D8.7 - Standardization methodology - initial version

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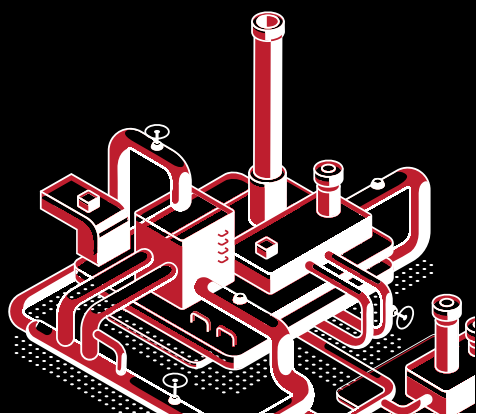

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	PP = Restricted to other programme participants (including the EC)
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Contents

Terms and abbreviations 5
Public Summary 6
1 Introduction 7
1.1 About this Deliverable 7
1.2 Document Structure 8
1.3 Relation with Other Tasks and Deliverables 9
2 Methodology 10
2.1 Data Spaces (led by DAO) 10
2.2 Internal Value Chains (led by ES) 11
2.3 External Value Chains (led by ES) 11
2.4 Ontologies (led by IAO) 12
2.5 Gap Analysis 12
3 Identified Standards in Thematic Areas 13
3.1 Data Spaces 13
3.2 Internal Value Chains 22
3.3 External Value Chains 25
3.4 Ontologies 26
3.4.1 Ontology Models and Languages 26
3.4.2 Standard Ontologies for Production / Manufacturing 28
3.4.3 Standard Ontologies for Supply Chains 29
4 Preliminary Gap Analysis – Initial Findings 29
4.1 Preliminary Gap Analysis - Data Space Standards 29
4.2 Preliminary Gap Analysis – Internal Value Chains Standards 31
4.3 Preliminary Gap Analysis – External Value Chains 32
4.4 Preliminary Gap Analysis – Ontologies 33
5 Next Steps and Collaboration with Standardization Bodies 33
5.1 Extension of Gap Analysis 34
5.2 Launch of Hackathons and Challenges (Part 3) 34
5.3 Engagement with Standardization Bodies 35
5.4 Integration with Project Work Packages 35
6 Conclusions 36

Tables

Table 2-1: Standardisation Gap Analysis Template 12
Table 3-1 Data interoperability standards 13
Table 3-2: Data Sovereignty and Trust Standards 16
Table 3-3: Data Value Creation Standards 20
Table 3-4: Circularity & Sustainability 22
Table 3-5: Resilience 23
Table 3-6: DT modelling 24
Table 3-7: External Value Chain Standards 25
Table 3-8: Ontology Models and Languages 27
Table 3-9: Standard Ontologies for Production / Manufacturing 28
Table 3-10: Standard Ontologies for Supply Chains 29
Table 4-1:Identified Gap: Access Controller 30
Table 4-2: Identified Gap: Compute-to-Data 30
Table 4-3: Identified Gap: Metadata Cache 30
Table 4-4: Identified Gap: Internal Value Chain 1 31
Table 4-5: Identified Gap: Internal Value Chains 2 31
Table 4-6: Identified Gap: External Value Chains 32
Table 4-7: Identified Gap: Ontologies 1 33
Table 4-8: Identified Gap: Ontologies 2 33

Terms and abbreviations

AAS	Asset Administration Shell
ASTM	ASTM International (American Society for Testing and Materials)
BFO	Basic Formal Ontology
CAPE-OPEN	Computer-Aided Process Engineering-Open
CEN	European Committee for Standardization
DSS	Decision-Support System
DSSC	Data Spaces Support Centre
DT	Digital Twin
FMI/FMU	Functional Mock-up Interface/Functional Mock-up Unit
IDSA	International Data Spaces Association
IEC	International Electrotechnical Commission
IOF	Industrial Ontologies Foundry
ISO	International Organization for Standardization
MaaS	Manufacturing as a Service
MQTT	Message Queuing Telemetry Transport
NGSI-LD	Next Generation Service Interface-Linked Data
OAGi	Open Applications Group
OAM	Open Assembly Model
OWL	Web Ontology Language
RDF	Resource Description Framework
SCOR	Supply Chain Operations Reference Model
SCOR DS	Supply Chain Operations Reference Model Digital Standard
SCRO	Supply Chain Reference Ontology
SPARQL	SPARQL Protocol And RDF Query Language
W3C	World Wide Web Consortium
WP	Work Package

Public Summary

The ACCURATE project, funded under the Horizon Europe programme, aims to enhance the competitiveness, sustainability, and resilience of European manufacturing value chains through a federated Manufacturing as a Service (MaaS) framework. Deliverable 8.7, Standardization Methodology – Initial Version, establishes a structured approach to align the project's innovative solutions—such as digital twins, decision-support systems, and decentralized data spaces—with existing standards while addressing gaps to foster interoperability and robustness. This deliverable, due in month 18, focuses on identifying relevant standards across four thematic areas: Data Spaces, Internal Value Chains, External Value Chains, and Ontologies. Led by partners deltaDAO AG, ENGINSOFT SPA, and Fraunhofer IAO, the methodology includes a comprehensive standards search (Part 1) and the initiation of a gap analysis (Part 2), with plans for future hackathons and engagement with standardization bodies (Part 3). By cataloging standards and identifying deficiencies, this deliverable lays the foundation for developing resilient, sustainable, and human-centered MaaS value chains capable of withstanding both short- and long-term disruptions. The final version, due in month 36, will refine these efforts, ensuring ACCURATE's contributions advance the global standardization landscape and support European manufacturing excellence.

1 Introduction

1.1 About this Deliverable

Deliverable 8.7, titled Standardization Methodology – Initial Version, represents a foundational step within the ACCURATE project to align research activities with existing standards and ensure that project outcomes enhance the competitiveness, sustainability, and resilience of European manufacturing value chains. Due in month 18 of the project timeline, this deliverable establishes a structured methodology to guide the consortium's efforts in identifying, evaluating, and integrating standardization principles across the diverse technical and operational domains addressed by ACCURATE. A final version of this deliverable, building on the initial findings and incorporating further refinements, is scheduled for submission in month 36.

The primary objective of Deliverable 8.7 is to define actionable steps that direct the project's research and development activities toward compliance with relevant standards while fostering innovation where gaps exist. To achieve this, involved partners will systematically collect and analyze information on standards and regulations pertinent to the project's scope, spanning IT standards, interoperability frameworks, modeling methodologies, human-system interactions, and process definitions. Given the project's focus on tackling complex industrial challenges—such as supply chain disruptions (including supply and demand shocks, interruption of production flows), vertical and horizontal integration of decision across the supply chain, and resilience to both short-term and long-term exogenous events—this deliverable ensures that ACCURATE's solutions are both viable and interoperable with existing industrial ecosystems.

The standardization methodology outlined in this deliverable is structured into three key phases:

- **Part 1: Search for Available Standards** – Identifying and cataloging existing standards relevant to the project's goals.
- **Part 2: Gathering Inputs from Partners** – Collaborating with consortium members to pinpoint gaps in current standards, propose improvements, and suggest the development of new standards where necessary.
- **Part 3: Launch of Hackathons and Challenges** – Engaging external stakeholders through collaborative events to refine and validate standardization approaches.

This initial version of the deliverable focuses primarily on Part 1, documenting the search and collection of available standards across four distinct thematic areas critical to the ACCURATE project. These areas, each led by a designated partner with specialized expertise, are:

- **Data Spaces** (led by deltaDAO AG) – Standards governing federated data ecosystems and interoperability for Manufacturing as a Service (MaaS).
- **Internal Value Chains** (led by ENGINSOFT SPA) – Standards related to intra-organizational processes and resilience within manufacturing systems.
- **External Value Chains** (led by ENGINSOFT SPA) – Standards addressing inter-organizational supply chain dynamics and responsiveness.
- **Ontologies** (led by Fraunhofer IAO) – Standards for semantic modeling and knowledge representation to support digital twin frameworks and decision-support systems.

As next step, Part 2 has been initiated, with the respective area leads (DAO, ES, and IAO) commencing a preliminary gap analysis based on the standards identified in Part 1. This initial assessment has begun to

highlight areas where existing standards may fall short in addressing the specific needs of the ACCURATE project. However, an extension of this gap analysis is deemed necessary to evaluate the currently developed artefacts, including digital twins, the decision-support system, and the MaaS framework. This extended analysis will ensure that the standardization methodology remains aligned with the project's evolving technical outputs. Furthermore, validation of the gap analysis by the broader consortium is required to confirm its findings, foster consensus, and refine the approach for subsequent phases.

