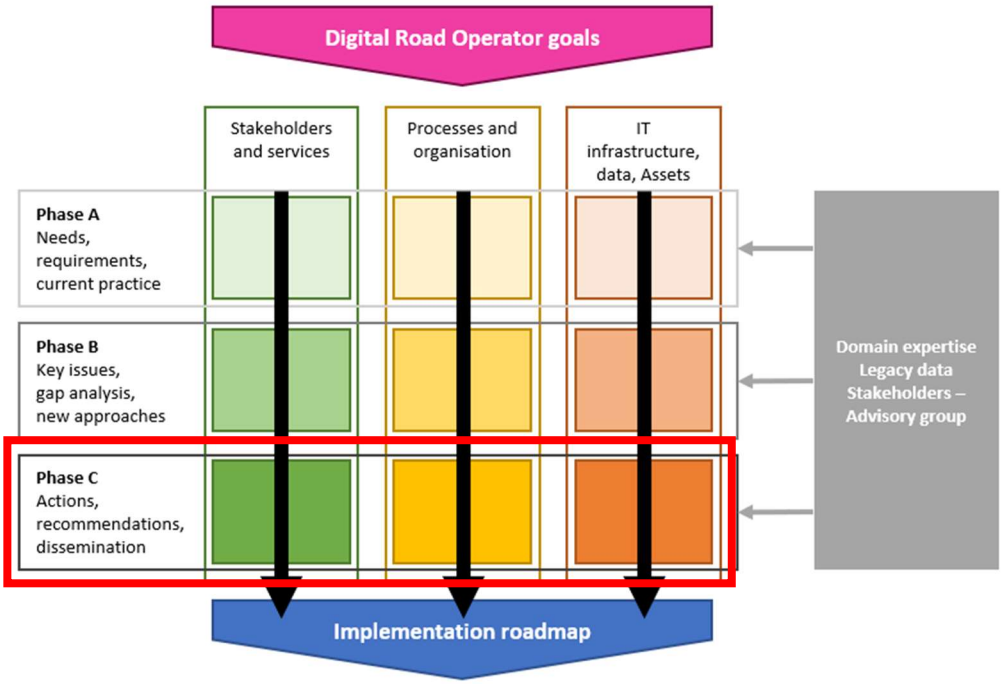

Figure 3: DROIDS project's Framework

This Work Package 2 and Work Package 3 deliverables 2.1 and 3.1 are part of the first horizontal DTF Phase A that determines needs, requirements, and current practices as shown in Figure 3.

2.2 Methodology and methods used to implement the data strategy

This chapter covers methods used when implementing the data strategy. This chapter does not cover methods used in the previous DROIDS research and deliverables, which are though shortly mentioned in the chapters and explained more in detail in the DROIDS deliverables referred to in this study.

The data strategy roadmap methodology is the final phase C in the previous chapter, where the DROIDS methodology is presented. This includes actions, recommendations, and the dissemination of results to stakeholders, as well as services, processes, organisations, IT, infrastructure, data, and assets.

The data strategy task started by preparing the basic structure of the strategy. This was then provided to the Conference of European Directors of Roads (CEDR), i.e., road operators mainly from the Project Executive Board (PEB), for their comments, and subsequently reworked until a feasible structure was agreed upon.

The Introduction chapter presented the CEDR Call 2022 Data digital road infrastructure DROIDS project in relation to other projects from the call, including PRESORT on third-party data and TIARA on trustworthy and secure data infrastructure. The data strategy roadmap builds on the results of the three mentioned projects.

The three above-mentioned CEDR projects resulted in recommendations for the road operators, which were extracted in this DROIDS deliverable 5.1 to provide basis for the data strategy for digital road operators.

Methods used when implementing the data strategy were literature, road operator and private industry expert collaboration as well as a workshop. The methods are presented more in detail in the following paragraphs.

Literature was used to collect previous research and best practices on data strategy content to help design and plan the strategy. Literature of the CEDR Call 2022 Data projects of DROIDS, PRESORT and TIARA projects results were used to collect recommendations from the results.

Collaboration with the three CEDR Call 2022 Data projects of DROIDS, PRESORT and TIARA and their work package (WPs) leaders and experts was done to ensure collection of the results recommendations for the use of data strategy. The below Figure 4 presents connections between the three projects WPs. Collaboration with the experts was done in project meetings and sending an email questions to provide results and feedback on the recommendations.

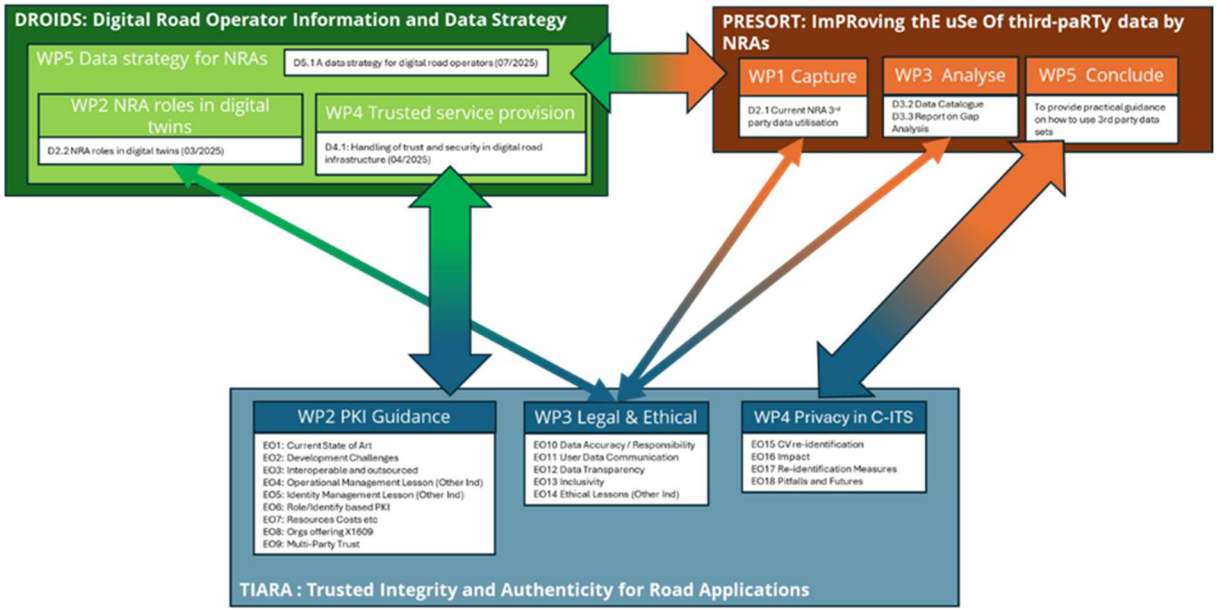

Figure 4: DROIDS, PRESORT and TIARA projects Work Packages (WPs) deliverables and expected outputs with dependencies and similarities between them.

Workshop on digital road operator data strategy was conducted on 17 June 2025 as a part of the CEDR Call 2022 Project Executive Board (PEB). The participants in the PEB meeting were road operators as well as DROIDS, PRESORT and TIARA projects experts. Aim of the workshop was to collect road operator input about the data strategy implementation.

