D2.12 – Standardisation (STAND) – Final

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Abstract

This intermediate iteration of STAND provides all standardisation contextual information existing since the beginning of SIGN-AIR's development activities, as well as insight and knowledge produced during the development activities and the refinement of the use cases the project aims to serve and demonstrate, which entail specific, prominent standardisation needs. Its goal is to support industrialisation activities and assist the entry into operations of the corresponding SESAR solution. Building upon the initial report (D2.2) and intermediate (D2.5), this deliverable offers insights into the project's progress, challenges, and opportunities in the context of various transportation modes, including rail, public transport, MaaS, and aviation. It highlights the most widely available and used data standards, as well as the specific standardisation needs identified for the project's use cases, goals and subgoals.

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SIGN-AIR

[IMPLEMENTED SYNERGIES, DATA SHARING CONTRACTS AND GOALS BETWEEN TRANSPORT MODES AND AIR TRANSPORTATION]

SIGN-AIR

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1. Executive summary

This document is the Final Standard Deliverable of the SIGN-AIR SESAR solution dealing with the development and piloting of a new platform, the SIGN-AIR platform, for an orchestrated sharing of data in multimodal traveling. D2.12 "Standardisation (STAND) – Final" is the third and closing iteration of a series of reports aiming to capture the standardisation needs of the SIGN-AIR SESAR solution (succeeding Deliverable D2.2 "Initial" and D2.5 "Intermediate"). This final standardisation needs document provides validated information to support industrialisation activities and assist the entry into operations of the corresponding SESAR solution, namely the SIGN-AIR platform. The STAND documents in tandem cover all standardisation contextual information that is considered relevant for SIGN-AIR, reflecting the maturity of the solution at the end of the project lifecycle.

In the context of the SIGN-AIR project, the SIGN-AIR platform is a digital platform that will provide the means for Transport Service Providers (TSPs) as well as Public Transport Authorities (PTAs) to register, reach Data Sharing Agreements and Smart Contracts with other TSPs and/or PTAs and manage their contractual relationships. The SIGN-AIR platform will only manage the contractual and data sharing aspects, without hosting or processing any operational transport data itself. TSPs will continue to manage their data and that of their customers. As an added value, the SIGN-AIR platform will provide a number of services to the stakeholders of multimodal travel through the analysis and exploitation of the contracts: (i) templates for contracts to simplify the legal management, (ii) electronic management and information provision about each specific contract, (iii) routing information for Travel Companions (TCs) with enriched information about the specific contracts for travellers/customers, and (iv) facilitation of single ticketing through the comprehensive understanding of the contracts and the data managed, among others. Interfacing with Travel Companion applications will ensure that travellers directly benefit from improved operator agreements – enabling seamless travel planning, ticket purchasing and reliable navigation, even in the face of disruptions.

To enable the SIGN-AIR platform's Monitoring Dashboard and Travel Companions (TCs) to effectively utilise standardised data, it is essential to identify, thoroughly understand and evaluate the relevant standards in multimodal passenger scenarios. This report provides a comprehensive review of key standards relevant for the SIGN-AIR solution, the project and its goals, with a focus on selected aviation and surface public transport standards, harmonising standards from these different contexts as well as aligning non-standardised data with existing standards. Additionally, it explores in more depth SIGN-AIR's goals and subgoals the TSPs aim to achieve, and their specific standardisation needs, aiming to outline the most applicable standards.

The body of this report identifies standards that are, at this time, considered crucial for the SIGN-AIR goals. In addition, a more complete overview of standards in the mobility context is given in an annex in order to demonstrate that the full context of standards in mobility was kept in mind during the review of standards and that standards relevant for SIGN-AIR use cases were selected after careful consideration of a number of different standards options. The report's goal is to support SIGN-AIR's demonstrations and to guide future initiatives that advance mobility standardisation.

2. Introduction

2.1 Purpose of the document

To successfully capture the current landscape of data standards relevant to various multimodal passenger scenarios addressed by SIGN-AIR, it is essential to first identify and analyse the most widely used data standards in each mode of transportation – including worldwide standards (IS) as well as European standards (EN), technical specifications (TS) or TR (technical reports). The successful completion of this task will provide a clear understanding on how to proceed regarding the compliance with relevant standards, and for determining whether amendments to current standards or the development of new ones are necessary. Accordingly, this STAND aims to identify and list the relevant standards that the SIGN-AIR solution must consider, particularly to enable the use of standardised data within the SIGN-AIR platform, and specifically the Monitoring Dashboard, as well as for communication with Travel Companions (TCs), with a specific focus on multimodality, as per the project's scope. The primary objective of STAND is to capture and document the standardizations needs of the SIGN-AIR platform, focusing on data standards essential for multimodal transport integration. It aims to identify standards relevant to the project goals and use cases of the respective solution, as a basis for discussions on any necessary amendments or extensions of already existing standards, and it highlights how SIGN-AIR leverages existing tools to facilitate harmonisation and standardisation aspects, as well as any gaps remaining

The main set of data standards applied in the aviation industry regarding the exchange of airline time schedules is the IATA Standard Schedules Information Manual (SSIM). It is the official set of standards, guiding the industry with recommended practices, messaging formats and data processing procedures that are to be used by all IATA member airlines and their business partners for the exchange of airline schedules, communication of airport coordination information and minimum connect time data.

The public transport sector as a whole is characterised by a highly fragmented standardisation landscape, differing significantly from the far more unified aviation standards ecosystem. Across Europe, a huge number of cities, regions, and organisations have developed their stand-alone localised solutions for ticketing, scheduling, and operational management, usually without interoperability in mind. As a consequence, multiple overlapping standards have emerged throughout the years, attempting to establish a common framework for data exchange.

The European Commission (DG MOVE) has recognised this challenge[1] and mandates the use of specific standards to improve interoperability. The Delegated Regulation on MultiModal Travel Information Services (MMTIS, revised in 2024) requires Member States to set up National Access Points (NAPs), as single points of access for data users to static, historic, observed and dynamic travel and traffic data of different transport modes, including data updates, provided by the data holders within the territory of a given Member State, using specific standards, both for static and dynamic data, per transport mode. Access to this data is governed by robust information security controls and tailored to the specific needs and roles of different user types, ensuring compliance with 'need-to-know' principles while

[1] The Sustainable and Smart Mobility Strategy (SSMS, 2020) has a strong multimodal focus and states that "*efforts to ensure multimodality and interoperability between different modes should be stepped up*" (recital 84).

maintaining data integrity and confidentiality.[2] Datasets are accompanied by a standardised set of metadata in order to facilitate their exchange and reuse. The implementation of the MMTIS provisions has proven challenging in practice, leading to several coordination and standardisation initiatives at EU level such as DATA4PT, CoRoM and NAPCORE, which aim to address remaining interoperability gaps and coordinate and harmonise more than 30 National Access Points, which currently differ in structure, data formats, and access interfaces.

Followingly, a comprehensive understanding of relevant transport data standards and how they are managed, as outlined in this STAND document, will provide a valuable source of input to the National Access Points (NAPs[3]) whose role is to provide a single interface through which transport-related data from various data providers are made accessible to authorised users. SIGN-AIR's work not only validates the feasibility of harmonising data exchanges across public transport and aviation but also offers actionable insights that NAPs can adopt to enhance data governance, discovery, and sharing at a national level. In doing so, SIGN-AIR contributes to the broader EU data strategy, supporting efforts to establish a unified and efficient mobility data ecosystem across Europe.

SIGN-AIR use cases contribute to alignment of data exchanges between different transport environments. By mapping key data attributes and establishing clear interoperability frameworks between disparate standards such as NeTEx, GTFS, IATA SSIM, and SIRI, SIGN-AIR will demonstrate in theory and practice that bridging gaps between various transport environments can be feasible.

Standardisation of data and their metadata is an endeavour closely related with the task T2.2 "Data Standardisation and Harmonisation Aspects", and specifically the tool developed in its context, the Field Matching Tool. An overview of the tool is provided in deliverable D2.21 "Standardisation and harmonisation of SIGN-AIR technical solution" (AETHON, 2024). The Field Matching Tool will detect the kind of data fields and associate non-standardised to standardised data, meaning it will provide in the form of suggestions the relevant standards that apply to the type of Transport Service Provider (TSP) that makes use of the platform and this specific feature and the data fields the TSP provided to the said platform, thus assisting in a clever way the TSP to comprehend which standard applies and thus the TSP needs to comply with. This tool will be implemented in the SIGN-AIR platform when the user (TSP) registers information to create their data attributes Catalogue.

SIGN-AIR will develop a standardisation mechanism for IATA SSIM that would then be connected to the SIGN-AIR platform for data retrieval and sending. The IATA SSIM tool for standardisation will involve the creation of the UI (map where the user can insert the information) and the database components (conversion from SCR and other formats to a Relational Database Management System). Detailed information about the IATA SSIM and specifically the relevant standardisation mechanism that is developed in the context of the SIGN-AIR project is provided in detail in D2.21 "Standardisation and harmonisation of SIGN-AIR technical solution" (AETHON, 2024).

[2] Description of NAP, official NAPCORE website: https://napcore.eu/description-naps/

[3] https://transport.ec.europa.eu/transport-themes/smart-mobility/road/its-directive-and-action-plan/national-access-points_en

Furthermore, another task to research is the aspect of data harmonisation. It is an aspect that has already, and quite successfully, been addressed by the Transmodel consortium.[4] The said consortium has executed a study on harmonising the industry standards and the EU-approved standards (Transmodel, NeTEx, SIRI, OJP and GTFS) that apply in the public transport sector. The SIGN-AIR project aims to build upon that knowledge by generating a study in a similar direction regarding NeTEx/SIRI and IATA SSIM harmonisation which will be possible after a successful mapping of all relevant data standards. This study is being introduced inD2.21"Standardisation and harmonisation of SIGN-AIR technical solution" (AETHON, 2024).

Finally, it is important to mention that the initial STAND (D2.2) focused on data standardisation and left a great part of the identification of standardisation need(s) required for the deployment of the SIGN-AIR platform for its next versions. The main reason was that the design and the architecture of the platform needed to be more advanced to allow us to be able to perform such a specific standardisation needs identification. The secondary reason is that the relation of the SIGN-AIR platform with the ATM system is not clear yet as the SIGN-AIR platform is targeting multimodality and not only air transport. In this report, as the developments of the technical solution have advanced to a certain extent, we attempt to provide a first overview of SIGN-AIR's needs and recommendations in terms of standardisation and harmonisation, considering the advancements so far, as well as additional details of the most prominent standards that apply in the goals and demonstrations scenarios the SIGN-AIR project aims to serve, in accordance with the architecture of the platform.

In this deliverable we also aim to describe the SIGN-AIR goals (see Table 1) for TSPs in an even more focused and detailed manner, compared to the initial and intermediate STAND reports (D2.2 and D2.5), highlighting the key selected standards to be utilised to facilitate the fulfilment of those goals in an efficient way. We inform the reader of the challenges the consortium has encountered so far, especially in the standardisation aspect, how some of those challenges are tackled, as well as opportunities and foreseeable specific needs that are to be grasped at a later stage of the project, and even beyond that.

2.2 Intended readership

The primary readership for this deliverable encompasses the European Air Traffic Management (ATM) community, in particular the European Air Traffic Management Master Plan (ATM MP) Stakeholder Consultation Group (EASCG). Additionally, this report holds relevance to other stakeholders, including the European Union's Single European Sky Coordination Group (EUSCG) and the European Standardisation Coordination Group (ESCG). The collaborative input and consideration of these key stakeholders are pivotal in advancing SESAR's contributions to standardisation activities, particularly in collaboration with organisations such as EUROCAE. Furthermore, key actors in the field of transportation, UITP, UIC and aviation bodies, as well as Transport Service Providers and the corresponding authorities (PTAs) are also crucial target audiences, especially if their strategic focus and current/future endeavours entail compliance with relevant standards and formation of partnerships with other relevant transport service providing parties and organisations.

[4] Outline comparison and Mapping between NeTEx & GTFS, April 2024: https://data4pt-project.eu/wp-content/uploads/2024/06/GTFS-NeTEx-Mapping-nk-v5.pdf

2.3 Background

Unlike aviation, where global standards such as IATA SSIM and AIDX have long been established and widely adopted, public transport remains highly fragmented, with a mix of regional, national, and modal-specific standards. This fragmentation stems from the historical development of custom solutions optimised for local transport networks, in by far most cases without a focus on cross-border or multimodal interoperability.

To address this, the European Commission (DG MOVE) has introduced policies requiring the adoption of standardised data formats, but full harmonisation of data exchange remains a challenge. While some countries are moving toward national approaches, the reality is that public transport still operates on a diverse set of standards, such as NeTEx, SIRI, GTFS, and OSDM, which are essential for different transport modes.

SIGN-AIR plays a critical role in bridging these gaps by enabling the smooth application of existing standards and data exchange between transport stakeholders, without requiring modifications to their existing systems. The platform acts as a facilitator, ensuring interoperability between different standards and allowing TSPs to align their operations without the complexity of developing new data models. Moreover, privacy compliance – a key challenge in public transport ticketing projects – is a core focus, ensuring that data exchanges between parties remain secure and regulatory-compliant.

. The list of SIGN-AIR use cases is included under section 1.2.2.4 'Description of Use-Cases' in the Description of the Action (Part B) of the Grant Agreement. As this is the final iteration of the STAND document (STAND Final), it reflects the mature state of the project where these use cases have been fully defined. To provide necessary context for the standardisation needs and goal analysis presented in subsequent sections, the specific SIGN-AIR use cases are listed below (The numbering of each use case is as per the Grant Agreement):

- **Use Case 1:** Single Ticket Services for the airport community employees
- **Use Case 2:** Single ticket inclusion of regional transport modes and operators
- **Use Case 3:** Disruption Management
- **Use Case 7:** New flight alternatives to the Greek islands
- **Use Case 9:** Collaboration between airports and vertiports (eVTOL)

The SIGN-AIR goals and subgoals are presented in Table 1 below:

Table 1: Goals and subgoals for data sharing agreements and smart contracts between TSPs

Goals	Sub Goals	Definition
G1. Mobility Packages	G1.1 Season ticket	A seasonal ticket is a comprehensive ticket contract designed to provide access to multiple transport services over a defined seasonal duration. This contract

		targets specific groups of passengers/travellers and is characterised by a starting and ending date.
	G1.2 Combined ticket	A combined ticket is a comprehensive ticket contract for a multimodal journey that consolidates separate transport contracts into a single, cohesive package. This integration is facilitated by a carrier, service provider, or intermediary on their own initiative, allowing passengers to purchase the entire journey with a single payment.
	G1.3 Single ticket	A single ticket is a comprehensive ticket contract representing a 'single multimodal contract' for a journey that includes successive transport services operated by one or more carriers. This contract is designed to provide passengers with a unified travel experience, ensuring protection in case of disruptions.
G2. Synchronisation of timetables	G2.1 Reach more flights	The arrivals/departures of a TSP are organised in a way to support the wave system structure of the flights at the airport to be able to cover the largest number of flight departures/arrivals. This type of synchronisation, high connectivity, increases the number of available options for passengers which transfer from rail to flights.
	G2.2 Reach more passengers	The arrivals/departures of a TSP are organised in a way to be aligned with long haul flights operated by large aircraft carrying larger number of passengers, the possibility to drop off and receive the luggage at the origin train station should be examined. Long-haul flights are most offered from major airports. Therefore, synchronising these flights with the rail system increases the catchment area of the airport. Passengers from smaller cities will have options to seamlessly travel on long-haul routes.
	G2.3 Substitution of short haul flights	The arrivals/departures of a TSP are organised in a way to be aligned with the international flights at the airport to be able to substitute domestic short-haul flights by long distance rail.
	G2.4 Dynamic Timetable Synchronisation for On-Demand Transport	This goal focuses on adaptive scheduling, where on-demand (eVTOL) and air transport dynamically adjust to flight departures and arrivals, minimising passenger transfer delays and optimising multimodal service.

G3. Disruption management	G3.1 Event detection and classification	The establishment of communication protocols and real-time data-sharing frameworks that enable the detection, classification, and impact calculation of events, such as minor delays or major disruptions, across multiple transport modes.
	G3.2 Event response coordination	Focuses on assessing the impact of disruptions and executing a series of coordinated actions between ecosystem actors to respond effectively. These actions include timely notifications to passengers, processing information about affected travellers, and optimising operational adjustments.
G4. Advanced Air Mobility Integration	G4.1 eVTOL Operations on Demand	This goal addresses the integration of innovative aerial services (Urban Air Mobility) into the multimodal chain. It focuses on the data exchanges required to manage on-demand flight operations for eVTOLs (Electric Vertical Take-Off and Landing aircraft), ensuring they connect seamlessly with commercial aviation schedules and ground transport.

2.4 Structure of the document

The structure of this STAND document is the result of the approach that was followed as described in the Background paragraph.

Chapter 3 in this report focuses on standards that are selected as key standards for the SIGN-AIR goals.

This chapter can be consulted in conjunction with the Annex, which contains an overview of all identified standards in more detail. Standards that are considered relevant in the wider mobility context but are, for now and based on current insights, not selected for direct use to fulfil the specific goals, were also included in the annex. Furthermore, a specific section encapsulates the sense of data harmonisation in terms of defining it, providing its goals, the benefits, several examples, and the overall progress in the area so far. In the same section several subsections have been added in an attempt to showcase the practical application of the standards detailed in the Annex section to the use cases of the SIGN-AIR platform and, additionally, note suggested security practises regarding compliance to specifications set by GDPR and NIS2 and, lastly, address the potential approach of achieving technical interoperability via the TOMP API.

At this time, the need for new or amended standards has not been identified. Additionally, chapter 4 reasons the complexity to create a new data standard or amend an existing one.

Important notice regarding the Annex: The extensive Annex in this document reflects the need to comprehensively map and document the diverse set of standards required for public transport interoperability. While aviation benefits from globally established data exchange protocols, public transport relies on a patchwork of standards that vary by country, region, city, and even operator. Public transport standardisation is highly complex due to its decentralised development, where local and regional agencies have historically created custom, locally optimised, non-interoperable solutions. Unlike aviation, public transport spans multiple modes (rail, metro, bus, DRT, ferry), each with distinct technical and operational requirements. While the EU mandates key standards like NeTEx and SIRI to enhance interoperability, local flexibility leads to multiple implementations. Additionally, multimodal journeys involve multiple standards to handle different operators, ticketing policies, and real-time scheduling updates, making seamless data exchange a significant challenge.

Given these complexities, the Annex at the end of this document provides a comprehensive overview of all relevant standards, not only those directly implemented in SIGN-AIR but also those that could play a role in future harmonisation efforts. The document serves as a reference for transport operators and policymakers, helping them navigate the intricate landscape of public transport data standards.

2.5 List of Acronyms

Table 2: Acronyms

Acronym	Definition
AIDM	*Airline Industry Data Model*
AIDX	*Aviation Information Data Exchange*
AIRIMP	*Airline Industry Reservations Interline Message Procedures*
AMDB	*Aerodrome Mapping Database*
AMXM	*Aerodrome Mapping Exchange Model*
API	*Advance Passenger Information*
API	*Application Programming Interface*
ATM	*Air Traffic Management*
AVL	*Automatic Vehicle Location*
BIX	*Baggage Information Exchange*
CEN	*European Committee for Standardisation*
CONOPS	*Concept of Operations*
CR	*Change Request*
CRS	*Central Reservation System*
DATEX	*Data Exchange for Traffic Telematics*
DRT	*Demand Responsive Transit*
E-ATMS	*European Air Traffic Management System*
EDI	*Electronic Data Interchange*
EU	*European Union*
eVTOL	*Electric Vertical Take-Off and Landing aircraft*
FAA	*Federal Aviation Administration*
FIXM	*Flight Information Exchange Model*
FTI&U	*Fast Track Innovation and Uptake*

GA	*Grant Agreement*
GDPR	*General Data Protection Regulation*
GDS	*Global Distribution System*
GIS	*Geographic Information System*
GTFS	*General Transit Feed Specification*
IATA	*International Air Transport Association*
ICAO	*International Civil Aviation Organisation*
IFMS	*Interoperable Fare Management System*
ISO	*International Organisation for Standardisation*
ITS	*Intelligent Transport System*
KPA	*Key Performance Area*
MMTIS	*Multimodal Travel Information Services (Delegated Regulation (EU) 2024/490 EU)*
NAP	*National Access Point*
NDC	*New Distribution Capacity*
NeTEx	*Network Timetable Exchange*
OGC	*Open Geospatial Consortium*
OI	*Operational Improvement*
OJP	*Open Journey Planner*
OpRa	*Operating Raw Data and statistics exchange*
OSDM	*Open Sales and Distribution Model*
PADIS	*Passenger and Airport Data Interchange Standards*
PIRM	*Programme Information Reference Model*
PNR	*Passenger Name Record*
PRM	*Person with Reduced Mobility*
PSN	*Person with Special Needs*
PT	*Public Transport*
PTA	*Public Transport Authority*
REG	*Regulatory deliverable*
SARPs	*Standards and Recommended Practices*
SCR	*Slot Clearance Request*
SIRI	*Service Interface for Real-time Information*
SJU	*SESAR Joint Undertaking (Agency of the European Commission)*
SPR-INTEROP/OSED	*Safety Performance Requirement-Interoperability Requirements/Operational Service Environment Description*

SSIM	*Standard Schedules Information Manual*
SSR	*Special Service Request*
SWIM	*System-Wide Information Management*
TC	*Travel Companion*
TS/IRS	*Technical Specification/Interface Requirement Specification*
TOMP	Transport Operator to Mobility Provider
TPER	*Trasporto Passageri Emilia Romagna*
TSP	*Transport Service Provider*
UC	*Use Case*
UIC	*International union of railways*
UITP	*Union Internationale des Transports Publics (international association of public transport)*
VIP	*Visually Impaired Person*
VRU	*Vulnerable Road User*
XML	*Extensible Markup Language*

3. Overview of relevant standards

Harmonising data standards across public transport modes begins with a thorough assessment of existing industry standards and best practices. This involves reviewing key documentation, guidelines, and frameworks established by regulatory bodies, industry organisations, and standardisation bodies. The SIGN-AIR project focuses on the following transport modes integral to its goals and the corresponding use cases: Public Transport, Rail Transport, Air Transport, Road Transport, and Other Data Standards relevant to these categories. Note that rail transport is considered, according to Transmodel, a subset of public transport, nevertheless we classify standards by their functional role in multimodal integration rather than strictly by transport mode, thus we highlight rail, air, road, and other, cross-domain standards separately to emphasise their unique requirements.

To ensure clarity and relevance, this report highlights the most prominent and applicable standards necessary to investigate and demonstrate the project's use cases through the fulfilment of the defined goals and subgoals as outlined briefly in Table 1: Goals and subgoals for data sharing agreements and smart contracts between TSPs (and in more detail in section 4). These selected standards align with the functional and non-functional requirements identified in the project lifecycle. Readers will find that while these are the most relevant standards for the current scope, additional standards are presented in the Annex, providing further context and insight. Furthermore, a specific section (3.2) encapsulates the sense of data harmonisation in terms of defining it, providing its goals, the benefits, several examples, and the overall progress in the area so far.

3.1 Overview of standards applicable to SIGN-AIR

In the following table, the most relevant standards are depicted, per goal of the project. The standards listed here with a "✓"are the ones that are applicable, meaning that the format of said standards is the correct one for the purpose of data sharing based on the goals the TSPs aim to achieve and the necessary data fields to share, and thus what the solution aims to facilitate. The standards are chosen based on the data attributes (public transport, long distance rail, aviation) foreseen as necessary to be exchanged between the TSPs, as defined in the Data Sharing Agreements the TSPs will establish via the SIGN-AIR platform. Additionally, the following standards listed in the table below are the ones not only relevant to the SIGN-AIR goals but also most prominent in the field of transport. The standards with a "(✓)" have the potential of being used for the respective goals, based on the content of the said standards and the relevance of parts of them to the specific goals. All standards investigated are duly detailed in the Annex of this document. In the Annex the reader can dive deeper into the content of the standards and thus comprehend what elements hold significance to the goals. The application of these standards is validated through specific Use Cases (UC) that directly operationalize the project goals. Goal 1 (Mobility Packages) is addressed by UC1, UC2, which focus on enabling single ticketing for airport employees and integrating regional transport modes by mapping IATA NDC offer data to NeTEx fare products. Goal 2 (Timetable Synchronisation) is driven by UC7 (Seaplanes) and UC9 (eVTOLs), where the alignment of IATA SSIM schedules with GTFS/NeTEx and FIXM flow data enables adaptive scheduling between commercial aviation and novel air modes. Finally, Goal 3 (Disruption Management) is demonstrated in UC3, utilizing a digital twin to trigger automated responses by harmonizing AIDX aviation disruption data with SIRI real-time surface transport feeds.

Table 3: Applicable standards per goal

Standards / Goals	Description	G1.1	G1.2	G1.3	G2.1	G2.2	G2.3	G3.1	G3.2
ISO 24014-1 IFMS	Focuses on interoperability in fare management systems, ensuring consistency in ticketing, fare calculation, and validation across multiple operators.	✓	✓	✓	✓	✓	✓	✓	✓
Transmodel	A conceptual data model for public transport, defining how data related to timetables, routes, stops, and operations is structured and exchanged.	✓	✓	✓	✓	✓	✓	✓	(✓)
NeTEx	A European standard for exchanging scheduled public transport data, including routes, schedules, and fares.	✓	✓	✓	✓	✓	✓	✓	
SIRI	Standard for exchanging real-time public transport data, such as vehicle locations, delays, and disruptions.		(✓)	✓	(✓)	(✓)	✓	✓	(✓)
OJP	A protocol for distributed journey planning, enabling integration of multimodal transport information for trip planning across regions.	(✓)	(✓)	(✓)	(✓)	(✓)	(✓)	(✓)	
GTFS	A widely used format for public transport schedules and associated geographic information.	✓	✓	✓	✓	✓	✓	✓	
OSDM	A standardised format for ticket sales and distribution, covering fare products, reservations, and ticketing.	(✓)	(✓)	✓	(✓)	(✓)			(✓)
SSIM	Used in aviation for publishing standardised flight schedules, supporting flight connections and capacity planning.	✓	✓	✓	✓	✓	✓	✓	✓
PADIS	Facilitates data exchange for passenger processing and airport management, focusing on passenger facilitation.		(✓)	(✓)				(✓)	(✓)
NDC	A data transmission standard for airlines, focusing on enhancing the retailing of airline products through indirect channels.		(✓)	(✓)					(✓)

AIDM	Provides a unified data model for aviation operations, ensuring consistency across systems.		(✓)	(✓)				(✓)	(✓)
AIDX	Facilitates standardised data exchange between airports, airlines, and other aviation stakeholders.							✓	✓
FIXM	Focuses on exchanging flight-related data, supporting air traffic management and flight operations.							✓	✓
Security and privacy standards	Always in focus (security by design, privacy by design).	✓	✓	✓		✓	✓	✓	✓

To understand the background of this document well and the compilation of the table above, the approach that was followed is described here:

First, a literature review was carried out. During this review, the most prominent and broadly used standards in mobility, either focusing on the region of Europe or worldwide, were gathered for each of the transport sectors involved.

In a second step, all investigated standards were grouped in sub-sections, depending on the type of transportation mode: public transport, air transport, road transport and MaaS. As information security and privacy protection are crucial in the transport environment as a critical infrastructure, relevant standards in these fields were also included in the standards review.

In a third phase, after thus having laid down a full overview of relevant standards in the mobility environment, a restricted number of standards of crucial importance for SIGN-AIR goals were selected and put in the core text of this report.

Finally, after the selection and elaboration of use case focused standards, important matters like data harmonisation and further capture of standardisation were elaborated.

The standards selected for the STAND are directly aligned with the requirements of the aforementioned goals, and thus the use cases, ensuring relevance and effectiveness:

- GTFS and NeTEx: These standards provide the fundamental data structures and formats to support schedule alignment and data exchange for public transport operations, especially vital for G1 and G2 goals, meaning ticketing and timetable synchronisation goals.
- SSIM: Facilitates integration with aviation schedules into the multimodal framework, critical for specifically G2.2 and G2.3. Please note that at this time, SSIM is the only aviation standard that was related to goals so far. Potential use of other aviation standards for goals is detailed in the Annex section, prominently in Air Traffic Management subsection.
- Transmodel and SIRI: Provide frameworks for data modelling and real-time information sharing, supporting ticketing (G1) and disruption management (G3).
- Information Security and Privacy Protection Standards (e.g., ISO 27001): Ensure robust security and privacy for data exchanges, which is crucial for all goals and use cases.

- ISO 24014-1: Architecture for roles, rules and ticketing processes in an Interoperable Fare Management System, a basic standard for all goals.
- OJP: Part of the Transmodel ecosystem on Application Programming Interfaces (APIs), potentially of relevance for all goals and especially G3.2 because of data exchanges.
- OSDM: Open Sales and Distribution Model, potentially important when (long-distance) rail is involved. Possibly relevant for goals G1.3 and G2.2.
- NDC: This IATA-endorsed initiative serves as a data transmission standard for airlines, based on XML. Its purpose is to amplify the potential for interactions between airlines and travel agents and is accessible to other external parties. NDC has the potential to be used for goals G1.1, G1.2, and G2.3. These goals relate to booking/purchasing mobility packages and timetable synchronisation involving air transport.
- PADIS: This technical specification facilitates data exchange for passenger processing and airport management, and could potentially be used in goals G1.3, G2.2 and G2.3, since those goals pertain to single ticketing and timetable synchronisation involving aviation, particularly concerning passenger data at airports.
- AIDM: This IATA technical specification provides a unified data model for aviation operations, aiming to ensure consistency across different systems. It is designed to generate interoperable messaging standards. It may be important to be considered for goals G2.2 and G2.3.
- AIDX: This IATA technical specification facilitates standardised data exchange between airports, airlines, and other aviation stakeholders. AIDX aims to improve the sharing of operational flight information. AIDX is considered applicable to goals G2.2 and G2.3, which are related to the synchronisation of aviation timetables with other transport modes.
- FIXM: FIXM focuses on exchanging flight-related data, supporting air traffic managem ent and flight operations. It provides harmonised data structures for richer route and trajectory descriptions. FIXM may be relevant to goals G2.2 and G2.3, which involve the integration of aviation schedules.

The standards listed in Table 3 are the most relevant due to their widespread adoption and alignment with multimodal transport needs. In applying these partly overlapping and even competing standards in SIGN-AIR, the project will address the challenge of what standards need to be selected and how they are to be applied in actual data exchanges in the context of the use cases. This provides a scalable foundation for future harmonisation efforts, paving the way for the potential amendment or creation of new standards to address emerging challenges and opportunities beyond the project's lifecycle.

The final STAND document, the last iteration of this series, has been updated to reflect the actual standards implemented and comprehensively analysed by the project's conclusion. This iterative approach ensures that the project maintains flexibility and incorporates emerging insights to meet its goals effectively.

For a comprehensive overview of all the data standards examined in relation to the STAND scope and the SIGN-AIR project, readers are encouraged to consult the annex (section 5) of this document, which provides additional detailed information.

3.2 Data Harmonisation

As outlined earlier in this document, transport and especially public transport operates within a highly fragmented standardisation landscape, vastly different from the more globally unified aviation standards ecosystem. This complexity poses a huge challenge and makes data harmonisation a critical necessity, ensuring that different transport modes can exchange information.

Harmonisation is essential notably when bridging the gap between aviation and public transport. A prime example is the integration of aviation schedules (IATA SSIM) with multimodal public transport timetables (NeTEx), which is not a straightforward process. Differences in data structures, scheduling formats, and update mechanisms create challenges that require dedicated harmonisation efforts.

SIGN-AIR plays a pivotal role in addressing these gaps by identifying common data elements, mapping fields between standards, and utilising transformation tools like TransiTool to facilitate interoperability without modifying existing standards. This ensures that aviation and public transport systems can communicate effectively, enabling seamless multimodal journeys for passengers.

In the following subsections, we will elaborate further on what harmonisation entails, how it differs from standards and standardisation, and why it is a crucial process in achieving interoperability in multimodal transport. Later, in section 4.4 we will present the practical implementation of the harmonisation effort that takes place in the context of SIGN-Air project.