By establishing a comprehensive baseline of existing standards in these domains, this deliverable lays the groundwork for the ongoing and future phases of the standardization task. Where gaps or limitations in available standards are identified, the ACCURATE project commits to proactive engagement with national, European (e.g., CEN), and international (e.g., ISO, ASTM) standardization bodies. This engagement will involve providing technical inputs, developing protocols, and contributing to measurement methodologies, ensuring that the project not only adheres to but also advances the global standardization landscape. Through this effort, ACCURATE aims to strengthen the resilience and adaptability of MaaS value chains, aligning with its broader vision of sustainable, human-centered, and disruption-robust manufacturing systems.

1.2 Document Structure

This deliverable, Standardization Methodology – Initial Version (Deliverable 8.7), is structured to present the ACCURATE project's initial standardization efforts clearly and concisely, focusing on Part 1 (search for available standards) while noting the start of Part 2 (gap analysis). It serves as a resource for consortium partners and stakeholders, with the following organization:

- **Chapter 1: Introduction**

  Provides an overview of Deliverable 8.7, its objectives, and its role in the ACCURATE project, including the three-phase standardization approach and the four thematic areas: Data Spaces, Internal Value Chains, External Value Chains, and Ontologies.

- **Chapter 2: Methodology**

  Describes the approach for identifying relevant standards in Part 1 and briefly notes the initiation of the preliminary gap analysis in Part 2 by area leads.

- **Chapter 3: Identified Standards in Thematic Areas**

  Presents the standards collected in Part 1 across the four thematic areas, led by DAO (Data Spaces), ES (Internal and External Value Chains), and IAO (Ontologies).

- **Chapter 4: Preliminary Gap Analysis – Initial Findings**

  Summarizes early findings from the gap analysis in Part 2, noting the need for an extended analysis and consortium validation.

- **Chapter 5: Next Steps and Collaboration with Standardization Bodies**

Outlines future steps for Parts 2 and 3, including gap analysis extension, hackathons, and engagement with standardization bodies (e.g., CEN, ISO, ASTM).

- **Chapter 6: Conclusions**

Highlights key outcomes and the deliverable's role in supporting the final version due in month 36.

1.3 Relation with Other Tasks and Deliverables

The standardization methodology outlined in Deliverable 8.7 is integral to most Work Packages (WPs) within the ACCURATE project, as it ensures that the standards identified and gaps addressed align with the technical and operational developments across the project. This deliverable supports the following WPs by providing a foundation for standard compliance and interoperability:

- **WP2: Products and Processes Ontology-Based Matchmaking**

  WP2 develops a federated ontology-based semantic framework for matchmaking and a Digital Twin (DT) registry. The standardization methodology ensures that the ontologies and DT registry align with relevant standards, particularly in the Ontologies area, enabling semantic interoperability across the ACCURATE ecosystem.

- **WP3: Digital Twins Supporting MaaS Production Adaptation**

  WP3 focuses on creating DT modeling frameworks and decision-support systems for resilient, sustainable, and human-centric production processes. The standards identified in this deliverable guide the development of these frameworks, ensuring they meet industry norms and can integrate with the broader MaaS digital backbone.

- **WP4: Supply Chain Resilience Design and Stress-Testing**

  WP4 delivers a decision-support system and tools for designing and managing resilient supply chains under disruptions. The standardization methodology ensures that these tools adhere to standards in internal and external value chains, facilitating robust and interoperable supply chain solutions.

- **WP5: Data Space Design and Implementation**

  WP5 designs and implements a decentralized data space for secure and efficient data sharing. The standards identified in the Data Spaces area directly inform the architecture and implementation, ensuring compliance with data sovereignty, privacy, and interoperability requirements.

- **WP6: Decision Support and MaaS Framework Development**

  WP6 integrates components from WP2-WP5 into the ACCURATE framework, defining its architecture and technical specifications. The standardization methodology ensures that the framework's components comply with relevant standards, enhancing seamless collaboration and technical coherence.

Additionally, this deliverable relates to the following deliverables, as they specify standards relevant to the developed artefacts:

- **D2.2**: Matchmaking model and DT registry service report.
- **D3.1**: Frameworks for resiliency- and sustainability-oriented production digital twins.
- **D3.2**: Human-centric decision-support system for MaaS production adaptation.
- **D4.1**: Simulation and optimization model for supply chain management and stress test.
- **D4.2**: Decision-support system algorithms for supply chain design, planning, and stress test.
- **D5.1**: Decentralized data space infrastructure.
- **D5.2**: Compute-to-Data environment.
- **D5.3**: Sovereign data sharing.
- **D6.1**: High-level ecosystem architecture.
- **D6.2**: DT-DSS and MaaS solutions.
- **D6.3**: ACCURATE framework.
- **D7**.1: Pilots' deployment strategy

By aligning with these WPs and deliverables, Deliverable 8.7 ensures that the ACCURATE project's outputs are standardized, interoperable, and capable of supporting resilient MaaS value chains.

2 Methodology

This chapter outlines the approach employed in developing the initial version of the Standardization Methodology (Deliverable 8.7) within the ACCURATE project. The approach focuses primarily on Part 1 of the standardization task—searching for and documenting available standards—while also noting the initiation of Part 2, which involves a preliminary gap analysis. The methodology reflects a collaborative and structured effort to ensure that the project's standardization activities align with its goals of enhancing the resilience, sustainability, and competitiveness of Manufacturing as a Service (MaaS) value chains.

Following extensive discussions within the consortium, we structured our goals and tasks to consolidate the most relevant standardization topics into four distinctive areas: Data Spaces, Internal Value Chains, External Value Chains, and Ontologies. Each area was assigned a lead partner best suited to oversee it, based on their expertise and alignment with the project's technical and operational objectives. This approach enables the consortium to comprehensively address all relevant aspects of the ACCURATE project while allowing for specialized strategies tailored to the unique requirements of each area. By distributing leadership among partners—DAO for Data Spaces, ES for Internal and External Value Chains, and IAO for Ontologies—we ensure efficient progress and targeted expertise, laying a solid foundation for both the standards search and the subsequent gap analysis. In parallel to the search for standards in these respective areas, relevant standardization bodies for each domain were gathered to support future engagement and collaboration efforts, ensuring that identified gaps can be addressed effectively with appropriate organizations.

2.1 Data Spaces (led by DAO)

The methodology for identifying standards in the Data Spaces area, led by DAO, began with a comprehensive research effort into the standardization activities of major data space associations, including IDSA, BDVA, FIWARE, Gaia-X, iSHARE, and the Data Spaces Support Centre (DSSC). During this research phase, relevant

standardization bodies were identified within these organizations, with Gaia-X and the DSSC emerging as the most critical stakeholders. Gaia-X was prioritized due to its role as the adopted governance framework for interoperability in the ACCURATE project, while the DSSC was recognized as the umbrella organization for all data space initiatives in Europe, notably for its role in collecting and categorizing standards. The DSSC's Collection of Standards and Technologies Landscape | Version 1.0 | October 2023 was therefore adopted as the starting point for identifying applicable standards. To enable early engagement, initial contact was established with both organizations: ACCURATE achieved Gaia-X lighthouse status, facilitating participation in their various working groups, and joined the DSSC communities to foster collaboration. Following this, the data space requirements engineering phase gathered requirements from pilot partners, aligned them with the ACCURATE project's goals, and incorporated interoperability needs (e.g., compliance with Gaia-X) and design requirements specified by the DSSC. In the subsequent data space architecture design and implementation phase, the ACCURATE data space architecture and its implementation were compared against the DSSC's collected standards, highlighting relevant standards and identifying gaps or underdescribed standards. These gaps were systematically documented using the "Standardisation Gap Analysis" template described in subchapter 2.5. The next steps will involve prioritizing the identified gaps based on their impact on the project's objectives and approaching the DSSC, which has an established process for contributing additional standards, to address these gaps effectively.

2.2 Internal Value Chains (led by ES)

The identification of relevant standards in the area of internal value chains has started by revising the scope of work for WP3, within the focus of the adaptation and reconfiguration of production processes within nodes of a MAAS network and from the perspectives of resiliency, sustainability, and DT-enabled decision support. Therefore, the work has focused on the areas of circularity and sustainability, resiliency and digital twin modelling and associated decision support systems. This work has been carried out in close collaboration with WP3 Partners and the standardisation topic has been raised in WP3 meetings as well as during dedicated meetings: the discussion has been driven by the requirements emerging from the actual implementation work and the related technological aspects.