3 European Data strategy and recommendations

Task 5.1 identifies recommendations based on the European data strategy and related initiatives such as operationalization of dataspaces to ensure safe, reliable, and trustworthy data sharing for NRAs and other stakeholders.

3.1 European dataspaces and the NRAs

This section presents recommendations on managing data as a strategic resource for digital road operations for NRAs based on findings from the IDSA, common European mobility data space, Mobility data space report, and the literature.

Recommendations on data governance

- Define rulebook (governance model) for the data space to support data sharing and exchange.
- Establish a clear data governance framework that defines roles, responsibilities and data use along with data protection measures.
- Clear data ownership and roles and strengthening data security and privacy.
- Enhancing datasets should be standardised and available through the NAP.
- Define a data quality management policy, including metrics and audits.
- Increased focus across the organisation and implementation of data governance principles.
- Use of an economic system architecture to enable non-discriminatory governance.
- Align with national standards (such as data acts, data governance acts, ITS directives, etc.), related to data sharing and exchange.

Recommendations for a sovereign data sharing approach

- Align with national standards and leverage open sources.
- Decide upon the data space reference architecture, including connector technologies.
- Select data space service offering/ data App.
- Assess the applicability of the current data space instances for mobility.
- Define technical and organisational requirements.

Recommendations on trusted data sharing and exchange

- Define rulebook (governance model) for the data space.

- Select the trust anchor strategy for the data space (NRA decision).
- Carryout data authentication schemes.
- Ensure transparency for data collection and processing formats.
- Implement independent certification.
- Carryout periodic data quality assessments.
- Deploy data redundancy and cross-verification.
- Use of standardised data formats.
- Support the implementation of system auditing.

Recommendations from deployment methodology for dataspaces

- Identify use cases and define the scope/purpose.
- Establish collaboration and communication between internal and external stakeholders
- Development of a clear digitalization strategy: align national and EU initiatives.
- Deploy a cocreation methodology (use case and stakeholder driven) for informed decision making and effective collaboration (CEDR Decision).

Finally, recommendations for implementing **skills and training** includes NRAs having competence in Digital Twins, IoT, Interoperability, Data Spaces, Data Governance, Data valuation, WEB3, Cyber security, Data science, Modelling, Cryptography, and DLT/Blockchain Technologies.

3.2 Data Space Design Principles for Digital Road Operations

Data Space design principles to be employed for achieving digital road operations by NRAs as derived from the IDSA, common European mobility data space is summarised in 13 areas as shown in Figure 3.

Figure 5 Data space design principles for digital road operations

4 Stakeholder Roles and Priority of use cases for road operators

The role of NRAs in the larger ecosystem of digital twins for road infrastructures, and how they should fulfil this role was described in the DROIDS deliverable 2.2 “NRA roles in digital twins” (Kulmala et al., 2025). The summary of the results is presented in table 3 below.

The roles were determined for each digital representation (model – shadow – twin) use case. The use cases were selected on the basis of the current use cases such as BIM and AIM but also taking into account the use cases in the research and development phase. The role tables were validated by the European road authorities and public as well as private entities in the project workshop and advisory group.

Table 2 compiles the results for road operators. It is important to bear in mind that the European NRAs have also other roles than the road operator depending on the national road transport system governance models. Thereby, many road operators have also the role of traffic managers, while some also have the role of traffic information service provider or road transport authority. The role tables including also those roles are presented in DROIDS deliverable 2.2. The role of the road operator, however, is common to all NRAs.

As indicated in Table 2, the road operator assumes an active role in the use cases dealing with the planning, building and maintaining the road infrastructure. The road operator carries the full responsibility for the digital representation in these domains either directly or via its contractors. It is also worth to note that road operators tend to be the users of the digital presentations available for all use cases as this likely increases the efficiency of the road operators’ own processes.

The use cases concerning the common operational picture for traffic management and the actual traffic management services (signal control, hard shoulder running, dynamic speed limits) lie usually under the responsibility of traffic managers (a role possibly for the NRA), and the road operator has a more passive role in many of those use cases. The road operator has an active role and can set up specific digital representations for own uses in the use cases directly supporting the road operator key tasks such as surface condition monitoring, road works and tunnel management.

For the electronic transport regulations, the road operators are active stakeholders in the maintenance of those digital representations by providing inputs of any changes in the regulations resulting from their own actions.

For the HD maps, the role of the road operator may vary according to the national situation. In general, the road operators have a digital road network description of their own including positioning data so that the properties of the road network can also be views via map interfaces. The road operators carry full responsibility for the development, operation and maintenance of their own digital representations (digital models).

In the case of connected and automated mobility, the key actors are likely the operators of the connected and automated vehicle fleets. The road operator’s role will likely be to provide data on any actions or changes on the road network due to the processes or contracts of the road operator.

Table 2 Summary of the road operator roles in digital representations use cases for road infrastructure. A means active (actually carrying out the task or commissioning it), P when more passive. ( ) means that the role is valid in some European countries only. A/P refers to possible Active or Passive role, 'DM' refers to Digital Model, 'own' refers to possible responsibility to developing their own digital representation.

Road operator roles	**Life cycle of road infrastructure digital model/shadow/twin**			
Use Case	**Development**	**Operation**	**Maintenance**	**Use**
Road planning and building (model)	A	A	A	A
Road maintenance (shadow)	A	A	A	A
Winter maintenance (shadow)	A	A	A	A
Asset management (model)	A	A	A	A
Common operational picture for traffic management				
➢ Traffic jam conditions and end of queue (shadow)	P	P	P	A
➢ Surface condition monitoring (shadow)	A - own	A - own	A - own	A
➢ Tunnel closure and management (shadow)	P/A - own	P/A - own	P/A - own	A
➢ Road works (shadow)	A - own	A - own	A - own	A
➢ Safety related incidents and incident management (model)	A/P	A/P	A/P	A
➢ Incident detection (shadow)	A/P	A/P	A/P	A
➢ Event management (model)	(A)	(A)	A	A
Electronic/Digital traffic rules/regulations				
➢ General traffic regulations (model)	P/A		A	A
➢ Speed limits (shadow)			A	A
➢ Access Control / UVAR (shadow)	A (road tolls etc)	A (road tolls)	A (road tolls)	A
Signal control (shadow / twin)	A/P	A/P	P	A
Hard shoulder running (shadow / twin)	A/P	A/P	P	A
Automated traffic enforcement (shadow)	P/A	P/A	P/A	P/A
HD Map (shadow / model)	A (DM) - own	A (DM) - own	A (DM) - own	A
Cooperative Connected and Automated Mobility (CCAM) – Distributed ODD attribute value awareness (shadow)			P/A	A

The types of digital representations relevant to the NRAs were also discussed in the DROIDS deliverable 2.2 mentioned above. The results were validated via CEDR workshops and advisory group discussions. The results in Table 4 present the estimated likelihood of digital representation deployment of the use cases by 2030. Digital models and digital shadows were

estimated of being very likely for the use cases deployment by 2030 by at least three Member States.

Table 4. The PEB-given priorities (1 means highest priority, - means no priority votes given by PEB) and the estimated likelihood of digital representation deployment of the various use cases by 2030 by at least three Member States. The digital representations are either DM (Digital Model), DS (Digital Shadow) or DT (Digital Twin).