3.2.1 Definition

Harmonisation involves aligning and reducing discrepancies among multiple standards that may have evolved independently, making them more compatible without eliminating variation. The process enables different systems and specifications to interoperate more smoothly while maintaining flexibility for diverse implementations. The term draws an analogy from music, suggesting the blending of discordant elements to achieve a cohesive and functional outcome.

Harmonisation is different from standardisation[5], though the two are complementary. Standardisation aims to establish a single, unified standard by reducing or eliminating variation, while at the same time it can remain to a certain degree flexible. Harmonisation, on the other hand, focuses on aligning existing standards to ensure compatibility and facilitate their coexistence. Both approaches are essential depending on the context: standardisation is ideal for creating uniform frameworks, while harmonisation addresses practical interoperability challenges where multiple standards coexist.

Standards themselves, while providing a foundation for interoperability, are often generic and allow room for interpretation and implementation differences. This flexibility is intentional, ensuring that standards remain adaptable to diverse markets and technologies. For example, significant efforts by Transmodel experts have been devoted to aligning standards in the Transmodel ecosystem, illustrating the ongoing nature of such work. These adjustments underscore the collaborative effort required to address evolving needs and ensure practical applicability.

It is important to recognise that both harmonisation and standardisation are deeply rooted in real-world needs, market requirements, and stakeholder collaboration. While standardisation can raise questions and lead to competing interests among vendors, this process also drives innovation and ensures solutions meet practical demands. The success of either approach lies in balancing technical rigor with market realities, ultimately fostering interoperability, innovation, and broader adoption.

[5] Pelkmans, J. (1987). "The New Approach to Technical Harmonisation and Standardization". JCMS: Journal of Common Market Studies. 25 (3): 249–269. doi:10.1111/j.1468-5965.1987.tb00294.x.

It is to be noted that EU regulations and standardisation documents are designed to address the practical needs and applications of standards within the transportation sector. This focus ensures that the standards developed are not just theoretical or overly rigid but are tailored to meet real-world requirements and challenges faced by stakeholders, such as transportation service providers (TSPs), regulators, and end-users. In transportation, where standards apply to aspects like schedules, routes, and ticketing, the emphasis is on creating standards that are both functional and relevant. For instance, standardising ticketing systems ensures that passengers can easily transition between different modes of transport or service providers without confusion or additional costs. Harmonisation might involve aligning the fare calculation methods or ticketing systems used by different providers, so that while each provider retains some flexibility, the overall system remains user-friendly and interoperable.

3.2.2 Goal

The goal for standard harmonisation is to find commonalities, identify critical requirements that need to be retained, and provide a common framework for standards setting organisations (SSO) to adopt. In some instances, businesses come together forming alliances or coalitions, also referred to multi-stakeholder initiatives (MSI) with a belief that harmonisation could reduce compliance costs and simplify the process of meeting requirements. Likewise, harmonisation may reduce complexity for those tasked with testing and auditing standards for compliance.

3.2.3 Industry Benefits

In simple terms, data harmonisation increases the value and utilisation of data. Data harmonisation also makes it possible for organisations to transform fragmented and inaccurate data into workable information – creating new analyses, insights, and visualisations. This means that data harmonisation helps the user reduce the time taken to access business intelligence, discover key insights, and detect early disruptions. It also significantly lowers the overall cost of complex data analysis and the cost of handling data in the long run. If an organisation is spending less time scrambling to find the right source of data, then it can spend that time more effectively elsewhere, such as in growing the business and making a significant revenue impact.

Whether an organisation has been around for several decades or is a recent start-up, it will inevitably gather a plethora of data. Along with it, there is the distinct possibility that the enormous array of information gathered from a wide variety of sources will have errors and misinformation. Besides this, the sheer volume of information collected over a company's lifespan can be unwieldy and overwhelming. With data harmonisation tools, this data can be a valuable mine of insights and business intelligence. Organisations can learn things about their customers, changing market forces, and even insights about competitors. The good news is that every company across the globe is mining and storing data to make smart business decisions and manage their customers. But first, to make sense of all that data, organisations need to harmonise it.

Most companies spend huge amounts of time and resources on commissioning surveys, conducting focus group sessions, and gathering information from the internet, news channels, and social media networks. However, this information often exists in disparate formats and varying levels of granularity, making it challenging to integrate and analyse effectively. Data harmonisation techniques play a crucial role in aligning and standardizing this information, creating a cohesive dataset that supports meaningful analysis. The term 'raw data' is context-dependent and can vary significantly across applications. Data that is considered raw in one process may already be processed for another. This fluidity highlights the importance of frameworks and the work of CEN standardisation groups, which provide methodologies for structuring and contextualizing data appropriately for specific uses. By leveraging these frameworks, organisations can transform fragmented datasets into actionable insights while maintaining the flexibility needed for diverse analytical requirements.[6]

3.2.4 Examples of Successful Harmonisation

Implementing and operating data systems for public transport is a complex undertaking that demands a significant investment of resources and effort. While standardisation plays a crucial role in simplifying these systems, reducing costs, and improving interoperability and capabilities, it's important to recognise that the adoption process is gradual and requires a strategic vision and patience over a span of years, rather than months.

Transmodel, as a conceptual tool, holds considerable value in gradually aligning various standards to converge onto a unified format. Transmodel has been employed over a 30+-year period (development started in the early nineties) to align key National European standards, leading up to the EC ITS directive promoting the use of pan-European standards for public transport (PT) data. GTFS (General Transit Feed Specification) could potentially be included in this alignment process as well. For the effective progression of standards, there needs to be a two-way flow of information between the concrete formats used in the field, encompassing real-life workflows and new business requirements, and the abstraction of those new features as common concepts within the Transmodel reference model. This iterative evolution is essential for harmonising and converting formats. It is imperative that this evolution continues to address future needs and advancements in the field.[7]

IATA aims to enhance the handling of Passenger Data by harmonising systems, establishing forward-looking standards, and educating countries about international standards. Passenger data has become crucial for Facilitation, but non-standard and inefficient transmission methods are common due to government requirements for Advance Passenger Information (API) and Passenger Name Records (PNR). IATA, in collaboration with ICAO and WCO, has developed an API-PNR Toolkit to assist stakeholders in understanding the global passenger data transmission framework. IATA cooperates with UN counter-terrorism structures to align API exchange programs with existing standards, utilising the Single Window concept for data requests. IATA contributes to the UN Counter-Terrorism Centre's API Project, promoting harmonised data exchange through workshops. Over 90 countries mandate API before flight arrival, with more planning to follow suit. IATA aims to standardise API requirements globally. Similarly, access to PNR is growing, and IATA seeks a global solution to ensure data protection while facilitating passenger flow.[8]

The OSDM API and related documents are Open Source and accessible to all interested parties. Introduced in 2013 and released in 2018, OSDM emerged from UIC's Tariff Model (nTM) and Full Service Model (FSM 2.0) initiatives. It comprises two standards: the Offline Model offering

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[6] https://en.wikipedia.org/wiki/Harmonisation (standards)

[7] https://www.transmodel-cen.eu/wp-content/uploads/2019/10/StandardsHarmonisation-2019-njsk-v1.0-1.pdf - page 74

[8] https://www.iata.org/en/programs/passenger/passenger-facilitation/passenger-data/

[10] https://osdm.io/

standardised static data on European rail distribution, and the Online Model facilitating consistent real-time booking and pricing across Europe. The team is presently encouraging adoption among European rail stakeholders and collaborating with European standards bodies to ensure compatibility[10].

4. Standardisation needs capture

4.1 Assessment of standardization needs for linking with goals of Smart Contracts and Data Sharing Agreements

In the SIGN-AIR project and thus for the respective solution no need for either a new standard or the amendment of an already existing standard has been detected. Instead of altering existing standards or creating new ones, SIGN-AIR is prioritising the use of well-established frameworks and utilising harmonisation and transformation tools, as the next sections will highlight.

Although it is difficult to capture at this moment all standardisation needs, the following paragraphs **intend to link the goals of data sharing agreements and/or smart contracts with standardisation needs** envisioning and outlining the challenges of such activities.

Considering the objective of SIGN-AIR, which is to allow TSPs to generate and monitor data sharing agreements and smart contracts, we list and explain the potential standards based on the data sharing goals that can be facilitated by the SIGN-AIR platform. These goals encompass not only data frameworks but also standards related to Interoperable Fare Management, including actors, rules, and processes, as well as security and privacy considerations.

All of SIGN-AIR's data sharing goals, such as single ticketing, coordinated timetables, optimised use of resources, increased passenger on demand services, increased access to passengers with reduced mobility (PRMs), disruption management and, more broadly, the digitalisation, harmonisation, and standardisation of sectoral processes and data exchanges – relate directly or indirectly to standards in one or more transportation sectors. Importantly, data sharing and smart contracts are not limited to the technical exchange of data; they also define the roles of entities involved, the rules governing data use, and the handling of data in rest and in motion during exchanges.

4.1.1 Overview of Goals, Use Cases and standardisation requirements

The SIGN-AIR solution defines specific multimodal data sharing goals (see below). These goals directly shape the use cases, establishing the functional and non-functional requirements essential for seamless data exchange across Transport Service Providers (TSPs), but also address critical aspects of 'who shares with whom', 'when data can be shared', and 'under what conditions'. These considerations are vital for defining roles, rules, and governance frameworks that ensure security, privacy, and compliance with regulatory standards in data sharing activities. By aligning scenarios with real operational needs, the goals provide a clear framework for system design and implementation.

The targeted use cases will be demonstrating the achievement of the specific multimodal data sharing goals and will address various contractual and operational needs within the multimodal transport ecosystem, as described in the Deliverable "DES HE SESAR solution SIGN-AIR TS/IRS – Part I".

SIGN-AIR main business services are:

- Creation of a Data Sharing Agreement and Smart Contract, which includes onboarding, discovery, negotiation, and settlement phases, which form the foundation for more complex workflows.
- Monitoring data sharing, which ensures effective management and monitoring of all contract elements throughout the contract's lifecycle.

Servicing the following Multimodality Goals:

- **Booking, Purchasing, and Issuing a Mobility Package (G1)**: Covers various ticketing types, such as **seasonal (G1.1), combined (G1.2), and single tickets (G1.3)**, to enhance passenger options and experience.
  - **Seasonal Ticket (G1.1)**: Designed for regular travellers, these tickets provide unlimited travel within a set period (e.g., monthly or yearly) at a discounted rate, improving passenger retention and satisfaction.
  - **Combined Tickets (G1.2)**: These offer bundled access to multiple transport modes (e.g., train and bus) within a single ticket, simplifying the travel experience and promoting multimodal journeys.
  - **Single Tickets (G1.3)**: A single ticket is a comprehensive ticket contract representing a 'single multimodal contract' for a journey that includes successive transport services operated by one or more carriers. This contract is designed to provide passengers with a unified travel experience, ensuring protection in case of disruptions.
- **Synchronisation of Timetables (G2)**: Ensures that transport schedules across modes are consistently updated and aligned, essential for reliable transfer times.
  - **Reach more flights (G2.1):** The TSP's arrival/departure schedule aligns with the airport's wave system, optimising flight connections and increasing passenger transfer options from rail to air.
  - **Reach more passengers (G2.2):** To maximise passenger potential, TSP schedules should align with long-haul flights, especially those operating from major airports. Offering luggage check-in and retrieval at origin stations can further enhance the attractiveness of rail-air intermodal travel, expand the catchment area of airports and providing seamless long-haul options for passengers from smaller cities.
  - **Substitute short-haul flights (G2.3)**: The TSP schedule should be optimised to align with international flights, enabling long-distance rail to replace domestic short-haul flights.
  - **Dynamic Timetable Synchronisation for On-Demand Transport (G2.4):** This synchronisation for on-demand transport ensures the alignment of eVTOLs with commercial airline schedules at airport hubs. Unlike static timetable coordination, this goal focuses on adaptive scheduling, where

on-demand (eVTOL) and air transport dynamically adjust to flight departures and arrivals, minimising passenger transfer delays and optimising multimodal service.

- **Disruption Management (G3):** Manages disruptions by monitoring and addressing issues in the post-settlement phase, supporting operational continuity.
  - **Real-time event monitoring (G3.1):** Develop protocols for detecting, classifying, and assessing the impact of disruptions across multiple transport modes.
  - **Coordinated Response (G3.2):** Implement strategies for timely passenger notifications, traveller information management, and adjustments to mitigate disruption impacts, such as implementation of notifications to the party impacted by the disruption.
- **Advanced Air Mobility Integration (G4)**: Facilitates the inclusion of next-generation aircraft into the transport ecosystem.
  - eVTOL Operations on Demand: Manages the specific data requirements for operating Electric Vertical Take-Off and Landing aircraft, bridging the gap between vertiport management, airport slot coordination, and the passenger's end-to-end itinerary.

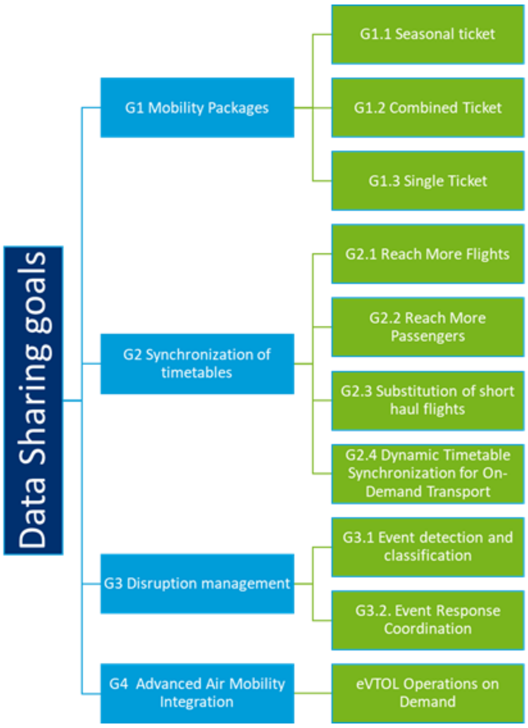

Figure 1: Multimodal data sharing goals

For the purposes of this report, the focus will be on the specific goals, because they directly highlight the standardisation needs required to enable interoperability and efficient data exchange among multiple transport modes that will be accommodated by the SIGN-AIR platform. To be more specific, the Mobility Package issuance (G1) involves standardising ticket formats across transport providers and thus requires harmonised data and protocols to ensure that different systems recognise and process each type consistently. For timetable synchronisation (G2), accurate and reliable schedule updates across various modes are required, so standardised data formats are of essence. This includes aligning with standards like NeTEx or GTFS to allow updates and efficient timetable coordination among airports, rail and bus operators. Furthermore, disruption management (G3) requires a standardised approach to incident classification, severity levels, and notifications, in order to efficiently enable smooth and automated communication of disruptions to all relevant stakeholders. Finally, Advanced Air Mobility Integration (G4) necessitates specific standards for flight data operations, such as extending aviation standards (like FIXM and AIXM) to cover the trajectory and operational characteristics of on-demand eVTOL services.

The practical application of these goals is explicitly defined in the SIGN-AIR Grant Agreement through specific use cases:

- Goal G1 (Mobility Packages/Ticketing) is directly addressed by Use Case 1 in the Grant Agreement, titled “Single Ticket Services for the airport community employees”, involving Bologna Airport (BLQ) and TPER, and Use Case 4, titled “Expansion of T-Mobilitat led by ATM”.
- Goal G2 (Synchronisation of timetables) regarding dynamic timetables is being addressed by Use Case 7 (“New flight alternatives to the Greek islands”), involving Hellenic Seaplanes as well as Use Case 9 (“Collaboration between airports and vertiports”), that involves Swiss Aeropole, where the synchronisation of schedules between novel air modes (Seaplanes/eVTOLs) and commercial aviation is crucial.
- Goal G3 (Disruption Management) is being addressed by Use Case 3 per the Grant Agreement (titled “Disruption Management”), which utilises a Digital Twin to manage emergencies between Bologna Airport and the railway station. The harmonisation of standards here is required to define the ‘Triggers’ and ‘Actions’ in the Smart Contracts that execute automatically when a disruption (e.g., Marconi Express failure) is detected via standard data exchanges.
- Goal G4 (Advanced Air Mobility Integration) is specifically addressed by Use Case 9 (“Collaboration between airports and vertiports”) and Use Case 7 (“New flight alternatives to the Greek islands”). Use Case 9 focuses on the “eVTOL Operations on Demand” subgoal, aiming to demonstrate how electric Vertical Take-Off and Landing (eVTOL) aircraft can act as a feeder service to commercial airports. This requires the SIGN-AIR platform to facilitate data exchange between Urban Air Mobility (UAM) and the scheduling of commercial aviation. Standardisation efforts here focus on mapping flight flow data (FIXM) and operational status (AIDX) to surface transport standards to ensure seamless passenger transfers. Use Case 7, while also supporting Goal G2 (Synchronisation), contributes to G4 by integrating a hybrid air-mode (seaplanes), that operates outside standard IATA definitions. This requires harmonising operational data into formats like GTFS or NeTEx to ensure these novel air services are visible and bookable within a multimodal itinerary alongside conventional flights.

This final iteration of the STAND document reflects the comprehensive developments regarding project goals, subgoals, and defined use cases, including the specific pairings of Transport Service Providers (TSPs) and the outcomes of the demonstrations conducted to validate these goals. For a detailed examination of the specific use cases and the corresponding application of standards, please refer to Section 4.5 (Applying Standards to Use Cases).

4.1.2 Harmonisation and alignment across goals – Potential amendments and considerations

The SIGN-AIR project emphasises the critical need for harmonising and aligning standards such as GTFS, NeTEx, IATA SSIM, and others across its goals. Achieving this is essential for enabling seamless multimodal transport operations, as these standards were developed independently and focus on specific transport domains. Without harmonisation, discrepancies in data structures, terminologies, and operational frameworks hinder integration and data exchange between Transport Service Providers (TSPs).

The standards identified in this STAND document form a strong foundation for data harmonisation across the various transport modes involved in SIGN-AIR, covering crucial areas like public transport (NeTEx, GTFS), real-time data exchange (SIRI), and aviation (IATA SSIM). These standards, together with harmonisation tools like TransiTool, enable effective data mapping and integration to meet the project's goals. The specific use cases and data attributes required for each TSP pair will be examined in subsection 4.5. The process of harmonisation will continue to evolve, nevertheless it is concrete at this point that the identified standards are sufficient for now for the harmonisation efforts.

Goals such as G2.2 (Reach More Passengers) and G2.3 (Substitution of Short-Haul Flights) rely heavily on aligning aviation and rail schedules. Harmonising NeTEx and IATA SSIM ensures effective integration, while OSDM could streamline ticketing related with long-distance rail transport. Standards like SIRI and SSIM underpin G3.1 (Event Detection) and G3.2 (Event Response Coordination) by enabling consistent, real-time data flows. Harmonisation across these standards could potentially ensure a unified approach to managing disruptions across transport modes. Harmonised standards support the end-to-end passenger experience, particularly for G1.x (Ticketing), by enabling interoperable ticketing solutions.

While standards like NeTEx and SSIM are effective within their domains, significant gaps and regulatory concerns arise in cross-domain applications such as the following: 1) Semantic and Structural Mismatches: Differences in data representations (e.g., schedules in NeTEx vs. slots in SSIM) require robust mapping tools to ensure compatibility; 2) OSDM Regulatory Compliance: ERA's findings indicate that OSDM's current architecture may violate competition law, particularly regarding the roles of service providers and sales agents. Harmonisation efforts must address these issues to ensure compliance; 3) Ticketing Interoperability: OSDM's limited alignment with aviation-focused standards highlights a need for amendments to support seamless multimodal journeys.

The SIGN-AIR project has proactively addressed some of the above mentioned challenges through the development of data mapping tools, which have the potential of bridging semantic and structural differences to a certain extent, enabling the different TSPs to achieve a mutual understanding and proceed with less barriers towards multimodal integration. In addition, since the project also entails certain demonstrations, these may also potentially validate the harmonised processes across the goals and thus demonstrate scalability and regulatory compliance.

4.2 Identification of amended or new standard(s)

This STAND document does not seek to impose specific standards, nor does it express a definitive need for amendments to existing ones. The process of developing or modifying standards is highly complex, requiring extensive effort, collaboration, and often years of deliberation, beyond the scope and timeline of the SIGN-AIR project.

Based on the prodigals, use cases, and the mapping of data attributes exchanged between TSPs, we do not currently foresee – nor by extension propose – any standard amendments or expansions. Instead, through extensive research and analysis, we have identified the most relevant existing standards (as outlined in Section 3 and summarised in Table 2) that TSPs can utilise when establishing agreements, exchanging data, and managing their contractual relationships within the SIGN-AIR platform. The platform does not dictate standards or interfere with the data itself but serves as a facilitating layer that enables interoperability and collaboration. Given the diversity of existing legacy systems, TSPs retain full autonomy in selecting the standards that best fit their needs and can leverage conversion tools, such as TransiTool (see Section 4.5), to bridge format differences where necessary, in accordance with the EU regulations. The objective is not to alter existing operational pipelines but to enhance compatibility, ensuring smoother multimodal integration and cooperation without disrupting established industry practices.

The only matter that has been identified as a gap is the harmonisation of GTFS, NeTEX and IATA SSIM which is presented in section 4.4.. Transport operators and service providers often face the challenge of translating data between standards, which increases complexity and the risk of errors. Harmonising GTFS, NeTEx, and SSIM addresses this issue by minimising the need for complex translations or middleware, ultimately reducing costs and improving data accuracy.

4.3 Considerations for standards development/amendment

Even though SIGN-AIR does not foresee the need for amending existing standards and/or developing a new one, it is useful to provide an overview of considerations that need to be made for future reference, regarding standard changes.

Deciding whether to create a new data standard or amend an existing one is a complex task that requires careful consideration of various aspects, and involves weighing technical, organisational and industry factors. It requires a comprehensive understanding of the current landscape, stakeholder needs, and long-term goals to ensure that the chosen path leads to a cohesive, efficient, and widely adopted solution. The difficulty in making this decision arises from several key challenges and considerations, presented below.

Compatibility and Interoperability: An essential aspect of any data standard is its ability to work cohesively with other existing standards and systems. Creating a new data standard could lead to compatibility issues with already established standards, potentially creating data silos and hindering data exchange between different stakeholders. On the other hand, amending an existing standard requires careful analysis of its impact on the current ecosystem, ensuring backward compatibility and smooth transition.

Stakeholder Alignment: Data standards involve multiple stakeholders, including government agencies, private companies, industry associations, and end-users. Each stakeholder may have different requirements, preferences, and vested interests. Deciding on a new standard or amendments requires aligning the diverse needs and finding common ground, which can be challenging and time-consuming.

Industry Acceptance and Adoption: The success of any data standard depends on its widespread acceptance and adoption by relevant industry players. Creating a new standard from scratch may face resistance from those already invested in existing systems. Conversely, amending an existing standard may require convincing stakeholders of the need for changes and overcoming inertia towards adopting new versions.

Time and Resources: Both creating a new standard and amending an existing one require significant time, effort, and resources. Developing a new standard involves research, testing, and validation, while amending an existing standard requires rigorous analysis and impact assessment. Deciding which path to take requires evaluating the available resources and understanding the potential risks and benefits of each approach.

Long-term Viability: Data standards should have longevity and adaptability to changing technological and industry trends. Creating a new standard could potentially lead to challenges in its long-term viability and relevance, especially if technological advancements outpace the standard's capabilities. Amending an existing standard requires careful consideration of its flexibility and potential for evolution to meet future needs.

Governance and Maintenance: Both creating and amending data standards require effective governance and ongoing maintenance. A new standard needs to establish a governing body and processes to ensure continuous development and updates. Similarly, amending an existing standard requires a governance framework that can handle versioning and ongoing maintenance.

Impact on Current Implementations: Decisions about data standards must consider the impact on existing implementations and systems. Creating a new standard could require substantial modifications to current infrastructures, whereas amending an existing standard may necessitate updates and adaptations to align with the changes.

4.4 Harmonisation of GTFS, NeTEX and IATA SSIM – Technical development support

From a technical standpoint, harmonisation often involves data mapping – aligning data fields, attributes, and structures between different standards to enable interoperability. Harmonisation extends beyond simple mapping. It requires standardising processes, ensuring semantic alignment, and enabling seamless data exchange across systems and stakeholders.

In the context of the SIGN-AIR project and the development of the respective solution, the harmonisation efforts focus on aligning specific standards to facilitate multimodal transport interoperability. The project identifies equivalent data fields across standards, ensuring that information such as timetables, fares, and disruptions can be exchanged reliably. Within the context of the project certain harmonisation efforts were made, specifically in regards to harmonisation of GTFS, NeTEX and IATA SSIM and mapping of common data elements and the respective data fields. This effort was detailed in D2.21, which has now been included in the TS/IRS document. The SIGN-AIR project has successfully developed and demonstrated technical solutions for the harmonisation of

GTFS, NeTEx, and IATA SSIM standards – in parallel with the development of the SIGN-AIR platform –, showcasing how interoperability across public transport and aviation can be achieved. These efforts underline the feasibility of aligning data structures and operational frameworks between diverse transport modes, providing a foundation for future harmonisation, amendments, and even the creation of new standards.

Key among these developments is the creation of robust data mapping and integration tools in the TransiTool[9] environment, which will be connected to the SIGN-AIR platform, as described both in the Description of The Action of the project, as well as in the TS/IRS document (Technical Specifications/Interface Requirements). These tools enable seamless translation between GTFS, NeTEx, and IATA SSIM, allowing transport schedules, stop locations, and service types to be aligned across modes. Crosswalk mechanisms have been meticulously designed to address mismatches in field definitions and data structures, ensuring compatibility and paving the way for standardised, multimodal data exchange. The tools not only solve current interoperability challenges but also provide a replicable methodology for future harmonisation efforts across additional standards and datasets. In particular, key steps included:

1. Identification of Common Data Elements: Key elements such as schedules, stops, routes, and operational metadata were extracted from GTFS, NeTEx, and SSIM.
2. Field Mapping and Crosswalk Development: Each standard's schema was analysed to map equivalent fields, ensuring compatibility. For example, SSIM flight schedules were matched with NeTEx and GTFS timetable data, allowing seamless alignment of aviation and public transport schedules.
3. Normalisation and Transformation: Tools were developed to normalise data into intermediate formats, bridging differences in time conventions (e.g., UTC/local time) and operational details.
4. Real-Time Data Exchange Testing: APIs were implemented to simulate real-world data exchanges between systems, validating the harmonisation for scalability and operational readiness.

This technical development is critical for Use Case 7, in which Hellenic Seaplanes must synchronise operations with conventional airlines. As Seaplanes operate using hybrid infrastructure, combining land and water transports, falling outside standard IATA definitions, their operational data will be mapped into a format (GTFS or NeTEx) that can be harmonised with IATA SSIM schedules used by partner airlines (e.g., Aegean). This ensures the SIGN-AIR platform can perform the matching mechanism described in the Grant Agreement.

This harmonisation between seemingly unrelated standards directly supports SIGN-AIR key goals:

- G2.2 and G2.3 require seamless synchronisation of schedules between aviation and rail/bus transport, achievable only through standard alignment and specifically to the data fields and attributes that are mandatory for those involved modes and are expected to be required to be exchanged and will be reflected in the corresponding Data Sharing Agreements.
- G3.1 and G3.2 depend on consistent, real-time data from diverse modes for effective disruption management.

[9] https://transitool.com/

By aligning GTFS, NeTEx, and SSIM, the project ensures the interoperability essential for multimodal planning, ticketing, and operational efficiency. This progress shows that harmonising standards across distinct transport domains is feasible and creates a framework that could be applied to other standards. It also lays the groundwork for potential updates to existing standards or the development of new multimodal ones, advancing a globally scalable transport ecosystem.

A key achievement is the integration of the Field Matching Tool into the SIGN-AIR platform. This tool automates the conversion of non-standardised data fields to standardised formats during contract negotiations, reducing manual work and ensuring compliance with accepted standards. Combined with TransiTool's extended support for IATA SSIM, GTFS, and NeTEx, this demonstrates the capability to harmonise scheduling data and updates, providing a proof-of-concept for broader multimodal applications.

The project's comprehensive testing and validation framework will enhance the credibility of the developed tools. Rigorous trials using standardised datasets for goals like timetable synchronisation and disruption management will prove the operational readiness of these harmonised systems, validating their effectiveness in minimising data inconsistencies and improving operational efficiency. The integration of APIs for dynamic data exchange will enable secure data sharing and synchronisation among TSPs while complying with GDPR and other regulations. This framework not only meets current project needs but establishes a scalable infrastructure for future interoperability.

SIGN-AIR's harmonisation efforts extend beyond the project's immediate goals, offering a replicable model for future initiatives. Insights gained can guide updates to OSDM, aligning with ERA recommendations, and contribute to the creation of unified multimodal standards that facilitate global data exchange across various transport modes. The methodologies developed could influence formal standardisation bodies, such as ISO, CEN, IATA, and EU technical committees, potentially leading to the adoption of comprehensive, cross-modal standards.

. While the project underscores the strategic importance of harmonising standards for seamless multimodal transport, it also acknowledges the broader challenges involved. Aligning data from different standards and ensuring interoperability in tooling is complex, requiring attention not only to data exchanges but also to organisational interoperability (defining who, what, how, and when data is shared), technical interoperability (ensuring systems can function together seamlessly), and security interoperability (managing need-to-know principles, access controls, and data protection).

In addition, compliance with privacy regulations is critical, requiring robust privacy protection measures integrated into systems and processes. The systems developed through SIGN-AIR must demonstrate operational effectiveness across these dimensions, showcasing not only technical feasibility but also the ability to address organisational, security, and privacy challenges. This comprehensive approach positions SIGN-AIR as a pioneering effort in advancing multimodal transport integration and interoperability.

To summarise, for SIGN-AIR, harmonisation primarily means aligning existing standards without modifying them, allowing stakeholders to continue using their preferred formats while enabling seamless data exchange. This is a pragmatic and scalable approach, avoiding the complexity of developing new standards while ensuring multimodal interoperability.

However, for the transport industry as a whole, harmonisation should be an ongoing effort, requiring collaboration between standardisation bodies (IATA, UIC, UITP, CEN, ISO, EU technical committees) to ensure that data exchange remains efficient, secure, and future-proof. The ultimate goal should be to move beyond field-to-field mapping towards a cohesive, multimodal transport data ecosystem that can evolve with new mobility trends and technological advancements.

4.5 Applying Standards to Use Cases

This subsection serves as the practical application layer of the STAND report. Its primary purpose is to bridge the gap between theoretical data standards, defined in the Annex section of this document, and real-world operational scenarios, by demonstrating how specific standards can interact to enable the functionality of the SIGN-AIR platform. This section also serves in validating the project's harmonisation strategy by breaking down traveller experiences detailed in the use cases in the Grant Agreement into data exchange requirements. By mapping specific data elements, this section aims to prove the technical feasibility of the proposed multimodal solutions. The tables within this section are used to visualise the harmonisation and data exchange between different transport modes, serving as a blueprint for implementation, with each table following a specific structure:

- **Information Type**: Identifies the specific business concept being exchanged (e.g., Employee Eligibility, Schedule Synchronisation). The tables currently represent a theoretical mapping based on standard specifications. As the project progresses and actual Data Sharing Agreements are signed, these mappings will be validated against the real-world data available from the specific partners.
- **Aviation Standard**: Specifies the source standard and the data elements used by the airline or airport.
- **Surface Standard**: Specifies the target standard and data elements used by the ground transport operator.
- **Action**: Describes the technical logic or transformation rule applied by the SIGN-AIR platform to convert the source data into a format the target system can understand.
- **Example Scenario**: Provides a narrative walkthrough of how this data mapping manifests as a tangible benefit to the user.

4.5.1 The Traveller Experience in Practice

The overarching goal across all use cases is to transform fragmented individual bookings and journeys into seamless, multimodal experiences facilitated by the SIGN-AIR platform. The specific traveller experiences being piloted include:

- **Single Ticket Services for Airport Employees:** Targets the Bologna Airport community to encourage a modal shift by bundling urban bus, monorail, and car-sharing into a single Employee Contract tariff accessible via the ROGER app.
- **Single Ticket Inclusion of New Modes:** Expands the concept to general travellers and tourists, enabling a Single Ticket purchase that covers both an international flight and the last mile transport (including taxis and bike-sharing) within the region.
- **Disruption Management:** Focuses on non-nominal scenarios using a Digital Twin approach, if for example a specific mode (e.g., monorail) fails or a flight is delayed, data sharing triggers immediate re-routing assistance and manages passenger rights between the airport and railway station.
- **New Flight Alternatives**: Connects conventional airlines with Hellenic Seaplanes to access Greek islands, synchronising the flexible, hybrid infrastructure of seaplanes with standard commercial aviation schedules to reduce wait times.