Regarding circularity and sustainability both the value networks and the technical aspects have been integrated in the analysis. Regarding resilience, the analysis identified the available organisational standards. Regarding the DTs development and integration, the research of the available standards focused on the simulation-based models for performance prediction, robust optimization, and responsive control of production processes. Regarding DT-enabled decision support, an area of investigation regarded the available standards to model manufacturing aspects of the enterprises as well as the performance indicators to guide the decision support.

2.3 External Value Chains (led by ES)

The methodology underpinning the identification work for standards in the external value chains area is similar to that defined for the internal value chains. The work has started analyzing the WP4 scope in close collaboration with Partners. The standardisation topic has been raised in WP4 meetings as well as during dedicated meetings, and the discussion has been driven by the requirements emerging from the actual research and development work as well as the review of the state of the art in the research and industrial landscapes. In full alignment with the scope of work, relevant standards have been identified regarding supply chain design, operation and control considering the materials flow, stress testing and optimization perspectives. Such exploration has pointed out the availability of relevant industry standards mostly brought forward by associations of industries and other stakeholders.

2.4 Ontologies (led by IAO)

The methodology to identify standards for ontologies which are related to Manufacturing as a Service and specifically the ACCURATE project begun by investigating efforts and results of THE standardization body concerned with web technologies, the World Wide Web consortium (W3C). The standards identified at the W3C served as a starting point for a systematic investigation of further standardization bodies with relevance. In this course, the Industrial Ontologies Foundry (IOF) was identified as an initiative with high relevance for the subject matter "industrial manufacturing", and partly for "supply chain", as the respective effort of the IOF is still in a preliminary state. The research to investigate relevant standards concerning ontologies which are related to ACCURATE was complemented by investigating work and results of the International Organization for Standardization (ISO), which is highly relevant for the manufacturing domain. The results of the overall effort are shown in subchapter 3.4.

2.5 Gap Analysis

The initial gap analysis, initiated as part of Part 2 of the standardization task, aims to identify discrepancies and limitations between the existing standards and the needs of the ACCURATE project. This preliminary effort, led by the area leads (DAO, ES, and IAO), will be expanded in scope to evaluate the currently developed artefacts, including digital twins, the decision-support system, and the MaaS framework, with validation by the broader consortium. To ensure consistency and clarity, we have developed a unified template titled "Standardisation Gap Analysis," which structures the analysis into key fields: **Description** (context of the gap), **Proposing Partner** (partner identifying the gap), **Notes** (additional observations), **Current State** (existing standardization areas deemed insufficient, with references to identified standards), **Desired State** (goals and motivation for improvement, such as new or enhanced standards), **Identified Gap** (areas requiring improvement or additional scope), and **Action Plan** (steps to achieve the desired state, including potential engagement with standardization bodies). The template is presented below in Table 2-1 as a 3x4 table, and for each identified gap, a table following this format will be provided to systematically document and address standardization needs.

Table 2-1: Standardisation Gap Analysis Template

	Description	**Proposing Partner**	**Notes**
Current state			
Desired state			
Identified gap			
Action plan			

This structured template ensures that gaps are analyzed comprehensively, providing a clear pathway from identifying deficiencies to proposing actionable solutions, which will be further refined in the extended gap analysis and validated by the consortium.

3 Identified Standards in Thematic Areas

This chapter presents the standards identified through the methodologies outlined in subchapters 2.1 to 2.4, covering the four thematic areas of the ACCURATE project: Data Spaces, Internal Value Chains, External Value Chains, and Ontologies. Each area, led by its respective partner, documents the relevant standards gathered during Part 1 of the standardization task.

3.1 Data Spaces

This subchapter documents the standards identified for the Data Spaces area, led by DAO, following the methodology outlined in subchapter 2.1. The standards are sourced from the "Collection of Standards and Technologies Landscape | Version 1.0 | October 2023," published by the Data Spaces Support Centre (DSSC) and last updated on 17 October 2023. This collection lists candidate standards and technologies for the implementation of data space building blocks, focusing on technical specifications as defined in the DSSC glossary. Organized by categories from the Building Blocks Taxonomy paper[1], the collection includes "Cross-domain standards" and "Reference Implementations," covering building blocks such as Data Models, Data Exchange, Provenance and Traceability, Identity Management, Trust, Access and Usage Policies, and more. The standards are structured into three categories: Data Interoperability Standards and Technologies Landscape (Table 3-1), Data Sovereignty and Trust Standards and Technologies Landscape (Table 3-2), and Data Value Creation Standards and Technologies Landscape (Table 3-3). Each standard is detailed with fields like Short Name, Long Name, Publisher, Type of Specification, and Link to Source. The relevant standards, identified based on the requirement engineering efforts in the Data Spaces work package (i.e., WP5) and the current implementation version of the ACCURATE data space, are marked in **bold**. This list will be reviewed for the final version of the deliverable in month 36, with additional standards added if necessary, based on further implementation efforts in accordance with the ACCURATE working plan.

Table 3-1 Data interoperability standards

Building Block	Short name	Long name	Publisher	Type of specification (referred to as spec for short)	Link
Data Exchange	**AAS API**	**Details of the AAS Part 2 - API**	**Platform Industrie 4.0**	**Industry body spec**	**Details of the AAS Part 2 - API**
Data Exchange	**AAS Metamodel**	**Details of the AAS Part 1 - Metamodel and Package File formats**	**Platform Industrie 4.0**	**Industry body spec**	**Details of the AAS Part 1 - Metamodel and Package File formats**
Data Exchange	ADMS		European Commission	EU Specifications	**https://semiceu.github.io/ADMS/releases/2.00/**
Data Exchange	EBSI-OpenID4VC	EBSI profile for OpenID for verifiable Credentials	European Commission	EU Specifications	
Data Exchange	eDelivery building block		European Commission	EU Specifications	https://ec.europa.eu/digital-building-

[1] DSSC Building Blocks, https://dssc.eu/space/BBE/178421761/Building+Blocks+%7C+Version+0.5+%7C+September+2023#Compare-your-architecture-using-the-building-blocks-taxonomy

					blocks/wikis/display/DIGITAL/eDelivery
Data Exchange	**Graph Query Language**	**GraphQL community**	**Facebook**	**Industry standard body spec**	**https://graphql.org/**
Data Exchange	Hypermedia as the Engine of Application State	Doctoral dissertation, titled "Architectural Styles and the Design of Network-based Software Architectures," by Roy Fielding	University of California	Formal standard spec	https://restcookbook.com/Basics/hateoas/
Data Exchange	IRS	Item Relationship Service	Catena-x	Industry consortia spec	Item Relationship Service
Data Exchange	ISO/IEC 19941:2017	Information technology — Cloud computing — Interoperability and portability	ISO	Industry standard body spec	https://www.iso.org/standard/66639.html
Data Exchange	ISO/IEC 21823-1:2019	Internet of things (IoT) — Interoperability for IoT systems	ISO	Industry standard body spec	https://www.iso.org/standard/71885.html
Data Exchange	LDES	Linked Data Event Streams	SEMIC	Industry body spec	https://github.com/SEMICeu/LinkedDataEventStreams
Data Exchange	MQTT	messaging protocol for the Internet of Things	OASIS Open	Industry standard body spec	https://mqtt.org/mqtt-specification/
Data Exchange	NGSI-LD	NGSI-LD	ETSI	Industry standard body spec	https://www.etsi.org/committee/cim
Data Exchange	NGSIv2	FIWARE-NGSI v2 specifications	FIWARE Foundation	Industry consortia spec	NGSI v2 specification
Data Exchange	Open Database Connectivity (ODBC)	Open Database Connectivity (ODBC)	Microsoft	Industry consortia spec	Open Database Connectivity (ODBC)
Data Exchange	OpenAPI specification	OpenAPI specification	OpenAPI initiative	Industry body spec	Open API Specification
Data Models	-	Basic Formal Ontology	ISO	Formal standard spec	ISO/IEC 21838
Data Models	-	Semantic Treehouse	TNO	Product spec	Semantic Treehouse
Data Models	-	SEM-003 Governance Process	Catena-x	Industry consortia spec	SEM-003 Governance Process