Pri-ority PEB		Estimated likelihood of deployment of use case by 2030 by at least three Member States		
	Use case	**Unlikely**	**Likely**	**Very Likely**
	Common operational picture for traffic management (network level use case)			
-	• Traffic jam conditions and end of queue	DT	DS	
-	• Surface condition monitoring	DT		DS
9	• Tunnel closure and management	DT	DS	
3	• Road works	DT	DS	DM (static RW data)
9	• Safety related incidents and incident management	DT and DS (all stakeholders)		DM
4	- Incident detection	DT		DS
-	• Event management	DT	DS (large events)	DM
8	Road maintenance	DT		DS
11	Winter maintenance	DT		DS
1	Asset management	DT	DS (high-risk assets)	DM
11	Road planning and building	DT (smart construction)	DS (smart construction)	DM
	Electronic/Digital traffic rules/regulations			
6	• General traffic regulations	DT	DS (dynamic)	DM
2	• Speed limits		DT (dynamic)	DS
4	• Access Control / UVAR		DT (dynamic)	DS
-	Automated traffic enforcement		DS	DM
-	Signal control		DT (dynamic)	DS
11	Hard shoulder running		DT	DS
11	HD Map	DT		DS
6	Cooperative Connected and Automated Mobility (CCAM) – Distributed ODD attribute value awareness		DT	DS

The restrictions of public sector budgets in road infrastructure and its operations mean that the NRAs have to move towards digital road operation as all evidence supports the view that digitalisation makes also NRA operations more efficient with high benefit-cost estimates. At the same time the restricted budgets mean that digital representations cannot be realised for every use case. The conclusion thereby is that the NRAs need to focus on some use cases. Table 4 provides support for the NRAs in selecting the use cases to prioritise as well as the type of digital representation to target.

The overall priority order for digitalisation for the next years is:

- asset management
- electronic traffic regulations – speed limits
- road works
- incident detection
- access control/ UVAR incl. road tolls
- electronic traffic regulations – general regulations
- CCAM – distributed ODD awareness

The priorities for the electronic traffic regulations use cases is related to the deployment of the ITS Directive's RTTI (Real-Time Traffic Information) delegated regulation (European Commission 2022).

Many of the use cases are expected be realised as digital shadows, i.e. the digital representation is automatically updated whenever the status of the physical counterpart is changing. For asset management and road works, however, the very likely 2030 situation will be digital models. For most critical parts of the infrastructure such as vulnerable bridges and tunnels, the asset management should likely be utilising digital shadows.

Each of the digital representation use cases presented in the Table 3 and 4 above are described in more detail in DRIODS D2.2 report (Kulmala et al., 2025).

As all the use cases are relevant for the NRAs, the NRAs should at the minimum liaise or otherwise agree with the active stakeholders in a use case, where the NRA itself is not actively involved in except for its use and providing support to its maintenance by providing information to it. In addition, the NRA should liaise with other stakeholders operating similar digital representations as having an identical view of the physical aspects of the transport system is in every stakeholder's interest.

To assist the NRAs in acting as recommended above, Table 5 compiles the active stakeholders in the development, operation and maintenance of the high priority use cases.

Table 5. The active stakeholder roles in Development (D), Operation (O), and Maintenance (M) for the different high priority digital representation use cases. The use case abbreviations are explained below the table.

	High priority use cases							
Stakeholders	**AM**	**RM**	**RW**	**ID**	**EGR**	**ESL**	**EAC**	**CCAM**
Transport authority (ministry, agency)			DO		DOM	DM	DOM	
Communication authority							D	
Land use authority (e.g. city, region)	DOM				M	M	DOM	M
Law enforcement				M	M	M		M
Rescue service provider				DOM		M	DOM	M
Road operator	DOM	DOM	DOM	DOM	M	M	DOM	M
Traffic manager		DOM	DOM	DOM	M	DOM		M
Road infrastructure planning contractor								
Road infrastructure building contractor	M		DOM			M		M
Road works or maintenance contractor	M	DOM	DOM	M		M		M
Traffic information service provider			DOM	DOM				M
Meteorological service provider	DM			M				M
Communication infrastructure provider								M
Digital map provider	M		M	M	DM	M		M
Vehicle fleet operator	M	OM	OM	DOM	DOM	M		DOM
Vehicle manufacturer					DM			M
Automated Driving Systems (ADS) provider	M	M	M	M	DO	M		M
Research / academic institutes								
Vehicle owner/ driver/ occupant	M	M		M		M		

AM-Asset Management, RM-Road maintenance, RW-Roadworks, ID-Incident Detection, EGR-Electronic Transport regulations/General regulations, ESL- Electronic Transport regulations/Speed limits, EAC- Electronic Transport regulations/Access Control (e.g. Road tolls); CCAM-Cooperative Connected and Automated Mobility

The data types, sources and uses differ considerably from one use case to the other. The NRAs developing the digital presentations should check those relevant for their own use case(s) in deliverables D2.2 (Kulmala et al., 2025) and D3.4 (Soni et al., 2025).

During the planning and building phase, BIM digital representations are crucial as they *represent* various attributes of the built infrastructure. The BIM information after the completion of the project represents a digital model of the as-built infrastructure. The BIM information is crucial for the NRAs to maintain since BIM models can be transitioned to asset information models (AIM). Furthermore, BIM information can also be potentially reused in HD maps for Automated Vehicles. For more details, check DROIDS deliverable D3.4 (Soni et al., 2025).

Asset information models (AIM) are relevant for the road operators during in the asset management and road maintenance phases. The asset information models pull the relevant information from as-built BIM digital representation from design and construction phase. As AIM is updated continuously during asset management, it represents a digital model of the physical road infrastructure and can form a strong basis for creating a digital shadow/twin. DROIDS deliverable D3.3 explored the potential of using AIM for digital shadow/twin creation.

The level of geometric and topological complexity from BIM and AIM models is usually sufficient for basic road operations such as construction and maintenance of the infrastructure. However, for advanced applications such as creating a digital shadow for connected/automated driving, the level of detail in such models is not sufficient. For applications in connected and automated driving, High-Definition (HD) maps offer more precise and accurate models. DROIDS deliverable D3.4 (Soni et al., 2025) discusses HD maps in detail and investigates the possibility of reusing BIM/AIM information for them.

The road operators must standardise the information by adopting ISO 19650 and implementing an object type library from early phases of digital representation development. By following a standardised approach, the information stored in digital representations is interoperable with variety of other applications.

With regard to traffic management and information provision to external services we today have only limited insight on best practices. Nevertheless, since traffic managers and traffic management services by NRAs and road operators are developing common real-time operational picture together with the stakeholders and they have an active role and ownership with these digital representations, they also have a high likelihood of ownership and being maintained by road operators.

Concerning HD maps, the HD map providers have indicated the potential to make connections of HD maps with AIM/BIM systems if the quality of information is good, standardised and validated. Today, it is a bit early for the road operators to take responsibility in managing the information for HD maps. They should, however, pilot the usefulness of BIM and AIM information within HD maps in cooperation with HD map providers. At an early stage, road operators can focus on making sure that the information related to assets such as GIS information is organised, updated, and complete.

It is questionable whether the HD maps would be NRAs core business even in the future especially when considering OEMs and service providers having vehicle fleets with substantial data collection capabilities to further enhance the HD maps and having a business case to use the map for example on automated driving.