- **Collaboration between Airports and Vertiports:** Integrates eVTOL aircraft into the high-end multimodal chain (e.g., Swiss Aeropole), facilitating seamless transfers between vertiports and commercial airports by coordinating on-demand urban air mobility with scheduled flights.

4.5.2 Gap Analysis and Harmonisation Strategy

The central challenge addressed across all use cases is the integration of diverse transport modes into a unified contract or synchronised operation. The harmonisation strategy mandates that data owners (like the product owner or the transport operator) register on the SIGN-AIR platform to establish a standardised data exchange environment. The platform bridges specific technical and operational gaps, such as the disconnect between Human Resources data and transport validation systems and the incompatibility between aviation retailing standards and regional public transport standards. While technical standards provide the format for data exchange, the operational authority to exchange this data within SIGN-AIR is governed by the electronic contracts established between TSPs, therefore before any use case can be launched or any data exchanged, a Data Sharing Agreement (DSA) and a Smart Contract should be established. As defined in the SIGN-AIR Grant Agreement (section 1.2.1.1), a Data Sharing Agreement (DSA) defines what data is shared, meaning that it is functioning as e-contract that sets out the specific terms and conditions for the lawful use of datasets provided by one TSP to another. Smart Contracts define how and when the collaboration operates by detailing the objectives of the DSA by specifying Triggers and Actions:

- Trigger: A condition agreed upon by the parties.
- Action: A contractual obligation executed automatically or manually when a Trigger is realised.

The data mapping tables presented in the subsequent sections (subsections 4.5.6 – 4.5.10) do not represent continuous, unconditional data streams, but more so the standardised data payload required by the SIGN-AIR Monitoring Dashboard to verify that a contractual Trigger has occurred and to execute the consequent Action (as mentioned in Grant Agreement, section 1.2.2.3, functionality 7). The harmonisation of standards such as NeTEx and IATA SSIM is the technical enabler that allows the platform to digitally monitor these contracts and automate the agreed rules.

4.5.3 Mapping and Detecting Essential Data Fields

To ensure real-time responsiveness within Travel Companion applications as well as with TSP's separate IT systems, in the initial phases, essential data fields must be mapped between disparate aviation and surface transport standards. This methodology involves identifying the governing standards for each mode, as is detailed in the Annex, and establishing cross-modal interoperability:

- **Schedule Data**: Mapping aviation location and schedule data (IATA SSIM, Location Codes) to surface transport structures (GTFS stops.txt/stop_times.txt, NeTEx) to anchor transport nodes and align timetables or slots.
- **Retailing and Validation**: Mapping aviation offer and passenger processing data (IATA NDC, PADIS, PNR) to surface transport fare and validation standards (NeTEx Fare Product, eTCD, ISO 24014-1 IFMS) to bundle dynamic pricing with static tariffs and enable interoperable ticket validation (e.g., using a PNR as a token for a rail gate).
- **Operational Data:** Mapping dynamic aviation status updates (AIDX Flight Status/Disruption Detail, FIXM flow information) to surface transport real-time feeds (SIRI Estimated

Timetable/Situation Exchange, DATEX II, GBFS) to trigger automated alerts, update availability, or manage disruptions across the multimodal chain.

4.5.4 Automation with TransiTool

The execution of the data integration process relies on TransiTool, which serves as the technological bridge to ingest, parse, and process operational data from the various Transport Service Providers. By automatically converting aviation-specific formats into structures compatible with surface transport standards (like GTFS, IATA SSIM and NeTEx), TransiTool harmonises data for the user interface. This automation allows the SIGN-AIR platform to validate connections (e.g., checking Minimum Connection Times), ingest availability and pricing for single ticketing, and execute Smart Contracts.

4.5.5 Some Crucial Security Principles

All data exchanges when the standards are being mapped, in order to satisfy the needs of a use case, should comply with the General Data Protection Regulation (GDPR) regarding personal data and the NIS2 Directive regarding the resilience of the critical transport infrastructure. In any case, the following security principles should be applied during the data mapping process. It is important to note that the specific demonstrations conducted within the project scope may utilise synthetic data or operate within limited, controlled environments. Therefore, the requirements listed below represent the specifications to be taken into account for a fully operational SIGN-AIR platform. The project use cases aim to demonstrate the technical feasibility and readiness of the platform to meet these obligations, even if full legal compliance is not mandatorily triggered during the research and pilot phase. The security and privacy principles detailed in this section, including the implementation of an Information Security Management System (ISMS) in accordance with ISO/IEC 27001 and compliance with GDPR, constitute a mandatory baseline for the entire SIGN-AIR platform. These requirements apply universally to all Use Cases and data exchanges outlined in the subsequent sections (4.5.6 through 4.5.10). Consequently, specific entries for ‘Data Security and Privacy Protection’ are not repeated within each individual data mapping table to avoid redundancy. However, every exchange of data—whether for ticketing, scheduling, or disruption management—must inherently adhere to these protocols to ensure the confidentiality, integrity, and availability of the multimodal transport ecosystem.

4.5.5.1 Data Minimisation and Purpose Limitation

Only the minimum data required to verify the “Right to Travel” (e.g., a hashed identifier or Boolean status) should be transferred between any SIGN-AIR participants or Transport Service Providers (TSPs) involved in a data exchange. This practice ensures compliance with Article 5(1)(c) of the GDPR, which mandates that personal data must be “adequate, relevant and limited to what is necessary in relation to the purposes for which they are processed” (Regulation (EU) 2016/679, 2016).

4.5.5.2 End-to-End Encryption

All data flows facilitated by the SIGN-AIR platform must be encrypted using TLS 1.3 or higher. This prevents “Man-in-the-Middle” attacks during the critical “handshake” phase of a smart contract execution, since essential entities are required to implement policies and procedures regarding the use of cryptography and, where appropriate, encryption under Article 21(2)(h) of the NIS2 Directive (Directive (EU) 2022/2555, 2022).

4.5.5.3 Pseudonymisation of Traveler Identity

When a passenger's identity is required to link a multimodal journey (e.g., a flight to a train ride), direct identifiers should be converted into pseudonyms or tokens before they enter the surface transport environment. This ensures that a breach in the local transport operator's system does not compromise the passenger's full aviation profile, which aligns with Article 32(1)(a) of the GDPR that defines the pseudonymisation and encryption of personal data as a primary technical measure to ensure a level of security appropriate to the risk (Regulation (EU) 2016/679, 2016). To meet the requirement for state-of-the-art security, pseudonymisation must be combined with encryption. All additional information required to re-identify the data must be kept separately and securely encrypted. This layered defence ensures that even if a local transport operator's system is breached, the pseudonymised tokens remain unintelligible and the passenger's full aviation profile is not compromised. This approach aligns with Article 32(1)(a) of the GDPR, which mandates both pseudonymisation and encryption as primary technical measures to ensure a level of security appropriate to the risk, and ENISA recommendations on data protection engineering.

4.5.5.4 Supply Chain Security and API Authentication

SIGN-AIR connects disparate systems, so the source of the data feeds must be authenticated. This prevents malicious actors from injecting false schedule data to disrupt operations. This complies with the NIS2 Directive that mandates supply chain security including security-related aspects concerning the relationships between each entity and its direct suppliers or service providers under Article 21(2)(d) (Directive (EU) 2022/2555, 2022).

4.5.5.5 Incident Logging and Traceability

The platform must maintain a log of all data transformation events so that, in the event of a data breach or operational failure, operators must be able to trace whether the error originated in the aviation feed or the translation layer to fulfil mandatory reporting windows. Significant incidents must be reported to competent authorities without undue delay under Article 23 of the NIS2 Directive (Directive (EU) 2022/2555, 2022).

4.5.6 Single Ticket Services for the airport community employees (Use Case #1)

Information Type	Aviation Standard	Surface Transport Standard	Action	Example Scenario
Employee Eligibility and Tariff Selection	**Standard: IATA NDC** **Elements**: Fare Families, Offer Data **Justification**: According to the Annex section, the IATA NDC standard is designed to distribute the	**Standard: NeTEx** **Elements**: User Profile, Fare Products. **Justification**: These data elements cover fare	Map NDC Fare Families, Offer Data to NeTEx User Profile and Fare Product to translate the airline's specific employee tariff rules into the corresponding	A BLQ technician opens the Roger App. The SIGN-AIR platform validates their status and offers the bundled "Airport Community"

	entirety of the airline's product range and includes Fare Families and Offer Data as Common Data Elements.	information, specifically mapped to specific user categories.	surface fare structure and eligibility criteria	monthly rate instead of standard public pricing.
Static Schedule Synchronisation	**Standard: IATA Location Codes** **Elements**: Airport Code **Justification**: Used to anchor the transport nodes to the airport infrastructure as referenced in the aviation overview.	**Standard: GTFS** **Elements**: stops.txt **Justification***:* According to Annex stops.txt table provides the ground truth for timetables and stop locations (e.g., Monorail station).	Map IATA Airport Code to GTFS stops.txt (stop_id field), to logically link the aviation location identifier with the specific surface transport stop coordinates for journey planning	The SIGN-AIR platform maps the generic "BLQ" IATA code to the specific GTFS stop_id for the Marconi Express station. This ensures the journey planner logically connects the flight arrival node with the correct surface transport departure node for accurate routing.
Shared Mobility Integration	**Standard: IATA NDC** **Elements**: Flight Information Availability **Justification**: Annex lists Flight Information Availability as a Common Data Element of NDC standard. This measures whether a seat is available for consumption.	**Standard: GBFS** **Elements**: free_bike_status (mapped to vehicles) **Justification**: As noted in Annex, GBFS provides real-time vehicle locations and availability for shared mobilities.	Map NDC Flight Information Availability to GBFS free_bike_status to align real-time aviation inventory availability with real-time shared vehicle location and status	An employee finishing a late shift checks the app. The system queries the GBFS feed to verify that a "Corrente" car is currently located 200m from the terminal and displays its status as "available" alongside the flight arrival information.

Interoperable Validation	**Standard: PADIS** **Element**: Ticketing, Ticketed Indicator **Justification**: PADIS is defined as the standard for "sharing passenger information" and includes the "ticketing/ticketed indicator" within Passenger Name Record (PNR) data. This status confirms the passenger has a valid right to travel.	**Standard: NeTEx** **Element**: Fare Structure, Access Rights (listed as a core functionality of Transmodel, the parent model of NeTEx) **Justification**: Annex defines access rights and "validation across multiple operators"	Map PADIS Ticketed Indicator from PNR, to NeTEx Fare Structure/Access Rights to convert the aviation right-to-travel status into a surface transport entitlement token	The SIGN-AIR platform translates the "Ticketed" status from the airline PNR into a valid NeTEx "Access Right" or "Fare Product" entitlement. This establishes the digital right for the employee to travel on the surface network, which can then be issued to the Travel Companion.

4.5.7 Single ticket inclusion of regional transport modes and operators (Use Case #2)

Information Type	Aviation Standard	Surface Transport Standard	Action	Example Scenario
Single Ticket Pricing	**Standard: IATA NDC** **Elements :** Offer Data, Data Fare Families, Payment and Billing Information **Justification***:* As detailed in Annex, NDC handles Offer Data and Fare Families. It enables the airline to create a dynamic offer that includes additional mobility services	**Standard: NeTEx** **Elements :** Fare products, Fare prices, Fare structures **Justification***:* Annex confirms NeTEx covers "Fare products" and "Fare prices". This allows the regional authority (TPER) to export tariff structures that the airline	Map IATA NDC Offer Data and Fare Families structures directly to NeTEx FareProduct and FarePrice frames, bundling dynamic flight pricing with static urban zone tariffs	A user buys a ticket on the Finnair website. The total price includes the flight and a validated TPER urban zone ticket, processed as a single "Mobility Package".

	(like a train ticket) beyond just the flight seat.	system can ingest.	into a single transaction entity	
Schedule Synchronisation	**Standard: IATA SSIM** **Elements :** Arrival time, Arrival airport code, Terminal and gate information **Justification***:* Annex lists "Arrival time" and "Terminal information" as core SSIM elements. This static data is required to determine when the passenger enters the surface transport network.	**Standard: GTFS** **Elements :** stop_times.txt, stops.txt, routes.txt **Justification***:* Annex describes GTFS stop_times.txt and routes.txt as the standard for public transport schedules. This is used to find the connecting surface transport vehicle matching the flight arrival.	Map IATA SSIM Arrival Time and Terminal location codes to GTFS stop_times.txt and stops.txt (stop_id) tables to calculate connection windows and identify the connecting surface transport vehicle	The flight arrives at BLQ at 14:00. The system queries the GTFS feed to find the Marconi Express departing at 14:45 to ensure a seamless connection.
Passenger Identity	**Standard: PADIS** **Elements :** Passenger Name Records (PNR), Ticketing/ticketed indicator **Justification***:* Annex notes PADIS covers "Passenger Name Records (PNR)" and "Ticketing indicators". This element identifies who holds the contract.	**Standard: eTCD (Electronic Ticket Control Database)** **Elements :** Ticket verification and usage, Ticket gate checks **Justification***:* Annex describes eTCD as a "centralised, real-time passenger ticket management system" used for the "exchange of control information... between ticket	Map PNR unique identifiers to eTCD Ticket Verification structures, transforming the airline PNR into a standard barcode token validated against the eTCD database for gate access	The airline PNR is encoded into a secure barcode compatible with the eTCD standard. When the passenger scans this barcode at the TPER gate, the gate validates the ticket status in real-time against the eTCD database to grant access.

		issuers and passenger carriers”. It specifically handles ticket verification and usage.		

4.5.8 Disruption management (Use Case #3)

Information Type	Aviation Standard	Surface Transport Standard	Action	Example Scenario
Flight Status Change	**Standard: AIDX** **Elements:** Operational Times, Status **Justification:** As detailed in Annex, AIDX elements including “Operational Times” and “Status” can provide the real-time trigger (e.g., when a flight is late).	**Standard: SIRI** **Elements:** Estimated Timetable Service (ET) **Justification:** Annex describes SIRI ET as supporting “the exchange of estimated schedules in real time, including updates”. This allows the surface transport system to see the new predicted arrival time of the passenger demand.	Map AIDX Operational Times (Estimated/Actual Arrival) directly to SIRI ET EstimatedTime	The flight AZ1312 from Rome is delayed. AIDX updates arrival from 14:00 to 14:45. SIRI ET is used in this case to update the “demand arrival” at the Monorail station.
Flight Cancellation	**Standard : AIDX** **Elements:** Disruption Detail and Status **Justification:** Annex lists “Disruption Detail” as a core AIDX element. This qualifies the nature of the event (e.g., Cancelled due to weather).	**Standard : SIRI** **Elements:** Situation Exchange Service (SX) **Justification:** Annex states that SIRI covers the “exchange of information describing an incident... typically an unplanned	Map AIDX Status and Disruption Detail to a SIRI SX SituationElement. The aviation cancellation event is converted into a SIRI SituationExchangeDelivery message, creating an alert that invalidates the specific	Flight cancelled due to strike. AIDX sends status CX. SIRI generates an alert for the traveller to not proceed to the boarding gate/monorail.

		event". This can be used to map the specific aviation incident to a surface transport context.	transport leg in the journey planner.	
Surface Transport Infrastructure Failure	**Standard: AIXM** **Elements:** Digital NOTAM **Justification:** NOTAMs and Aeronautical Information Updates are described by ICAO Annex 15 as covering "unplanned events" and the status of "facilities".	**Standard: SIRI** **Elements:** Situation Exchange Service (SX) **Justification:** Annex confirms SIRI SX is used for unplanned events such as a disruption regarding equipment or sites. This is the source trigger for the Monorail breakdown.	Map SIRI SX Situation Element to Aviation Operational Alerts. SIRI ValidityPeriod and Description of the monorail failure are ingested and mapped to an aviation alert format to flag late passenger probability for specific flights.	Marconi Express fails. SIRI SX broadcasts "Service Suspended" and SIGN-AIR platform flags this to the Airline to anticipate late arrivals for departing flights.
Passenger Notification	**Standard: PADIS** **Element:** Passenger Name Records (PNR), Contact Details **Justification:** Annex defines PADIS (Passenger and Airport Data Interchange Standards) as the standard for "sharing passenger information between airlines, airports... and others". It explicitly covers PNR (Passenger Name Records), "contact details", and "flight check-in updates", which are the core components	**Standard: OSDM** **Elements:** Interface for Booking/Reservations and After-sales **Justification:** Annex defines OSDM (Open Sales and Distribution Model) as the interface for "booking/reservations". It is designed to be customer centric.	Map PADIS Contact Details to the OSDM After-sales workflow. Passenger identity and contact data from PADIS are used to authenticate the OSDM Booking Reference, enabling the specific push notification and re-booking options within the Travel Companion app.	In the case of flight ABC-123 being delayed, the platform utilises the PADIS PNR to retrieve the linked OSDM booking. An OSDM 'After-sales' process is triggered to re-book the passenger onto the 15:00 Monorail service, and the updated digital ticket is pushed to the user's app.

	required to manage a passenger disruption.			

4.5.9 New flight alternatives to the Greek islands (Use Case #7)

Information Type	Aviation Standard	Seaplane / Surface Standard	Action	Example Scenario
Schedule Synchronisation	**Standard: IATA SSIM** **Elements:** Departure time / Arrival time **Justification:** Annex states SSIM is the official set of standards for the exchange of airline schedules. The text defines this standard as the governing standard for the airline's slot system.	**Standard: GTFS** **Elements:** stop times.txt table **Justification:** Annex describes GTFS as a lighter format composed of text files like stop_times.txt. This description makes the standard suitable as the likely format for the seaplane's flexible schedule.	Extract arrival/departure timestamps from the GTFS stop_times.txt file and convert them into the SSIM schedule message format. This allows the calculation of Minimum Connection Times (MCT) to validate that the seaplane schedule aligns with the airline slot system.	Seaplane departs Corfu (Water) at 10:00. This is mapped to an SSIM slot to ensure it connects with Aegean Flight A3-404 departing Corfu (Airport) at 12:00.
Location Definition	**Standard: SSIM** **Elements:** IATA Location Codes **Justification:** Annex lists "Departure/Arrival airport code" as Common Data Elements. There is a need to reconcile these codes with non-standard locations.	**Standard: GTFS** **Elements:** stop_id field from stops.txt table **Justification:** Annex defines stops.txt table for tracking the locations. This will be used to handle the "water field" definitions lacking in standard aviation databases.	Assign a pseudo–IATA Location Code to the specific GTFS stop_id representing the water landing field. This mapping enables the airline's Global Distribution System (GDS) to recognise and process the non-standard location as a valid destination code within the SSIM data structure.	Paxus (Water Field) is defined as GTFS stop PAX_W. This is mapped to a pseudo IATA code in the SIGN-AIR platform so it appears on the airline ticket.
	Standard: SSIM **Elements:** Aircraft Type	**Standard: NeTEx** **Elements:** vehicle data	Translate NeTEx vehicle data regarding the seaplane's characteristics into a compatible SSIM "Aircraft Type"	The seaplane (NeTEx vehicle) is mapped to a specific SSIM Equipment Code,

Operational Mode Translation	**Justification:** Annex lists Aircraft Type as a common data element in SSIM. Airlines need this to calculate capacity and block times.	**Justification:** Anne x lists "vehicle data" as a common data element within the NeTEx standard.	or Equipment Code. This ensures the airline system accurately reflects capacity, block times, and transfer constraints.	which updates the airline system to reflect the specific seat capacity for inventory and the slower block times required for the water landing approach.

4.5.10 Collaboration between airports and vertiports (eVTOL - Use Case #9)

Information Type	Airline Standard	Surface Transport Standard	Action	Example Scenario
Schedule Synchronisatio n	**Standard: SSIM** **Elements :** Departure/Arrival times, airport codes, frequency, operating carrier code **Justification:** Anne x states SSIM is the official set of standards for "airport coordination information and minimum connect time data". It provides the schedule anchor for the commercial flight.	**Standard: NeTEx** **Elements :** Timed departure/arrivalstop s, routes, days of operation **Justification:** Annex defines NeTEx as the standard for "exchanging Public Transport schedules" including "timed departure/arrival". Both aviation and surface standards regarding this information type describe a Static Timetable and use equivalent data entities.	Map SSIM Departure/Arrival times and Airport codes to NeTEx Timed departure/arrival and Stop points and align SSIM Frequency and Operating carrier code with NeTEx Service Journey and Day types to harmonise static schedules across modes	An eVTOL departs a suburban vertiport at 10:00. This is mapped via FIXM to an SSIM slot at the hub airport to ensure the passenger can catch Flight LH-1234 departing at 11:30.
	Standard: AIXM **Elements:** Aerodrome/Helipo rt movement areas, points and navaids, routes	**Standard: AMXM** **Elements:** Spatial layout geometry runways, parking stands **Justification:** Annex explains that AMXM	Map AMXM Spatial layout (geometry described as points, lines, polygons) of	Vertiport Stand A2 is defined in AMXM with specific coordinates. It is mapped to an

Definition of Infrastructures	**Justification:** Annex states that AIXM defines the "scope of data including aerodromes and airspace structure". It allows the ATM system to understand constraints.	is used for Aerodrome Mapping Databases (AMDB), providing the spatial layout of features like "parking stands" and "runways".	specific features like Parking stands to AIXM Aerodrome/Heliport definitions	AIXM "Heliport" feature in the SIGN-AIR platform so the hub airport can manage its landing slot.
Ground-to-Air Transition	**Standard**: **AIDX** **Elements**: Operational Times, Status and Remarks **Justification**: Annex defines AIDX as the standard for "operational flight information", specifically "flight updates and operational status".	**Standard**: **SIRI** **Elements:** Estimated Timetable Service (ET), Vehicle Monitoring Service **Justification**: Annex defines SIRI as the standard for "real-time information" and "real-time progress information about individual vehicles".	Map SIRI Estimated Timetable Service and Vehicle Monitoring Service to AIDX Operational Times and Status. Translate ground delays into AIDX-compatible Flight updates	A passenger is on a bus to the vertiport. The SIRI Vehicle Monitoring Service reports a 20-minute delay due to traffic. The SIGN-AIR platform translates this surface delay into an AIDX status update, alerting the airline that the passenger may miss their connection.
Real-Time Disruption Management	**Standard**: **AIDX** **Element:** Disruption Detail, Status and Remarks **Justification**: Annex states AIDX improves "sharing of operational flight information" and handles "Disruption Detail" as a common data element.	**Standard**: **SIRI** **Element:** Situation Exchange Service (SX), incident descriptions **Justification**: Annex defines SIRI for "real-time information exchange," specifically the Situation Exchange (SX) for unplanned incidents.	Map SIRI Situation Exchange Service (SX) data to AIDX Disruption Detail and Status fields and use SIRI incident descriptions to populate AIDX Remarks for shared situational awareness	A monorail breakdown is detected via SIRI SX. The SIGN-AIR platform maps this alert to an AIDX update, notifying the airline that 50 transfer passengers will be late.

Terminal Transfer Navigation	**Standard: AMXM** **Elements:** Spatial layout, object identifiers **Justification:** Annex describes AMXM as a standard that provides "the spatial layout of an aerodrome in terms of features" such as geometry described as "points, lines, or polygons".	**Standard: IndoorGML** **Elements**: Cells and Spaces, Geometry, Topology, Levels and Floors. **Justification**: This standard is described in Annex as being able to provide a "cellular concept of space" for navigation where "space differs from Euclidean norms".	Map AMXM Spatial layout and Object identifiers to IndoorGML Cells and Spaces and Topology elements. Convert AMXM geometry features into IndoorGML Cellular space representations to enable navigation where Euclidean norms do not apply	The ROGER TC app guides the traveller through the terminal. The time spent navigating the IndoorGML path is used to confirm the passenger is on track for the next flight leg.

4.6 Achieving Technical Interoperability via TOMP API

While the formal standards discussed in the Annex (e.g., NeTEx, SIRI, OSDM, …) provide the necessary semantic and structural models for transport data, they are primarily focused on the informational aspect of multimodality, meaning that they oversee telling the traveller what is available and when. To achieve the transactional goals of SIGN-AIR, specifically G1 (Mobility Packages) and G3 (Disruption Management), a technical interface is required to handle the "handshake" between different providers. For this purpose, this section of the STAND document is dedicated to identifying the TOMP (Transport Operator to Mobility Provider) API as a potential enabler for this task.

4.6.1 Description of TOMP API

The TOMP API is an open-source, intermediate technical specification designed to standardise the interface between Transport Service Providers (TSPs) and Mobility-as-a-Service (MaaS) platforms or Travel Companions. It is a functional REST API specification based on the OpenAPI (Swagger) specification, which allows for rapid implementation across diverse IT environments (TOMP-API Working Group, 2023).

CEN/TS 16614-5 (NeTEx Part 5) acknowledges the necessity of such APIs for multimodal integration: "Mobility services are implemented by many different stakeholders in many different countries and there are a number of significant de facto standards being used for APIs. Such APIs provide dynamic services that are outside the scope of NeTEx, but which variously share common reference data".

The core of TOMP is its modular architecture, meaning that a TSP is not required to implement the entire specification but can select specific modules relevant to their service level:

- **Planning:** Allows the SIGN-AIR platform to query a TSP for real-time options, routes, and specific pricing (e.g., employee-specific tariffs specified in UC1).

- **Booking:** Facilitates the actual reservation of a seat, vehicle, or service, exchanging unique booking identifiers between the platform and the operator.
- **Trip Execution:** Handles the operational phase, such as digitally unlocking vehicles or validating a "Single Ticket" via a QR code.
- **Support and Monitoring:** Provides a standardised channel for reporting malfunctions or status changes.

4.6.2 Application within the SIGN-AIR Platform

The SIGN-AIR platform acts as a facilitating layer for Data Sharing Agreements. TOMP API assists in the technical execution of these agreements in three primary ways:

- **Enables Transactional Multimodality:** G1.3 (referring to Single Ticket implementation), requires a comprehensive contract covering successive transport services. Bookings of last mile taxis and car shares can be addressed by utilising the TOMP API, which will enable the ROGER Travel Companion to move beyond displaying an itinerary to executing the booking (TOMP-API Working Group, 2023).
- **Automated Disruption Management:** In the event of a vehicle breakdown or a localized delay in surface transport, the TSP can push a standardised notification via the TOMP API to the SIGN-AIR Monitoring Dashboard. Then the Smart Contracts can automatically calculate the impact on the passenger's mainline flight and suggest re-routing options via the Travel Companion. While traditional MaaS frameworks originally introduced these automated disruption principles primarily for surface and alternative transit (MaaS Alliance, 2020), SIGN-AIR can extend this API-driven disruption management to integrate with the commercial aviation sector.
- **Bridges the Gap between Aviation and Surface Transport**: A significant challenge, as detailed in Section 3.2 of this document, is the integration of aviation (IATA SSIM/NDC) with public transport. While aviation does not currently utilise TOMP, the utilisation of TOMP API as the target transactional format for multimodal integration involving air travel is proposed. The platform translates aviation retailing data (IATA NDC) into the transactional modules of TOMP. This ensures that a single payment from a traveller is correctly apportioned and a booking is secured across both an airline and a local mobility provider (e.g., in the context of Use Case 7 regarding new flight alternatives or Use Case 9 regarding eVTOLs). In other words, TOMP API can serve as a target format, the output standard that aviation data is translated into, by mapping the retailing capabilities of IATA NDC to the transactional modules of TOMP, ensuring that a single payment from a traveller is correctly apportioned and a booking is secured across both an airline and a local mobility provider.

4.6.3 Industry Alignment with TOMP API

The claim that TOMP API is a good fit for the SIGN-AIR platform is justified by its alignment with current European policy and industry trends:

- **Policy Compliance:** The European Commission's MMTIS Delegated Regulation (Regulation (EU) 2017/1926, amended by (EU) 2024/490) mandates the accessibility of data. TOMP is an industry-recognised method for making that data actionable for booking and distribution (European Commission, 2023).

- **Reduction of Integration Complexity:** TSPs had to develop custom APIs for every new partner. TOMP creates a "one-to-many" integration model, which aligns with SIGN-AIR's mission to reduce barriers for small TSPs to join multimodal chains (TOMP-API Working Group, 2023).
- **Complementary Nature:** TOMP API does not compete with NeTEx or OSDM, but complements them by handling the API-level communication that these data models describe.

4.7 Conclusions

A thorough investigation and mapping of data attributes between TSPs revealed that existing standards cover the necessary data exchanges for single ticketing, timetable synchronisation, and disruption management. The project assessed prominent and widely used standards across public transport, rail transport, air transport, road transport, as well as standards and specifications related to Mobility-as-a-Service (MaaS) to address the integration gaps in shared mobility and multimodality in a journey, including relevant security and privacy standards.

The analysis identified a core set of standards aligned with SIGN-AIR goals, including:

- GTFS: a widely used, lightweight data standard primarily designed for public transport timetables, routes, and geographic data in a structured format.
- NeTEx: a European public transport data standard designed for detailed, structured transport network and timetable data exchange.
- *Both GTFS and NeTEx support timetable data structuring and multimodal journey planning.*
- IATA SSIM: defines formats and procedures for the exchange of airline schedule data between airlines, airports, and other stakeholders.
- SIRI: standardised data exchange protocol developed to facilitate real-time information sharing in public transport networks, even real-time disruption management.
- Transmodel: A prominent public transport reference framework for organising and structuring data across various public transport domains.
- OJP: European data standard and API framework designed to enable distributed multimodal journey planning across different transport modes and service providers.
- OSDM: A rail-specific data format developed for long distance rail ticketing and distribution.
- NDC: an IATA-endorsed initiative that serves as a data transmission standard for airlines, aiming to enhance interactions with travel agents and other involved parties.
- PADIS: a technical specification for data exchange in passenger processing and airport management.
- AIDM: a unified data model for aviation operations to ensure consistency across systems and create interoperable messaging standards.
- AIDX: an aviation standard that facilitates standardised data exchange between airports, airlines, and other aviation stakeholders to improve the sharing of operational flight information.
- FIXM: a standard that focuses on exchanging flight-related data for air traffic management and flight operations, providing harmonised data structures for route descriptions.
- ISO 27001: Addressing security and privacy in transport data exchanges.
- ISO 24014-1: Defining architecture and rules for Interoperable Fare Management Systems.

Overall, the selected standards are well aligned with the defined goals. GTFS and NeTEx provide the fundamental data structures and formats for schedule alignment and data exchange, which are critical for the ticketing and timetable synchronisation goals (G1 and G2). IATA SSIM is essential for integrating aviation schedules into the multimodal framework, specifically supporting G2.2 and G2.3, while Transmodel and SIRI form the backbone for modelling public transport data and managing real-time updates, thereby addressing both ticketing (G1) and disruption management (G3). Information Security and Privacy Protection Standards, such as ISO 27001, ensure that data exchanges are secure and compliant, a necessity across all goals. ISO 24014-1 establishes the architectural framework for roles, rules, and processes in interoperable fare management, which underpins all operational goals. OJP, as part of the Transmodel ecosystem, facilitates API-based data exchanges across modes, being relevant for most goals except for the specific needs of disruption management (G3.2). Finally, OSDM—although primarily rail-focused—is considered for scenarios like single ticketing (G1.3) and expanding passenger reach (G2.2) where long-distance rail plays a significant role. In summary, these standards collectively address the diverse technical, operational, and security requirements needed for seamless multimodal integration, while providing a scalable foundation for future harmonisation efforts.

A significant conclusion of this STAND iteration is that harmonisation does not happen automatically but, as detailed in the use case analysis, specific data field mapping is required to bridge the gap between aviation (IATA SSIM, NDC, AIDX) and surface transport (GTFS, NeTEx, SIRI) standards and specifications. Tools like TransiTool are essential to automate these conversions.

While data standards (like NeTEx and OSDM) handle the informational aspect of multimodality, they do not fully address the transactional handshake required for booking and execution across providers. To address this, the TOMP API has been identified as a possible enabler for technical interoperability. It complements the data standards by managing the planning, booking, and trip execution phases, effectively bridging the gap between aviation retailing standards (NDC) and local mobility providers.

Finally, the investigation into use cases emphasised that interoperability must be secure. Beyond standard compliance with ISO 27001, the implementation of specific security principles is made as a suggestion for the secure exchange of sensitive passenger data between air and ground transport operators.