Data Models	BAMM	SEM-002 BAMM Aspect Meta Model	Catena-x	Industry consortia spec	SEM-002 BAMM Aspect Meta Model
Data Models	CMD	Coordinated Metadata Catalogue Model (EU EIP SA46)	EU-EIP	EU Specifications	https://www.its-platform.eu/wp-content/uploads/ITS-Platform/AchievementsDocuments/NAP/EU%20EIP_Coord.%20Metadata%20Catalogue_v2.0_191115.pdf
Data Models	Core Vocabularies		European Commission	EU Specifications	Core Vocabularies | Joinup (europa.eu)
Data Models	Data quality W3C	Data on the Web Best Practices: Data Quality Vocabulary (w3.org)	W3C	Industry standard body spec	https://www.w3.org/TR/vocab-dqv/
Data Models	DPV	Data Privacy Vocabulary	W3C	Industry standard body spec	https://w3c.github.io/dpv/dpv/
Data Models	Dublin core		ISO	Formal standard spec	https://www.dublincore.org/
Data Models	INSPIRE	Infrastructure for Spatial Information in the European Community	European Commission	EU Specifications	https://inspire.ec.europa.eu/data-specifications/2892
Data Models	ISO/IEC 20546:2019	Information technology — Big data — Overview and vocabulary	ISO	Industry standard body spec	https://www.iso.org/standard/68305.html
Data Models	ISO/IEC 20944-1:2013	Metadata Registries Interoperability and Bindings (MDR-IB)	ISO	Industry standard body spec	https://www.iso.org/standard/51914.html
Data Models	JSON-LD	JavaScript Object Notation for Linked Data	W3C	Industry standard body spec	JSON-LD
Data Models	MyOntology		IEEE	Industry standard body spec	https://opensource.ieee.org/myontology-group
Data Models	ODATA	Open Data Protocol (Odata)	ISO	Formal standard spec	ISO - ISO/IEC 20802-1:2016
Data Models	OGC	OGC standards	Open Geospatial Consortium	Industry consortia spec	OGC Standards | OGC
Data Models	OPC UA	OPC Unified Architecture	OPC Foundation	Industry consortia spec	https://opcfoundation.org/about/opc-technologies/opc-ua/
Data Models	OSLO	OSLO vocabulary	Digital Flanders	Formal standard spec	https://joinup.ec.europa.eu/collection/oslo-open-standards-linked-organisations-0/about

Data Models	Resource Description Framework Schema	W3C	W3C	Industry standard body spec	https://www.w3.org/wiki/RDFS#:~:text=RDFS%20is%20a%20vocabulary%2C%20in,connections%20are%20allowed%2C%20between%20SubjectPredicateObject.
Data Models	SAREF	Smart Appliances REFerence	ETSI	Industry standard body spec	https://saref.etsi.org/
Data Models	Schema.org		W3C	Industry standard body spec	https://schema.org/
Data Models	SDM	Smart Data Models	Smart Data Models initiative	Industry consortia spec	https://smartdatamodels.org/
Data Models	SIOC	Semantically Interlinked Online Communities	Insight	Industry consortia spec	http://sioc-project.org/
Data Models	SKOS	Simple Knowledge Organization System	W3C	Industry standard body spec	https://www.w3.org/TR/skos-reference/
Data Models	UBL	Universal Business Language	OASIS Open	Industry standard body spec	https://www.oasis-open.org/committees/tc_home.php?wg_abbrev=ubl
Data Models	W3C Personal Data	Data Privacy Vocabularies and Controls Community Group (w3.org)	W3C	Industry standard body spec	https://www.w3.org/community/dpvcg/
Data Models	XML	XML schema	W3C	Industry standard body spec	XML Core Working Group Public Page
Provenance and Traceability	PROV-O	PROV Ontology	W3C	Industry standard body spec	https://www.w3.org/TR/prov-o/

Table 3-2: Data Sovereignty and Trust Standards

Building Block	Short name	Long name	Publisher	Type of specification	Link
Access and usage policies and control	Access Control Paradigm	IAM - 003 IAM & Access Control Paradigm	Catena-X	Industry consortia spec	IAM - 003 IAM & Access Control Paradigm
Access and usage policies and control	Accounting API		TM Forum	Industry standard body spec	https://tmf-open-api-table-documents.s3.eu-west-1.amazonaws.com/Open

					ApiTable/4.0.0/user_guides/TMF666_Account_Management_API_REST_Specification_R19.0.0.pdf
Access and usage policies and control	DAPS	Dynamic Attribute Provisioning Service (DAPS)	IDSA	Industry body spec	DAPS
Access and usage policies and control	DAPS	IAM - 006 Company Role by the Connector	Catena-X	Industry consortia spec	IAM - 006 Company Role by the Connector
Access and usage policies and control	EDC	SOV-001 Eclipse Data Space Connector (EDC)	Catena-X	Product spec	SOV-001 Eclipse Data Space Connector (EDC)
Access and usage policies and control	IDS Connector	IDS Connector	IDSA	Industry body spec	IDS Connector (Dataspace Connector) GitHub Repository
Access and usage policies and control	Interoperability Testbed	Interoperability Testbed	European Commission	EU Specifications	https://joinup.ec.europa.eu/interoperable-europe/interoperability-test-bed
Access and usage policies and control	**ODRL Information Model**	**ODRL Information Model**	**W3C**	**Industry standard body spec**	**ODRL Information Model 2.2**
Access and usage policies and control	Online Access Act (OZG)	BMI (Bundesministerium des Innern und für Heimat)	German Government	EU Specifications	https://www.onlinezugangsgesetz.de/Webs/OZG/DE/startseite/startseite-node.html
Access and usage policies and control	OPA	Open Policy Agent	Cloud Native Computing Foundation	Industry consortia spec	https://www.openpolicyagent.org/docs/latest/policy-language/
Access and usage policies and control	**Policy rules and labelling (functional specs) & Trust framework (tech specs)**	**Policy Rules & Label document, Trust framework**	**GAIA-X**	**Industry body spec**	**Gaia-X Framework**
Access and usage policies and control	SAML 2.0	SAML 2.0	Internet Engineering Task Force (IETF)	Industry standard body spec	SAML 2.0
Access and usage policies and control	Single Digital Gateway (SDG)	EU	German Government	Industry consortia spec	https://link.springer.com/chapter/10.1007/978-3-030-79851-2_5
Access and usage	UMA	User-Managed Access (UMA) 2.0	Kantara	Product spec	User-Managed Access (UMA) 2.0

policies and control					
Access and usage policies and control	XACML	Extensible Access Control Markup Language (XACML)	OASIS Open	Industry standard body spec	Extensible Access Control Markup Language (XACML)
Identity Management	**DID**	**Decentralized Identifiers**	**W3C**	**Industry standard body spec**	**Decentralized Identifiers**
Identity Management	EBSI-DID	EBSI Decentralized Identifiers Profile	European Commission	EU Specifications	Home - EBSI - (europa.eu)
Identity Management	EBSI-VC	EBSI Verifiable Credentials Profile	European Commission	EU Specifications	https://ec.europa.eu/digital-building-blocks/wikis/display/EBSIDOC/
Identity Management	eID	eID building block	European Commission	EU Specifications	https://ec.europa.eu/digital-building-blocks/wikis/display/DIGITAL/eID
Identity Management	**eIDAS**	**eIDAS**	**European Commission**	**EU Specifications**	**eIDAS regulation**
Identity Management	**eIDAS2**	**eIDAS2**	**European Commission**	**EU Specifications**	**EU post on eIDAS2**
Identity Management	Electronic Signatures and Infrastructures	Electronic Signatures and Infrastructures	ETSI	Industry standard body spec	ESI
Identity Management	EUDI RAF	EUDI Wallet Architecture & Reference Framework	European Commission	EU Specifications	EUDI Wallet Architecture & Reference Framework
Identity Management	**ICAM**	**Identity Credential and Access Management**	**GAIA-X**	**Industry body spec**	**GXFSv2 Identity and Access Management**
Identity Management	Identity Management Paradigm	IAM - 003 IAM & Access Control Paradigm	Catena-X	Industry consortia spec	IAM - 003 IAM & Access Control Paradigm
Identity Management	Identity of Employees and Technical Users	IAM - 002 Identity of Employees and Technical Users	Catena-X	Industry consortia spec	IAM - 002 Identity of Employees and Technical Users
Identity Management	Identity of Member Companies	IAM - 001 Identity of Member Companies	Catena-X	Industry consortia spec	IAM - 001 Identity of Member Companies
Identity Management	OAuth 2.0 Authorization Server Metadata	OAuth 2.0 Authorization Server Metadata	Internet Engineering Task Force (IETF)	Industry standard body spec	OAuth 2.0 Authorization Server Meta Data
Identity Management	**OIDC4VCI**	**OpenID for Verifiable Credential Issuance**	**OpenID foundation**	**Industry consortia spec**	**OpenID for Verifiable Credential Issuance**