Services and data that are typical and core business for NRA as a road operator and often a traffic manager, and their operational services and common operational picture should be shared with the road traffic management ecosystem. These services and data can provide benefits for example on traffic safety and flow as well as reducing emissions. Important part of the benefits comes from OEMs and service providers who build their services by utilising the road operator and traffic manager data and services. Many of the data sources and information relate to services that the NRA offer today. Depending on the ambition and available budget and capacity that NRAs have, additional services and data that may benefit new services

outside of the current NRA's scope and responsibility could be expected to be shared. For instance, certain ODD attribute values that can augment CCAM services fall in that category.

However, all data and services should not be shared. For example, data that has been bought from third-party service providers and data that is under ecosystem agreement, such as Data for Road Safety ecosystem, are outside of sharing scope.

Furthermore, data that is shared should not cause harm or damage. The damage can involve for example security or privacy related issues. The sufferer of the damage can be a road user, public or private organisation, national authority or member state. Therefore, a risk analysis is needed to evaluate any privacy, security or other risks that the data and services provided by the NRAs could include. Data privacy, security, legal ethical issues are discussed further in the CEDR funded TIARA project (Aesin 2025).

5 Information life cycle, maintenance and regulations

Digital representations and twins information, life cycle and regulations were discussed in the following DROIDS project reports:

- D3.2 Information maintenance and availability (Soni 2024)
- D3.3 BIM representation for full life cycle of road infrastructure (Soni 2024)
- D3.4 Digital twin use cases – Digital transport regulations, opening new roads, automated lane level navigation (Soni et al. 2025)

The above-mentioned deliverables results provided the following recommendations and guidelines for the NRAs.

Information maintenance and availability

- **Identify use cases and define the scope/purpose:** Having a well-defined scope helps align the project with the organization's objectives and ensures that resources are focused effectively.

- **Invest in skills and education:** With appropriate skills and knowledge, the organisations can assess their current state of standardisation, choose correct technologies for implementation, understand complex standards, perform validation and testing, and determine which data/information/process need to be standardised.

- **Adopt Open Data Standards:** Embrace open data standards for improved interoperability, flexibility, and cost-effectiveness. This will facilitate data exchange with other systems and stakeholders, enable easier integration with future technologies, and reduce reliance on proprietary software solutions.

- **Align with National Standards:** Ensure that information management practices comply with relevant national standards. This will promote consistency across different organizations, facilitate data sharing at a national level, and create a foundation for further collaboration and innovation. Road operators can start with

- **Prioritize Major Projects for Information Management Upgrades**: When implementing new information management standards or systems, focus on major projects first to gain experience, establish workflows, and realize benefits more quickly. Minor projects can be addressed later, leveraging the knowledge and infrastructure developed during the initial implementation.

- **Move Towards Integrated Asset Management Systems:** NRAs can prioritize transitioning away from siloed asset management systems (e.g., separate databases for pavements, bridges, signs) towards integrated solutions based on open standards. This will reduce data duplication, improve consistency, and enable seamless data sharing and analysis across different asset types. Consider partnering with other road operators to explore collaborative standardisation efforts.

- **Phased Implementation**: Recognize that transitioning to integrated systems and open standards may take time. A phased approach, starting with pilot projects and gradually expanding, can mitigate risks and ensure a smooth transition.

- **Change Management**: Implementing new information management systems often requires changes in processes and workflows. Invest in change management strategies to ensure successful adoption.

BIM representation for full life cycle of road infrastructure

In order to maintain the BIM information throughout the lifecycle of road infrastructure, road operators have recommended following considerations:

- Implement ISO 19650: Implement ISO 19650 as the framework for information management and exchange throughout the project lifecycle.
- BIM standards: Create or adapt existing BIM standards and guidelines that specify the requirements for data exchange, level of detail, and format (e.g., IFC, openBIM standards).
- Develop and implement OTL: Create or use a detailed OTL that defines the properties and attributes of each asset type. This will ensure consistency and interoperability across different projects and organizations.
- Establish collaboration and communication: Active collaboration between internal stakeholder such as BIM and AIM departments ensures mutual understanding of requirements and capabilities. On the other hand, collaboration with external stakeholders such as contractors, design and engineering firms, consultants, technology providers etc helps in identifying information requirements and ensuring the needs of every stakeholder.

In order to reap the benefits of standardisation emerging from OTL implementation and possible extension, road operators could consider the following key components:

- Data Dictionary Foundation: Build upon existing data dictionaries to establish standard definitions and meanings.
- Leverage Open Sources: Utilize open-source libraries like bSDD and Uniclass to establish a solid foundation and ensure continuous updates.
- Extend with New Attributes: Incorporate new attributes to accommodate dynamic information and future needs.
- Collaborative Development: Involve multiple stakeholders to ensure the OTL meets diverse needs and facilitates data exchange.
- Continuous Adaptation: Regularly review and update the OTL to adapt to evolving requirements and technologies.
- Standardization and Interoperability: Ensure the OTL is standardized and interoperable with other systems and platforms.
- ISO Standards Implementation: Adopt ISO 19650 to provide a framework for information management and exchange.

To improve the BIM information reuse, road operators should implement BIM standards within their organisation for information management and try implementing an OTL to provide structure to asset information. European policies for standardised OTL such as EuroOTL as described in previous CEDR INTERLINK project, would be helpful in ensuring that different organisations can work together with each other and use common resources.

8. **Early engagement in standardization:** Road operators should engage in the METR standardization process as early as possible. This includes actively following the ongoing development and gaining a deep understanding of the relevant standards, particularly the foundational elements outlined in the initial parts of the ISO standards for METR. Participating in standardization efforts at both national and European levels will enhance the operators' maturity and knowledge, facilitating smoother METR implementation.

9. **Local perspective and requirement sharing**: Road operators should thoroughly assess their local requirements and specific use cases for METR. Sharing these specific requirements with standardization bodies will ensure that METR is adaptable to a wide range of situations. Collaboration and knowledge exchange among road operators will promote alignment of interests and ensure interoperability across different regions.

10. **Phased digitalization of traffic rules**: Begin with the digitalization of simple and easily achievable regulations, such as speed limits, which are mandated for the Trans-European Transport Network (TEN-T) by December 2025 and the entire public road network by December 2028. Gradually expand digitalization to include other traffic rules and information signs, following a prioritized approach.

11. **Development of a clear digitalization strategy**: Road operators must develop a comprehensive digitalization strategy that outlines specific objectives, priorities, and timelines for the transformation. Ensure alignment with both national and European Union level initiatives.

12. **Uniform Traffic Regulation Order (TRO) processes**: Standardize and digitize the processes for creating Traffic Regulation Orders (TROs).

13. **BIM standardisation**: Road operators should develop or implement OTL within their BIM/AIM process to improve quality, standardisation and understandability of the data. This would enable opportunities to integrate BIM/AIM data within the HD maps.

14. **Ensuring high-quality infrastructure for Automated Driving Systems (ADS):** Conduct regular assessments of road infrastructure to ensure the effective functioning of ADAS like Intelligent Speed Assistance (ISA). Identify and address issues with both digital information and physical infrastructure elements, such as the visibility and durability of road signs.