Furthermore, one can safely conclude that, achieving the SIGN-AIR goals goes beyond merely aligning data standards; it requires a comprehensive approach to interoperability that encompasses organisational, technical, and security and privacy dimensions. Effective contracts and collaborations must define clear processes and rules, ensure seamless integration of systems, and safeguard sensitive information while meeting regulatory requirements. Notably, privacy protection remains a critical challenge that demands meticulous integration into operational and legal frameworks. SIGN-AIR's holistic strategy addresses all these aspects, laying a robust foundation for true multimodal transport integration.

Rather than modifying existing standards or developing new ones, SIGN-AIR is focusing on leveraging well-established frameworks and employing harmonisation and transformation tools, such as TransiTool, to bridge gaps between different data formats. This approach ensures practical, scalable, and industry-aligned solutions, supporting multimodal integration without altering fundamental industry frameworks. Significantly, the project also addresses the challenge of selecting and applying the right standards in real-world use cases, ensuring secure, privacy-compliant, and effective data exchanges. The project will take up the challenge to demonstrate that interoperability challenges can be effectively addressed through robust data mapping, harmonisation techniques, and the integration of automated conversion mechanisms rather than modifying the standards themselves. By enabling seamless data exchanges across transport modes without altering fundamental industry frameworks, SIGN-AIR ensures practical, scalable, and industry-aligned, as well as secure and privacy regulation compliant solutions for multimodal transport integration.

TransiTool plays a crucial role in SIGN-AIR by acting as a data converter and validator, enabling seamless interoperability between different transport standards without requiring modifications to existing frameworks. Its core functionality lies in data digestion and transformation, such as converting IATA SSIM to GTFS, ensuring that aviation and public transport schedules align efficiently. By leveraging TransiTool for format bridging, SIGN-AIR avoids the complexity and industry-wide implications of proposing amendments to existing standards. Instead, it provides a practical, scalable, and adaptable solution that allows TSPs to work with their preferred standards while ensuring smooth data exchange. The flexibility of this approach aligns with industry needs, ensuring minimal disruption to legacy systems while achieving full interoperability across transport modes.

Lastly, in regard to future contributions for harmonisation between standards, while SIGN-AIR currently focuses on practical, project-specific data interoperability – achieved through data mapping and transformation tools like TransiTool – its work can lay the foundation for future, large-scale harmonisation efforts. True harmonisation goes beyond aligning data fields; it requires semantic consistency, governance frameworks, and widespread industry adoption. Since harmonisation becomes even more essential when bridging the gap between aviation and public transport**,** SIGN-AIR plays a pivotal role in addressing these gaps. It may not be creating or proposing the creation of new standards, but its methodology paves the way for deeper, formalised standardisation efforts in the future. By proving that multimodal integration is possible with existing standards and transformation tools, SIGN-AIR offers a low-risk, high-impact model that can be expanded upon by regulators, standardisation bodies, and mobility stakeholders.

5. Annex

The Annex provides a comprehensive overview of the standards relevant to the SIGN-AIR project, supporting its goals and the contractual and operational needs of Transport Service Providers (TSPs). It details the key standards applicable to the goals, as well as those with the potential for partial implementation based on specific project objectives. Additionally, it includes supplementary standards that, while not central to the immediate goals and use cases outlined in this STAND, may play a significant role in future harmonisation efforts and broader multimodal transport integration.

By presenting this extensive review, the Annex equips stakeholders with a broader understanding of the existing standardisation landscape, enabling informed decision-making and adaptability as project needs evolve. In the current, final STAND deliverable, these standards have been reassessed to reflect the project's finalised scope, implementation outcomes, and any emerging industry developments. This Annex is the result of meticulous research and in-depth analysis of multimodal transport standards, including those governing aviation, ensuring a solid foundation for the interoperability and scalability of the SIGN-AIR platform.

It is important to emphasise that the SIGN-AIR project and its developed solution do not seek to impose specific standards. Instead, this STAND document, and thus this extensive Annex, presents the results of extensive investigations, outlining existing standards while leaving the choice to TSPs. Each TSP remains free to determine which standards best align with its operational needs and requirements, legacy systems, and contractual agreements within the platform. SIGN-AIR serves as a facilitating layer, providing the technological means for reaching data sharing agreements and establishing smart contracts, but not dictating decisions beyond the scope of its solution.

5.1 Public Transport

According to UITP, the international association of public transport, Public Transport refers to any inland transport service that is advertised and available for use by the public (possibly under some conditions).[10] A public transport service can be scheduled or on demand. Examples of transport means in public transport for collective use are bus, tram, cable car, metro, train and ferry. Examples of transport means in public transport for shared and individual use are publicly accessible shared cars, shared bikes and shared e-scooters.

UIC, the international union of railways, uses a definition of public transport that is quite comparable with the UITP definition. A recent internal report of a UIC door-to-door mobility project enumerates the same transport modalities that are mentioned in the UITP definition, from the long-distance rail perspective but meant to be aligned with the perspectives of the other public transport modalities. Reflecting this multimodal focus, UIC is working on integrated mobility and developed the UIC Open Multi-Modal Toolkit (OMMT). OMMT is an open framework designed to facilitate cooperation among diverse transportation modes and service providers, enabling them to deliver a seamless end-to-end mobility experience for customers.

[10] This definition of Public Transport was discussed and agreed with UITP, the International Association of Public Transport.

Transmodel is a well-established EU reference standard that provides a structured data model for planned, real-time, and operational data across multiple public transport modes. The new version of the extensive Transmodel data framework, published in November – December 2025, adopts a wide definition of public transport which, as featured on the recently revised Transmodel website (https://transmodel-cen.eu/), also comprises waterborne transport and aviation services. Nevertheless, while Transmodel provides an excellent foundation, in the context of SIGN-AIR's use cases and goals, certain interoperability gaps emerge when integrating aviation, contractual frameworks, and emerging transport modes, requiring a complementary approach to standardisation. To be more specific, while Transmodel-based standards (NeTEx, SIRI, OJP) provide a solid foundation for public transport, they do not inherently support aviation standards (SSIM, AIDX) or fully cover cross-modal disruption coordination (G3.1, G3.2). Additionally, OSDM, though emerging as a key standard for ticketing and contractual agreements, remains incomplete in its integration with Transmodel.

Rather than recommending new standards or modifications to existing ones, SIGN-AIR adopts a practical harmonisation approach by mapping data attributes between standards and facilitating interoperability through transformation tools. TransiTool, as a key technical enabler, ensures that data from NeTEx, GTFS, IATA SSIM, and other relevant standards and specifications can be translated, normalised, and made interoperable, allowing TSPs to exchange information efficiently without modifying their legacy systems. For more technical details please refer to the TS/IRS document.

These standards and specifications are applied across various use cases in SIGN-AIR.. See subsection 4.5 (Applying standards to use cases), for further information.

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5.1.1 ISO 24014-1 – Interoperable Fare Management System (IFMS)

Table 4: Overview of ISO 24014-1 IFMS

Name	ISO 24014-1:2021 Public transport – Interoperable fare management system – Part 1: Architecture
Official Website	https://www.iso.org/standard/72507.html
Managing Organisation	ISO
Standard Type	IS, International Standard
Exchange Data File	None; the standard contains an architecture
Introduction	This document gives guidelines for the development of multi-operator/multi-service interoperable public surface (including subways) transport fare management systems (IFMSs) on a national and international level. This document is applicable to bodies in public transport and related services which agree that their systems need to interoperate.

	This document defines a conceptual framework which is independent of organisational and physical implementation. Any reference within this document to organisational or physical implementation is purely informative.
Overview	This document defines a reference functional architecture for IFMSs and establishes the requirements that are relevant for ensuring interoperability between several actors in the context of the use of electronic tickets. The IFMS includes all the functions involved in the fare management process, such as: • management of media, • management of applications, • management of products, • security management, and • certification, registration, and identification. This document defines the following main elements: • identification of the different sets of functions in relation to the overall IFMS and services and media from non-transport systems which interact with fare management systems; • a generic model of an IFMS describing the logical and functional architecture and the interfaces within the system, with other IFMSs and with services and media from non-transport systems; • use cases describing the interactions and data flows between the different sets of functions; • security requirements. In its annexes, this document provides a framework for mobility platforms that integrate fare management and travel information for inter- and multimodal travel (see Annex A). It also elaborates on specific subjects covered in document and offers some national examples with regard to IFMS implementations (see Annex B, Annex C, Annex D and Annex E). This document does not define: • the technical aspects of the interface between the medium and the medium access device; • the data exchanges between the medium and the medium access device (NOTE: the data exchanges between the medium and the medium access device are proposed by other standardisation committees); • the financial aspects of fare management systems (e.g., customer payments, method of payment, settlement, apportionment, reconciliation).
Benefits	In the past years, ISO 24014-1 has been implemented in a number of countries like France, Germany, the United Kingdom and Japan.

	Fare management comprises all organisational and technical processes related to the distribution and use of fare products (i.e. tickets, travel entitlements) in a public transport environment including appropriate measures related to security and data protection. Fare management is interoperable when the traveller is enabled to use a medium that is able to communicate with ticketing devices. Examples of media are a smartcard or a smartphone. Examples of ticketing devices are fare gates to tap in when entering or tap out when exiting railway stations or equipment to tap-in or tap-out when entering or exiting a vehicle. Precondition for interoperable fare management is an overall system architecture that comprises a common definition of processes as well as roles and rules with regard to actors involved in the fare management ecosystem. This can serve as a basis for commercial and legal agreements between cooperating public transport parties. Interoperable fare management offers benefits to travellers like convenience (e.g., special and combined fares), well-guided travel with different transport modalities as well as seamless travel within the boundaries of the interoperable transport ecosystem. Benefits for public transport authorities and public transport operators relate to better traveller service, improved efficiency and smoother procurement as many public transport parties as well as suppliers know and understand the standard. In addition, the standard contributes to widening interoperability between different fare management systems. An IFMS is a closed ecosystem but can be linked with other IFM systems after agreeing of cooperating parties on organisational roles and rules as well as technical matters, security and data protection measures to be taken. Cooperative IFMSs can span regions but can also cross country boundaries and may also be widened to an international scale.
Actual status	The crucial reference data framework Transmodel standard CEN EN 12896 was aligned with ISO 24014-1. New ISO technical reports related to mobility integration including Mobility-as-a-Service (MaaS) were also aligned with ISO 24014-1. Please refer to ISO TR 4447, ISO TR 7878 and ISO TR 22625. Right now, Norway is widening interoperability of yet fragmented IFM systems on a national scale. In Japan, 10 IFM systems are being connected in order to offer seamless travel in the whole country. In addition, since some years, almost all European countries work on national interoperable travel solutions. CEOs of public transport scheme providers in a

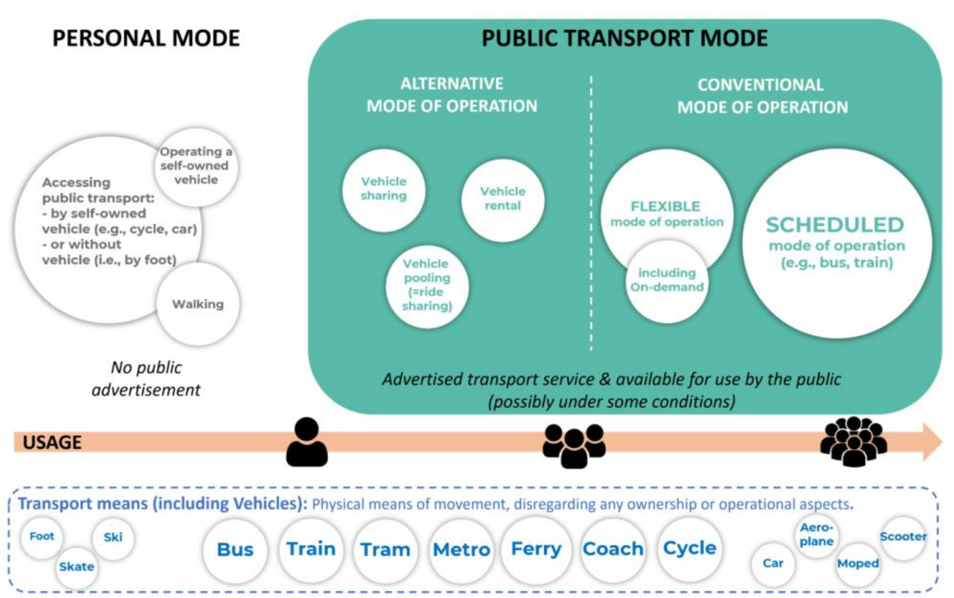
	number of countries share information about these developments with each other. Right now, seamless travel beyond borders is yet only visible in some small-scale pilots but international cooperation intensifies. The IFMS standard serves as a basic standard for such cooperation also across country borders. At this time, a new ISO technical report ISO TR 24852 is being prepared related to ISO 24014-1. The actual version of the standard is, in principle, based on a situation where lots of data are being dealt with locally, like in ticketing gates and smartcards. With account-based ticketing (ABT), the bulk of data will be dealt with in remote servers and by way of far more central processing. The new ISO report will describe what roles, rules, processes and interfaces may be different related to account-based ticketing, also called server-based ticketing (SBT).
Common Data Elements	N/A

5.1.2 Transmodel – Public Transport Reference Data Model

Table 5: Overview of Transmodel

Name	CEN EN 12896 (Transmodel) – Public Transport – Reference Data Model
Official Website	https://www.transmodel-cen.eu/
Managing Organisation	CEN-CENELEC
Standard Type	EN Technical Specification
Exchange Data File	None; Transmodel is a conceptual model
Introduction	Transmodel provides an abstract model of common public transport concepts and data structures that can be used to underpin many different kinds of public transport information systems, in particular in the domain of public transport network management, timetabling, vehicle scheduling, fares management, operations monitoring and control, trip planning, driving personnel management. Transmodel is designed for multimodality: it covers both **conventional** (i.e. scheduled and flexible) and **alternative** (e.g., vehicle sharing, taxis) modes of operations. The figure below represents what Transmodel covers (in green) and its definition of Public Transport. By default, Transmodel does not cover any personal mode of transport. Currently the needs of the land transport means, such as bus, tramway, light-rail, metro, coach, long distance rail, are taken into account. Other land transport

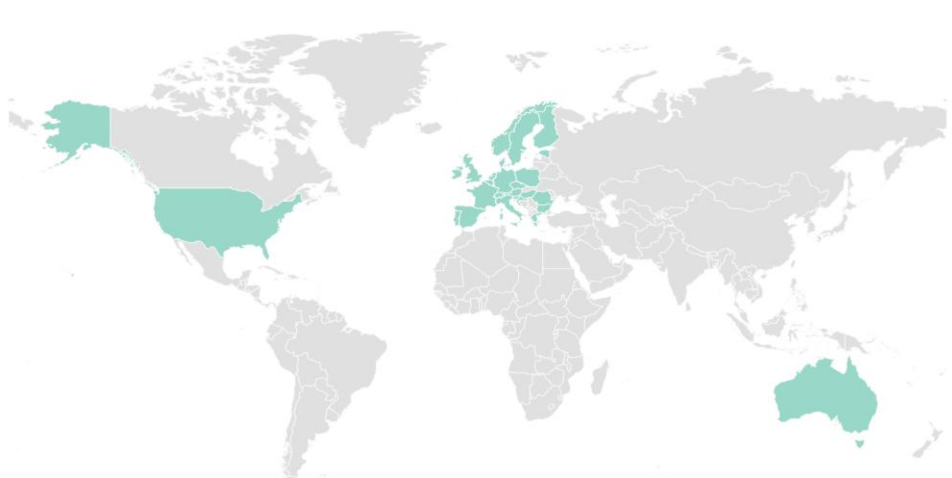
means, such as cars, (e-)cycles, (e-)scooters, etc. are only considered in the context of vehicle sharing, vehicle pooling or vehicle rental but not within a purely personal operation. Transmodel also covers in principle other means of public transport which are not based on land transport, but waterborne (e.g., maritime cabotage, vaporetto, some local ferries) or used for air services (e.g., airplanes).



Transmodel data structures are currently implemented as data exchange standards: NeTEx for planned (static) data, SIRI for real time (dynamic) data, OpRa for observed data, or are used by APIs (e.g., OJP). This means that Transmodel is implemented wherever NeTEx, SIRI, OJP, OpRA are implemented. To be noted that a number of European countries under the obligation of the **European Delegated Regulation (EU) 2024/490 (MMTIS)** (updating the DR EU 2017/1926) which have implemented National Access Points provide their Multimodal Travel Information using Transmodel-based formats.

What are the countries involved in Transmodel development and implementation?[11]

[11] https://transmodel-cen.eu/

	
Overview	Public transport services rely increasingly on information systems to ensure **reliable, efficient operation and widely accessible, accurate passenger information**. These systems are used for a range of specific purposes, in particular: setting schedules and timetables, managing vehicle fleets and driving personnel, providing access rights to transport services, validating and controlling the acquired access rights entered on travel documents, providing real-time information on service running, calculating the best trip options according to user preferences. **“Transmodel” is the short name for the European Standard “Public Transport Reference Data Model”** (EN 12896). It improves a number of features of public transport information and service management. In particular, the standard facilitates interoperability between the information processing systems of the transport operators and agencies by using matching definitions, structures and meanings for their data for the component systems. This applies both when connecting different applications within an organisation, and when connecting applications between collaborating organisations (for instance, a public authority and a transport operator). **The Transmodel standard provides a framework for defining and agreeing data models**, and covers the whole area of public transport operations. By making use of this European Standard, and of data exchange formats derived from it, **it is possible for operators, authorities and software suppliers to work together much more easily towards integrated systems**. Moreover, the breadth of the standard helps to ensure that future systems’ developments can be accommodated with a minimum of difficulty.[12]
Parts of this standard series	1. Common concepts 2. Public transport network 3. Timing information & vehicle scheduling 4. Operations monitoring & control

[12] https://transmodel-cen.eu/index.php/purpose/

	5. Fare management 6. Passenger information 7. Driver management 8. Management information & statistics 10. Alternative modes One additional part complements this series: Part 9 – Informative documentation (CEN TR 12896-9).
Benefits	The Transmodel standard establishes a framework for delineating and concurring upon data models, encompassing the entire scope of public transport operations. Through adoption of this European Standard and its resultant data models, operators, authorities, and software providers can collaborate more effectively to create integrated systems. Furthermore, the comprehensive nature of the standard ensures that forthcoming advancements in system development can be accommodated with minimal complications.
Common Data Elements	Service Journey, Line, Transport mode, Vehicles, Stop places, Accessibility Assessment, Scheduled Stop Point, Quay, Journey Pattern, Vehicle Journey, Operating day, Service journey, Block, Driver, Duty, Operator, Agency
Actual status	Transmodel is a reference data model. This means that it is not necessary for individual systems or specifications to implement Transmodel as a whole. When designing, developing and supplying information systems for public transport, Transmodel may be distilled, refined, or adapted to form a comprehensive data model for the organisation and/or for the product suite. As a reference data model, Transmodel is particularly suited to specify the information architecture of an organisation, databases as well as data exchange interfaces. In the last few years, much work was done to align the reference standard Transmodel with • NeTEx (Network Timetable Exchange, 5.1.3) • SIRI (Service Interface for Real-time Information, 5.1.4) and, to a lesser extent, • OJP (Open API for Distributed Journey Planning, 5.1.5) and • OpRa (Operating Raw Data and Statistics Exchange, 5.1.6). This work was carried out in order to create more coherence between these frameworks towards what is called now the Transmodel ecosystem. Transmodel was not just aligned only within the Transmodel ecosystem. Alignment was carried out with quite some other standards like • ISO 24014-1 (Interoperable Fare Management System (IFMS), 5.1.1)

	• GTFS (General Transit Feed Specification, 5.1.x) • Integrated mobility standards: ISO TR 4447 (5.2.1), ISO TR 7878 (5.2.2) and ISO TR 22625 (5.2.3) • Rail transport standards. OSDM (Open Sales and Distribution Model, 5.3.1) is a key example • Road traffic standards like DATEX II (Data exchange specifications for traffic management and information) • Parking standards, e.g. CEN TS 16157-6 (Parking publications) • Aviation standards – as far as alignment was made possible. Aligning with IATA aviation standards was less successful as IATA standards were considered proprietary and confidential – but space-related topologic components could be aligned in some degree within the scope of the INSPIRE directive. A range of new versions of Transmodel standard documents with major changes and alignments of content of documents within the Transmodel standard series, with other European standards like NeTEx as well as with other data frameworks like OSDM and GTFS, while including a much more elaborated data dictionary, was published in November/December 2025. From 2020 until 2024, in an informal liaison with the responsible European standardisation working group CEN TC278 WG3, the **DATA4PT** project[13] has been supporting the development of data exchange standards and models in order to advance data-sharing practices in the public transport environment. Key goal of the project was to contribute to interoperability and a seamless door-to-door travel ecosystem across Europe covering all mobility services including public transport and Mobility-as-a-Service. Transmodel is working together with the **NAPCORE** project[14]. NAPCORE (National Access Point Coordination Organisation for Europe) is the name of the formed organisation to coordinate and harmonise more than 30 mobility data platforms across Europe. Existing National Access Points (NAPs) are quite different in their setup and data access interfaces. Also, the data formats and standards used differ throughout Europe. To work on a better alignment the NAPCORE project was launched as coordination mechanism to improve interoperability of the National Access Points as backbone of European mobility data exchange. NAPCORE improves the interoperability of mobility data in Europe with mobility data standard harmonisation and alignment. Also, NAPCORE increases access and expands availability to mobility related data by coordinated data access and better harmonisation of the European NAPs. Furthermore, NAPCORE empowers National Access Points and National Bodies by defining and implementing common procedures and strategy, strengthening the position and the role of NAPs, supporting steps towards the

[13] https://data4pt-project.eu/about/

[14] https://napcore.eu/

creation of European-wide solutions to better facilitate the use of EU-wide data.[15] These activities comprise an aligned glossary and data definitions.

Key components of NAPCORE for fares are NeTEx and OSDM. Key components of NAPCORE for timetables are NeTEx and MERITS Edifact.

Parties in NAPCORE are working on some strategic themes:

- Parking: alignment between ADPS (Alliance for Parking Data Standards), DATEX II and Transmodel
- Cycling: mapping of GBFS and NeTEx, alignment of national implementations
- Rail: Mapping messages on timetables (Edifact and NeTEx) and tariffs (OSDM and NeTEx)
- Training programs and tools to support implementation of multimodal EU standards.

The second phase of the project, NAPCORE-X, was started on 1 July 2025.

NAPCORE-X will be a continuation of NAPCORE and DATA4PT:

- Project will run from mid-2025 until end 2027
- Project will focus stronger on multimodality
- European directory of public transport stops
- Harmonising national profiles
- Offering recommendations for the Transmodel ecosystem.

In 2023, the **CoRoM** project was started. According to the project summary, the objective of CoRoM is to facilitate the interoperability of data exchanges between the various stakeholders involved in public transport trips, including the "first and last mile" legs of the travel. The work is expected to improve attractiveness and efficiency of the public transport offer and ecosystem across Europe. Specifically, it will address existing lack of interoperability between different data models used by different stakeholders in the public transport ecosystem. The work will focus on (1) ticketing and (2) timetables. The CoRoM project complements the EU projects DATA4PT and NAPCORE, offering a way to identify the remaining gaps and to develop a means of ensuring the expected level of interoperability.[16]

The most recent version of part 1 of the Transmodel standard series (December 2025) summarises the activities of the CoRoM work as: undertaking work on fare data with the objective of recommendations to

[15] https://napcore.eu/.

[16] https://www.cencenelec.eu/media/CEN-CENELEC/News/CallForTender/Documents/2023/COROM/projectplan.pdf

	achieve interoperability of fare data in OSDM for rail with Transmodel-based and other formats mainly in the context of distribution APIs. It also adds the following information: The project work on comparing OSDM and other formats will lead to the publication of a Technical Report for the building of Purchase (including basic after sales) interfaces using Transmodel. It should also result in updates for Transmodel Parts 5 and 6. End of June 2025, the Technical Report, one of the main deliverables of the CoRoM project, with the title "Public transport – Guidelines for building multimodal travel purchase APIs based on Transmodel" was distributed in a comment version within the CEN standardisation environment. Formal publication is to be expected. The scope of the project includes both "conventional" public transport and "alternative modes". The CoRoM project relates to pre-normative activities preparing for changes in existing standards or proposals for new work items for standards. Deliverables contain high-level mappings of recommendations for API development. Adapting Transmodel part 5 on Fare management and NeTEx part 3 Public Transport Fare Exchange Format is part of the project goals. At the beginning of this project, discussions about the OSDM API took off. In a first report, a high level comparison between Transmodel and OSDM on the level of functional coverage was carried out. The basic comparison was continued and additional requirements from EU Commission were included, among others: to specify an API for sales, booking and payment. In elaborating subjects like these further, CoRoM comprises more than Fare management, which is the subject of Transmodel part 5. The traveller experience is key here: travellers must enjoy the opportunity to have a ticket and travel document "in a one-stop-shop" instead of having to surf along a number of websites and/or make several calls to arrange their trip. Another challenge (to be addressed later on) is how to guarantee a seamless trip for travellers, which includes legs and combinations of legs of a trip. Queries are an important tool. The project delivers a list of queries – which is considered to be an API. Reason of this is: an API is based on queries or a combination thereof – to be based on APIs as they exist now. Right now, quite a number of countries in Europe have implemented Transmodel to a certain extent.[17] EU DG MOVE expressed expectations and focuses on further developments and implementations of Transmodel-based standards in order to ensure

[17] https://transmodel-cen.eu

	consistency and interoperability in data exchanges as the way forward towards seamless integrated transport in Europe.

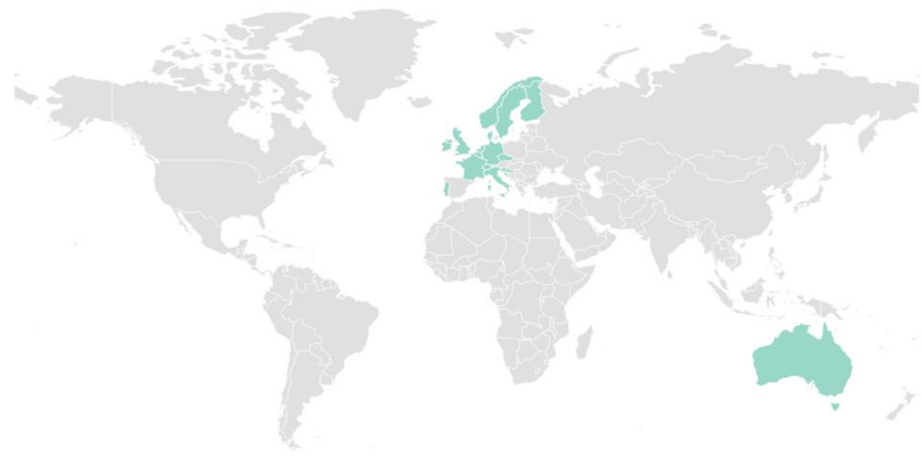
5.1.3 NeTEx – Network Timetable Exchange

Table 6: Overview of NeTEx

Name	CEN TS 16614 (NeTEx): Public Transport – Network Timetable Exchange (NeTEx)
Official Website	https://transmodel-cen.eu/index.php/netex/
Managing Organisation	CEN-CENELEC
Standard Type	Technical Specification
Exchange Data File	Extensible Markup Language (XML)
Introduction	What is NeTEx? NeTEx (**Ne**twork **T**imetable **Ex**change) is a CEN Technical Standard for exchanging Public Transport schedules and related data. NeTEx provides a means to exchange data for passenger information such as stops, routes timetables and fares, among different computer systems, together with related operational data. It can be used to collect and integrate data from many different stakeholders and to reintegrate it as it evolves through successive versions. More information can be found on the NeTEx Github[18].
Overview	NeTEx is intended to be a general purpose XML format designed for the efficient, updatable exchange of complex transport data between distributed systems. This allows the data to be used in modern web service architectures and to support a wide range of passenger information and operational applications. While there are a number of standards for timetables, NeTEx is the first systematically developed standard that also covers multimodal fares. The NeTEx scheme is freely usable under a GPL licence and its development is controlled by the CEN standards process. For additional details on national NeTEx profiles, please visit the DATA4PT Wiki[19].

[18] https://github.com/NeTEx-CEN/NeTEx

[19] https://data4pt.org/w/index.php?title=National_Implementations#NeTEx_national_profiles_inventory_%F0%9F%8C%90



All six parts covered by NeTEx use the same framework of reusable components, versioning mechanisms, validity conditions, global identification mechanisms, etc., defined in a NeTEx framework in Part 1. NeTEx also includes container elements called "version frames" to group data into coherent sets for efficient exchange.

NeTEx schema can thus be used to exchange:

- Public Transport schedules including stops, routes, departures times / frequencies, operational notes, and map coordinates
- Routes with complex topologies such as circular routes, cloverleaf and lollipops, and complex workings such as short working and express patterns; connections with other services can also be described.
- The days on which the services run, including availability on public holidays and other exceptions
- Composite journeys such as train journeys that merge or split trains
- Information about the Operators providing the service
- Additional operational information, including positioning runs, garages, layovers, duty crews, useful for AVL and on-board ticketing systems
- Data about the Accessibility of services to passengers with restricted mobility
- Data is versioned with management metadata allowing updates across distributed systems
- Fare structures, (flat fares, point to point fares, zonal fares)
- Fare products (single tickets, return tickets, day, and season passes, etc.)
- Fare prices that apply at specific dates.

How is NeTEx used?