Identity Management	**OIDC4VP**	**OpenID Connect for Verifiable Presentations (OIDC4VP)**	**OpenID foundation**	**Industry consortia spec**	**OpenID Connect for Verifiable Presentations (OIDC4VP)**
Identity Management	**OpenID Connect**	**OpenID Connect**	**OpenID foundation**	**Industry consortia spec**	**OpenID Connect**
Identity Management	SAML 2.0	SAML 2.0	Internet Engineering Task Force (IETF)	Industry standard body spec	SAML 2.0
Identity Management	SCIM	SCIM	Internet Engineering Task Force (IETF)	Industry standard body spec	SCIM
Identity Management	SIOPv2	Self-Issued OpenID Provider v2	OpenID foundation	Industry consortia spec	Self-Issued OpenID Provider v2
Identity Management	SOLID	Social Linked Data	MIT	Industry consortia spec	Solid Project
Identity Management	U2F	U2F	W3C	Industry standard body spec	FIDO U2F Raw Message Formats
Identity Management	**Verifiable Credentials Data Model**	**Verifiable Credentials Data Model**	**W3C**	**Industry standard body spec**	**Verifiable Credentials Data Model**
Trust	-	Trusted Issuer Registry API	EBSI	EU Specifications	Trusted Issuers Registry
Trust	**-**	**DID resolution**	**W3C**	**Industry standard body spec**	**Decentralized Identifiers Resolution (DID resolution)**
Trust	-	Trusted Participants Registry API	FIWARE Foundation	Industry consortia spec	Participants Registry API
Trust	**Architecture**	**Gaia-X Architecture**	**Gaia-X**	**Industry body spec**	**https://docs.gaia-x.eu/technical-committee/architecture-document/22.10/**
Trust	BPN	BPM-001 Business Partner Number (BPN)	Catena-X	Industry consortia spec	BPM-001 Business Partner Number (BPN)
Trust	Business Partner Data Pool API	BPM-003 Business Partner Data Pool API	Catena-X	Industry consortia spec	BPM-003 Business Partner Data Pool API
Trust	Certificate Authority (CA)	Certificate Authority (CA)	IDSA	Industry body spec	IDSA GitHub Repository
Trust	Company Attribute Verification	IAM - 004 Company Attribute Verification	Catena-X	Industry consortia spec	IAM - 004 Company Attribute Verification
Trust	EBSI Trust Model	EBSI Trust Model to onboard trust frameworks	European Commission	EU Specifications	Home - EBSI - (europa.eu)
Trust	EBSI-VC SF	EBSI Verifiable Credential Status framework	European Commission	EU Specifications	Home - EBSI - (europa.eu)
Trust	eSignature-DSS	eSignature building block	European Commission	Industry standard body spec	https://ec.europa.eu/digital-building-blocks/wikis/display/DIGITAL/eSignature

Trust	eSignature-EU LOTL	eSignature building block	European Commission	Industry standard body spec	https://ec.europa.eu/digital-building-blocks/wikis/display/DIGITAL/eSignature
Trust	eSignature-MRA	eSignature building block	European Commission	EU Specifications	https://ec.europa.eu/digital-building-blocks/wikis/display/DIGITAL/eSignature
Trust	eSignature-TCTL	eSignature building block	European Commission	EU Specifications	https://ec.europa.eu/digital-building-blocks/wikis/display/DIGITAL/eSignature
Trust	Experience Application Programming Interface	Advanced Distributed Learning (ADL) Initiative, which is part of the U.S. Department of Defense.	Rustici Software LLC	Industry consortia spec	https://adlnet.gov/projects/xapi/
Trust	Issuing Agency	BPM-002 Issuing Agency	Catena-X	Industry consortia spec	BPM-002 Issuing Agency
Trust	Participant Information System (ParIS)	Participant Information System (ParIS)	IDSA	Industry body spec	IDSA GitHub Repository
Trust	**Policy rules and labelling**	**Policy Rules & Label document**	**Gaia-X**	**Industry body spec**	**https://docs.gaia-x.eu/policy-rules-committee/policy-rules-labelling/22.11/**
Trust	Registration API	ONB-004 CX Registration API	Catena-X	Industry consortia spec	ONB-004 CX Registration API
Trust	Trust Framework	Gaia-X Trust Framework	Gaia-X	Industry body spec	https://docs.gaia-x.eu/policy-rules-committee/trust-framework/22.10/
Trust	**Verifiable Credentials Data Model**	**Verifiable Credentials Data Model**	**W3C**	**Industry standard body spec**	**Verifiable Credentials Data Model**

Data Value Creation Standards:

Table 3-3: Data Value Creation Standards

Building Block	Short name	Long name	Publisher	Type of specification	Link
Data, Services and Offerings descriptions	Credential Transparency Description Language	Standards Network Description Language	Credential Engine	Industry standard body spec	https://credreg.com/

Data, Services and Offerings descriptions	Breg-DCAT-AP		European Commission	EU Specifications	https://joinup.ec.europa.eu/collection/access-base-registries/solution/abr-bregdcat-ap/release/200
Data, Services and Offerings descriptions	DCAT-AP for High Value Datastes		European Commission	EU Specifications	https://semiceu.github.io/DCAT-AP/releases/2.2.0-hvd/
Data, Services and Offerings descriptionsData Models	DCAT-NAP-AP	Specifcation for Metadata in National Access Points (NAPs) in Europe	EU-EIP	EU Specifications	https://eueip.github.io/napDCAT-AP/
Data, Services and Offerings descriptions	Geo-DCAT-AP		European Commission	EU Specifications	https://semiceu.github.io/GeoDCAT-AP/drafts/latest/
Data, Services and Offerings descriptions	STAT-DCAT-AP		European Commission	EU Specifications	https://joinup.ec.europa.eu/collection/semantic-interoperability-community-semic/solution/statdcat-application-profile-data-portals-europe/release/100
Marketplaces	-	IDS Clearing House	IDSA	Industry body spec	Clearing House
Marketplaces	App Store	App Store	IDSA	Industry body spec	IDSA GitHub Repository
Marketplaces	**Digital Clearing House**	**Digital Clearing House**	**GAIA-X**	**Industry body spec**	**https://gaia-x.eu/gxdch/**
Marketplaces	**Federated Catalogue**	**Federated Catalogue**	**GAIA-X**	**Industry body spec**	**Gaia-X Architecture Document**
Marketplaces	Open API Table	Open API Table	TM Forum	Industry standard body spec	TM Forum information model
Marketplaces	Solid Protocol	Solid Protocol	Solid	Industry body spec	Solid Protocol
Publication and Discovery	CCR	CLARIN Concept Registry	CLARIN	Product spec	https://concepts.clarin.eu/ccr/browser/
Publication and Discovery	D&S-001 EDC Discovery API	Data Discovery Services	Catena-x	Industry consortia spec	Catena-X Data Discovery Services
Publication and Discovery	**Data Exchange Services**	**Data Exchange Services**	**GAIA-X**	**Industry body spec**	**Data Exchange Services Specifications**
Publication and Discovery	DCAT-AP	DCAT-AP	SEMIC	EU Specifications	DCAT-AP
Publication and Discovery	DCATv2	Data Catalog Vocabulary (DCAT) - Version 2	W3C	Industry standard body spec	Data Catalog Vocabulary (DCAT) - Version 2
Publication and Discovery	**DCATv3**	**Data Catalog Vocabulary (DCAT) - Version 3**	**W3C**	**Industry standard body spec**	**Data Catalog Vocabulary (DCAT) - Version 3**
Publication and Discovery	IDS Information model	IDS Information model	IDSA	Industry body spec	IDSA GitHub Repository

Publication and Discovery	LDES	Linked Data Event Streams	European Commission	EU Specifications	Linked Data Event Streams (LDES) | Joinup (europa.eu)
Publication and Discovery	MS-OWL	META-SHARE ontology - v2	W3C	Industry standard body spec	http://w3id.org/meta-share/meta-share
Publication and Discovery	OMTD-SHARE	OMTD-SHARE	W3C	Industry standard body spec	http://w3id.org/meta-share/omtd-share

3.2 Internal Value Chains

This section lists the relevant standards identified for the Internal Value Chains area, following the methodology outlined in subchapter 2.2. Standards relevant to circularity, sustainability and resilience (see Table 3-4 – 3-6) are mostly sourced from review of scientific state of the art led by AU in T3.2 Resilience-Oriented Circularity & Sustainability Assessment. Standards relevant to DT modeling have been identified by Partners during T3.3 and T3.5 led by ES. These lists have been cross-checked for completeness by comparing with the work carried out by the ICT Standardisation Observatory and Support Facility in Europe[2].