6 Use of third-party data

The PRESORT project (ImPRoving thE uSe Of third-paRTy data by NRAs) was part of the same CEDR Call 2022 Data funded projects as the DROIDS project. The PRESORT objective was to deliver an evidence-based decision support guide that can be used to enable National Road Authorities (NRAs) to make better decisions regarding how and when to acquire and use third-party transport data. The project's expected outcomes included a comprehensive understanding of the challenges and opportunities related to third-party data usage in NRAs, identification of specific use cases where third-party data can provide the most significant benefits, development of an actionable guide and data catalogue as well as dissemination of knowledge and best practices related to third-party data utilization.

The following PRESORT deliverables were reviewed to provide input for the data strategy, mainly of recommendations and main lessons learned:

- Deliverable 2 (D2): Improving the use of third-party data by NRAs – Baseline report (Stephenson & Spillard 2024)
- Deliverable 3.3 (D3.3): Report on Gap Analysis. (Soni & Oskina 2024)
- Deliverable 4.1 (D4.1): Report on Deep Dive (Huisken & Zhang 2024)
- Deliverables 5 (D5): Improving the use of third-party data by NRAs. Report on WP5 Conclude. Guidelines final report with
    - Deliverable 5.1. Use case identification and validation framework,
    - Deliverable 5.2. Data Acquisition and Quality Assurance Guidelines
    - Deliverable 5.3. Best Practices. (Laine et al. 2025)

The D2 baseline report by Stephenson & Spillard (2024) was a literature search to capture the **current state of third-party data usage**, and feedback from a questionnaire to relevant organisations on their experience of the use of third-party data. Therefore, the baseline report provided current state-of-the-art and input for other PRESORT project phases.

The report on Gap Analysis (D3.3) by Soni & Oskina (2024) provided **recommendations for successful collaboration between NRAs and third-party data providers** to fully utilise the potential of third-party data within NRAs. The following key strategies were recommended to be employed:

- Establish a Shared Vision: NRAs and third-party data providers should align their data visions, recognizing the value of specific datasets in relation to data quality levels. This shared understanding will facilitate a more effective partnership.
- Invest in Staff Education: Educating staff in digitization will help them understand the potential value of data sharing and encourage adoption across the organization.
- Foster Collaboration and Innovation: Regular collaborative workshops and mutual learning meetings will facilitate the exchange of ideas, the exploration of synergies, and the gradual introduction of innovative solutions.
- Prioritize Data Coverage: Given that certain critical data (e.g., traffic rules, infrastructure access, road work planning) can only be provided by road authorities, cooperation between NRAs and third-party data providers is crucial to ensure comprehensive data coverage.
- Adopt a Use-Case-Centred Approach: Focusing on specific use cases allows NRAs to assess existing data within their organization and identify gaps that third-party data providers can fill. As NRAs transition towards becoming digital road operators, addressing these gaps becomes a natural part of their development process.

- Strategically Integrate AI and Sensors: While AI shows promise, a gradual approach that combines AI with sensors initially is more prudent. This allows for careful monitoring, evaluation, and the gradual replacement of outdated methods with more effective ones.
- Address Data Quality Concerns: NRAs should be mindful of potential data quality issues in less populated regions, where third-party data providers often operate. Integrating this understanding into their data vision and collaborating with third-party data providers to identify necessary improvements will ensure data reliability.
- Develop Standardized Frameworks and Agreements: The development of standardized frameworks and collaborative agreements will be crucial for addressing data quality, privacy, and compatibility concerns, ensuring the seamless integration of third-party data into the transportation sector.

The Report on Deep Dive (D4.1) by Huisken & Zhang (2024) provided **insights into the practical use of third-party data** with in-depth overview of the outcomes and lessons learned by the selected NRAs in procuring, implementing, and utilising third-party data. The report included three use cases: Floating Vehicle Data (FVD) for traffic management, ROad MOnitoring 1 and 2 (ROMO1&2) In-Vehicle Data for road and asset management, and eCall Data for road safety and traffic management. The five main lessons learned included the following which are here summarised by main topic:

6. Pre-procurement phase
    a. Pre-studies
    b. Market consultation
7. Procurement phase
    a. Balancing quality and cost
    b. Setting minimum requirements and award criteria
8. Implementation phase
    a. Data integration: System operation and data extraction of procured data require ensuring compatibility with existing platforms and proper adaptation for smooth integration
    b. Understand the data that is procured
    c. Addressing data attributes
    d. Data access control for procured data and its derivatives must balance open access for public use and controlled distribution for private entities.
9. Maintenance and monitoring phase
    a. Ongoing data quality assurance and data understanding: Regular monitoring and validation of data quality are essential for maintaining effectiveness of third-party data.
    b. System flexibility: Adaptability in systems and data management processes is crucial for handling updates and changes in third-party data providers.
10. Overarching phase: Service Level Agreement (SLA), scalability, barriers/challenges, and risk
    a. SLA monitoring: third-party data providers meet the expected standards for data delivery and quality.
    b. Scalability challenges when aiming full-scale implementation with increased data coverage with accuracy and performance maintained.
    c. Risk mitigation

The report on Improving the use of third-party data by NRAs by Laine et al. (2025) provided **step-by-step guidance** for all phases of the process from pre-procurement studies to the actual procurement phase and follow-up activities during the contract period.

The 5.1 Use Case Identification and Validation Framework provided NRAs guidance on how to assess the possibility of using 3rd party data as an input in their core business processes, before the actual decision has been made for proceeding to data procurement. The process is presented in Figure 6 below.

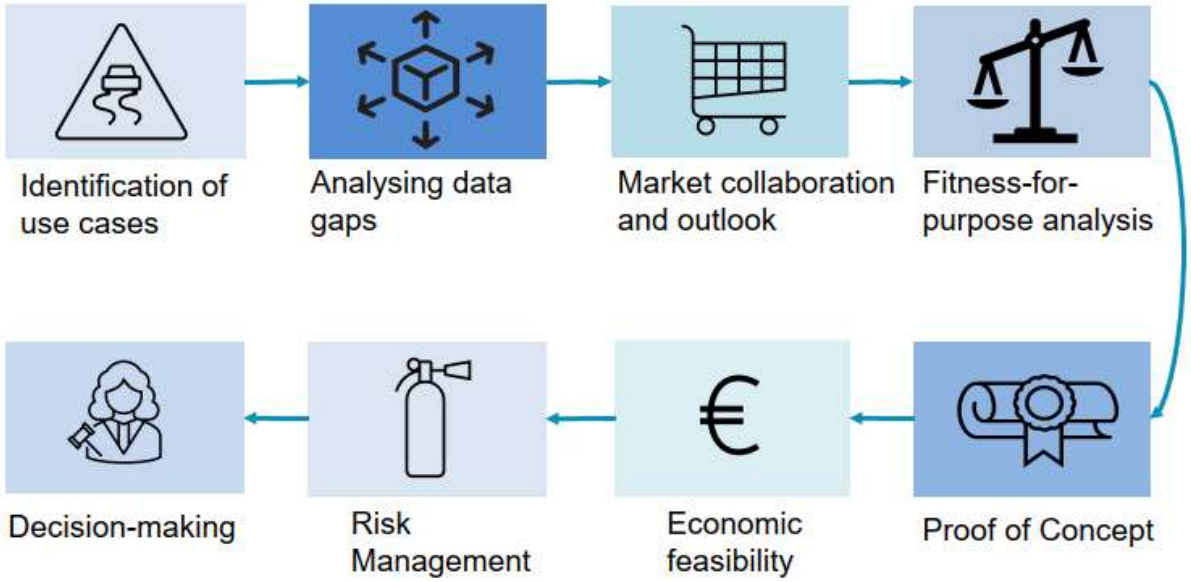

Figure 6: Step-by-step framework for use-case identification and validation. (Laine et al. 2025)

The D5.2 provided NRAs guidelines and decision-support how to successfully perform a 3rd party data acquisition process in each phase presented in Figure 7 below. Best practices for the process were further provided in the D5.3 with practical examples from European implementations.