Data in NeTEx format is encoded as XML documents that must conform exactly to the schema – conformance can be checked automatically by standard XML validator tools. The schema can also be used to create bindings to different

	programming languages to assist automating part of the implementation process for creating software that supports NeTEx formats. A NeTEx service only needs to implement the elements that are relevant to its business objectives – extraneous elements present in the binding can be ignored. Parties using NeTEx for a particular purpose will typically define a "profile" to identify the elements that must be present, and the code sets to be used to identify them. How is data exchanged between systems? Documents in NeTEx format are computer files that can be exchanged by a wide variety of protocols (http, FTP, email, portable media, etc). NeTEx publication documents can be used to define files suitable for the bulk exchange of XML documents representing whole data sets (for example all the timetables for an operator). In addition, a SIRI based NeTEx protocol is specified for use by online web services. It defines NeTEx request and response messages that can be used to request and return data in NeTEx format, and also publish/subscribe messages for push distribution. The responses return a NeTEx XML document that satisfies the request criteria (and also conforms to the NeTEx schema). There is a WSDL binding for this NeTEx service to make it easy to implement services. Information about the various existing tools can be found in the wiki[20].
Parts of this standard series	NeTEx is divided into six parts, each covering a functional subset of the CEN Transmodel for Public Transport Information: • Part 1 describes the Public Transport Network topology (CEN/TS 16614-1:2014) • Part 2 describes Scheduled Timetables (CEN/TS 16614-2:2014) • Part 3 covers Fare information (CEN/TS 16614-3:2015) • Part 4 European Passenger Information Profile – EPIP (CEN/TS 16614-4:2017) • Part 5 Alternative modes exchange format (CEN/TS 16614-5:2021) • Part 6 European Passenger Information Accessibility Profile – EPIAP (CEN/TS 16614-6:2024). In addition to CEN Specification documents (listed above), NeTEx deliverables also comprise: • A data model presented in UML notation and available in electronic form that can be viewed with design tools; • A W3C XML schema providing a formal electronic description that can be used by data processing software. Some example XML documents

[20] https://data4pt.org/w/index.php?title=NeTEX

	encoding different transport data sets are also provided with the schema. Material can be found in NeTEx Github.
Benefits	• Reducing development and support costs • Increasing function and design quality • Reducing complexity • Protection of investment
Common Data Elements	Public Transport schedules including stops, routes, departures times / frequencies, operational notes, and map coordinates, Routes, Connections, days of operation, composite journeys such as train journeys that merge or split trains, agency information, positioning runs, garages, layovers, duty crews, useful for AVL and on-board ticketing systems, accessibility information, Fare structures, Fare products and vehicle data.
Actual status	In the last few years, much work was done to align the data frameworks Transmodel, NeTEx, SIRI and, to a lesser extent, OJP and OpRa. This work was carried out in order to create more coherence between these frameworks towards what is called now the Transmodel ecosystem. In October 2025, parts 1, 2, 3, 4 and 5 of the NeTEx standard series were published in a new version. Alignment between Transmodel and NeTEx was quite intensive and this includes that all standards from another source that were linked with Transmodel also were related to NeTEx (see Transmodel description). NeTEx standardisation information adds that NeTEx also linked with GBFS (General Bikeshare Feed Specification) and made some changes to align with IXSI (carsharing interface). In addition, NeTEx takes into account the requirements formulated by the ERA (European Rail Agency), TAP/TSI (Telematics Applications for Passenger/ Technical Specification for Interoperability, entered into force on 13 May 2011 as the Commission Regulation (EU) No 454/2011), based on UIC directives. Right now, a number of countries in Europe have implemented NeTEx to a certain extent.[21] EU DG MOVE expressed expectations and focuses on further developments and implementations of Transmodel-based standards in order to ensure consistency and interoperability in data exchanges as the way forward towards seamless integrated transport in Europe. At this time, all 6 parts of the NeTEx standard series are Technical Specifications. DG MOVE expects that all these parts will be European standards (EN) within 3 years: end of 2028. The reason for this requirement, as EU DG MOVE explained, is that CEN Technical Standards (TS) may be adopted as national standards but

[21] See also: https://data4pt.org/w/index.php?title=National_Implementations#NeTEx_national_profiles_inventory_%F0%9F%8C%90

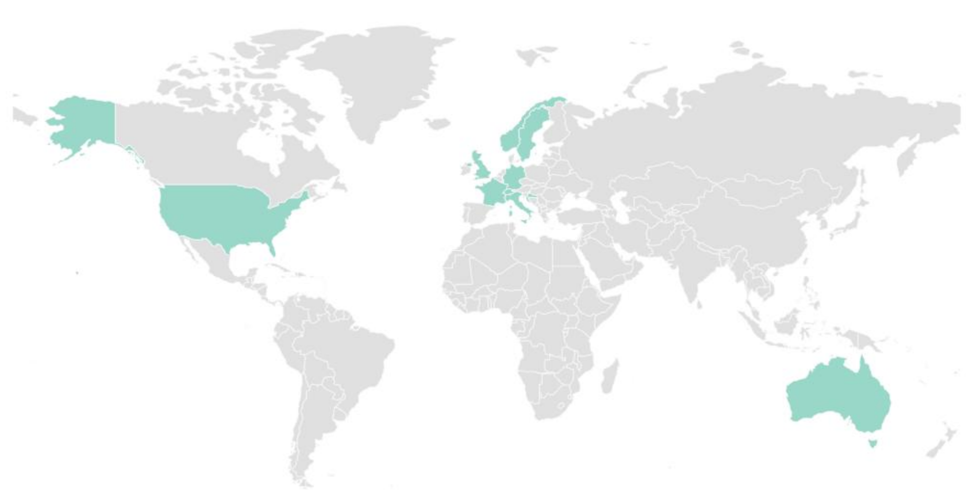
	that, then, conflicting national standards may continue to exist. European Standards (EN) are required key components of the Single European Market. According to expectations of EU DG MOVE, NeTEx part 7 (EU Fare Profile) is going to be developed as a new Technical Specification (TS) until September 2027. After achieving this result, this TS will be developed further as a European standard (EN) until end of 2029.

5.1.4 SIRI – Service Interface for Real-time Information

Table 7: Overview of SIRI

Name	CEN TS 15531 (SIRI): Service Interface for Real-time Information
Official Website	https://transmodel-cen.eu/index.php/siri/
Managing Organisation	CEN-CENELEC
Standard Type	Technical Specification
Exchange Data File	Extensible Markup Language (XML)
Introduction	SIRI is a European standard that enables real-time information about public transportation to be shared between different computer systems. It is used by many different organisations, including public transportation operators, traffic management agencies, and travel information providers.
Overview	For additional details on national SIRI profiles, please visit the DATA4PT Wiki[22].

22 https://data4pt.org/w/index.php?title=National_Implementations#SIRI_National_profiles_inventory_%F0%9F%8C%90



What sort of information does SIRI exchange?

SIRI allows pairs of server computers to exchange structured real-time information about schedules, vehicles, and connections, together with general informational messages related to the operation of the services.

SIRI is a natural complement to NeTEx, NeTEx providing the scheduled information and SIRI the real time one. Both SIRI and NeTEx share a common conceptual model provided by Transmodel.

The information provided by SIRI can be used for many different purposes, for example:

- To provide real time-departure from stop information for display on stops, internet and mobile delivery systems;
- To provide real-time progress information about individual vehicles;
- To manage the movement of buses roaming between areas covered by different servers;
- To manage the synchronisation of guaranteed connections between fetcher and feeder services;
- To exchange planned and real-time timetable updates;
- To distribute status messages about the operation of the services;
- To provide performance information to operational history and other management systems.

SIRI Services

SIRI comprises eight different concrete services, each consisting of request and delivery message pairs, and all using a common architecture, terminology, reference data:

Production Timetable Service: Supports the dynamic exchange of planned schedules for a specific day, including updates (update of a calendar based schedule, most often previously exchanged with NeTEx). These may be used by AVMS systems to predict and monitor vehicle progress.

	Estimated Timetable Service: Supports the exchange of estimated schedules in real time, including updates. These may be used by AVMS systems to predict and monitor vehicle progress. **Stop Timetable Service**: Provides information about schedules for arrivals and departures at a Stop point. **Stop Monitoring Service**: Provides information about arrivals and departures at a Monitoring, i.e. Stop point. It has a similar scope as the Production Timetable service but with a stop centric point of view. **Vehicle Monitoring Service**: Provides information about the movement of a vehicle, and its progress against the target schedule. **Connection Timetable Service**: Provides information about schedules for interchanges at a connection point. **Connection Monitoring Service**: Provides information for interchanges at a connection point to support guaranteed connection services. **General Message Service**: Supports the exchange of general text messages (usually related to a stop, a line, etc.). **Situation Exchange Service**: Covers the exchange of information describing an incident, typically an unplanned event such as a disruption, but also planned events that affect public transport or its use, such as engineering works, or major public events that will affect the use or availability of transport. This information is structured in a way that makes it usable by a journey planner in its optimisation algorithm. **Facility Monitoring Service**: Covers the exchange of information concerning the current status of facilities (equipment, sites, etc.). It provides a short description of the facility itself, the availability status and specifically the impact of the availability status for various categories of disabled or incapacitated people. How is SIRI used? Each system wishing to exchange information implements the SIRI protocols as XML services (JSON is also available, but mostly targeted for end-user's devices). SIRI comprises a general communications architecture, and a number of specific services which operate within that architecture. The communications architecture supports two different patterns of interchange: • A synchronous request/response protocol: each exchange of data consists of a request message from a client consumer, and a response message from a producer server. • An asynchronous subscribe/publish protocol: the client subscribes to information by sending a message to the server containing both request information, and sensitivity criteria with which to filter messages. The

	producer server establishes a subscription for the consumer and will send messages back to the consumer whenever the criteria are satisfied, until the subscription ends. This pattern is 'stateful', that is to say, both parties in the interaction must manage the use of subscriptions that persist over time through successive interactions. In both cases messages consist of XML documents, whose tags and content are exactly specified by the SIRI XML Schemas. SIRI allows implementers to make different trade-offs as to message size, use of bandwidth, frequency of update, verbosity of data, sensitivity to change, etc. This is reflected in particular in support for two different patterns of message exchange to return data from a producer server to a consumer client: • A direct delivery protocol: the data returned in response to a request or subscription consists of a single delivery message, sent directly from the producer server to a client consumer. • A fetched delivery protocol: the data returned in response to a request or subscription is delivered through an exchange of messages, comprising a notification from the producer server to a client consumer, followed by a request / response interaction from the consumer to the client to fetch the actual payload data. This is also a stateful pattern of communication. SIRI also has services to monitor the system status and to provide basic information on reference data such as stops, lines, etc. Information about the various existing tools can be found in the wiki[23].
Parts of this standard series	SIRI is divided into seven parts, each covering a functional subset of the CEN Transmodel for Public Transport Information: • Part 1 describes Context and Framework (EN 15531-1:2015) • Part 2 describes Communications (EN 15531-2:2015) • Part 3 describes Functional Service Interfaces (EN 15531-3:2015) • Part 4 describes Functional Service Interfaces: Facility Monitoring (CEN/TS 15531-4:2011) • Part 5 describes Functional Service Interfaces: Situation Exchange (CEN/TS 15531-5:2016) • Part 6 describes Functional Service Interfaces: Control Actions (CEN/TS 15531-6:2024) • Part 7 describes the European Real Time Passenger SIRI Information Profile (CEN/TS 15531-7:2024) – under approval process.
Benefits	**Real-Time Updates:** SIRI enables the delivery of real-time information about public transport services, including vehicle locations, arrival predictions, and service alerts. This information allows passengers to stay informed about the

[23] https://data4pt.org/w/index.php?title=SIRI

	current status of their journeys, reducing uncertainty and improving their travel experience. **Enhanced Passenger Experience:** By leveraging SIRI, transit agencies and application developers can create passenger-facing applications that provide accurate and up-to-date information. Passengers can access real-time arrival times, service disruptions, and alternative routes, enabling them to make informed decisions and plan their trips more efficiently. **Multi-Modal Integration:** SIRI supports the integration of real-time information across different modes of transportation, such as buses, trains, trams, and ferries. This integration allows passengers to view and plan their journeys seamlessly, even when using multiple modes of transport, promoting the use of public transportation as part of a connected transportation network. **Standardisation and Interoperability:** SIRI establishes a common standard for real-time information exchange, ensuring compatibility and interoperability between different systems and stakeholders. It simplifies the integration of real-time data from various sources, making it easier for transit agencies, application developers, and other stakeholders to collaborate and share information. **Dynamic Service Management:** SIRI facilitates dynamic service management by allowing transit agencies to send service updates, notifications, and alerts to both passengers and operational staff. This capability enables proactive management of service disruptions, changes in schedules, or other operational issues, leading to better service reliability and responsiveness. **Efficient Resource Utilisation:** SIRI enables transit agencies to monitor and manage their fleets more effectively. By having real-time visibility into vehicle locations and operational data, agencies can optimise their resources, improve dispatching, and respond more efficiently to changing conditions, ultimately leading to more reliable and efficient public transport services.
Common Data Elements	Production Timetable Service, Estimated Timetable Service, Stop Timetable Service, Stop Monitoring Service, Vehicle Monitoring Service, Connection Timetable Service, Connection Monitoring Service, General Message Service, Situation Exchange Service, Facility Monitoring service
Actual status	In the last few years, much work was done to align the data frameworks Transmodel, NeTEx, SIRI and, to a lesser extent, OJP and OpRa. This work was carried out in order to create more coherence between these frameworks towards what is called now the Transmodel ecosystem. The EU DATA4PT project, briefly described in the Transmodel description, was also focussed on support for SIRI. Right now, a number of countries in Europe have implemented SIRI to a certain extent.

EU DG MOVE expressed expectations and focuses on further developments and implementations of Transmodel-based standards in order to ensure consistency and interoperability in data exchanges as the way forward towards seamless integrated transport in Europe.

At this time, some parts of the SIRI standard series are Technical Specifications. DG MOVE expects that these parts, parts 4-7, will be European standards (EN) within 3 years: end of 2028. The reason for this requirement, as EU DG MOVE explained, is that CEN Technical Standards (TS) may be adopted as national standards but that, then, conflicting national standards may continue to exist. European Standards (EN) are required key components of the Single European Market.

5.1.5 OJP – Open API for Distributed Journey Planning

Table 8: Overview of OJP

Name	CEN TS 17118 (OJP): Open API for distributed journey planning
Official website	https://transmodel-cen.eu/index.php/ojp/
Managing Organisation	CEN-CENELEC
Standard Type	Technical Specification
Introduction	What is OJP? The Open Journey Planner (OJP) is a standardised framework designed to improve journey planning by providing access to multi-modal transport data. It enables users to plan trips that involve various forms of transportation – such as buses, trains, trams, ferries, or even bicycles and walking – across different transport operators and regions. OJP offers a flexible and open interface that allows for seamless integration of real-time and scheduled transport information, making it easier to coordinate complex trips across different systems. Key features **Multi-Modal Travel Planning:** Supports trips that involve different modes of transportation, ensuring efficient connections and providing a cohesive experience for travellers. **Real-Time Data Integration:** Leverages real-time transport data to offer accurate and dynamic travel plans. **Distributed Planning:** OJP supports distributed journey planning, which means that trip plans are generated by combining data from multiple, independent sources. Instead of relying on a single centralised system, OJP can query different transport providers and systems in real-time to deliver a

	comprehensive, multi-modal travel plan. This distributed architecture ensures flexibility, scalability, and better data integration across various networks. **Interoperability:** Allows for communication between different transport operators and systems, improving the flow of data and making it easier to manage transport services across regions or countries. More information can be found on the OJP GitHub[24].
Overview	The Open Journey Planner (OJP) is built on the foundations of Transmodel, the European reference data model for public transport. Transmodel defines the structure and semantics of public transport information, ensuring uniformity across systems. OJP utilises these standardised data models, which guarantees compatibility and interoperability between different transport operators and systems, making it easier for them to collaborate and share data. The development of OJP aligns with the European Commission's Delegated Regulation (EU) 2017/1926, which mandates the provision of EU-wide, multimodal travel information services (MMTIS), amended by Regulation (EU) 2024/490. This regulation is part of the broader Intelligent Transport Systems (ITS) Directive (2010/40/EU), aimed at establishing an integrated framework for smarter transport services in the EU. The regulation requires member states to ensure that comprehensive, accurate, and multimodal travel information is accessible across Europe. By adhering to these regulations, OJP contributes to the creation of an interoperable and seamless travel information network across the EU, allowing travellers to access trip planning services that cover multiple modes of transportation across borders. The following open-source tools have been developed based on the Swiss OJP implementation: Demo application for OJP 2.0 (https://tools.odpch.ch/ojp-demo-v2/search) and API explorer for OJP (https://opentdatach.github.io/api-explorer2/).
Benefits	OJP allows a system to engineer just one interface that it can make available rather than having to engineer separate APIs for each bipartite exchange arrangement that may be required with other systems.
Actual status	In the last few years, much work was done to align the data frameworks Transmodel, NeTEx, SIRI and, to a lesser extent, OJP and OpRa. This work was carried out in order to create more coherence between these frameworks towards what is called now the Transmodel ecosystem.

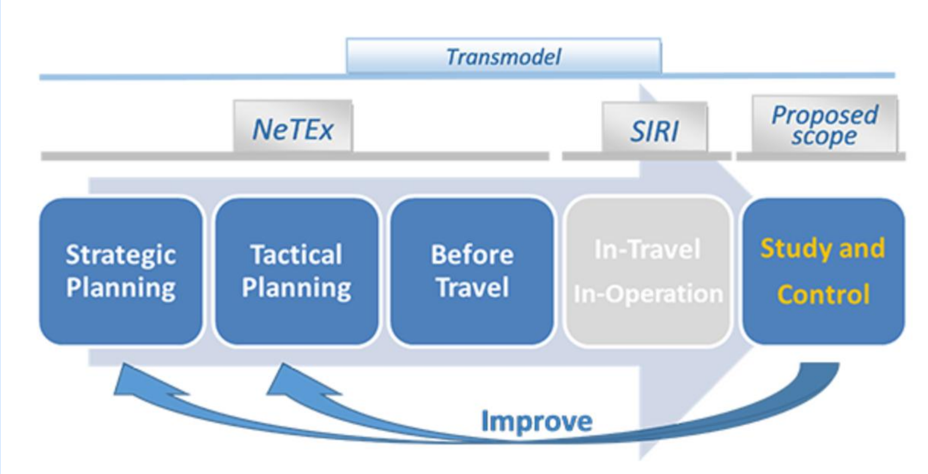
[24] https://github.com/VDVde/OJP

	Right now, some countries in Europe have implemented OJP to a certain extent: Austria, Germany and Switzerland. EU DG MOVE expressed expectations and focuses on further developments and implementations of Transmodel-based standards in order to ensure consistency and interoperability in data exchanges as the way forward towards seamless integrated transport in Europe. At this time, OJP is a Technical Specification. DG MOVE expects that OJP will be a European standard (EN) within 3 years: end of 2028. The reason for this requirement, as EU DG MOVE explained, is that CEN Technical Standards (TS) may be adopted as national standards but that, then, conflicting national standards may continue to exist. European Standards (EN) are required key components of the Single European Market.
Common Data Elements	tbd

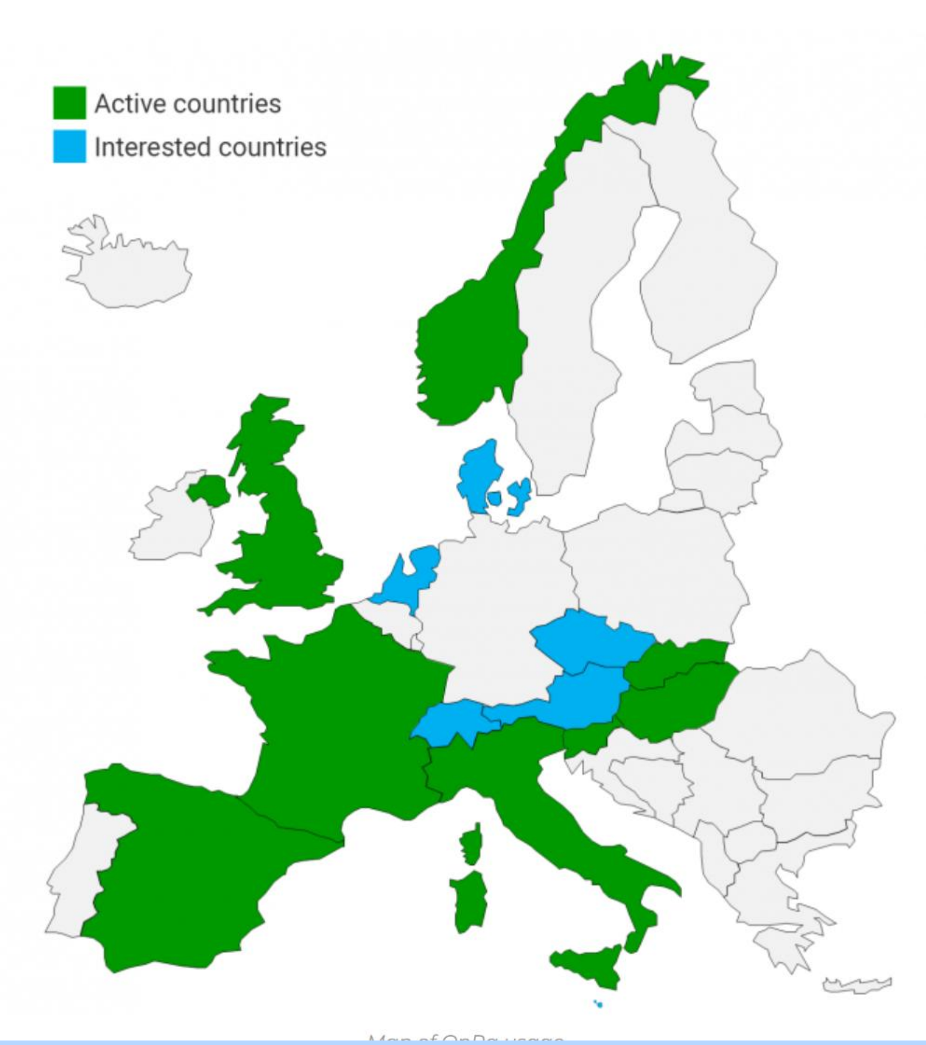
5.1.6 OpRa - Operating Raw Data and Statistics Exchange

Table 9: Overview of OpRa

Name	CEN TR 17370 (OpRa): Operating raw data and statistics exchange
Official website	https://transmodel-cen.eu/index.php/opra/
Managing Organisation	CEN-CENELEC
Standard Type	Technical Report
Exchange Data File	tbd
Introduction	OpRa is a CEN initiative with main focus on the identification of Public Transport raw data to be exchanged, gathered and stored in order to support Study and Control of Public Transport Service. The work consists in the production of a CEN Technical Report, to document the results of the performed analysis, in order to precisely define the scope of the following Technical Specification (TS) or European Norm (EN) definition work. Particular attention on raw data identification is focused on actual and measured information, i.e. information which cannot be changed anymore in the future.
Overview	OpRa work scope is coherent with those covered by NeTEx, SIRI and Transmodel as depicted in the following picture:



In this perspective, a deep study of Public Transport Service is performed with Information exchanges with stakeholders (mainly authorities, operators and system providers) to clearly identify the needs and define Use Cases.



How is OpRa used?

The work consists in the production of a Technical Report, to document the results of the performed analysis, in order to precisely define the scope of the following Technical Specification (TS) or European Norm (EN) definition work.

OpRa will mainly focus on the identification of actual and measured information, i.e. information which cannot be changed anymore in the future.

This information is mainly an output of the Transmodel (TRM) domains

- "Operations monitoring & control";
- Management Information and statistics" (raw data for indicators calculation).

It will describe the recorded reality of operation, like delays and cancelled vehicle journeys, etc. either through individual measurements at a given sampling interval or in an aggregate way (statistics).

	• Strategic Planning: definition of network elements (lines, stops), main service parameters (vehicles sizes, operation intervals, service intervals for important time demand types), and guaranteed interchanges are planned (NeTEx, TRM). • Tactical Planning: operators plan their resource usage (vehicles, rolling stock, personnel), with detailed timetables for each resource unit (NeTEx, TRM). • Before Travel: all planned networks and timetables are published. Passengers and other type of clients may plan their use of the offered transportation services via printed and electronic media, and make their reservations as needed (NeTEx, TRM). • In-Travel: The transportation service is conducted. Real-time information exchange is available while this takes place and may be recorded (SIRI, TRM). • Study and control: in this stage, operators and authorities review the history of actual operations, which may lead to improvements through operational changes, or an optimisation of strategic and tactical planning (OpRa, TRM).[25]
Benefits	In December 2025, a new TR (Technical Report) version of the OpRa deliverable was distributed within the CEN standardisation environment. This internal version contains the following motivation that also relates OpRa to other parts of the Transmodel ecosystem: Measured Public Transport data describing the public transport network fulfilment are essential for studies, control, service improvement and contractual relations between stakeholders. It is important that they can be shared among PTO, PTA, engineering and design office, researchers, and other actors in a clear and unambiguous way, to provide accurate and intelligible information. Furthermore, the OpRa covered scope is fully complementary to other existing exchange standards and allows covering one of the remaining gaps of public transport standardisation, with references to Transmodel, NeTEx and SIRI. Using these standards, scheduled and real-time information can be made available for passenger information, and for operations and for process review. However, there is still one final aspect missing, just after real-time: to provide information about what has been performed, with the same overall view as for scheduled information. Such data allows a feedback loop to improve existing services. The OpRa standard is therefore about operating raw data and statistics, regularly requested by PTAs.

[25] https://transmodel-cen.eu/index.php/opra/

Actual status	After publishing the CEN Technical Report in 2019, further activities on OpRa stopped for some time. In 2023, further work started in the 3 year project OpRa+. Goals of this project are: • To enrich the Transmodel standard series with a data exchange format for historical data Note: These raw data are being analysed, can contribute to a deeper understanding of mobility circumstances and can lead to optimisation of data exchanges between mobility partners. This includes data that are not (yet) listed in the Transmodel data framework but that can still prove to be important for Public Transport Operators. • To coordinate with NAPCORE as well as Transmodel, NeTEx and OJP. Core tasks of the OpRa+ project team are the following: 1. To draft a Technical Specification (TS) for historic data 2. To deliver an update for Transmodel Part 8, Management information &statistics 3. To deliver an update for Transmodel Part 6, Passenger information 4. To deliver an update for NeTEx Part 1, Public transport network topology exchange format 5. To draft a Technical Report (TR) with a Common Glossary harmonising the goal, terms and definitions from existing Data Dictionaries in mobility. This task is considered to be a huge challenge due to the amount of terminology to be dealt with. In December 2025, the OpRa "Common Glossary" for operating raw data and statistics exchange was published within the CEN environment. Primary purpose of this glossary is to fulfil "a strong need to harmonise terms and definitions used in Public Transport because various legislations have adopted general terms and definitions which are not aligned". OpRa+ aims to harmonise such misaligned terms and definitions to secure consistency and interoperability of mobility data. The actual CEN/TR "Common glossary" was, in fact, not developed from the operating raw data and statistics exchange perspective. This CEN deliverable is hosted by OpRa+ project but, according to the OpRa+ team, the common glossary activity is a side activity to the OpRa specification. One could say that the OpRa common glossary is the "**+**" of OpRa**+**. After careful consideration of this purpose, it appeared clearly that the most helpful method to promote harmonisation would be to highlight the differences between various use contexts rather than try to produce a unique standard set of terms, which would appear as yet another standard on top of others. The Glossary contains a separate section for each of the 30 selected terms. Each such section contains sub-sections detailing the contexts the term

	is used in, related terms, any unifying concept, source references to the full definitions, and usage recommendations. NOTE: Interestingly, one of the deliverables of the SIGN-AIR project is a Glossary. The team working on this glossary arrived at the same conclusion: not to add yet another glossary to a large number of already existing mobility glossaries but to respect most commonly used different terms and definitions used in different contexts and add these to the common SIGN-AIR glossary. The approach here, however, was different: show definitions in a transparent way in a practical tool in order to increase understanding use of terms in different contexts – which is quite useful in setting up contracts, dealing with data exchanges in different environments, and dealing with disruptions. In addition, work in SIGN-AIR was done within a wider scope, involving European regulation but also strongly focusing on aviation and public transport in a much wider mobility environment. EU DG MOVE expressed expectations and focuses on further developments and implementations of Transmodel-based standards in order to ensure consistency and interoperability in data exchanges as the way forward towards seamless integrated transport in Europe.
Common Data Elements	tbd

5.1.7 GTFS – General Transit Feed Specification

Table 10: Overview of GTFS

Name	GTFS – General Transit Feed Specification
Official Website	https://gtfs.org/
Managing Organisation	Google
Standard Type	Technical Specification
Exchange Data File	Comma-separated values (CSV)
Introduction	The General Transit Feed Specification (GTFS) is an Open Standard used to distribute relevant information about transit systems to riders. It allows public

	transit agencies to publish their transit data in a format that can be consumed by a wide variety of software applications. GTFS consists of two main parts: GTFS Schedule and GTFS Realtime.[26]
Overview	GTFS Schedule GTFS Schedule is a feed specification that defines a common format for static public transportation information. It is composed of a collection of simple files, mostly text files (.txt) that are contained in a single ZIP file. Each file describes a particular aspect of transit information such as stops, routes, trips, etc. At its most basic form, a GTFS Schedule dataset is composed of 7 files: agency.txt, routes.txt, trips.txt, stops.txt, stop_times.txt, calendar.txt and calendar_dates.txt. Along with this basic set of files, additional (optional) files can also be grouped to provide information of other service elements, such as fares, translations, transfers, in-station pathways, etc. Currently there are more than 15 optional files that extend the basic elements of GTFS, including locations.geojson which introduced a new format besides text files (.txt) which can be used to represent geographical areas. The source of truth for all GTFS Schedule files is the official GTFS Schedule Reference, which provides detailed information on the requirements for all information elements in each file that composes a GTFS Schedule dataset. GTFS Realtime GTFS Realtime is a feed specification that allows public transportation agencies to provide up-to-date information about current arrival and departure times, service alerts, and vehicle position, allowing users to smoothly plan their trips. The specification currently supports the following types of information: • Trip updates – delays, cancellations, changed routes • Service alerts – stop moved, unforeseen events affecting a station, route or the entire network • Vehicle positions – information about the vehicles including location and congestion level. GTFS Realtime was designed around ease of implementation, good GTFS interoperability and a focus on passenger information. This was possible through a partnership of the initial Live Transit Updates partner agencies, a number of

[26] https://gtfs.org/documentation/overview/

	transit developers and Google. The specification is published under the Apache 2.0 License. The GTFS Realtime data exchange format is based on Protocol Buffers which is a language- and platform-neutral mechanism for serialising structured data (think XML, but smaller, faster, and simpler). Similarly to GTFS Schedule, the GTFS Realtime Reference is the source of truth that establishes the rules and requirements for any GTFS Realtime feed, while the gtfs-realtime.proto file defines the hierarchy of elements and their type definitions that are used. [27]
Benefits	**Improved rider experience:** GTFS empowers riders with accurate schedules, and real-time updates, leading to reduced wait times and informed travel decisions. **Global reach and seamless trips:** Over 10,000 agencies in 100+ countries use GTFS, ensuring consistent data for multi-agency trips and simplifying travel across regions. **Simple and easy to use:** GTFS makes it easy for transit agencies by relying on a simple data structure, fostering collaboration and interoperability. **Access to a wide range of applications:** By adopting GTFS, agencies reach a wider audience through the vast pool of app developers utilising the standardised data format. **Open source community:** GTFS thrives on community collaboration, ensuring its continuous evolution and relevance, with a primary focus on passenger-facing information within the specification. **More than just schedules:** While schedule information is at its core, GTFS also offers additional features that enhance the transit experience, such as fares, flexible services, and real-time updates.[28]
Common Data Elements	Agency, Route, Stop, Trip, Calendar and calendar dates, stop times, transfers
Actual status	Compared with the Transmodel data framework, GTFS is a relatively simple specification. Some years ago, in France, mapping GTFS and Transmodel proved

[27] https://gtfs.org/documentation/overview/

[28] https://gtfs.org/

to be challenging as, due to its simplicity, GTFS data contain far less data and much less data content on mapped data than the extensive Transmodel data model.

GTFS was aligned with the Transmodel ecosystem, e.g.:

- Transmodel reference data framework standard part CEN EN 12896-1 mentions: Informal liaison with the General Transit Feed Specification (GTFS) group established a mapping of GTFS Schedule content to a subset of Transmodel / NeTEx for basic stop and timetable data.
- NeTEx data framework CEN TS 16614-1 contains a frame definition for a frame to hold data elements to provide a GTFS timetable export.

5.1.8 ISO 24192-1 Communication between readers and media, part 1

Table 11: Overview of ISO 24192-1

Name	ISO/IEC TS 24192-1:2021 Cards and security devices for personal identification – Communication between contactless readers and fare media used in public transport – Part 1: Implementation requirements for ISO/IEC 14443 (all parts)
Official Website	https://www.iso.org/standard/78063.html
Managing Organisation	ISO/IEC
Standard Type	TS, Technical Specification
Exchange Data File	None; the standard deals with communication between Interoperable Fare Management (IFM) system components.
Introduction	This document defines the technical requirements to be met by contactless public transport (PT) devices in order to be able to interface together using the ISO/IEC 14443 (all parts) contactless communications protocol. This document applies to PT devices: • PT readers which are contactless fare management system terminals acting as a Proximity Coupling Device (PCD) contactless reader based on ISO/IEC 14443 (all parts); • PT objects which are contactless fare media acting as a Proximity Integrated Circuit Card (PICC) contactless object based on ISO/IEC 14443 (all parts).
Overview	This document addresses interoperability of consumer-market Near Field Communication (NFC) mobile devices, compliant with NFC Forum specifications, with above mentioned PT devices, aligns with ISO/IEC 14443 (all parts) and does not seek to limit compliance for PT readers with EMV (Europay, MasterCard, Visa) Contactless Interface Specification.

Benefits	Interoperability of ticketing media and ticketing devices is crucial with regard to seamless travel. Use of interoperable ticketing components is very convenient for the traveller. It is also very efficient for the public transport operators as ticketing media and devices work as required, can be trusted and can be linked with other ticketing systems based on the same standard.[29]
Actual status	As interoperability is crucial and the technical elaboration of readers and media as described in the specification is related to other technical specifications, a specific check on interoperability was done and laid down in a related technical report: ISO TR 20527: 2022 Interoperability between interoperable fare management (IFM) systems and near field communication (NFC) mobile devices. The standard is being revised in ISO working group JCT1 SC17 WG8. A number of minor technical improvements and minor changes is being discussed. This work will probably be finalised in the first part of 2026. Please refer to ISO/IEC TS 21492 part 2 for testing and certification as well as some information related to implementation.
Common Data Elements	N/A

5.1.9 ISO 24192-2 Communication between readers and media, part 2

Table 12: Overview of ISO 24192-2

Name	ISO/IEC TS 24192-2:2021 Cards and security devices for personal identification – Communication between contactless readers and fare media used in public transport – Part 2: Test plan for ISO/IEC 14443 (all parts)
Official Website	https://www.iso.org/standard/78066.html
Managing Organisation	ISO/IEC
Standard Type	TS, Technical Specification
Exchange Data File	None; the standard deals with communication between Interoperable Fare Management (IFM) system components.
Introduction	This document lists all the test conditions to be performed on a PT reader or a PT object in order to ensure that all the requirements specified in ISO/IEC TS 24192-1 are met for the PT device under test.