Table 3-4: Circularity & Sustainability

Building Block	Short name	Long name	Publisher	Type of specification	Link
Circular Economy		ISO 59000 series	ISO	Standard	https://www.iso.org/committee/7203984.html
Circular economy	Measuring and assessing circularity performance	ISO 59020:2024	ISO	Standard	https://www.iso.org/standard/80650.html
Product Environmental Footprint		Product Environmental Footprint	EU	Framework	https://green-business.ec.europa.eu/environmental-footprint-methods_en
Life Cycle Assessment		ISO 14040 series	ISO	Standard	https://www.iso.org/standard/37456.html
Sustainable Manufacturing		ASTM E-3012	ASTM International	Standard	https://www.astm.org/e3012-22.html
GHG emissions		GHG Protocol	GHG Protocol	Standard	https://ghgprotocol.org/ghg-protocol-standards-and-guidance-update-process-0

[2] (see https://standict.eu/landscape-analysis-reports) with a specific reference to the Report of TWG Digital Twins: Landscape of Digital Twins (see https://zenodo.org/records/6556917).

GHG emissions		Science Based Targets	SBTI	Framework	https://sciencebasedtargets.org
Manufacturing Systems Architecture		IEC 81346	IEC	Standard	https://www.iso.org/standard/82229.html
Product Data eXchange		IPC-2571	IPC	Standard	https://standards.globalspec.com/std/805075/ipc-2571
Product data representation and exchange		ISO 10303	ISO	Standard	https://www.iso.org/standard/84675.html

Table 3-5: Resilience

Building Block	Short name	Long name	Publisher	Type of specification	Link
Organizational resilience	ISO 22316:2017	Security and resilience - Organizational resilience - Principles and attributes	ISO	Standard	https://www.iso.org/standard/50053.html
Organizational resilience	BS 65000:2022	Organizational resilience. Code of practice	BSI	Standard	https://knowledge.bsigroup.com/products/organizational-resilience-code-of-practice?version=tracked
Organizational resilience	ANSI/ASIS SPC.1-2014	Organizational Resilience: Security, Preparedness, and Continuity Management	ASIS	Standard	https://standards.globalspec.com/std/1214841/asis-spc-1

		Systems–Requirements with Guidance for Use			

Table 3-6: DT modelling

Building Block	Short name	Long name	Publisher	Type of specification	Link
DT Models representation	ISO23247-1	Automation systems and integration: Digital twin framework for manufacturing	**ISO**	**International body spec**	**https://www.iso.org/obp/ui/en/#iso:std:iso:23247:-1:ed-1:v1:en**
DT models implementation method	IEC/TC65-63283	Industrial-process measurement, control and automation	**IEC**	**International body spec**	**https://www.iec.ch/dyn/www/f?p=103:23:501791615723937::::FSP_ORG_ID,FSP_LANG_ID:1250,25**
Interfaces between enterprise activities and control activities including standard models and terminology	IEC 62264-1	Enterprise-control system integration	**IEC**	**International body spec**	**https://www.iso.org/standard/57308.html**
KPIs for manufacturing operations management	ISO 22400	Automation systems and integration - Key performance indicators (KPIs) for manufacturing operations management	**ISO**	**International body spec**	https://www.iso.org/standard/54497.html

Asset administration	OPC 30270: Industry 4.0 Asset Administration Shell	OPC 30270	**OPC**	**Standard**	https://reference.opcfoundation.org/I4AAS/v100/docs/
FMI/FMU	FMI	Functional Mock-up Interface	**Modelica Association**	**Standard**	https://fmi-standard.org/
CAPE-OPEN	CAPE-OPEN	The CAPE-OPEN standard	**CO-LaN**	**Standard**	https://www.colan.org/
Digital Capabilities Model for Supply Networks	DCM	Digital Capabilities Model for Supply Networks	**ASCM Association for Supply Chain Management**	**Industry standard / Reference Model**	https://dcm.ascm.org/

3.3 External Value Chains

This subchapter documents the standards identified for the External Value Chains area, led by ES, and following the methodology outlined in subchapter 2.3. This table (Table 3-7) will be reviewed for the final version of the deliverable (M36), with additional standards added as necessary, based on further implementation efforts carried out in WP4.

Table 3-7: External Value Chain Standards

Building Block	Short name	Long name	Publisher	Type of specification	Link
Business activities associated with all phases of satisfying a customer's demand – Key capabilities: Plan, Source, Make, Deliver,	SCOR	Supply Chain Operations Reference Model	**APICS**	**Industry standard / Reference Model**	**https://www.apics.org/docs/default-source/scor-training/scor-v12-0-framework-introduction.pdf?sfvrsn=2**

Return, Enable (advanced towards SCOR DS, see below)					
Business activities associated with all phases of satisfying a customer's demand – new version of SCOR (see above)	SCOR DS	Supply Chain Operations Reference Model Digital Standard	**ASCM Association for Supply Chain Management**	**Industry standard / Reference Model**	**https://www.ascm.org/corporate-solutions/standards-tools/scor-ds/**
Interfaces between enterprise activities and control activities including standard models and terminology	IEC 62264-1	Enterprise-control system integration	**IEC**	**International body spec**	**https://www.iso.org/standard/57308.html**
Digital Capabilities Model for Supply Networks	DCM	Digital Capabilities Model for Supply Networks	**ASCM Association for Supply Chain Management**	**Industry standard / Reference Model**	**https://dcm.ascm.org/**

3.4 Ontologies

The overview about standards concerning ontologies which are related to Manufacturing as a Service and especially the ACCURATE project is divided into chapters for general ontology models and languages, standards for ontologies concerned with production and manufacturing, respectively, a standard ontologies concerning supply chains.

3.4.1 Ontology Models and Languages

Identified standard ontology models and languages are the Resource Description Framework (RDF), Web Ontology Language (OWL), the SPARQL Protocol And RDF Query Language (SPARQL), Resource Description

Framework Schema (RDFS), the semantic markup language DARPA Agent Markup Language and Ontology Inference Layer (DAML+OIL), all by the World Wide Web Consortium (W3C), as well as the Metamodel Framework for Interoperability (MFI), Information technology Top-level ontologies (TLO) Part 2: Basic Formal Ontology (BFO), and Topic Maps, all by the International Organization for Standardization (ISO). The standard ontology models and languages are summarized in the Table 3-8.

Table 3-8: Ontology Models and Languages

Building Block	Short name	Long name	Publisher	Type of specification	Link
Data Model (Graph Data Format)	RDF	Resource Description Framework	W3C	International body spec	https://www.w3.org/RDF/
Semantic Web Language	OWL	Web Ontology Language	W3C	International body spec	https://www.w3.org/2001/sw/wiki/OWL
Query Language	SPARQL	SPARQL Protocol And RDF Query Language	W3C	International body spec	https://www.w3.org/2001/sw/wiki/SPARQL
RDF Language	RDFS	Resource Description Framework Schema (RDFS)	W3C	International body spec	https://www.w3.org/2001/sw/wiki/RDFS
Data Model + Data Format	Topic Maps	Topic Maps	Topic Maps Community	ISO/IEC 13250	https://topicmaps.org/
Semantic Markup Language	DAML+OIL	-	W3C	International body spec	https://www.w3.org/TR/daml+oil-reference/
Metamodel framework for interoperability	MFI	ISO/IEC 19763-3:2020 Information technology. Metamodel framework for interoperability (MFI). Part 3: Metamodel for ontology registration	ISO/IEC	International standard	https://www.iso.org/standard/76581.html
Basic Formal Ontology	BFO	ISO/IEC 21838-2:2021 Information technology Top-level ontologies (TLO) Part 2: Basic Formal Ontology (BFO)	ISO/IEC	International standard	https://www.iso.org/standard/74572.html

3.4.2 Standard Ontologies for Production / Manufacturing

Identified standard ontologies for production and manufacturing are the standard ontology for digital manufacturing by the Industrial Ontologies Foundry (IOF), the Process Specification Language (PSL), Standard for the Exchange of Product Data (STEP), and the formal semantic models for the configuration of global production networks by the ISO, the Open Assembly Model (OAM) by the National Institute für Standards and Technology (NIST), as well as the ontology for product footprint concepts stemming from the project BONSAI. The standard ontologies for production and manufacturing are summarized in Table 3-9.