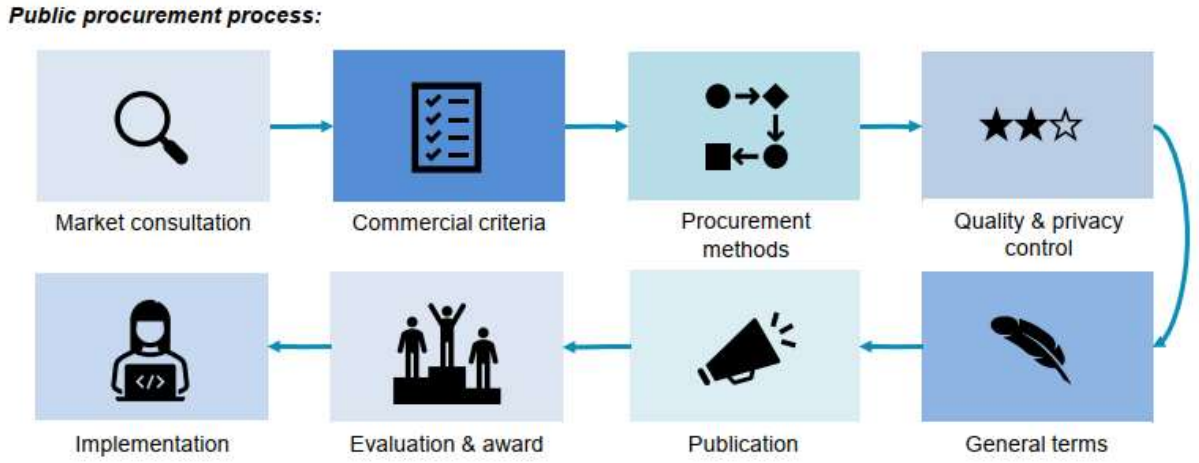

Figure 7: Public procurement process (Laine et al. 2025).

7 Trust in data and service provision

The TIARA project (Trusted Integrity and Authenticity for Road Applications) was part of the same CEDR Call 2022 Data funded projects as the DROIDS project. The objective of the TIARA project was to provide the National Road Authorities (NRAs) an increased understanding of what is required to achieve a trustworthy and secure data infrastructure. The project results include recommendations for Public Key Infrastructure (PKI) development, legal and ethical aspects as well as privacy in Cooperative Intelligent Transport Systems (C-ITS).

The following TIARA deliverables were reviewed to provide input for the data strategy, mainly of recommendations and main lessons learned:

- Deliverable 2.1 (D2.1): Operation of Public Key Infrastructures: State-of-the-art and best practices (Wille, Skytterholm & Meland 2025)
- Deliverable 2.2 (D2.2): Guidance on the implementation of the C-ITS PKI. (Wille, Skytterholm & Meland 2025)
- Deliverable 6 (D6): National Road Authority guidance on legal and ethical use of data (Kotilainen & Kulmala 2025)
- Deliverable 8 (D8): Connected vehicle deanonymisation research review and impact study. (Maerivoet & Ons 2025)

The TIARA project D2.1 on Operation of Public Key Infrastructures: State-of-the-art and best practices provided a comprehensive **overview of the ongoing roll-out of the C-ITS PKI** within the European NRAs.

- Overview of PKI roll-out
- Multiple PKIs
- Lessons from other sectors

D2.2 on Guidance on the implementation of the C-ITS PKI both by Wille, Skytterholm & Meland (2025)

- Guidance on procurement and costs
- Roadmap

The TIARA project D6 report on National Road Authority guidance on legal and ethical use of data by Kotilainen & Kulmala (2025) aim was to **review the legal and ethical ramifications for NRAs when making use of ITS and C-ITS data**, and of how these change the role of the NRA. The study included responsibility of data accuracy, ethical use of data, inclusive communication and development of ITS and C-ITS services to road users. For the forementioned topics, the report provided the following seven recommendations for the NRAs:

8. The NRA should embed legal, contractual and ethical responsibilities for data accuracy in their operation
9. Identify the road users and involve them in communication and real-world development of the services
10. Understand and acquire expertise on C-ITS services, use cases and their limitations
11. Follow inclusive and transparent communication recommendations
12. Develop inclusive services by using the human-centred design principles
13. Apply basic principles and processes for ethical use of data
14. Carry out risk evaluation when communicating and developing ITS/C-ITS services

The TIARA project D8 report on Connected vehicle deanonymisation research review and impact study by Maerivoet & Ons (2025) provided knowledge on the privacy impacts of the processed road user location data, as well as recommendations to improve the location privacy-preservation.

The following recommendations were extracted from the DROIDS project work package WP4 –Trusted service provision comprises of "Trust in the system" and "Trust with the system" (Author, forthcoming)

"Trust in the system (information)" means the user's trust in the content of the information and/or in the information's ability to portray what it is supposed to.

"Trust with the system" means user's awareness or attitude towards the limitations of the information and their subsequent ability and willingness to adapt their use to accommodate for the limitations in order to deliver the expected benefit using the information.

The recommendations for NRAs as related to "Trust in the system"

- R 4.1.1. - Reputation-based trust
- R 4.1.2. - Identify potential conflicts of interest with OEMs
- R 4.1.4. - Independent Third-Party Certification
- R 4.1.6. - Ensure Adherence to standards
- R 4.1.7. - Use of Standardised Data Formats
- R 4.1.8. - System auditing
- R 4.1.9. - Data Authentication
- R 4.1.10. - Maintain Access Control and Audit Trails
- R 4.1.14. - Data Redundancy and Cross-Verification

The recommendations for NRAs as related to "Trust with the system"

- R 4.2.1. - Transparency of Data Collection and Processing
- R 4.2.2. - Develop clear requirements for data provisioning
- R 4.2.4. - Assess risks associated with data
- R 4.2.5. - Document Assumptions and Use Constraints
- R 4.2.7. - Validate Data Against Ground Truth
- R 4.2.8. - Encourage Use of Complementary Data Sources
- R 4.2.9. – Define Baseline for Data Quality
- R 4.2.11. - Periodic Data Quality Assessments
- R 4.2.14. – Cross-NRA cooperation
- R 4.2.15. - Training and Capacity Building for NRAs

8 Conclusions

This study presented a data strategy for digital road operator as a set of recommendations concerning the acquirement, processing, use, exchange and dissemination of data and the development, operation, maintenance and use of digital representations of the data related to the business processes of the road operator.

The data strategy results included the following five recommendation categories based on the previously mentioned three CEDR funded DROIDS, PRESORT and TIARA projects, which are further shortly summarises in the following paragraphs.