[29] https://www.iso.org/standard/78063.html.

	This document applies to PT devices only: • PT readers which are contactless fare management system terminals acting as a Proximity Coupling Device (PCD) contactless reader based on ISO/IEC 14443 (all parts); • PT objects which are contactless fare media acting as a Proximity Integrated Circuit Card (PICC) contactless object based on ISO/IEC 14443 (all parts).
Overview	This document applies solely to the contactless communication layers described in ISO/IEC 14443 (all parts). Application-to-application exchanges executed once contactless communication has been established at RF level fall outside the scope of this document. However, a test application is used to make end-to-end transactions during tests on the RF (radio-frequency) communication layer. This document does not duplicate the contents of ISO/IEC 14443 (all parts) or ISO/IEC 10373-6. It makes reference to the ISO/IEC 10373-6 applicable test methods, specifies the test conditions to be used and describes the additional specific test conditions that can be run.[30]
Benefits	Interoperability of ticketing media and ticketing devices is crucial with regard to seamless travel. Use of interoperable ticketing components is very convenient for the traveller. It is also very efficient for the public transport operators as ticketing media and devices work as required, can be trusted and can be linked with other ticketing systems based on the same standard.
Actual status	The technical specification was tested extensively in order to prepare certification of ticketing media and ticketing devices. The certification processes have been finalised and can be used both for media and devices since Autumn 2025. First certification products are available now. Compliance with ISO/IEC TS 24192 is required according to the Calypso "guide to drafting tenders for cards, NFC mobile ticketing and terminals based on the Calypso standard"[31]. One example of a large implementation of ISO/IEC 24192 is being prepared for Île-de-France-Mobilités in and around Paris, France. The standard is being revised in ISO working group JCT1 SC17 WG8. A number of minor technical improvements and minor changes is being discussed. This work will probably be finalised in the first part of 2026.
Common Data Elements	N/A

[30] https://www.iso.org/standard/78066.html

[31] https://calypsonet.org/document/guide-for-calypso-ticketing-systems-in-calls-for-tenders-v1-230125/.

5.1.10 CEN 13149 series

Table 13: Overview of CEN 13149 series

Name	CEN EN 13149: Public transport – Road vehicle scheduling and control systems
Official website	https://www.cencenelec.eu/european-standardization/european-standards/
Managing Organisation	CEN-CENELEC
Standard Type	European Standard (EN)
Parts of this standard series	7. System and network architecture 8. Physical layer for IP communication 9. Time service 10. Location service 11. Vehicle platform interface service (note: parts 1-6 were withdrawn)
Exchange Data File	tbd
Introduction	The CEN 13149 series of European standards (EN) and specifications (TS) concerns on-board data communication systems on public transport vehicles.
Overview	Public Transport (PT) vehicles have an increasing array of information and communications systems, including ticket machines, Automated Vehicle Location (AVL) systems, destination displays, passenger announcement systems, vehicle monitoring systems, etc. In addition, equipped PT vehicles will usually have a communications facility to enable voice and data to be exchanged with the control centre, other PT vehicles, PT infrastructure and roadside devices for instance in requesting priority at traffic signals. Many types of communication channel are used including public and private wireless communication networks. These systems may be provided by a number of different suppliers and may need to be integrated. For instance: — a ticket machine may need location information to update fare stages; — next-stop and destination information may be drawn from schedule information held in the ticket machine; — vehicle location systems may be used to drive signal priority requests. As data exchange between functional units becomes more widespread, a networked approach begins to become efficient. With standardised underlying

	technology, the PT vehicle begins to look like a local area network: making use of IEEE 802 communications and the Internet Protocol (IP) suite.
Benefits	This series provides for data services that enable open and managed sharing of relevant information.
Actual status	Without a clear technology framework, integrating systems in PT vehicles would require complex technical discussions every time a device is procured. The existing EN 13149 standards recognised this long ago in respect of the core vehicle systems, but these have not been adapted to IP networking. Six historical parts of EN 13149, namely Parts 1 to 6, have now been withdrawn in favour of the new IP-based approach. The core of this new approach was specified in two Technical Specifications (TS): part 7 and 8 of the CEN 13149 series of European standards (EN) and specifications (TS). Building on this, a series of specific services are being specified: part 9, 10 and 11 of the CEN 13149 series of European standards (EN) and specifications (TS). It is considered to elaborate an extension of Transmodel – or to draft an extension in the standard series that is based on Transmodel. Data related to maintenance and repair of vehicles can then be described. This will probably prove to be challenging as a massive amount of CAN (Controller Area Network) data in vehicles is to be elaborated then.
Common Data Elements	tbd

5.1.11 – General Bikeshare Feed Specification

Table 14: Overview of GTBS

Name	GBFS – General Bikeshare Feed Specification
Official Website	https://gbfs.org/documentation/faq/
Managing Organisation	NABSA (North American Bikeshare & Scootershare Association (NABSA)
Standard Type	Specification
Exchange Data File	tbd
Introduction	The General Bikeshare Feed Specification, or GBFS, is an open data standard for shared mobility information, developed through a consensus-based process on GitHub. GBFS enables the exchange of information in a way that ensures all parties agree on what the information represents. You can think of it like a

	dictionary, where each term has a definition and a set of rules for how it can be used. GBFS is a real-time data specification. It describes the current status of a mobility system at this point in time. GBFS does not support, and is not intended for historical data such as trip or maintenance records.
Overview	GBFS was created to make real-time shared mobility information available in a standardised format to support the development of traveller facing applications. GBFS specifies how shared mobility data should be structured for proper interoperability of systems. Before the creation of GBFS, shared mobility systems each used different proprietary data formats, making it difficult for application developers to create tools for travellers. **Why is it important for GBFS data to be openly available?** Public GBFS feeds help facilitate the discovery of mobility services, increasing access to shared mobility. Third party applications built using these data can lead to increased visibility and customer acquisition for shared mobility services. Public data provides transparency around businesses that are permitted to operate in the public right of way. This transparency can increase public trust of shared mobility operators and their services.
Benefits	**What are the benefits of using GBFS?** For providers, GBFS means an end to a patchwork of regulation that requires different data in different formats for each city in which they operate. Standardisation provides assurance to providers that data requests can be clearly defined and are fully implementable. As a consensus-based, open source standard, providers have an equal voice along with cities in the ongoing development of the GBFS specification. Comprehensive documentation and resources are available to cities and providers alike to aid in implementation. For consumers, data standardisation allows application developers to aggregate data from multiple providers across multiple markets. GBFS can eliminate the need for bespoke solutions for each mobility service. For cities, requiring GBFS data as part of a shared mobility program can help to increase access to shared mobility services. GBFS provides municipalities and agencies with a standardised way to ingest, analyse, and compare data generated by shared mobility systems. Standardisation of mobility data through GBFS has resulted in a growing marketplace of data management software and services. These products and services are used to assist cities in working with GBFS data to effectively manage and regulate mobility services.[32]

[32] https://gbfs.org/documentation/faq/#uses-of-gbfs

Actual status	The GBFS specification was mapped with the Transmodel ecosystem, e.g., with NeTEx part 5.
Common Data Elements	tbd

5.2 MaaS

5.2.1 ISO TR 4447

MaaS[33] stands for Mobility as a Service and is an approach to mobility that seamlessly integrates various transport modes (public transport, biking, ride-sharing, taxis, car rentals) into a single, user-friendly platform. This unified service offers benefits like simplified payment, improved accessibility, and reduced reliance on private cars. By optimising transportation options and providing real-time information, MaaS aims to enhance urban mobility, reduce congestion, and promote sustainable transportation choices.

Table 15: Overview of ISO TR 4447

Name	Mobility integration — Comparison of two mainstream integrated mobility concepts
Website	https://www.iso.org/standard/79979.html
Managing Organisation	ISO
Standard Type	Technical Report
Exchange Data File	N.A.
Introduction	This document describes the core services and roles and responsibilities models in the “mobility as a service” (MaaS) and “mobility on demand” (MOD) ecosystems. The description is based on a literature review of the references listed in the Bibliography. This document also includes a comparison of the basic services and roles and responsibilities in order to map any similarities that can potentially be used for bridging and merging the two mainstream concepts in integrated mobility, i.e. MaaS and MOD.[34]

[33] Mobility as a Service (MaaS) and Sustainable Urban Mobility Planning, ERTICO, September 2019: https://urban-mobility-observatory.transport.ec.europa.eu/document/download/6b706858-11c6-41c2-b9f7-466e2bec0499_en?filename=maas_and_sustainable_urban_mobility_planning.pdf

[34] https://www.iso.org/standard/79979.html

Overview	The Technical Report offers a generic description mapping existing and foreseen concepts for MaaS and MOD.
Benefits	MaaS and MOD projects and implementations are evolving in many countries, regions and cities. A common description is useful in order to establish a common basis and to enable interoperability and seamless mobility with different transport modalities.
Actual status	The Technical Report describes the different core services, roles and responsibilities in MaaS (mobility-as-a-service) and MOD (mobility on demand). The document was aligned with the standard on processes, roles and responsibilities in an interoperable fare management system (IFMS): ISO 24014-1. Editors also aligned the report with Transmodel.
Common Data Elements	N.A.

5.2.2 ISO TR 7878

Table 16: Overview of ISO TR 7878

Name	Mobility integration – Enterprise view
Official Website	https://www.iso.org/standard/82966.html
Managing Organisation	ISO
Standard Type	Technical Report
Exchange Data File	N.A.
Introduction	This document describes the enterprise view (see ISO/TS 14812:2022, 3.1.4.3) of integrated mobility based on the role and responsibility models in the mobility as a service (MaaS) and mobility on demand (MOD) ecosystems as described in ISO/TR 4447. Other ISO documents (e.g. ISO 24014-1, ISO 17573-1 and ISO/TR 21724-1) have been reviewed in order to enhance and merge the MaaS and MOD role models.
Overview	The enterprise view addresses the relationships between organisations and users, and the roles those entities play in the delivery and consumption of mobility services. Relationships between entities are dependent on the roles those entities take in the delivery of user services. Enterprise objects interact to exchange information, manage and operate systems beyond the scope of one organisation. The enterprise view focuses on the relationships between those enterprise objects, but also defines how

	enterprise objects interact with physical objects, which appear in the enterprise view as “resources”. This document focuses on mobility service concepts where the included transport services are publicly available.
Benefits	The Enterprise view describes a common role and responsibility model in MaaS and MOD. The enterprise view addresses the relationships between the entities (e.g. organisations) that cooperate in the provision of the mobility services.
Actual status	This Technical Report was built on the basis of ISO TR 4447 and was aligned with ISO 24014-1. Editors also aligned the report with Transmodel.
Common Data Elements	Tbd

5.2.3 ISO TR 22625

Table 17: Overview of ISO TR 22625

Name	Mobility integration – Physical and Functional view
Official Website	https://www.iso.org/standard/87226.html
Managing Organisation	ISO
Standard Type	Technical Report
Exchange Data File	Tbd
Introduction	This document describes the physical and functional views defined in ISO/TS 14812 on integrated mobility, based on the role and responsibilities models in the mobility-as-a-service (MaaS) and mobility on demand (MOD) ecosystems as described in ISO/TR 4447 and ISO/TR 7878. This document focuses on mobility service concepts where the included transport services are publicly available.[35]
Overview	Integrated mobility concepts like MaaS and MOD are evolving around the world but are being developed in many different ways. Fragmented solutions are a result and need to be aligned in order to be able to offer seamless transport from door to door. The objective of the report is to describe integrated mobility from a physical and functional view, based on earlier developed standards ISO TR 4447 and ISO

[35] https://www.iso.org/standard/87226.html

	7878. The physical and functional view can be used for a mapping with existing implementations of MaaS and MOD.
Benefits	As a result of the mapping as mentioned above, a common understanding, an exchange of information and knowledge, and a convergence towards one world-wide integrated mobility concept description is enabled. The concept description of the report contributes to interoperable, integrated and seamless multimodal transport services.
Actual status	This Technical Report was built on the basis of ISO TR 4447 and ISO TR 7878 as a mobility integration architecture and was aligned with ISO 24014-1. Editors also aligned the report with Transmodel.
Common Data Elements	Tbd

5.3 Rail Transport

Rail transport involves the movement of passengers by trains on railways. It includes various types of trains, such as commuter trains, regional trains, and long-distance trains. Rail transport can be part of public transit systems, comprising long-distance rail between countries or within a country, commuter trains that serve urban areas, or also luxury trains designed for specific purposes, such as tourism or business travel. Private transport (on rail in private trains) is not considered to be public transport.

5.3.1 OSDM – Open Sales and Distribution Model

Table 18: Overview of OSDM

Name	OSDM – Open Sales and Distribution Model
Official Website	https://osdm.io/ & https://uic.org/projects-99/osdm
Managing Organisation	UIC – International union of railways
Exchange Data File	Extensible Markup Language (XML)
Standard Type	Technical Specification
Parts of this standard series	The Open Sales and Distribution Model (OSDM) is a rail sector specification enabling interoperable ticket sales for trains and other modes of transport and is defined in the new UIC International Railway Solution (IRS) 90918-10. Parts of the specification series include: • IRS 90918-0: Electronic seat/berth reservation and electronic production of travel documents – General regulations

	• IRS 90918-1: Electronic reservation of seats/berths and electronic production of travel documents – Exchange of messages • IRS 90918-4: e-Ticket Exchange for Control • IRS 90918-6: Electronic reservation of assistance for persons with reduced mobility – Exchange of messages • IRS 90918-8: Layout for electronically issued rail passenger tickets • IRS 90918-9: Digital Security Elements for Rail Passenger Ticketing • IRS 90918-10: Open Sales and Distribution Model OSDM.
Introduction	The aims of the **Open Sales and Distribution Model (OSDM)** are twofold: (1) to substantially **simplify and improve the booking process for customers** of public transport trips and (2) to **lower complexity and distribution costs** for retailers, distributor and carriers. OSDM has the potential to strengthen rail and public transport as a convenient and ecological means of transportation by simplifying distribution. Finally, it lays a solid fundament which can be extended to the distribution of other means of transportation. The OSDM Online API and specification essentially consists of two parts: **Offline Model** and **Online API**. The Online API works in two modes: **Retailer Mode** and **Distributor Mode**. The Distributor Mode differs from the Retailer Mode only in that additionally to **Admissions (aka. tickets)**, **Reservations**, or **Ancillaries** also **Fares (a.k.a. priced segments)** are offered and can be booked. The OSDM API and documents are **Open Source** and freely available to all parties interested. The OSDM-Online API is modelled in YAML, fully supporting the REST paradigm.
Overview	**Design Goals** The design of the OSDM-Online API focuses on three main goals: 1. To provide a convenient way for a customer to book an international train service, including refund and exchange processes. 2. To provide a specification that can be supported by existing or upcoming systems without major investments. 3. To reduce unnecessary message conversions between callers as they provide no business value. To address the first goal we started with the customer experience and worked backwards to define the sales and distributions processes supported by OSDM. This resulted in a booking process modelled by the following steps: • Searching for trips

	• Getting offers • Booking an offer • Confirmation of the booking • Fulfilment of the booking Analogously, the after-sale process is modelled in the following steps: • Getting a refund/exchange offers • Booking a refund/exchange offer • Fulfilment of the booking[36]
Benefits	OSDM (Open Sales and Distribution Model) defines an API to enable and simplify the sale of transport products. The API allows Retailers to access transport products provided by distributors. It also allows Distributors to access transport product bricks provided by carriers or fare providers to build combined transport products. The aim of OSDM is to provide a simple API to access required information online, however OSDM also provides an offline data exchange of fares. The API covers the full sales process including time table / offer search, prebooking and booking, refund, exchange including special processes to handle delays, change of material and compensation. OSDM covers scheduled multimodal transport services (trains, busses, trams, …). On Demand services are currently covered with some functional limitation. The OSDM API is rich and can be overwhelming at start. Reason for its feature richness (leading to its complexity) is the fact that it aims to cover all possible public transportation products and distribution processes within Europe and beyond. The products can be split roughly split into three categories: • *admissions*: the right to ride on a train, resulting in a ticket • *reservations*: seat or couchette or bed in case of night trains • *ancillary*: ancillary services such WIFI, 3-Menu plate. Between these categories, relationships are modelled to express whether it is optional or mandatory to have a certain seat reservation or ancillary on a given

[36] https://osdm.io/

	vehicle. In an open system (e.g. Switzerland) having a reservation is optional. In contrast on a closed system (e.g. France) a seat reservation is a mandatory.[37]
Common Data Elements	
Actual status	OSDM is an open standard: the standard can be downloaded for free and a lot of information is available on the internet, like on a Github website.[38] CER, the Community of European Railway and Infrastructure Companies, is promoting OSDM as a basic standard not just for long-distance rail but also for public transport. Other parties[39] however promote the standards of the Transmodel ecosystem and consider OSDM as a long-distance rail standard. At this time, the OSDM specification is about rail, not public transport in a wider sense. In one European country, Sweden, Samtrafiken is implementing OSDM as a national ticketing solution. According to Samtrafiken, this OSDM solution, however, is considered a good solution for long-distance transport like rail or Flixbus, but it is not supposed to deliver a full ticketing solution for multimodal travels which means that additional work needs to be done to cover multimodal travels in full.. UIC believes that OSDM is an enabler of multimodal mobility, rather than just a rail ticketing standard. UIC also understands that the full OSDM standard is not appealing to other modes as it is complex and a large part of the contents is of interest for railways only. However, UIC wants to link with other modalities. A working group has developed the UIC Open Multi-Modal Toolkit, a new framework set to transform the passenger experience of door-to-door mobility.[40] Sweden, having a national OSDM basis now, and Norway, having a Transmodel ecosystem basis, are working on aligning and meet quite some challenges in doing so. The CoRoM project, mentioned earlier in this document (see Transmodel), focuses on the data model within Transmodel and references this towards OSDM in order to find gaps and similarities. The latest (internal) published version of Transmodel standard part CEN 12896-1 (December 2025) mentions OSDM and notes: A working group with UIC (*Union Internationale des chemins de fer*, International Union of railways) and CEN

[37] https://osdm.io/spec/getting-started/

[38] https://osdm.io/spec/getting-started/

[39] Distinct example, AllRail: https://www.allrail.eu/mediaposts/for-multi-modal-door-to-door-bookings-in-ground-public-transport-transmodel-netex-is-the-best-technical-standard/

[40] https://uic.org/passenger/passenger-services-group/ommt

	compared the OSDM (Open Sales and Distribution Model) data format for rail timetables with Transmodel/NeTEx and established a mapping of data elements.
Notice	Important notice: ERA, the European Union Agency for Railways, published a report in October 2024: "Comparative analysis of rail ticket distribution rules in the Open Sales and Distribution Model (OSDM), the TAP TSI, the Rail Passenger Rights Regulation, and the recent competition decisions and national rulings under unfair trade law". The conclusion of this report was, in brief: "There is a substantial risk that the implementation of the current OSDM architecture and of its proposed booking process concerning the access to booking interfaces and to yielded fares are in conflict with the guidance provided by competition cases or national judgments under unfair trade law." In the report, ERA focused on fair, reasonable and non-discriminatory (FRAND) principles for cooperation between cooperative parties in public transport. As an example: some OSDM functions are not compliant with regulatory competition, e.g., public transport parties could have a double role of service provider and sales agent. The report describes some measures that must be taken in order to solve the issue.[41] This notice was addressed while working on further improvements of OSDM.

5.3.2 TAP-TSI

Table 19: Overview of TAP-TSI

Name	TAP-TSI – Telematics Applications for Passenger Services. Technical Specifications for Interoperability
Official Website	https://www.era.europa.eu/domains/technical-specifications-interoperability/telematics-applications-passenger-service-tsi_en
Managing Organisation	ERA
Standard Type	Technical Specification
Exchange Data File	Tbd
Introduction	The Technical Specifications for Interoperability (TSIs) define the technical and operational standards which must be met by each subsystem or part of subsystem in order to meet the essential requirements and ensure the interoperability of the railway system of the European Union.

[41] https://www.era.europa.eu/content/analysis-distribution-rules-tap-osdm-and-recent-competition-cases

	Directive (EU) 2016/797 defines the subsystems, either structural or functional, forming part of the railway system of the European Union. The TAP-TSI concerns the telematics applications subsystem and applies to applications for passenger services, including systems providing passengers with information before and during the journey, reservation and payment systems, luggage management and management of connections between trains and with other modes of transport. The reference data (company codes, location codes) can be found in the TAF/TAP-TSI reference data portal[42].
Overview	The TAP Master Plan shall include: 1. The identification of the activities necessary to achieve the implementation of the system. 2. A migration plan which includes a set of phases that is conducive to intermediate and verifiable tangible results, from the current framework of stakeholders' information and communication systems to the system itself. 3. A detailed milestone plan. 4. A risk assessment of the crucial phases of the master plan. 5. An assessment of the total lifecycle costs (LCC) associated with the deployment and operation of the system, together with a subsequent investment plan and the relevant cost-benefit analysis.[43]
Benefits	The purpose of the TAP-TSI is to define European-wide procedures and interfaces between all types of railway industry actors (passengers, railway undertakings, infrastructure managers, station managers, public transport authorities, ticket vendors and tour operators). It will contribute to an interoperable and cost-efficient information exchange system for Europe that enables the provision of high quality journey information and ticket issuing to passengers in a cost effective manner, thus also fulfilling requirements of the Passenger Rights Regulation related to (real-time) data sharing between infrastructure managers, railway undertakings, ticket vendors, tour operators and station managers (Regulation (EC) No 2021/782).
Actual status	According to the Data4PT website (https://data4pt-project.eu/data-models/transmodel/), Transmodel is also being used to harmonise the TAP-TSI rail standards into a uniform pan-European model, and, therefore, it is also of direct relevance to rail carriers. TAP-TSI is being implemented across the European Union. The Co-operation Group for the Implementation of Telematics Applications for Passengers assesses the TAP-TSI implementation in cooperation with National Contact

[42] https://teleref.era.europa.eu/

[43] https://www.era.europa.eu/system/files/2022-11/tap_master_plan_delivery_en_0.pdf

	Points (NCPs) in Member States and with Representative Bodies (RB). Status reports on the implementation progress can be found on the website of the European Railway Agency (https://www.era.europa.eu/domains/technical-specifications-interoperability/telematics-applications-passenger-service-tsi_en). The European Commission has published a draft Act on 14. February 2025, laying down new/ updated rules on common, specific and interface requirements for interoperable data sharing in rail transport by establishing a technical specification for interoperability (TSI) relating to the 'telematics applications for passenger and freight services' subsystem of the rail system in the Union.[44]
Common Data Elements	Tbd

5.3.3 MERITS

Table 20: Overview of MERITS

Name	MERITS – Multiple East-West Railways Integrated Timetable Storage
Official Website	https://uic.org/passenger/passenger-services-group/merits
Managing Organisation	UIC
Standard Type	Database
Exchange Data File	Tbd
Introduction	MERITS (Multiple East-West Railways Integrated Timetable Storage) is a database, owned by UIC, containing the integrated timetable data of many European countries, comprising a few hundred railway undertakings (RUs), which are published four times a week. MERITS today is not an application for the general public, but a tool designed for railway companies, which decide themselves on how their information and distribution channels are supplied based on their own commercial policy. Today, EDIFACT is the single format used for importing and exporting the data (SKDUPD and TSDUPD messages).[45]

[44] https://ec.europa.eu/info/law/better-regulation/have-your-say/initiatives/14273-Rail-interoperability-technical-specifications-for-the-telematics-applications-subsystem_en

[45] https://uic.org/passenger/passenger-services-group/merits.

Overview	The MERITS timetable data consist of: • Schedules of trains, a significant number of (inter)regional and long-distance busses and some ship services, including service brand (e.g. Eurostar), generic service mode (e.g. high-speed train, Intercity, bus, ship etc.), and service attributes (1st and 2nd class, reservation advised/mandatory, restaurant car etc.). It contains about 600.000 services in Europe. Many, but not all, RUs deliver the departure and arrival platforms with their timetable data. • Location database, containing about 67.680 European stations and stops, including geo-coordinates and UIC location codes (9-digit number: 4N + 5N). • MCT's (minimum connection time) per location in minutes + exceptions, defined as service pairs with their specific MCT (this can be a higher or lower number than the location MCT). Also: pedestrian links and connections between locations. Timetable period represented in MERITS: • Most railway companies publish a 12-month timetable, running from mid-December to mid-December +1. Some publish separate winter and summer timetables. From mid-October, the next 12-month c. q. 6-month timetable becomes available, and MERITS then contains up to two 12-month periods. • A few RUs publish a calendar year timetable (Jan – Dec) and a few others only publish the period between each update and mid-December. • Services (mainly high-speed trains) hosted in the French inventory system Resarail, e.g. TGV, Eurostar and Thalys, publish their timetable according to their booking horizon, i.e. 4-6 months ahead. NB: real-time information is not part of the MERITS database.
Benefits	See description in Introduction section
Actual status	Alignment of TAP-TSI with a number of different sources, including NeTEx (CEN TS 16614 technical specification series), was undertaken.
Common Data Elements	Tbd

5.3.4 eTCD

Table 21: Overview of eTCD

Name	eTCD – Electronic Ticket Control Database
Official Website	https://www.hitrail.com/etcd

Managing Organisation	Hit Rail
Standard Type	Database
Exchange Data File	Tbd
Introduction	The eTCD, electronic Ticket Control Database, is a centralised, real-time passenger ticket management system developed by Hit Rail, offered as a service for the UIC and in use by railway companies around the world. The service is defined by UIC IRS 90918-4, the common specification for the exchange of control information on railway tickets between ticket issuers and passenger carriers. The eTCD service is provided by Hit Rail in a Software as a Service (SaaS) mode. The technical components of the solution are deployed in Hit Rail's cloud environment, for a high degree of flexibility in response to varying loads and future changes.[46]
Overview	The eTCD helps railway companies to control non-reservation barcode ticket information onboard trains for all rail travel. Information is exchanged in real-time between ticket issuers and passenger carriers. This means: • Ticket issuers receive up-to-date information on railway ticket verification and usage and • Railway carriers receive complete information on the lifecycle of tickets, including when tickets are checked by other organisations and/or cancelled by the issuers.
Benefits	Thanks to eTCD, ticket security and fraud prevention are increased with real-time exchange of information on: • Cancellation and refunding of tickets after ticket inspection on trains • Refunding of tickets in another country at ticket offices • Re-use of tickets on the same train or on subsequent train journeys. In addition, the eTCD service also communicates information on the extension of validity, delay confirmation, declaration of non-used tickets, class upgrades and downgrades as well as ticket gate checks. What are the benefits of eTCD for passenger rail travel?

[46] https://www.hitrail.com/etcd

	The eTCD service enables full paperless ticketing, thus marking the end of paper train tickets. This increases ticket security, prevents fraud and reinforces electronic ticketing capabilities. In addition, this smart ticketing technology facilitates seamless multimodal door-to- door mobility, combining rail journeys with urban and local transport modes, and giving passengers a wider choice of multimodal travel options. eTCD offers numerous advantages for rail passengers in terms of security, flexibility, cost and convenience. The service enables faster boarding, helps cancel and refund tickets more easily, and informs passengers of changes to their tickets in real-time, thus enhancing the overall travel experience and more effectively meeting customer needs.[47]
Actual status	Tbd
Common Data Elements	Tbd

5.3.5 RailML – Railway Markup Language

Table 22: Overview of RailML

Name	RailML – Railway Markup Language
Official Website	https://www.railml.org/en/
Managing Organisation	railML.org
Standard Type	Technical Specification
Exchange Data File	Extensible Markup Language (XML)
Introduction	railML® is an open-source railway markup language designed to facilitate seamless communication among diverse railway applications. The data structure of the railML® interface is based on the XML language. It is described using the widely supported and standardised XML schema definition language (XSD) which allows syntactic validation and generation of parser code.
Overview	A wide range of extensive computer programmes exist for railroad planning processes. In today's world, connecting various railway software packages often presents significant challenges. railML® offers an XML-based solution for simplifying data exchange between railway applications.

[47] https://www.hitrail.com/etcd

	Beside the machine-readable description of the standard, railML® offers comprehensive documentation to support the efficient implementation of interfaces and easy understanding as well as an active community that can be used to quickly resolve any remaining ambiguities.[48]
Benefits	railML® has been established as an ISO standard. Benefits are indicated in the description related to the standard below.
Actual status	Since 2022, railML® has been established as an ISO standard (ISO/TS 4398) worldwide under the marketing name RailDax (Railway Data Exchange). The purpose of RailDax is to facilitate the planning of railway operations between organisations in the transportation sector and enable efficient, more accurate and less ambiguous data exchange. RailDax has been developed on the basis of railML 2.5 (railway Markup Language 2.5), which is managed by railML.org. It provides an open XML-based data format that allows data to be exchanged between different applications: connecting information on the infrastructure, rolling stock and timetable data required for capacity management and timetable planning. The standard is intended for railway and transport authorities, infrastructure managers, train operators and rolling stock manufacturers. Currently, railML.org, with the support of its partner Jernbanedirektoratet is planning to update the standard to the upcoming railML 3.X version between 2025 and 2027.[49]
Common Data Elements	Railway infrastructure elements, track network elements, Geometry, the track geometry can be described in terms of radius and gradient, railway infrastructure elements (balises, platform edges, and level crossings), speed profiles and track conditions, rolling stock elements (railway vehicle including locomotives, multiple units, passenger and freight wagons), Timetable and Rostering elements(Operating Periods, Train Parts, Trains, Connections, Rostering[50]

5.4 Air Transport

Air transport involves the movement of passengers by airplanes and helicopters. It includes commercial airlines, chartered flights, and general aviation. Air transport offers both domestic and international travel options, connecting cities and countries across the globe.

5.4.1 ATM - Air Traffic Management

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[48] https://www.railml.org/en/about-railml

[49] https://www.railml.org/en/about-railml

[50] https://wiki2.railml.org/wiki/Main_Page

Table 23: Overview of ATM

Name	Air Traffic Management (ATM) Framework
Official Website	https://www.icao.int/safety/airnavigation/pages/atm.aspx
Managing Organisation	ICAO (International Civil Aviation Organisation)
Standard Type	Technical Specification / Global Framework
Exchange Data File	Extensible Markup Language (XML)
Overview	The Air Traffic Management (ATM) framework defines the integrated management of air traffic and airspace to ensure safe, orderly, and efficient operations globally. It encompasses systems, procedures, and standards for flight planning, airspace design, trajectory management, and collaborative decision-making. ATM is supported by ICAO's SWIM (System Wide Information Management) concept, which enables standardised data exchange across stakeholders.
Benefits	Provides global interoperability for air traffic services, improves safety and efficiency, supports real-time data sharing for flight planning and operations, and enables collaborative decision-making among airlines, airports, and ANSPs (Air Navigation Service Providers).
Common Data Elements	Flight Identification, Flight Plan Data, Trajectory Information, Aerodrome and Airspace Data, Weather Information, Operational Status, Resource Requirements, and Performance Monitoring
Actual Status	Global framework under constant evolution. Major implementations include SESAR (Single European Sky ATM Research) in Europe and NextGen in the US, moving towards trajectory-based operations (TBO).

5.4.1.1 ICAO Annex 15 – Aeronautical Information Management (AIM) Requirements

Table 24: Overview of AIM

Name	Aeronautical Information Management (AIM) Requirements
Official Website	https://www.icao.int/
Managing Organisation	ICAO (International Civil Aviation Organisation)
Standard Type	International Standard (SARPs – Standards and Recommended Practices)
Exchange Data File	Digital Data Sets (AIP, Terrain, Obstacle, Aerodrome Mapping, Instrument Flight Procedure)
Overview	AIM requirements are considered vital as part of ICAO's transition from traditional Aeronautical Information Services (AIS) to Aeronautical Information Management (AIM). It supports global ATM through digital, quality-assured data exchange, covering

	information management requirements, data quality specifications, and verification procedures.
Benefits	Enhances data integrity and traceability across the entire aeronautical information chain, supports System Wide Information Management (SWIM) and global interoperability, improves efficiency through automation and standardised exchange models and provides a framework for quality assurance and certification.
Actual Status	ICAO Annex 15 provisions are applicable globally.