Table 3-9: Standard Ontologies for Production / Manufacturing

Building Block	Short name	Long name	Publisher	Type of specification	Link
Standard Ontology for digital manufacturing	IOF Core	IOF Core	IOF	IOF Standard	https://github.com/iofoundry/ontology/tree/master/core
Process Specification Language	PSL	ISO 18629-11:2005 Industrial automation systems and integration. Process specification language. Part 11: PSL core	ISO	International standard	https://www.iso.org/standard/33529.html
"STEP"	"STEP"	ISO 10303-1:2024 Industrial automation systems and integration — Product data representation and exchange Part 1: Overview and fundamental principles	ISO	International standard	https://www.iso.org/standard/83105.html
		ISO/DIS 20534: 50.00 (2018) Industrial automation systems and integration. Formal semantic models for the configuration of global production networks	ISO/DIS	International standard	https://www.iso.org/standard/68274.html
OAM	OAM	Open Assembly Model	NIST	Technical specification	https://tsapps.nist.gov/publication/get_pdf.cfm?pub_id=822185

Product footprint	BONSAI	ontology for product footprint concepts		Project result	https://github.com/BONSAMURAIS/BONSAI-ontology-RDF-framework

3.4.3 Standard Ontologies for Supply Chains

An identified preliminary standard ontology for supply chains is the Supply Chain Reference Ontology (SCRO) by the Industrial Ontologies Foundry (IOF). Worth mentioning is also the current version of the Supply Chain Reference Model Digital Standard (SCOR DS) of the Association for Supply Chain Management (ASCM), as this is formally seen not an ontology in a respective language, but a digital representation of a well-known reference model in supply chain operations. Ontologies concerning supply chains are listed in the following table (Table 3-10).

Table 3-10: Standard Ontologies for Supply Chains

Building Block	Short name	Long name	Publisher	Type of specification	Link
Supply Chain Reference Ontology ~~Standard Ontology for Supply Chain~~	~~SCOR~~SCRO	Supply Chain Reference Ontology	OAGi / IOF	IOF Standard in preliminary state	ontology/supplychain at master · iofoundry/ontology· GitHubhttps://github.com/iofoundry/ontology/tree/master/supplychain
Supply Chain Operations Reference Digital Standard	SCOR DS	Supply Chain Operations Reference Digital Standard	ASCM	Industry reference model	https://www.ascm.org/corporate-solutions/standards-tools/scor-ds/
Digital Capabilities Model for Supply Networks	DCM	Digital Capabilities Model for Supply Networks	ASCM	Reference model to guide the development of digital supply networks	https://dcm.ascm.org/

4 Preliminary Gap Analysis – Initial Findings

This chapter summarises the initial gap analysis for each area within the respective subchapter, as well as the initial findings, which will be evaluated by the Consortium and external experts in the following steps.

4.1 Preliminary Gap Analysis - Data Space Standards

For WP5, the Requirements Engineering Phase identified several requirements from Gaia-X, the Data Spaces Support Centre (DSSC), and the ACCURATE-specific project. To meet these requirements, the data space architecture was designed based on the free, open-source Ocean Enterprise stack. Further details can be found in Deliverable 5.1.

However, the Ocean Enterprise Framework is not currently part of the DSSC's collection of standards, meaning that several components need to be added. The identified gaps are described below in Table 4-1 – Table 4-3:

Table 4-1:Identified Gap: Access Controller

Status	**Description**	**Proposing Partner**	**Notes**
Current state	Access Controller component (Connector) from the Ocean Enterprise stack not part of the DSSC collection of standards. Component already added to DSSC toolbox and therefore formally recognized.	deltaDAO AG	
Desired state	Access Controller component listed in DSSC.		
Identified gap	Missing standard.		
Action plan	Reach out to DSSC via standardized form and add standard.		

Table 4-2: Identified Gap: Compute-to-Data

Status	**Description**	**Proposing Partner**	**Notes**
Current state	Compute-to-Data component from the Ocean Enterprise stack not part of the DSSC collection of standards. Component already added to DSSC toolbox and therefore formally recognized.	deltaDAO AG	
Desired state	Compute-to-Data component listed in DSSC.		
Identified gap	Missing standard.		
Action plan	Reach out to DSSC via standardized form and add standard.		

Table 4-3: Identified Gap: Metadata Cache

Status	**Description**	**Proposing Partner**	**Notes**
Current state	Metadata Cache component from the Ocean Enterprise stack not part of the DSSC collection of standards. Component already added to DSSC toolbox and therefore formally recognized.	deltaDAO AG	

Desired state	Metadata Cache component listed in DSSC.		
Identified gap	Missing standard		
Action plan	Reach out to DSSC via standardized form and add standard.		

4.2 Preliminary Gap Analysis – Internal Value Chains Standards

For DT standards, the gaps identified are described below in Table 4-4 and 4-5:

Table 4-4: Identified Gap: Internal Value Chain 1

Status	**Description**	**Proposing Partner**	**Notes**
Current state	As identified in the ACCURATE collection of standards living document, particularly for ISO23247-1 and IEC/TC65- 63283 standards, where the actual state describes the requirements for digital twin implementation and reference architecture in manufacturing services. The reference architecture relies on functional views described via interfaces containing basic information attributes for the observable manufacturing elements.	AU	
Desired state	To enable the integration of models having dynamic and diverse interfaces, coming from proprietary simulation tools, via common API definitions to abstract the invocation of models that could be located locally, remotely or hybrid.		
Identified gap	There is an immediate need to encapsulate and abstract the architecture-driven invocation of digital twin models implemented using proprietary tools. The interfaces, as defined now, consist of the functional attributes to retrieve, whereas “how” to fetch those attributes in connection with the deployment architecture is missing.		
Action plan	Engage with the platform owners to synthesize architecture-dependent interfaces enabling, for the mostly adopted digital twin protocols such as MQTT, to encapsulate the interface attributes into protocol-dependent API. Engage with standardisation bodies to promote this extension.		

Table 4-5: Identified Gap: Internal Value Chains 2

	Description	**Proposing Partner**	**Notes**
Current state	As identified in the ACCURATE collection of	AU	

	standards living document, particularly for FMI/FMU and CAPE-OPEN standards, digital twin models are implemented using a conventional/standard interface to ease up local integration of models and automate the orchestration synthesis.		
Desired state	A revision of the integration and invocation of distributed models to enable the incorporation of models deployed as cloud solutions and web-services. The revision needs to include architectures and protocols for invocation, mechanisms to deal with security & privacy requirements such as compute-to-data, and paradigms for hybrid deployment.	AU	
Identified gap	There is an immediate need for architectures and deployment strategies for digital models given that, thanks to cloud technology, the models do not need to be deployed in a monolithic centralized platform, rather it can be a constellation of distributed models with different privacy and security requirements.	AU	
Action plan	Engagement with the platform owners such as Modelica and CO-LaN to identify the common approach and best practices for hybrid models integration and promote to be standardized with standardisation bodies.	AU	

4.3 Preliminary Gap Analysis – External Value Chains

For external value chains, the gaps identified are described below in Table 4-6:

Table 4-6: Identified Gap: External Value Chains

	Description	**Proposing Partner**	**Notes**
Current state	The identified collection of standards provides a very limited support for Stakeholders to improve the resilience of the Supply Chain, e.g., SCOR DS references resilience only in OE10.5 “Strengthen the Supply Chain's Resilience to Disruptions”.	ES (IMT)	
Desired state	A standard providing a methodology to consistently evaluate Supply Chain resilience to disruptive events is provided together with the corresponding necessary information and KPIs		
Identified gap	A methodological standard to evaluate supply chain resilience is missing.		
Action plan	Engagement with standardisation bodies and industrial associations (e.g., ASCM) to discuss an interest towards a definition of a standardisation scope.		

4.4 Preliminary Gap Analysis – Ontologies

For ontologies, the gaps identified are described below in Table 4-7 – Table 4-8:

Table 4-7: Identified Gap: Ontologies 1

Status	Description	Proposing Partner	Notes
Current state	No international standard as supply chain management ontology. E.g., IOF Supply Chain Reference Ontology (SCRO) is not complete.	IAO	
Desired state	Ontology for supply chain management as international standard.		
Identified gap	Missing standard, or at least missing elements in quasi-standard (IOF).		
Action plan	Elaborate extensions for IOF SCOR, publish and suggest them to OAGi/IOF.		