1. European data strategy and recommendations
2. Stakeholder roles and priority of use cases for road operators
3. Information life cycle, maintenance and regulations
4. Use of third-party data
5. Trust in data and service provision

A major conclusion is that the NRAs and other road operators benefit from digitalisation and the use of digital models, shadows and twins. The development, operation, maintenance and use of the digital representations are estimated to have high benefit to cost ratios in most use cases.

European data strategy recommendation topics based on European data strategy and related initiatives such as operationalization of dataspaces to ensure safe, reliable, and trustworthy data sharing for NRAs and other stakeholders, were as follow:

- Recommendations on data governance
- Recommendations for a sovereign data sharing approach
- Recommendations on trusted data sharing and exchange
- Recommendations from deployment methodology for dataspaces
- Implementing skills and training

A conclusion is that the in a multistakeholder European-wide digital ecosystem, liaison between stakeholders and data exchange according to the guidelines of the European mobility data space are essential for the NRAs and other road operators.

For an individual NRAs and road operators, the most beneficial use cases can differ from one another. The work carried out in DROIDS recommends considering in any case the following priority use cases identified at CEDR workshops:

- asset management
- electronic traffic regulations – speed limits
- road works
- incident detection
- access control/ UVAR incl. road tolls
- electronic traffic regulations – general regulations
- CCAM – distributed ODD awareness

Basically, the NRAs should start with the use cases that are the most beneficial and cost-effective for them. The priority use cases above should at least be considered as they are likely relevant for most NRAs.

DROIDS did not assess the costs of digital representations for the different use cases, although the costs are essential for the NRAs that usually have to deal with very restricted

budgets in relation to the needs of road operation. As some NRA interviews indicated, the best policy is to deploy the digital representations for individual roads and roads sections during instances when they are most cost-effective to deploy. For instance, a BIM for a road section tends to be developed and deployed when a new or upgraded road infrastructure is being planned and built. Usually, the most cost-effective road network locations are either the ones with most traffic or the ones with specific severe problems (e.g. bridges with physical deterioration risks or sections with frequent severe adverse weather conditions).

Information life cycle, maintenance and regulations included the following recommendations for the digital road operators on information maintenance and availability:

- Identify use cases and define the scope/purpose
- Invest in skills and education
- Adopt Open Data Standards
- Align with National Standards
- Prioritize Major Projects for Information Management Upgrades
- Move Towards Integrated Asset Management Systems
- Phased Implementation
- Change Management

BIM representation for full life cycle of road infrastructure included the following recommendations to maintain the BIM information throughout the lifecycle of road infrastructure:

- Implement ISO 19650
- BIM standards: Create or adapt existing BIM standards and guidelines
- Develop and implement OTL
- Establish collaboration and communication

In order to reap the benefits of standardisation emerging from OTL implementation and possible extension, road operators could consider the following key components:

- Data Dictionary Foundation: Build upon existing data dictionaries to establish standard definitions and meanings.
- Leverage Open Sources: Utilize open-source libraries like bSDD and Uniclass to establish a solid foundation and ensure continuous updates.
- Extend with New Attributes: Incorporate new attributes to accommodate dynamic information and future needs.
- Collaborative Development: Involve multiple stakeholders to ensure the OTL meets diverse needs and facilitates data exchange.
- Continuous Adaptation: Regularly review and update the OTL to adapt to evolving requirements and technologies.
- Standardization and Interoperability: Ensure the OTL is standardized and interoperable with other systems and platforms.
- ISO Standards Implementation: Adopt ISO 19650 to provide a framework for information management and exchange.
- Also, to improve the BIM information reuse, road operators should implement BIM standards within their organisation for information management and try implementing an OTL to provide structure to asset information.

Digital twin use cases – Digital transport regulations, opening new roads, automated lane level navigation, included the following recommendations:

15. Early engagement in standardization
16. Local perspective and requirement sharing
17. Phased digitalization of traffic rules
18. Development of a clear digitalization strategy
19. Uniform Traffic Regulation Order (TRO) processes
20. BIM standardisation
21. Ensuring high-quality infrastructure for Automated Driving Systems (ADS)

Third-party data usage recommendations for successful collaboration between NRAs and third-party data providers to fully utilise the potential of third-party data within NRAs were as follows:

- Establish a Shared Vision
- Invest in Staff Education
- Foster Collaboration and Innovation
- Prioritize Data Coverage:
- Adopt a Use-Case-Centred Approach
- Strategically Integrate AI and Sensors
- Address Data Quality Concerns
- Develop Standardized Frameworks and Agreements

Insights into the practical use of third-party data with in-depth overview of the outcomes and lessons learned by the selected NRAs in procuring, implementing, and utilising third-party data provided five main lessons learned included the following which are here summarised by main topic:

11. Pre-procurement phase
    a. Pre-studies
    b. Market consultation
12. Procurement phase
    a. Balancing quality and cost
    b. Setting minimum requirements and award criteria
13. Implementation phase
    a. Data integration: System operation and data extraction of procured data require ensuring compatibility with existing platforms and proper adaptation for smooth integration
    b. Understand the data that is procured
    c. Addressing data attributes
    d. Data access control for procured data and its derivatives must balance open access for public use and controlled distribution for private entities.
14. Maintenance and monitoring phase
    a. Ongoing data quality assurance and data understanding: Regular monitoring and validation of data quality are essential for maintaining effectiveness of third-party data.
    b. System flexibility: Adaptability in systems and data management processes is crucial for handling updates and changes in third-party data providers.
15. Overarching phase: Service Level Agreement (SLA), scalability, barriers/challenges, and risk
    a. SLA monitoring: third-party data providers meet the expected standards for data delivery and quality.
    b. Scalability challenges when aiming full-scale implementation with increased data coverage with accuracy and performance maintained.

c. Risk mitigation

Improving the use of third-party data by NRAs provided step-by-step guidance for all phases of the process from pre-procurement studies to the actual procurement phase and follow-up activities during the contract period. Furthermore, Use Case Identification and Validation Framework provided NRAs guidance on how to assess the possibility of using 3rd party data as an input in their core business processes, before the actual decision has been made for proceeding to data procurement. Also, NRAs guidelines and decision-support how to successfully perform a 3rd party data acquisition process in each phase was presented with practical European case examples.

Trust in data and service provision recommendations included following, which start with an *overview of the ongoing roll-out of the C-ITS PKI* within the European NRAs, including overview of PKI roll-out, multiple PKIs and lessons from other sectors. Furthermore, *guidance on the implementation of the C-ITS PKI* include guidance on procurement and costs as well as a roadmap.

Review of legal and ethical ramifications for NRAs when making use of ITS and C-ITS data, and of how these change the role of the NRA, included responsibility of data accuracy, ethical use of data, inclusive communication and development of ITS and C-ITS services to road users. For the forementioned topics, the report provided the following seven recommendations for the NRAs:

15. The NRA should embed legal, contractual and ethical responsibilities for data accuracy in their operation
16. Identify the road users and involve them in communication and real-world development of the services
17. Understand and acquire expertise on C-ITS services, use cases and their limitations
18. Follow inclusive and transparent communication recommendations
19. Develop inclusive services by using the human-centred design principles
20. Apply basic principles and processes for ethical use of data
21. Carry out risk evaluation when communicating and developing ITS/C-ITS services

Connected vehicle deanonymisation research review and impact study provided knowledge on the privacy impacts of the processed road user location data, as well as recommendations to improve the location privacy-preservation.