5.4.1.2 ICAO Annex 15 – Aeronautical Information Products and Services

Table 25: Overview of Aeronautical Information Products and Services

Name	Aeronautical Information Products and Services
Official Website	https://www.icao.int/
Managing Organisation	ICAO (International Civil Aviation Organisation)
Standard Type	PANS (Procedures for Air Navigation Services)
Exchange Data File	AIXM (Aeronautical Information Exchange Model)
Overview	Defines the framework for providing aeronautical information in standardised formats and digital data sets. It ensures products meet global interoperability requirements. It specifies requirements for AIP (Aeronautical Information Publication), Digital data sets (terrain/obstacle/mapping), Distribution services, and Pre-flight/Post-flight information services.
Benefits	Facilitates global harmonisation of aeronautical information, Supports SWIM and digital data exchange, Improves accuracy, timeliness, and accessibility for flight planning, Enables electronic AIP (eAIP) and integration with modern navigation systems.
Common Data Elements	AIP Sections (GEN, ENR, AD), NOTAM text, Digital Dataset identifiers, Chart overlays, Route definitions.
Actual Status	ICAO Annex 15 provisions are applicable globally.

5.4.1.3 ICAO Annex 15 – Data Quality Specifications

Table 26: Overview of Data Quality Specifications

Name	Data Quality Specifications
Official Website	https://www.icao.int/
Managing Organisation	ICAO (International Civil Aviation Organisation)
Standard Type	International Standard (SARPs – Standards and Recommended Practices)
Overview	Critical for ensuring the integrity and reliability of aeronautical information within global ATM. Provisions define required levels of: Accuracy, Resolution, Integrity (Routine, Essential, Critical), Traceability, Timeliness, Completeness, and Format.
Benefits	Enhances safety by reducing risks from corrupted data, Supports performance-based navigation (PBN), Enables global interoperability through standardised quality requirements, Facilitates automation and digital data exchange.
Actual Status	ICAO Annex 15 provisions are globally applicable.

5.4.1.4 ICAO Annex 15 – Scope of Aeronautical Data and Metadata

Table 27: Overview of Scope of Aeronautical Data and Metadata

Name	Scope of Aeronautical Data and Metadata
Official Website	https://www.icao.int/
Managing Organisation	ICAO (International Civil Aviation Organisation)
Standard Type	International Standard (SARPs – Standards and Recommended Practices)
Exchange Data File	Digital data sets, Metadata (ISO 19115).
Overview	Defines the scope of data including national regulations, aerodromes, airspace structure, ATS routes, instrument procedures, radio navaids, obstacles, and geographic info. It mandates metadata collection at all stages to enable traceability and interoperability, supported by ISO 19115 and PANS-AIM (Doc 10066).
Benefits	Ensures completeness and consistency of aeronautical data, Facilitates interoperability between systems, Improves data quality management via traceability, supports digital data exchange and SWIM integration.
Common Data Elements	Aerodrome Reference Points, Runway thresholds, Radio Frequencies, Airspace Boundaries (Lat/Long), Obstacle positions.

Actual Status	Globally applicable

5.4.1.5 ICAO Annex 15 – Aeronautical Information Updates

Table 28: Overview of Scope of Aeronautical Information Updates

Name	Aeronautical Information Updates
Official Website	https://www.icao.int/
Managing Organisation	ICAO (International Civil Aviation Organisation)
Standard Type	International Standard (SARPs — Standards and Recommended Practices)
Exchange Data File	NOTAM (Digital/Text), AIP, digital data sets.
Overview	Establishes requirements for keeping data up to date via the AIRAC (Aeronautical Information Regulation and Control) system. It covers the 28-day cycle for significant changes, update procedures for AIP and NOTAMs, and requirements for digital data set amendments.
Benefits	Enhances predictability and planning for operators. Supports navigation database integrity. Facilitates global harmonisation through standardised AIRAC cycles.
Common Data Elements	Effective Date, NOTAM duration
Actual Status	AIRAC system is widely implemented. Challenges remain in synchronising updates across multiple platforms (paper vs. digital datasets) and integrating digital NOTAMs.

5.4.1.6 ICAO Annex 15 – Aerodrome Mapping Data Sets

Table 29: Overview of Aerodrome Mapping Data Sets

Name	Aerodrome Mapping Data Sets
Official Website	https://www.icao.int/
Managing Organisation	ICAO (International Civil Aviation Organisation)
Standard Type	International Standard (SARPs – Standards and Recommended Practices)
Exchange Data File	Digital data sets.

Overview	A critical component of AIM providing digital representation of aerodrome features (runway thresholds, taxiway lines, parking stands, aprons). Features are characterised as points, lines, or polygons with attributes to support surface navigation and electronic charting.
Benefits	Enhances safety and efficiency in ground operations and taxiing. Supports electronic flight bags (EFB) and cockpit display systems. Facilitates integration with SWIM. Enables precision in airport planning.
Common Data Elements	Runway thresholds, taxiway guidance lines, parking stand areas
Actual Status	ICAO Annex 15 provisions are globally applicable.

5.4.1.7 ICAO Annex 11 – Air Traffic Flow Management (ATFM)

Table 30: Overview of Air Traffic Flow Management (ATFM)

Name	Air Traffic Flow Management (ATFM)
Official Website	https://www.icao.int/
Managing Organisation	ICAO (International Civil Aviation Organisation)
Standard Type	International Standard (SARPs – Standards and Recommended Practices)
Overview	Ensures that air traffic demand does not exceed declared ATC capacity. ICAO Annex 11 establishes the framework for ATFM implementation, regional coordination, and capacity management. It involves coordination between ATFM units and ATC to manage demand through ground delays (slots) and airborne measures.
Benefits	Prevents overload of ATC sectors, Optimises airspace and airport capacity, Provides operators with advance notice of delays, Ensures standardised practices.
Actual Status	Implemented on the basis of regional air navigation agreements or multilateral agreements.

5.4.1.8 Eurocontrol - SPEC – 198

Table 31: Overview of Eurocontrol – SPEC -198

Name	EUROCONTROL-SPEC-198 – Airport Collaborative Decision Making (A-CDM)
Official Website	https://www.eurocontrol.int/concept/airport-collaborative-decision-making
Managing Organisation	EUROCONTROL, Airport Operations Team

Standard Type	EUROCONTROL Specification
Overview	This specification describes Airport Collaborative Decision Making (A-CDM) and supports its implementation at an airport by providing requirements to Airport Operators, Air Navigation Service Providers, Aircraft operators, and Ground Handlers.
Benefits	Contributes to the implementation of the essential requirements of the EASA Basic Regulation and enables the implementation of the ATM Functionality 2 of the CP1 Regulation 2021/116. It supports enhancing airport performance to improve network predictability.
Actual Status	Implemented in major European airports and integrated with the Network Manager to provide real-time updates on flight status.

5.4.1.9 Eurocontrol – SPEC – 192

Table 32: Overview of Eurocontrol – SPEC – 192

Name	EUROCONTROL Specification for Data Link Common Services for the Aeronautical Telecommunication Network (ATN)
Official Website	https://www.eurocontrol.int/publication/eurocontrol-specification-data-link-common-services-aeronautical-telecommunication
Managing Organisation	EUROCONTROL
Standard Type	Technical Specification
Overview	This specification contains requirements for the ground implementation of data link common services for the Aeronautical Telecommunications Network (ATN) as defined by ICAO Annex 10 (Volume III, Part 1). It includes general, functional, performance, configuration, management, and monitoring requirements for a Logon Service (DLIC) and an ADS-C common service. It relies on the EUROCONTROL Specification for Data Link Ground Distribution SWIM Services (EUROCONTROL-SPEC-193) for ground distribution.
Benefits	Facilitates the ground implementation of data link common services for the Aeronautical Telecommunications Network (ATN). It enables the deployment of initial trajectory information sharing (supported by EUROCONTROL-GUID-194) and contributes to optimised operational performance.

5.4.1.10 Eurocontrol - SPEC – 193 – SWIM

Table 33: Overview of Eurocontrol – SPEC – 193 – SWIM

Name	Specification for Data Link Ground Distribution SWIM Services
Official Website	https://www.eurocontrol.int/publication/eurocontrol-specification-data-link-ground-distribution-swim-services
Managing Organisation	EUROCONTROL
Standard Type	Technical Specification
Overview	This specification details the SWIM services of the Logon Service and an ADS-C common service defined by the EUROCONTROL Specification for Data Link Common Services for the Aeronautical Telecommunication Network (ATN) (EUROCONTROL-SPEC-192).
Benefits	Enables the deployment of initial trajectory information sharing (supported by EUROCONTROL-GUID-194) by detailing SWIM services for Logon and ADS-C common services. It contributes to optimised operational performance.

5.4.1.11 DS SoC.005 Extended arrival management (EAMAN)

Table 34: DS SoC.005 Extended arrival management overview

Name	DS SoC.005 – Extended Arrival Management (E-AMAN)
Official Website	https://www.eurocontrol.int/
Managing Organisation	EASA, EUROCONTROL
Standard Type	Detailed Specifications
Overview	Provides the minimum requirements for ATM/ANS equipment supporting extended arrival management (EAMAN).

5.4.1.12 DS SoC.006 Departure management (DMAN)

Table 35: DS SoC.006 Departure management (DMAN) overview

Name	DS SoC.006 – Departure Management (DMAN)
Official Website	https://www.eurocontrol.int/

Managing Organisation	EASA, EUROCONTROL
Standard Type	Detailed Specifications
Overview	Provides the minimum requirements for ATM/ANS equipment supporting departure management (DMAN).

5.4.1.13 DS SoC.004 MET data distribution

Table 36: DS SoC.004 MET data distribution overview

Name	DS SoC.004 – Meteorological (MET) Data Distribution
Official Website	https://schemas.wmo.int/iwxxm/2021-2/
Managing Organisation	EASA, EUROCONTROL
Standard Type	Detailed Specifications
Exchange Data File	IWXXM
Overview	Provides the minimum requirements for ATM/ANS equipment supporting system wide information management (SWIM) services supporting distribution of MET data.

5.4.2 SSIM – Standard Schedules Information Manual

Table 37: Overview of IATA SSIM

Name	SSIM – Standard Schedules Information Manual
Official Website	https://guides.developer.iata.org/docs
Managing Organisation	IATA
Standard Type	Technical Specification
Exchange Data File	Extensible Markup Language (XML)
Introduction	The International Air Transport Association (IATA) publishes the Standard Schedules Information Manual (SSIM), which serves as a comprehensive guide outlining the global standards and protocols for the exchange of airline schedules and various data, including aircraft types, airports, terminals, and time zones.

Overview	Enabling a smooth and effective sharing of flight details within the aviation sector necessitates the establishment and adoption of uniform methods, regulations, and fundamentals. To simplify the process of sharing data and to establish uniform procedures for managing schedule and slot information, the Standard Schedules Information Manual (SSIM) is released on a yearly basis. It includes the official set of standards, guiding the industry with recommended practices, messaging formats and data processing procedures that are to be used by all IATA member airlines and their business partners for the exchange of airline schedules, communication of airport coordination information and minimum connect time data.[51] Airlines utilise the SSIM format to exchange schedule and route data with Global Distribution Systems (GDSs) and other entities involved in the aviation industry. GDSs rely on this standard to facilitate tasks such as assigning airline tags, updating flight schedules, and managing inventory. Furthermore, the SSIM format is also employed to update location and air traffic control systems with the most up-to-date flight information.
Benefits	The SSIM format guarantees uniform and consistent data across multiple airlines and systems, leading to a decrease in errors and an increase in automation. It enables automated data synchronisation between airlines and GDSs, resulting in reduced time and effort required for technical data entry. It enables faster and more precise updates to flight schedules, thereby improving reliability and enhancing customer satisfaction.
Common Data Elements	Flight number, Departure airport code, Arrival airport code, Departure time, Arrival time, Aircraft type, Flight duration, Operating carrier code, Marketing carrier code, Codeshare information, Frequency, Flight status, Aircraft registration number, Block time, Stopover information, Connecting flight details, Flight restrictions, Terminal and gate information, Baggage allowance, Special service requests (SSRs), Fare class codes, Ticketing and reservation information, Schedule change effective dates

5.4.3 PADIS – Passenger and Airport Data Interchange Standards

Table 38: Overview of PADIS

Name	PADIS – Passenger and Airport Data Interchange Standards
Official Website	https://www.iata.org/contentassets/18a5fdb2dc144d619a8c10dc1472ae80/pnrgov20xml20implementation20guide2016_1.pdf
Managing Organisation	IATA
Standard Type	Technical Specification

[51] https://www.iata.org/en/publications/store/standard-schedules-information

Exchange Data File	Extensible Mark-up Language (PNRGOV XML)
Overview	PADIS is created by IATA as a standardised means (new standards, harmonised regulations and adequate infrastructure) for sharing passenger information between airlines, airports, governments and others in the aviation industry. It aims to simplify the passenger process towards a more seamless, inclusive and secure passenger experience while improving efficiency and reducing industry costs. The shared data encompasses Advance Passenger Information (API) and Passenger Name Records (PNR) data. It is a subset of electronic data interchange (EDI) messages designed for use with both EDIFACT and XML syntaxes. It enables airlines to facilitate the exchange of data relevant to government requirements on PNR data and Airlines reservation systems. PADIS covers all standard passenger interactions, such as flight check-in updates, boarding pass reprints, baggage transfers, itinerary pricing requests and ticketing control requests, among others. It uses EDIFACT messages in booking, departing, and ticketing to communicate with other airlines and GDSs. The format of individual EDIFACT messages is defined by PADIS.
Benefits	PADIS allows airlines to share passenger sensitive data (API and PNR) with other airlines, airline service suppliers and States, seamlessly and safely. These data can be a useful tool for governments' border control or security processing as it can help them pre-identify travellers and patterns.
Common Data Elements	Advance Passenger Information (API): full name, date of birth and nationality Passenger Name Records (PNR): passenger name, contact details, payment information (credit card numbers), an itinerary (or a group of passengers travelling together), passport details, email addresses, IP addresses, telephone numbers and a ticketing/ticketed indicator

5.4.4 NDC – New Distribution Capacity

Table 39: Overview of NDC

Name	NDC – New Distribution Capacity
Official Website	https://www.iata.org/en/programs/airline-distribution/retailing/ndc/
Managing Organisation	IATA
Standard Type	Technical Specification

Exchange Data File	Extensible Markup Language (XML)
Introduction.	NDC (New Distribution Capability) stands as an initiative endorsed by the travel sector, established by IATA (International Air Transport Association), with the purpose of creating and fostering the acceptance of a fresh data transmission standard rooted in XML (Extensible Markup Language). This standard, known as the NDC Standard, amplifies the potential for interactions between airlines and travel agents. Furthermore, it is accessible to all external parties, intermediaries, IT service providers, and entities beyond the IATA membership, enabling them to integrate and employ this standard.[52]
Overview	NDC represents the modernisation of outdated data exchange standards that were established for ticket distribution over 40 years ago, a time predating the invention of the Internet. This initiative emerged within a swiftly changing airline industry environment in response to three primary trends, with the goal of harmonising distribution channels and ensuring transparency: (1) The current industry caters to a significantly transformed passenger base with heightened demands regarding their air retail experiences. (2) Airlines have made substantial technological investments and are preparing to efficiently manage their own offers and their distribution. These newfound capabilities within airline distribution are placing pressure on the realm of indirect sales, potentially disrupting the equilibrium of the customer experience. This situation necessitates the integration and interaction with a multitude of innovative technologies. (3) Travel agencies employ a varied assortment of channels to arrange flights for their clients. As airlines have redefined both their offerings and sales strategies, travel agents have adapted accordingly. The travel agency community is also undergoing a transformation to accommodate these changes.[53]
Benefits	• Provide comprehensive airline product and service details to corporate buyers, minimising the need for bookings that don't comply with company policies. • Display and compare all available air travel choices and their associated fares. • Choose the most suitable travel option based on preferences such as quality, service level, schedule, and price. • Receive personalised offers from preferred sellers based on individual travel history and preferences. • Gain access to the complete range of airline products, including add-ons and special fares. • Work with real-time information on offers, products, and policies.

[52] https://www.iata.org/en/programs/airline-distribution/retailing/ndc/#tab-2

[53] https://www.iata.org/contentassets/6de4dce5f38b45ce82b0db42acd23d1c/get-started-ndc.pdf

	• Enhance the ability to compare offerings for customers based on product and service features, not just price. • Provide tailored service by considering customers' complete travel history and preferences if they opt for recognition. • Distribute the entirety of the airline's product range, along with ancillary services and promotional fares. • Present airline products in an engaging manner using visually appealing formats like photos and videos. • Increase the depth of information available for each product, covering attributes, facilities, policies, and passenger reviews. • Introduce value-added products and services where relevant. • Achieve more efficient and quicker implementations, leading to cost savings.[54]
Common Data Elements	Offer Data, Passenger Data, Flight Information Availability, Data Fare Families, NDC Standard Messages, Payment and Billing Information, Booking References Passenger Loyalty, Profile Data, Travel Agency and Intermediary Data Travel Documents Itinerary Details

5.4.5 AIDM – Airline Industry Data Model

Table 40: Overview of AIDM

Name	AIDM – Airline Industry Data Model
Official Website	https://guides.developer.iata.org/docs
Managing Organisation	IATA
Standard Type	Technical Specification
Exchange Data File	Extensible Markup Language (XML)
Overview	IATA's Airline Industry Data Model (AIDM) is an infrastructure project aimed at enhancing current messaging standards development capabilities. It aims to become a single point of access to store structured information that includes industry-agreed vocabulary, data definitions and their relationships and related business requirements. Each message development project can easily leverage existing models developed by other standards groups to generate interoperable messaging standards faster and with higher quality. The standards developed within AIDM are the result of collaboration between IATA's business-driven governing bodies, specifically a Business Sponsoring Board

[54] https://www.iata.org/contentassets/6de4dce5f38b45ce82b0db42acd23d1c/get-started-ndc.pdf

	and the Architecture and Technology Strategy Board. These developments follow IATA Resolution 009[55], which establishes guidelines for modernising data exchange standards across the airline industry (IATA's Resolution 009 establishes the governance structure for the Passenger Standards Conference (PSC), which oversees the development and adoption of passenger-related standards within the airline industry). As part of this framework, all new data exchange standards must adhere to AIDM methodology and incorporate industry-approved data definitions from the AIDM repository.[56] All new data exchange standards must follow the AIDM methodology and leverage industry agreed data definitions in the AIDM repository.
Benefits	• Enhanced uniformity in defining and formatting data exchanges enhances cross-industry compatibility • Accelerated introduction of new or revised data exchange standards to the market • Swifter implementation of industry standards driven by their quality and prominence[57]
Common Data Elements	Flight Identification, Codeshare, Line of Work, Operational Times, Disruption Detail, Status and Remarks, Airport Resource Requirement, Passenger, Baggage, Fuel, Cargo, Aircraft Detail[58][59]

5.4.6 AIDX – Airline Industry Data Exchange

Table 41: Overview of AIDX

Name	AIDX – Aviation Information Data Exchange
Official Website	https://www.iata.org/en/publications/info-data-exchange/
Managing Organisation	IATA
Standard Type	Technical Specification

[55] https://www.iata.org/contentassets/c33c192da39a42fcac34cb5ac81fd2ea/psgc-brochure.pdf

[56] https://guides.developer.iata.org/v221/docs

[57] https://www.iata.org/en/about/corporate-structure/passenger-standards-conference/architecture-technology-strategy/industry-data-model/

[58] https://aixm.aero/sites/default/files/imce/library/ATIEC_2015/34_day3_aviation_information_data_exchange_aidx.pdf

[59] https://www.iata.org/en/publications/info-data-exchange/

Exchange Data File	Extensible Markup Language (XML)
Overview	Aviation Information Data Exchange (AIDX) is the global XML messaging standard for exchanging flight data between airlines, airports, and any third party consuming operational data. AIDX is generally used in the operational window of a flight, but there are implementations that have extended AIDX messaging considerably beyond this temporal scope. It is endorsed as a standard by IATA Recommended Practice 1797A, ACI Recommended Practice 501A07, ATA Recommended Practice 30.201A.[60]
Benefits	Adoption of the AIDX industry standard delivers substantial benefits to airlines, operational partners responsible for updating operational flight information and industry stakeholders consuming operational flight data. Some of the benefits include: • Cost savings through the use of a single, common, authorised standard • Utilises common IATA code sets and XML schemas • Fewer costly data feed changes will be needed as systems evolve and standardise on AIDX • Faster time to market • Use of a mature standard • Support from product vendors • XML technology allows AIDX to join other XML-crafted standards such as: TypeX (as the delivery envelope), BCBP (Passenger Data Exchange), SIDX – Schedule Information Data Exchange (SSM/SSIM/ASM), XML for Slot processes (Chapter 6 in SSIM manual), EDI/XML for PNR Push/AQQ/API. Numerous airlines, airports and vendors have deployed AIDX, are planning AIDX efforts or are waiting on others to spur their developments in the future.[61]
Common Data Elements	Flight Identification, Codeshare, Line of Work, Operational Times, Disruption Detail, Status and Remarks, Airport Resource Requirement, Passenger, Baggage, Fuel, Cargo, Aircraft Detail[62]

5.4.7 FIXM – Flight Information Exchange Model

Table 42: Overview of FIXM

Name	FIXM – Flight Information Exchange Model

[60] https://www.iata.org/en/publications/info-data-exchange/#tab-1

[61] https://www.iata.org/contentassets/cfe998bcf9214859afda9c8bf4ff75c3/aidx-xml-imp-guide-v22.1.pdf - page 9

[62] https://aixm.aero/

Official Website	https://www.fixm.aero/
Managing Organisation	ICAO, ATMRPP
Standard Type	Technical Specification
Exchange Data File	Extensible Markup Language (XML)
Overview	The FIXM is a global exchange standard capturing Flight information. FIXM is implemented in Unified Modelling Language and XML and fully supports the data exchange requirements for the FF-ICE concept, as defined by the ICAO ATM Requirements and Performance Panel (ATMRPP).[63] The Flight Information Exchange Model (FIXM) is an exchange model capturing Flight and Flow information that is globally standardised. FIXM is the equivalent, for the Flight domain, of AIXM (Aeronautical Information Exchange Model) and WXXM (Weather Information Exchange Model) both of which were developed in order to achieve global interoperability for, respectively, AIS and MET information exchange. FIXM is therefore part of a family of technology independent, harmonised and interoperable information exchange models designed to cover the information needs of Air Traffic Management. According to the ICAO SWIM concept[64], FIXM is one of the models that belong to the "Information Exchange Models" layer of the ICAO SWIM Global Interoperability framework. FIXM contains flight information items that satisfy, and are traceable to, ICAO requirements for Flight information exchanges.[65]
Benefits	FIXM offers standardised data formats for flight information within the FF-ICE scope. This encompasses detailed flight plan data, including more comprehensive route and trajectory descriptions.[66]
Common Data Elements	Flight Identification, Flight Information, Aircraft Information, Weather Conditions, Airspace Information, Flight Plans, Operational Status, Airport Resources, Air Traffic Control Information, Performance Monitoring

5.4.8 AIRIMP – Reservations Interline Message Procedures

[63] https://www.icao.int/safety/airnavigation/pages/atm.aspx

[64] Manual On System Wide Information Management (SWIM) Concept, (Advanced Edition – 2015), ICAO Doc 10039

[65] https://www.fixm.aero/releases/FIXM-4.1.0/FIXM_Core_v4_1_0_Primer.pdf

[66] https://www.eurocontrol.int/model/flight-information-exchange-model

Table 43: Overview of AIRIMP

Name	AIRIMP – Airline Industry Reservations Interline Message Procedures
Official Website	https://www.iata.org/en/publications/store/airline-industry-reservations-interline-message-procedures-airimp/
Managing Organisation	IATA
Standard Type	Technical Specification
Exchange Data File	Teletype (Type-B) messages
Overview	AIRIMP refers to standards developed by IATA for the handling of Passenger Reservations Interline Messages. The AIRIMP standards are used in transactions between travel agency and airline systems, and by airline to airline systems, when making interline reservations, whether by manual, mechanical or computerised reservations systems (CRS) in order to ensure uniformity, understanding, accuracy and economy. After a passenger books an itinerary, the airline, the travel agent or travel website user creates a PNR (Passenger Name Record) in the CRS (e.g., Amadeus, Sabre, or Travelport – Apollo, Galileo, and Worldspan). This is the Master PNR for the passenger and the associated itinerary. The PNR is identified in the particular database by a record locator. In the case when part of the journey is not provided by the holder of the Master PNR, then copies of the PNR information are sent to the CRSs of the airlines that will be providing transport. These CRSs will open copies of the original PNR in their own database to manage the portion of the itinerary for which they are responsible. The record locators of the copied PNRs are communicated back to the CRS that owns the Master PNR, so all records remain tied together. This allows exchanging updates of the PNR when the status of trip changes in any of the CRSs. Nowadays, airline systems can also be used for bookings of hotels, car rental, airport transfers, and train trips, so this will be part of PNR.
Benefits	• Easy exchange of reservation information in case passengers required flights of multiple airlines to reach their destination; • Facilitates communication between IATA/ATA members and CRS suppliers, between the applicable CRS Suppliers and, where permitted, either directly or via a CRS Supplier, with auxiliary service operators
Common Data Elements	Passenger Name Records (PNR): passenger name, contact details, payment information (credit card numbers), an itinerary (or a group of passengers travelling together), passport details, email addresses, IP addresses, telephone numbers and a ticketing/ticketed indicator

5.4.9 AIXM – Aeronautical Information Exchange Model

Table 44: Overview of AIXM

Name	AIXM – Aeronautical Information Exchange Model
Official Website	https://www.aixm.aero/
Managing Organisation	EUROCONTROL in coordination with FAA
Standard Type	Technical Specification
Exchange Data File	Extensible Markup Language (XML)
Introduction	The Aeronautical Information Exchange Model (AIXM) is crafted to facilitate the digital handling and dissemination of Aeronautical Information Services (AIS) data. AIXM employs the Geography Markup Language (GML) and serves as a specific GML Application Schema tailored for the aeronautical sector. It emerged through collaboration among the US Federal Aviation Administration (FAA), the US National Geospatial Intelligence Agency (NGA), and the European Organisation for the Safety of Air Navigation (EUROCONTROL). The present iteration stands as AIXM 5.1.1.[67]
Overview	AIXM enables the provision in digital format of the aeronautical information that is in the scope of aeronautical information services (AIS). The AIS information/data flows are increasingly complex and made up of interconnected systems. They involve many actors including multiple suppliers and consumers. There is also a growing need in the global air traffic management (ATM) system for high data quality and for cost efficiency.[68] In order to meet the requirements of this increasingly automated environment, AIS is moving from the provision of paper products and messages to the collection and provision of digital data. AIXM supports this transition by enabling the collection, verification, dissemination, and transformation of digital aeronautical data throughout the data chain, in particular in the segment that connects AIS with the next intended user.
Benefits	To overcome the drawbacks of textual NOTAMs a joint project between EUROCONTROL and the Federal Aviation Administration (FAA) was launched in 2010 (EUROCONTROL & Federal Aviation Administration, 2011b). The aim was to replace textual NOTAMs with digital NOTAMs. Digital NOTAMs represent structured data sets which can be read and interpreted by automated systems. In order to provide an encoding for digital NOTAMs, the existing Aeronautical Information Exchange Model (AIXM) was used and extended (Geospatial Intelligence TWG, 2006). AIXM allows to represent ATM elements such as event scenarios or features like airports, airspaces or routes. The machine-interpretable

[67] https://en.wikipedia.org/wiki/AIXM

[68] https://www.aixm.aero/

	data structure allows filtering of NOTAMs without the need of human interpretation. Thus the flood of NOTAMs retrieved by flight crews and other flight personnel can be minimised using this automated filtering capabilities. This reduces the information overload and stress of the crew which positively affects their situation awareness.[69]
Common Data Elements	Aerodrome/Heliport including movement areas, services, facilities, etc., Airspace structures, Organisations and units, including services, Points and Navaids, Procedures, Routes, Flying restrictions

5.4.10 AMXM – Aerodrome Mapping Exchange Model

Table 45: Overview of AMXM

Name	AMXM – Aerodrome Mapping Exchange Model
Official Website	https://www.amxm.aero/
Managing Organisation	EUROCAE WG-44/RTCA SC-217 committee
Standard Type	Technical Specification
Exchange Data File	Extensible Markup Language (XML)
Introduction	The AMXM stands as an openly accessible technical asset managed by EUROCAE / RTCA. Its purpose is to assist with AMDB (Aerodrome Mapping Database) data interchange. Various user categories gain advantages from employing AMDBs, including pilots, air traffic controllers, aerodrome administrators, and emergency/security personnel stationed at aerodromes.[70]
Overview	It is developed under the support of the joint aeronautical databases committee EUROCAE WG-44/RTCA SC-217 as an open technical resource for supporting Aerodrome Mapping Databases (AMDB) data exchange. AMDBs are produced and exchanged as datasets using global standards and tools of mainstream Geographic Information System (GIS) technology. The AMXM is based on the ISO19100 series of standards maintained by the ISO TC211. An AMDB dataset describes the spatial layout of an aerodrome in terms of features (e.g., runways, taxiways, parking stands) with geometry described as points, lines or polygons, and with attributes (e.g., surface type) providing further information. AMDBs use pilots, controllers, aerodrome managers, and aerodrome emergency/security personnel as a format to exchange data.

[69] http://www.dke.jku.at/rest/dke_web_res/publications/theses/MT1505/MT1505_copy.pdf - page 9

[70] https://www.amxm.aero/

Benefits	• Promotes interoperability • Improves the pilot's situational awareness for surface navigation • Increasing safety • Increasing operational efficiency
Common Data Elements	The spatial layout of an airport, the geometry of features (e.g., runways, taxiways, buildings) described as points, lines and polygons, further information characterising the features and their functions which are stored as attributes (e.g., surface type, name/object identifier, runway slope)

5.4.11 BIX – Baggage Information Exchange

Table 46: Overview of BIX

Name	BIX – Baggage Information Exchange
Official Website	https://www.iata.org/en/programs/ops-infra/baggage/baggagemessaging
Managing Organisation	IATA
Standard Type	Technical Specification
Exchange Data File	Extensible Markup Language (XML)
Introduction	Baggage management is undergoing rapid advancements, with ongoing introductions of new processes. However, the existing messaging standards, established since 1985, do not adequately facilitate baggage system integration and innovation. The current standards contribute to baggage mishandling due to message failures or rejections. To address these issues, new baggage messaging standards based on the IATA Airline Industry Data Model (AIDM) are being implemented. These updated standards aim to enhance clarity in communicating baggage information, making it easier for airlines, airports, and baggage handling vendors within the industry to understand and exchange relevant data.[71]
Overview	Baggage Information Exchange (BIX), the new messaging standard, uses the AIDM as a basis for constructing Baggage Messages using a business capability language, e.g., XML (Extensible Markup Language), JSON (JavaScript Object Notation) or other equivalent languages. The new messaging standard is also used in other areas outside the Baggage world, e.g., NDC and Cargo. BIX also defines the mode of communication for exchanging messages in a more secured and standard way to keep up with current and evolving IT systems.
Benefits	**Cost reduction:** The updated messaging standard allows the utilisation of cost-effective cloud-based infrastructure, resulting in lower transaction costs. Additionally, it offers a simpler, human-readable data structure compared to its predecessor.