Table 4-8: Identified Gap: Ontologies 2

Status	Description	Proposing Partner	Notes
Current state	Lack of internationally standardized ontology for Manufacturing as a Service (MaaS) hinders application of MaaS, and interoperability of MaaS-ecosystems.	IAO	
Desired state	Simple application of MaaS as well as facilitation of information exchange between MaaS-ecosystems by availability of a common data model.		
Identified gap	Missing standard.		
Action plan	Elaborate extensions for IOF SCOR, publish and suggest them to OAGi/IOF.		

5 Next Steps and Collaboration with Standardization Bodies

This chapter outlines the planned activities for advancing the standardization methodology in the ACCURATE project, building on the standards identified in Part 1 and the preliminary gap analysis initiated in Part 2. It

details the next steps for extending the gap analysis, engaging external stakeholders through hackathons and challenges (Part 3), and collaborating with national, European, and international standardization bodies to address the identified gaps and contribute to the global standardization landscape. These efforts aim to ensure that the ACCURATE project's outcomes—such as digital twins, the decision-support system, and the MaaS framework—are interoperable, support resilience mechanisms, and aligned with industry needs.

5.1 Extension of Gap Analysis

The preliminary gap analysis, initiated by the area leads (deltaDAO AG for Data Spaces, ENGINSOFT SPA for Internal and External Value Chains, and Fraunhofer IAO for Ontologies), has identified initial discrepancies between existing standards and the ACCURATE project's requirements. The next step involves extending this analysis to evaluate the project's evolving technical artefacts, including digital twin models, the decision-support system, and the MaaS framework. This extended analysis will:

- **Incorporate Artefact-Specific Requirements**: Assess how current standards support or fall short in enabling (i) the integration and interoperability of digital twins (WP3) for circularity, sustainability and resilience purposes, (ii) supply chain tools (WP4), (iii) data spaces (WP5), and (iv) the overarching MaaS framework (WP6).
- **Engage Consortium Partners**: Conduct workshops and validation sessions with all consortium members to review and refine the preliminary findings. This collaborative approach will ensure consensus on identified gaps and prioritize areas for standardization improvements.
- **Refine the Standardization Gap Analysis Template**: Update the template (see Table 2-5) to include additional fields, such as "Impact on Project Objectives" and "Alignment with MaaS Vision", to better quantify the significance of each gap and its relevance to the project's goals of sustainability and resilience. The extended gap analysis will be documented in a dedicated report, serving as an interim deliverable to guide subsequent standardization efforts and inform the final version of Deliverable 8.7 in month 36.

5.2 Launch of Hackathons and Challenges (Part 3)

To validate and refine the standardization methodology, Part 3 of the standardization task will involve organizing hackathons and challenges to engage external stakeholders, including industry practitioners, researchers, and standardization bodies. These events will:

- **Test Identified Standards**: Use real-world scenarios to evaluate the applicability of standards identified in chapter 3, focusing on their effectiveness in supporting MaaS value chains under disruptive conditions (e.g., supply chain interruptions, demand dynamics, deglobalization trends).
- **Address Identified Gaps**: Encourage participants to propose solutions for gaps identified in chapter 4, such as missing standards for the Ocean Enterprise stack components (Data Spaces), distributed digital twin models (Internal Value Chains), or MaaS-specific ontologies (Ontologies).
- **Foster Innovation**: Promote the development of new protocols or extensions to existing standards, particularly in areas like compute-to-data environments, hybrid model deployment, and supply chain ontologies. Hackathons will be organized in collaboration with pilot partners and aligned with the project's work packages (WP2–WP6). For example, WP5 hackathons will focus on data space interoperability, leveraging the ACCURATE project's Gaia-X lighthouse status to involve Gaia-X

working groups. Outcomes from these events will be documented and used to refine the standardization methodology, ensuring that proposed solutions are practical and industry-relevant.

5.3 Engagement with Standardization Bodies

To address gaps and advance the standardization landscape, the ACCURATE project will proactively engage with relevant standardization bodies at national, European, and international levels. Key activities include:

- **Data Spaces**: deltaDAO AG will continue collaboration with the Data Spaces Support Centre (DSSC) and Gaia-X. This includes submitting proposals for including Ocean Enterprise stack components (e.g., Access Controller, Compute-to-Data, Metadata Cache) in the DSSC's standards collection via their standardized contribution process. Additionally, participation in Gaia-X working groups will ensure alignment with interoperability frameworks.
- **Internal and External Value Chains**: ENGINSOFT SPA will engage with ISO, IEC, and ASTM to propose extensions to standards like ISO 23247-1, IEC 62264-1, and SCOR DS. For instance, proposals will address gaps in digital twin model invocation (e.g., MQTT-based APIs) and supply chain resilience metrics, ensuring compatibility with MaaS requirements.
- **Ontologies**: Fraunhofer IAO will collaborate with the Industrial Ontologies Foundry (IOF) and ISO to extend ontologies like SCRO and develop a MaaS-specific ontology. This includes submitting technical inputs to OAGi/IOF and participating in ISO technical committees to standardize semantic models for manufacturing and supply chains. Engagement will involve submitting technical contributions, participating in working groups, and presenting ACCURATE's findings at standardization forums. A timeline for these activities will be established, targeting key milestones before the final deliverable in month 36. By contributing to standards development, ACCURATE aims to enhance the interoperability and resilience of MaaS value chains, supporting the project's vision of sustainable and disruption-robust manufacturing systems.

5.4 Integration with Project Work Packages

The standardization efforts will be closely aligned with the technical developments in WP2–WP6 to

- **WP3 (Digital Twins)**: Standards extensions will enable robust integration of distributed digital twin models and ensure semantic-based framework and digital twin registry.
- **WP4 (Supply Chain Resilience)**: Engagement with bodies like ASCM will refine supply chain standards for resilience and stress-testing.
- **WP5 (Data Spaces)**: Collaboration with DSSC and Gaia-X will ensure the data space architecture meets interoperability and sovereignty requirements.

WP6 (MaaS Framework): Standardization outcomes will inform the architecture and technical specifications of the ACCURATE framework. Regular coordination that standardization activities support the project's deliverables. For example:

- **WP2 (Ontologies)**: Standardization inputs will guide the development of the federated ontology-meetings with work package leads will ensure that standardization activities remain aligned with technical progress, fostering a cohesive approach to achieving the project's objectives.

6 Conclusions

Deliverable 8.7, "Standardization Methodology – Initial Version" represents a critical milestone in the ACCURATE project's efforts to enhance the competitiveness, sustainability, and resilience of European manufacturing value chains through a federated Manufacturing as a Service (MaaS) framework. This deliverable establishes a robust foundation for aligning the project's innovative solutions—digital twins, decision-support systems, and decentralized data spaces—with existing standards while identifying gaps that require further development. By focusing on Part 1 (search for available standards) and initiating Part 2 (preliminary gap analysis), the consortium has systematically cataloged standards across four thematic areas: Data Spaces, Internal Value Chains, External Value Chains, and Ontologies. These efforts ensure that the project's technical outputs are interoperable and aligned with industry norms.

Key outcomes of this deliverable include:

- A comprehensive inventory of standards relevant to the ACCURATE project, sourced from authoritative bodies such as ISO, IEC, W3C, and the Data Spaces Support Centre (DSSC), covering critical areas like data interoperability, supply chain resilience, and semantic modeling.
- Initial identification of gaps, such as missing standards for Ocean Enterprise stack components (Data Spaces), distributed digital twin model integration (Internal Value Chains), and MaaS-specific ontologies (Ontologies), providing a clear roadmap for future standardization efforts.
- The establishment of a structured gap analysis template to systematically document deficiencies and propose actionable solutions, ensuring consistency and collaboration across the consortium.
- Early engagement with standardization bodies, such as Gaia-X and DSSC for Data Spaces and IOF for Ontologies, laying the groundwork for contributing to the global standardization landscape.

This deliverable supports the ACCURATE project's vision of creating disruption-robust MaaS value chains by ensuring that its technical developments are standardized, interoperable, and capable of addressing both short- and long-term exogenous disruptions. The next steps, outlined in chapter 5, will extend the gap analysis, validate findings through hackathons, and deepen collaboration with standardization bodies, culminating in the final version of this deliverable in month 36.