Trusted service provision recommendations for road operators as related to *"Trust in the system"* included the following recommendations:

- R 4.1.1. - Reputation-based trust
- R 4.1.2. - Identify potential conflicts of interest with OEMs
- R 4.1.4. - Independent Third-Party Certification
- R 4.1.6. - Ensure Adherence to standards
- R 4.1.7. - Use of Standardised Data Formats
- R 4.1.8. - System auditing
- R 4.1.9. - Data Authentication
- R 4.1.10. - Maintain Access Control and Audit Trails
- R 4.1.14. - Data Redundancy and Cross-Verification

The recommendations for road operators as related to "*Trust with the system"* were as follows:

- R 4.2.1. - Transparency of Data Collection and Processing

- R 4.2.2. - Develop clear requirements for data provisioning
- R 4.2.4. - Assess risks associated with data
- R 4.2.5. - Document Assumptions and Use Constraints
- R 4.2.7. - Validate Data Against Ground Truth
- R 4.2.8. - Encourage Use of Complementary Data Sources
- R 4.2.9. – Define Baseline for Data Quality
- R 4.2.11. - Periodic Data Quality Assessments
- R 4.2.14. – Cross-NRA cooperation
- R 4.2.15. - Training and Capacity Building for NRAs

Validation of the proposed above recommendations in this study and a roadmap for them was done in the CEDR DROIDS project deliverable D5.2 Data strategy roadmap (Kvalvik et al. 2025). The mentioned validation and roadmap were completed by DROIDS work package leaders, road operators, and the DROIDS Advisory Group, which included public, private, and industry members.

References

Aesin (2025). Welcome to TIARA (Trusted Integrity and Authenticity for Road Applications). https://aesin.org.uk/tiara/

Bastiaansen, H., Bratzel, S., Drees, H., Groot, D., Mollema, R., Pretzsch, S., Rittershaus, L., Thoemmes, J. & Vikram, A. (2021). Data Move People – Mobility Data Spaces International Data Spaces Association. Anthology | Version 1.0 | October 2021. https://internationaldataspaces.org/wp-content/uploads/IDSA-Anthology-Data-Move-People-Mobility-Data-Spaces-Version-1.0.pdf

Dalmolen, S., Bastiaansen, H. J. M., Somers, E. J. J., Djafari, S., Kollenstart, M., & Punter, M. (2019). Maintaining control over sensitive data in the Physical Internet: Towards an open, service oriented, network-model for infrastructural data sovereignty.

European Commission (2022). Commission Delegated Regulation (EU) 2022/670 of 2 February 2022 supplementing Directive 2010/40/EU of the European Parliament and of the Council with regard to the provision of EU-wide real-time traffic information services. Available online: https://eur-lex.europa.eu/eli/reg_del/2022/670/oj/eng

Huisken, G. & Zhang, X. (2025). Report on Deep Dive. CEDR funded ImPRoving thE uSe Of third-paRTy data by NRAs (PRESORT) project. Deliverable 4.1, 11 March 2025, version 1.1.

IDSA (2023). International Data Spaces Association-4.3.2 Data Governance Model. https://docs.internationaldataspaces.org/ids-knowledgebase/ids-ram-4/perspectives-of-the-reference-architecture-model/4_perspectives/4_3_governance_perspective/4_3_2_data_governance_mode

Kotilainen, I. & Kulmala, R. (2025). National Road Authority guidance on legal and ethical use of data. CEDR funded Trusted Integrity and Authenticity for Road Applications (TIARA) project. Deliverable 6, 12 June 2025, version 1.01.

Kulmala, R., Alkim, T., Kotilainen, I. & Soni, S. (2025). NRA roles in digital twins. CEDR funded Digital Road Operator Information and Data Strategy (DROIDS) project. Deliverable 2.2, 1st of April 2025, version: 1.02.

Kvalvik, P., Bokolo Jr, A., Farbrot, J. E., Kulmala, R. & Kotilainen, I. (2025). A roadmap for implementing the data strategy. CEDR funded Digital Road Operator Information and Data Strategy (DROIDS) project. Deliverables 5.2, 4th of September 2025, version: 1.0.

Laine, T., Isoranta, V., Kulmala, R. & Kotilainen, I. (2025). Improving the use of third-party data by NRAs. Report on WP5 Conclude. Guidelines final report. CEDR PRESORT project Deliverable 5. https://www.cedr.eu/docs/view/682daa0e2fa30-en

Maerivoet, S. & Ons, B. (2025). Draft report on connected vehicle deanonymisation research review and impact study. CEDR funded Trusted Integrity and Authenticity for Road Applications (TIARA) project. Deliverable 8, draft version unknown.

Mügge, J., Grosse Erdmann, J., Riedelsheimer, T., Manoury, M. M., Smolka, S. O., Wichmann, S., & Lindow, K. (2023). Empowering End-of-Life Vehicle Decision Making with Cross-Company Data Exchange and Data Sovereignty via Catena-X. Sustainability, 15(9), 7187.

Pretzsch, S., Drees, H., & Rittershaus, L. (2022). Mobility Data Space: A Secure Data Space for the Sovereign and Cross-Platform Utilization of Mobility Data. In Designing Data Spaces: The Ecosystem Approach to Competitive Advantage (pp. 343-361). Cham: Springer International Publishing.

Soni, S. & Oskina (2024). Report on Gap Analysis. CEDR PRESORT project Deliverable 3.3. https://www.cedr.eu/docs/view/677e85009b7f1-en

Soni, S., Chaudhary, R., Alkim, T., Kotilainen, I. & Kulmala, R. State of the Art of Digital Twins for Road Infrastructure. CEDR funded Digital Road Operator Information and Data Strategy (DROIDS) project. Deliverables 2.1 and 3.1, 12th of April 2024, version: 1.1.

Soni, S. (2024). Information maintenance and availability. CEDR funded Digital Road Operator Information and Data Strategy (DROIDS) project. Deliverable 3.2, 14th of June 2024, version: 1.0.

Soni, S. (2024). BIM representation for full life cycle of road infrastructure. CEDR funded Digital Road Operator Information and Data Strategy (DROIDS) project. Deliverable 3.3, 15h of November 2024, version: 1.0.

Soni, S., Rashed, S., Kotilainen, I, (2025). Digital twin use cases – digital transport regulations, opening new roads, automated lane level navigation. Deliverable D3.4 Version 1.0

Stephenson, S. & Spillard (2024). PRESORT Capture Baseline report. PRESORT project Deliverable 2. Version 1.0. https://www.cedr.eu/docs/view/677e84a783626-en

Stockburger, L., Kokosioulis, G., Mukkamala, A., Mukkamala, R. R., & Avital, M. (2021). Blockchain-enabled decentralized identity management: The case of self-sovereign identity in public transportation. Blockchain: Research and Applications, 2(2), 100014.

Wille, E., Skytterholm, A. & Meland P. H. (2024). Operation of Public Key Infrastructures: State-of-the-art and best practices. CEDR funded Trusted Integrity and Authenticity for Road Applications (TIARA) project. Deliverable 2.1, 30 August 2024, version 1.0.

Wille, E., Skytterholm, A. & Meland P. H. (2025). Guidance on the implementation of the C-ITS PKI. CEDR funded Trusted Integrity and Authenticity for Road Applications (TIARA) project. Deliverable 2.2, 2025, draft version unknown.