[71] https://www.iata.org/contentassets/6bb095b194bc4ebf851ed73c83266c20/bix-guidance-document.pdf

	Enhanced data content: The new messaging standard enables the inclusion of more data content, opening doors to new passenger services and functions. It facilitates the introduction of new data through experimental evaluation and sharing of pros and cons with the BWG committee for approval. **Simplified complexity:** The updated messaging standard significantly reduces the variety of message formats, providing a much simpler method for determining the format. This leads to connected systems that are more reliable, cost-effective to maintain, and easier to enhance. **Improved resilience:** The new messaging standard enhances the resilience of baggage messaging by localising failures to the affected system, allowing for easy recovery with minimal impact on dependent systems. This is achieved through communication via multiple point-to-point connections instead of relying on a central authority. **Enhanced security:** Unlike the current messaging system that lacks data security, the new standard ensures end-to-end encryption and data exchange signature, guaranteeing the security and authenticity of the information. **Enabling new product offerings:** The updated messaging standard introduces additional features and attributes for comprehensive end-to-end bag journey solutions. Examples include arrival tracking, baggage pre-clearance, mishandled bag image recognition, and passenger applications. **Backward compatibility:** The new standard accommodates the introduction of new fields and formats while allowing for flexibility in retaining current and old formats. Systems can selectively produce and process messages without affecting new or modified fields.[72]
Common Data Elements	Aerodrome/Heliport including movement areas, services, facilities, etc., Airspace structures, Organisations and units, including services, Points and Navaids, Procedures, Routes, Flying restrictions

5.5 Road Transport

5.5.1 DATEX II – Data Exchange for Traffic Telematics

Road transport refers to passenger travel by road using vehicles such as cars, motorcycles, buses, and taxis. While public buses and some forms of shared transportation services like ride-sharing or carpooling can be considered part of public transit, road transport also encompasses private vehicles that individuals use for personal transportation.

[72] https://www.iata.org/contentassets/6bb095b194bc4ebf851ed73c83266c20/bix-guidance-document.pdf

Table 47: Overview of DATEX II

Name	DATEX II – Data Exchange for Traffic Telematics
Official Website	https://www.datex2.eu/
Managing Organisation	DATEX II Forum
Standard Type	Technical Specification
Exchange Data File	Extensible Markup Language (XML)
Introduction	DATEX II is a standard for the exchange of traffic and travel-related data in road transport. It covers real-time traffic information, traffic events, travel times, and road network data.
Overview	DATEX II serves as the electronic medium utilised across Europe to facilitate the exchange of both traffic data and traffic-related information. Its inception traces back to the early 1990s, arising from the necessity to share data between motorway operator traffic centres. This demand subsequently expanded to encompass service providers, revealing the limitations of the original DATEX I due to its reliance on outdated technical principles. This led to the development of DATEX II in the early 2000s. The essence of DATEX II lies in its capacity to disseminate traffic management and traffic information devoid of language and presentation format constraints. This eradicates the potential for misinterpretations and translation errors by recipients. Instead, recipients have the freedom to select options such as spoken text, map-based visuals, or integration into navigation computations. In many ways, it mirrors natural language, possessing a grammar framework and a lexicon. At its core, DATEX II establishes a standard for the traffic and travel information sector, enabling data sharing that culminates in a comprehensive end-user information service. The impetus for DATEX II's creation emerged from a European task force that aimed to standardise the interface between traffic control and information centres. In practice, DATEX II equips road operators and data providers with a suite of resources including documentation, a Unified Modelling Language (UML) model, and tools based on the eXtensible Markup Language (XML). This framework guarantees the uniform exchange of road data across diverse entities.[73][74]
Benefits	Enabling the direct exchange of traffic information among operational systems in control rooms significantly enhances the safety and efficiency of transportation networks. This approach ensures that exchanges occur at the level of systems,

[73] https://docs.datex2.eu/user-guide/Background/

[74] https://docs.datex2.eu/user-guide/XMLSchema/

	leading to instantaneous data transfer without operator intervention. This results in quicker and more responsive management of road networks, exemplifying the core concept of Intelligent Transport Systems (ITS). The notion of a “dynamic system state” serves as the cornerstone of ITS. When one considers the volume, accuracy, and availability of data, coupled with the diverse indicators of traffic conditions, the significance of this concept becomes evident. The standardisation and alignment of data structures and data exchange services pose fundamental challenges for both the realm of information technology and ITS. In this context, DATEX II emerges as a specification designed to operate as well as represent the bridge between the dynamic traffic domain and information technology. The effective coordination and synchronisation of traffic management strategies among road operators constitute a pivotal element in optimising the capacities of road networks. This optimisation aims to mitigate the adverse impacts of congestion while simultaneously enhancing safety.
Common Data Elements	Operator actions, Impacts, Measured or elaborated data (e.g. travel times, measured traffic speed, elaborated traffic status, weather measurements, etc.), Messages displayed on Variable Message Signs (VMS), Service information (no rest area, delays on trains, etc.)

5.5.2 ISO 17573-1:2019 – Electronic Fee Collection

Table 48: Overview of ISO 17573-1:2019 Electronic Fee Collection

Name	Electronic fee collection – System architecture for vehicle-related tolling
Website	https://www.iso.org/standard/71982.html
Managing Organisation	ISO
Standard Type	Architecture
Exchange Data File	Tbd
Introduction	Standard series consisting of a number of parts. The relevant reference part is ISO 17573 – Part 1: Reference model. This document defines the architecture of electronic fee collection (EFC) system environments, in which a customer with one contract may use a vehicle in a variety of toll domains with a different toll charger for each domain.

	EFC systems conforming to this document can be used for various purposes including road (network) tolling, area tolling, collecting fees for the usage of bridges, tunnels, ferries, for access or for parking. From a technical point of view the considered toll systems may identify vehicles subject to tolling by means of electronic equipment on-board in a vehicle or by other means (e.g. automatic number plate recognition, ANPR). From a process point of view the architectural description focuses on toll determination, toll charging, and the associated enforcement measures. The actual collection of the toll, i.e. collecting payments, is outside of the scope of this document. The architecture in this document is defined with no more details than required for an overall overview, a common language, an identification of the need for and interactions among other standards, and the drafting of these standards.
Overview	This document as a whole provides: • the enterprise view on the architecture, which is concerned with the purpose, scope and policies governing the activities of the specified system within the organisation of which it is a part; • the terms and definitions for common use in an EFC environment; • a decomposition of the EFC systems environment into its main enterprise objects; • the roles and responsibilities of the main actors. This document does not impose that all roles perform all indicated responsibilities. It should also be clear that the responsibilities of a role may be shared between two or more actors. Mandating the performance of certain responsibilities is the task of standards derived from this architecture; • identification of the provided services by means of action diagrams that underline the needed standardised exchanges; • identification of the interoperability interfaces for EFC systems, in specialised standards (specified or to be specified).
Benefits	See description in Introduction
Actual status	Tbd
Common Data Elements	Tbd

5.6 Parking – CEN TS 16157

This technical standard (CEN/TS 16157-5) establishes a framework for sharing parking information within the DATEX II system. It defines the structure, relationships, and data types for publishing static (e.g., parking area descriptions) and dynamic (e.g., occupancy) parking information. This includes both urban and truck parking, as well as information about specific parked vehicles. The standard is part of the broader DATEX II platform, but excludes location information, which is covered in a separate standard (CEN/TS 16157-2).

Table 49: Overview of CEN TS 16157

Name	CEN TS 16157: Intelligent transport systems – DATEX II data exchange specifications for traffic management and information – Part 6: Parking publications
Official Website	https://www.allianceforparkingdatastandards.org/
Managing Organisation	CEN CENELEC
Standard Type	Technical Specification
Exchange Data File	Tbd
Introduction	The PD CEN/TS 16157-6:2022 is a comprehensive standard that forms a crucial part of the Intelligent Transport Systems (ITS) framework. This document focuses on the DATEX II data exchange specifications for traffic management and information, specifically addressing Part 6: Parking Publications. Released on August 31, 2022, this standard is an essential resource for professionals involved in traffic management, urban planning, and smart city initiatives.[75]
Overview	The standard covers a wide range of topics related to parking data exchange, including: • **Data Models:** Detailed specifications for data models used in parking information exchange. • **Communication Protocols:** Guidelines for the communication protocols to be used for data exchange. • **Data Formats:** Specifications for the data formats to ensure consistency and interoperability. • **Use Cases:** Practical examples and use cases to illustrate the application of the standard. • **Security and Privacy:** Guidelines for ensuring the security and privacy of data exchanged.[76]

75 https://www.en-standard.eu/pd-cen-ts-16157-6-2022-intelligent-transport-systems-datex-ii-data-exchange-specifications-for-traffic-management-and-information-part-6-parking-publications/?srsltid=AfmBOopnf4XTjg-ZklNtajOlqrShoBBXCqlMCSKZTIZoVSSCnvTKjcc2

76 https://www.en-standard.eu/pd-cen-ts-16157-6-2022-intelligent-transport-systems-datex-ii-data-exchange-specifications-for-traffic-management-and-information-part-6-parking-publications/?srsltid=AfmBOopnf4XTjg-ZklNtajOlqrShoBBXCqlMCSKZTIZoVSSCnvTKjcc2

Benefits	The PD CEN/TS 16157-6:2022 offers several benefits: • **Enhanced Traffic Management:** By providing detailed specifications for parking data exchange, this standard helps improve traffic flow and reduce congestion in urban areas. • **Interoperability:** Ensures seamless data exchange between different systems and platforms, facilitating better coordination and efficiency. • **Future-Proofing:** Incorporates the latest technological advancements, ensuring that your systems remain relevant and effective in the long term. • **Compliance:** Adhering to recognised standards helps organisations meet regulatory requirements and industry best practices.[77]
Actual status	In Europe, we have two primary families of CEN standards, from different domains, which define parking data using unaligned models, concepts and definitions. These CEN standards covering parking data are: • the Transmodel[78] ecosystem of CEN standards for public transport, specifically standard series EN 12896 ("Transmodel") and standard series ("NeTEx"), the EN 16157 "DATEX II" series of CEN standards (most specifically CEN TS 16157-6) covering traffic management and information These CEN standards are referenced in EU Delegated Regulations. Additionally, a global industry initiative, the Alliance for Parking Data Standards (APDS), responding to parking industry and kerbside management stakeholder needs from within Europe and beyond, is developing specifications that they consider represent the data exchange requirements of their stakeholders. The APDS specifications form the basis of ISO Technical Specification ISO/TS 5206-1 (2023) with strong European parking sector support.[79]
Common Data Elements	Tbd

5.7 Other Data Standards – Indoor Mapping – IndoorGML

Another intermediate level of data which stands between the passenger, the infrastructure and other services are the indoor mapping solutions. Large airports & rail stations are a main component in a passenger trip, and are most likely the place where interchanges happen. All airports inevitably experience a significant volume of multimodal movements, involving various modes of transportation

[77] https://www.en-standard.eu/pd-cen-ts-16157-6-2022-intelligent-transport-systems-datex-ii-data-exchange-specifications-for-traffic-management-and-information-part-6-parking-publications/?srsltid=AfmBOopnf4XTjg-ZklNtajOlqrShoBBXCqlMCSKZTIZoVSSCnvTKjcc2.

[78] https://transmodel-cen.eu/

[79] https://www.mobilityits.eu/parking

for user access and egress. With the exception of air-to-air transfers, other transportation modes come into play. These movements can be categorised into two types: those involving local transportation for access or egress within the immediate vicinity of the airport and those connecting to interurban modes. The former has been the traditional focus, with significant efforts directed towards facilitating smooth interconnections for residents and visitors to the airport's local area. However, a more recent development is the direct linkage of air services through airports to other medium and long-distance transportation modes. This change has been partly driven by congestion on major air service routes and environmental considerations. Additionally, the influence of railway interest groups in decision-making processes may have played a role in this shift.[80]

Technologies and systems for indoor positioning, mapping, and navigation (IPMN) have rapidly developed over the last decade due to advanced radio and light communications, the internet of things, intelligent and smart devices, big data, and so forth. Several IPMN technologies, systems, standards, and solutions exist. However, currently there is no proposed solution that can satisfy all indoor application requirements. One of the biggest challenges is lack of standardisation, even though several IPMN standards have been published by different standard developing organisations (SDOs).[81]

Table 50: Overview of IndoorGML

Name	IndoorGML
Official Website	http://www.indoorgml.net/
Managing Organisation	Open Geospatial Consortium
Standard Type	Technical Specification
Exchange Data File	Extensible Markup Language (XML)
Introduction	Indoor spaces dominate our daily activities, growing complex due to urbanisation and high population density in limited areas. Spatial information becomes crucial for indoor location-based services, similar to outdoor contexts. However, disparities between indoor and outdoor spaces make it challenging to directly apply outdoor geospatial technologies indoors. The key difference lies in spatial reference systems; outdoor uses coordinates assuming Euclidean space, unfit for indoors. Instead, indoor locations are often denoted by identifiers like room numbers. Indoors, space differs from Euclidean norms, altering distance computation due to obstacles.[82]
Overview	This guideline relies on a cellular concept of space, viewing an indoor area as a collection of distinct, non-overlapping cells. It comprises two primary module

[80] https://www.itf-oecd.org/sites/default/files/docs/05rt126.pdf - page 36

[81] https://www.mdpi.com/2305-6703/2/2/12

[82] https://isprs-archives.copernicus.org/articles/XLI-B4/701/2016/isprs-archives-XLI-B4-701-2016.pdf

	categories: the core module and extension module. The core module encompasses four fundamental components for both conceptualisation and implementation (geometric model defining cells, cell-to-cell topology, semantic cell interpretation, and multi-layered spatial representation). Extension modules have the potential to be established upon the core module to serve specific application domains. In its initial iteration, the standard introduces an extension tailored for indoor navigation.[83]
Benefits	• Indoor Navigation: IndoorGML enables more accurate and reliable indoor navigation solutions, helping people find their way within complex indoor environments like airports, shopping malls, hospitals, and large buildings. • Location-Based Services: It supports the development of location-based services within indoor spaces, such as indoor positioning, location-aware marketing, and personalised user experiences. • Emergency Management: IndoorGML aids emergency response teams in navigating and managing incidents within indoor environments, improving evacuation procedures and coordination. • Facility Management: It facilitates effective facility management by providing a detailed and standardised representation of indoor spaces, aiding in space utilisation, maintenance, and resource allocation. • Retail and Marketing: Retailers can use IndoorGML to optimise store layouts, track customer movement, and offer targeted promotions based on customer location within stores. • Public Transportation: IndoorGML can assist in improving navigation within transportation hubs like airports, train stations, and bus terminals. • Accessibility: It contributes to making indoor spaces more accessible for individuals with disabilities by enabling accurate mapping of features like ramps, elevators, and accessible routes. • Augmented Reality (AR) and Virtual Reality (VR): IndoorGML can enhance AR and VR experiences by providing accurate spatial information for virtual content placement within indoor environments. • Building Information Modelling (BIM) Integration: It can be integrated with BIM models to create a comprehensive representation of both the exterior and interior of buildings. • Research and Analysis: Researchers and urban planners can use IndoorGML to study people's movement patterns, analyse traffic flow, and conduct spatial analysis within indoor spaces. • Security Planning: IndoorGML aids security personnel in planning and executing security measures within buildings and crowded indoor areas. • Efficient Infrastructure Planning: Organisations can use IndoorGML for efficient infrastructure planning, optimising resources, and designing spaces that align with functional requirements.

[83] https://isprs-archives.copernicus.org/articles/XLI-B4/701/2016/isprs-archives-XLI-B4-701-2016.pdf

Common Data Elements	Cells and Spaces, Geometry, Topology, Semantics, Levels and Floors, Navigation Information, Furniture and Objects, Attributes and Properties, Relationships, Extensions etc.

5.8 Other Standards – Information Security, Cybersecurity and Privacy Protection

5.8.1 ISO/IEC 27001:2022

Table 51: Overview of ISO 27001

Name	ISO/IEC 27001:2022 Information security, cybersecurity and privacy protection — Information security management systems — Requirements
Official Website	https://www.iso.org/standard/27001
Managing Organisation	ISO
Standard Type	IS, International Standard
Introduction	ISO/IEC 27001 is the world's best-known standard for information security management systems (ISMS). It defines requirements an ISMS must meet. The ISO/IEC 27001 standard provides companies of any size and from all sectors of activity with guidance for establishing, implementing, maintaining and continually improving an information security management system. Conformity with ISO/IEC 27001 means that an organisation or business has put in place a system to manage risks related to the security of data owned or handled by the company, and that this system respects all the best practices and principles enshrined in this International Standard.[84] Note: As the standard is applicable for "companies of any size and from all sectors of activity", requirements in the standard are

[84] https://www.iso.org/standard/27001

	generic. Depending on context, size and risk levels of an organisation, risks may be quite different per organisation. Fulfilling requirements of the standard presupposes that risk management measures are taken on a sufficient level that fits with a specific organisation. Requirements in the standard refer to three core risk areas: confidentiality (of sensitive data), integrity (correctness of data) and availability (data must be available when needed).
Overview	With cyber-crime on the rise and new threats constantly emerging, it can seem difficult or even impossible to manage cyber-risks. ISO/IEC 27001 helps organisations become risk-aware and proactively identify and address weaknesses. ISO/IEC 27001 promotes a holistic approach to information security: vetting people, policies and technology. An information security management system implemented according to this standard is a tool for risk management, cyber-resilience and operational excellence. Note: ISO/IEC 27001 is very much about the What and Why related to information security requirements. The standard is often used closely together with ISO/IEC 27002, the standard that answers the practical question of How to implement mitigation measures as required in ISO/IEC 27001.
Benefits	• Resilience to cyber-attacks • Preparedness for new threats • Data integrity, confidentiality and availability • Security across all supports • Organisation-wide protection • Cost savings Note: Organisation-wide protection, mentioned hereabove, also comprises data processing activities that are outsourced to an IT service organisation or data that is shared with another organisation (business partner). This can be

	arranged by contracts and monitoring of follow-up of contract agreements.
Actual Status	Organisations are more and more aware of the need to **prevent** information security incidents, and to **detect** and **respond** to these as quickly as possible if these may occur. Therefore, addressing information security requirements of the ISO/IEC 27001 standard is considered an important task in many organisations ranging from very large to very small right now. EU regulations and also national regulations on information security encourage implementing information security more and more strictly. For new regulations like NIS2 and, recently, the Cyber Security Act, ISO/IEC 27001 is a very often used reference framework as this standard is a well-known basis that covers many information security needs for any organisation. Many audits, checking compliance with requirements of the standard are based on ISO/IEC 27001. In case of non-fulfilment of a requirement, the principle of "comply or explain" is usually applied. It is possible to obtain ISO/IEC 27001 certification in order to show that requirements of the standard, on a somewhat generic level, are fulfilled. Every few years, recertification is needed in order to prove that compliance is still in order. Vendors of IT products and services use such certifications as part of their quality management measures but also because a growing number of clients ask for such certification. Other organisations also arrange certification, especially when information security risks are relatively high.

5.8.2 ISO/IEC 27002:2022

Table 52: Overview of ISO 27002

Name	ISO/IEC 27002:2022 Information security, cybersecurity and privacy protection — Information security controls
Official Website	https://www.iso.org/standard/75652.html
Managing Organisation	ISO
Standard Type	IS, International Standard
Introduction	ISO/IEC 27002 is an international standard that provides guidance for organisations looking to establish, implement, and improve an Information Security Management System (ISMS) focused on cybersecurity. While ISO/IEC 27001 outlines the requirements for an ISMS, ISO/IEC 27002 offers best practices and control objectives related to key cybersecurity aspects including access control, cryptography, human resource security, and incident response. The standard serves as a practical blueprint for organisations aiming to effectively safeguard their information assets against cyber threats. By following ISO/IEC 27002 guidelines, companies can take a proactive approach to cybersecurity risk management and protect critical information from unauthorised access and loss. Note: As ISO/IEC 27002 is applicable for “companies of any size and from all sectors of activity”, good practices as elaborated in the standard are generic. Depending on context, size and risk levels of an organisation, measures (“controls”) may be quite different. Fulfilling requirements of standard ISO 27001 presupposes that risk management measures are taken on a sufficient level that fits with a specific organisation.
Overview	Just like ISO/IEC 27001, the standard related to the Information Security Management Systems (ISMS) and information security implementation requirements, this standard helps organisations become risk-aware and proactively identify and address weaknesses.

	ISO/IEC 27002 elaborates the holistic approach to information security that is addressed in ISO 27001: vetting people, policies and technology. ISO/IEC 27002 elaborates good practices based on practical experiences in a very large number of organisations laid down in the good practices standard. Thus, this standard contributes pragmatically to ISO 27001 as a tool for risk management, cyber-resilience and operational excellence. Note: ISO/IEC 27002 is the extensive generic standard that answers the practical question of How to implement mitigation measures as required in ISO 27001, the standard about Information Security Management Systems and related requirements. Therefore, ISO/IEC 27002 is nearly always used closely together with ISO/IEC 27001.
Benefits	• Comprehensive Security Framework: Provides a detailed set of guidelines and best practices covering various dimensions of information security. • Risk Management: Enables organisations to identify, assess, and effectively manage information security risks. • Enhanced Stakeholder Trust: Demonstrates a commitment to safeguarding sensitive data, bolstering the organisation's credibility. • Regulatory Compliance: Assists in adhering to various legal, contractual, and regulatory data protection mandates. • Operational Resilience: Reduces the likelihood of security incidents that can disrupt business operations. • Competitive Advantage: In a data-driven marketplace, having a robust information security posture can

	differentiate an organisation from its competitors.[85] Note: Organisation-wide protection, mentioned as a key goal in ISO 27001 and somewhat implicitly touched in the list of benefits hereabove, also comprises data processing activities that are outsourced to an IT service organisation or data that is shared with another organisation (business partner). This can be arranged by contracts and monitoring of follow-up of contract agreements.
Actual Status	Organisations are more and more aware of the need to **prevent** information security incidents, and to **detect** and **respond** to these as quickly as possible if these may occur. Therefore, addressing information security requirements of the ISO/IEC 27001 standard is considered an important task in many organisations ranging from very large to very small right now. ISO 27002 is an excellent tool with solutions related to implementing information security measures (controlled) based on lessons learned and good practices of a very large number of organisations worldwide. EU regulations and also national regulations on information security encourage implementing information security more and more strictly. For new regulations like NIS2 and, recently, the Cyber Security Act, ISO/IEC 27001 is a very often used reference framework as this standard is a well-known basis that covers many information security needs for any organisation. For implementations, ISO 27002 is a great tool to be used (for specific business sectors and particular goals, other standards in the ISO 27000 series with specific additional requirements have been published in the last years). Many audits, checking compliance with requirements of the standard are based on ISO/IEC 27001. In such audits, ISO 27002 is often

[85] https://www.iso.org/standard/75652.html

	used as a reference standard, requiring “ISO 27002 type measure or at least equivalent”. It is possible to obtain ISO/IEC 27001 certification in order to show that requirements of the standard, on a somewhat generic level, are fulfilled. Implementation measures that relate to ISO 27002 are considered a good reference while solutions that are different usually require additional clarification in order to justify the deviating “control”.

5.8.3 ISO/IEC 27010:2015

Table 53: Overview of ISO 2710:2015

Name	ISO/IEC 27010:2015 (confirmed in 2021) Information technology — Security techniques — Information security management for inter-sector and inter-organisational communications
Official Website	https://www.iso.org/standard/68427.html
Managing Organisation	ISO
Standard Type	IS, International Standard
Introduction	ISO/IEC 27010:2015 provides guidelines in addition to the guidance given in the ISO/IEC 27000 family of standards for implementing information security management within information sharing communities. This International Standard provides controls and guidance specifically relating to initiating, implementing, maintaining, and improving information security in inter-organisational and inter-sector communications. It provides guidelines and general principles on how the specified requirements can be met using established messaging and other technical methods.
Overview	This International Standard is applicable to all forms of exchange and sharing of sensitive information, both public and private, nationally and internationally, within the same industry or

	market sector or between sectors. In particular, it may be applicable to information exchanges and sharing relating to the provision, maintenance and protection of an organisation's or nation state's critical infrastructure. It is designed to support the creation of trust when exchanging and sharing sensitive information, thereby encouraging the international growth of information sharing communities.
Benefits	Exchanging and sharing (sensitive) information between organisations is an important subject, especially in case of a critical infrastructure (transport, including public transport, is considered to be a critical infrastructure). Clarity related to what and how information to share, and who has a need-to-know is important as this is helpful in managing information on a sufficient security level.
Actual Status	The actual version of the standard dates from 2015. ISO standards need to be reviewed every 5 years. The formal website states: "This publication was last reviewed and confirmed in 2021. Therefore this version remains current"[86].

5.8.4 ISO/IEC 27017:2015

Table 54: Overview of ISO/IEC 27017:2015

Name	ISO/IEC 27017:2015 (confirmed in 2024) Information technology – Security techniques – Code of practice for information security controls based on ISO/IEC 27002 for cloud services
Official Website	https://www.iso.org/standard/43757.html
Managing Organisation	ISO
Standard Type	IS, International Standard
Introduction	This Recommendation/International Standard provides controls and implementation guidance

[86] https://www.iso.org/standard/68427.html

	for both cloud service providers and cloud service customers.
Overview	ISO/IEC 27017:2015 gives guidelines for information security controls applicable to the provision and use of cloud services by providing: • additional implementation guidance for relevant controls specified in ISO/IEC 27002; • additional controls with implementation guidance that specifically relate to cloud services.
Benefits	A large number of organisations, including organisations in the public transport sector, make use of cloud services. These services grow in importance, also because there is a tendency towards centralisation of data processing. In public transport, account-based ticketing (also called server-based ticketing) is an example of this. One of the key challenges in outsourcing data related to cloud services is how to arrange agreements including responsibilities of involved parties in such a way that information is managed on a sufficient professional and secure level. The standard offers guidelines to deal with this, based on lessons learned and good practices from a large number of organisations.
Actual Status	The actual version of the standard dates from 2015. ISO standards need to be reviewed every 5 years. The formal website states: "This publication was last reviewed and confirmed in 2024. Therefore this version remains current"[87].

5.8.5 ISO/IEC 27701:2025

Table 55: Overview of ISO/IEC 27701:2025

[87] https://www.iso.org/standard/43757.html

Name	ISO/IEC 27701:2025 Information security, cybersecurity and privacy protection – Privacy information management systems – Requirements and guidance
Official Website	https://www.iso.org/standard/27701
Managing Organisation	ISO
Standard Type	IS, International Standard
Introduction	This document specifies requirements and provides guidance for establishing, implementing, maintaining and continually improving a Privacy Information Management System (PIMS) in the form of an extension to ISO/IEC 27001 and ISO/IEC 27002 for privacy management within the context of the organisation.
Overview	This document specifies PIMS-related requirements and provides guidance for PII (Personally Identifiable Information) controllers and PII processors holding responsibility and accountability for PII processing. This document is applicable to all types and sizes of organisations, including public and private companies, government entities and not-for-profit organisations, which are PII controllers and/or PII processors processing PII within an ISMS.
Benefits	Standards ISO/IEC 27001 and ISO/IEC 27002 are known and used in many organisations all over the world as a basis for an information security management system. All key risk areas of information security – availability, integrity and also confidentiality – are covered in these standard documents. Fulfilling requirements related to confidentiality is certainly a good basis also for privacy protection. However, since a number of years, quite some experts made comments regarding to privacy as privacy protection requires additional measures (controls) that need to be taken. This standard complements the ISO/IEC 27001 and ISO/IEC 27002 standards with a Privacy

	Information Management System (PIMS) and related privacy management requirements. As the standard is an ISO standard, it can be used in Europe but needs attention for the specific European context then: due care is needed that specific European regulation, like the General Data Protection Regulation (GDPR) is taken into account.
Actual Status	ISO/IEC 27701:2019 was withdrawn and replaced in 2025 by ISO/IEC 27701:2025.[88]

5.8.6 ISO 29100:2024

Table 56: Overview of ISO 29100:2024

Name	ISO 29100:2024 Information technology – Security techniques – Privacy framework
Official Website	https://www.iso.org/standard/85938.html
Managing Organisation	ISO
Standard Type	IS, International Standard
Introduction	This document is applicable to natural persons and organisations involved in specifying, procuring, architecting, designing, developing, testing, maintaining, administering, and operating information and communication technology systems or services where privacy controls are required for the processing of PII (Personally Identifiable Information).
Overview	This document provides a privacy framework which: • specifies a common privacy terminology; • defines the actors and their roles in processing personally identifiable information (PII);

88 https://www.iso.org/standard/71670.html

	• describes privacy safeguarding considerations; • provides references to known privacy principles for information technology.
Benefits	Standards ISO/IEC 27001 and ISO/IEC 27002 are known and used in many organisations all over the world as a basis for an information security management system. All key risk areas of information security – availability, integrity and also confidentiality – are covered in these standard documents. Fulfilling requirements related to confidentiality is certainly a good basis also for privacy protection. However, since a number of years, quite some experts made comments regarding to privacy, as privacy protection requires additional measures (controls) that need to be taken. This standard complements the ISO/IEC 27001 and ISO/IEC 27002 standards with a privacy framework and related privacy management requirements. As the standard is an ISO standard, it can be used in Europe but needs attention for the specific European context then: due care is needed that specific European regulation, like the General Data Protection Regulation (GDPR), is taken into account.
Actual Status	Standard was reviewed recently and is now available in a 2024 version.

5.8.7 ISO/IEC 15408-1:2022

Table 57: Overview of ISO/IEC 15408-1:2022

Name	ISO/IEC 15408-1:2022 Information security, cybersecurity and privacy protection – Evaluation criteria for IT security – Part 1: Introduction and general model
Official Website	https://www.iso.org/standard/72891.html
Managing Organisation	ISO
Standard Type	IS, International Standard

Introduction	The ISO/IEC 15408 series, often referred to as "Common Criteria", is a framework for cybersecurity certifications of IT products. "Security by design" is a key development principle. The standard is listed for the case that, eventually, a final product would be elaborated and should a vendor plan to put the product on the market. The introduction part of the standard series is presented here as this contributes to product security awareness. Use of other parts of the standard series is not considered. This document establishes the general concepts and principles of IT security evaluation and specifies the general model of evaluation given by various parts of the standard which in its entirety is meant to be used as the basis for evaluation of security properties of IT products.
Overview	This document provides an overview of all parts of the ISO/IEC 15408 series. It describes the various parts of the ISO/IEC 15408 series; defines the terms and abbreviations to be used in all parts of the standard; establishes the core concept of a Target of Evaluation (TOE); describes the evaluation context and describes the audience addressed by the evaluation criteria. An introduction to the basic security concepts necessary for evaluation of IT products is given. This document introduces: • the key concepts of Protection Profiles (PP), PP-Modules, PP-Configurations, packages, Security Targets (ST), and conformance types; • a description of the organisation of security components throughout the model; • the various operations by which the functional and assurance components given in ISO/IEC 15408 2 and ISO/IEC 15408 3 can be tailored through the use of permitted operations;

	• general information about the evaluation methods given in ISO/IEC 18045; • general information about the pre-defined Evaluation Assurance Levels (EALs) defined in ISO/IEC 15408-5; • information in regard to the scope of evaluation schemes. The standard series Information security, cybersecurity and privacy protection — Evaluation criteria for IT security consists of the following parts: • Part 1: Introduction and general model • Part 2: Security functional components • Part 3: Security assurance components • Part 4: Framework for the specification of evaluation methods and activities • Part 5: Pre-defined packages of security requirements.
Benefits	Important as a basis for thorough evaluation of security properties of IT products.
Actual Status	ISO standards are usually being reviewed every 5 years. The ISO website reports: "Expected to be replaced by ISO/IEC DIS 15408-1 within the coming months"[89], without providing a specific date.

5.8.8 ISO/IEC 27032:2023

Table 58: Overview of ISO/IEC 27032:2023

Name	ISO/IEC 27032:2023 Cybersecurity – Guidelines for Internet security
Official Website	https://www.iso.org/standard/76070.html
Managing Organisation	ISO
Standard Type	IS, International Standard

[89] https://www.iso.org/standard/72891.html

Introduction	(Internet information is very concise, see Overview)
Overview	This document provides: - an explanation of the relationship between Internet security, web security, network security and cybersecurity; - an overview of Internet security; - identification of interested parties and a description of their roles in Internet security; - high-level guidance for addressing common Internet security issues. This document is intended for organisations that use the Internet.
Benefits	ISO/IEC 27032 is a complement to ISO/IEC 27001 to address Internet security issues. The standard can be considered for SIGN-AIR, given that an internet-based platform will be developed, connecting with Travel Companions.
Actual Status	According to the standards review insights, so far, the standard was not listed in other similar projects.

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COM/2020/789 final https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52020DC0789

Commission Delegated Regulation (EU) 2024/490 of 29 November 2023 amending Delegated Regulation (EU) 2017/1926 supplementing Directive 2010/40/EU of the European Parliament and of the Council with regard to the provision of EU-wide multimodal travel information services

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