



NARRATE

Regenerative Resilient Smart Manufacturing Networks

D7.5 Standardisation Report

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D7.5 STANDARDISATION REPORT

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Authors	Thomas Knothe
Reviewers	Álvaro Parejo (F6S), Frank Werner (BLU), Mike Papazoglou (SERV)
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STATEMENT ON MAINSTREAMING GENDER

The NARRATE consortium is committed to including gender and intersectionality as a transversal aspect in the project's activities. In line with EU guidelines and objectives, all partners – including the authors of this deliverable – recognise the importance of advancing gender analysis and sex-disaggregated data collection in the development of scientific research. Therefore, we commit to paying particular attention to including, monitoring, and periodically evaluating the participation of different genders in all activities developed within the project, including workshops, webinars and events but also surveys, interviews and research, in general. While applying a non-binary approach to data collection and promoting the participation of all genders in the activities, the partners will periodically reflect and inform about the limitations of their approach. Through an iterative learning process, they commit to plan and implement strategies that maximise the inclusion of more intersectional perspectives in their activities.

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The NARRATE Consortium is the following:

Participant number	Participant organisation name	Short name	Country
1	INSTITUTO TECNOLOGICO METALMECANICO, MUEBLE, MADERA, EMBALAJE Y AFINES-AIDIMME	AID	ES
2	SCIENTIFIC ACADEMY FOR SERVICE TECHNOLOGY EV	SERV	DE
3	FRAUNHOFER GESELLSCHAFT ZUR FORDERUNG DER ANGEWANDTEN FORSCHUNG EV	FhG	DE
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7	SYNESIS-SOCIETA CONSORTILE A RESPONSABILITA LIMITATA	SYN	IT
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Abbreviations

WP	Work Package
AI	Artificial Intelligence
AIAG	Automotive Industrial Action Group
ANSI	American National Standards Institute
BSI	British Standards Institution
C4ISR	Command, Control, Communications, Computers, Intelligence, Surveillance, and Reconnaissance
CEN	European Committee for Standardisation
CENELEC	European Committee for Electrotechnical Standardisation
DIN	Deutsches Institut für Normung
DPP	Digital Product Passport
DT	Digital Twin
EC	European Commission
EIF	European Interoperability Framework
eTOM	Enhanced Telecom Operations Map
ETSI	European Telecommunications Standards Institute
IDTA	Industrial Twin Association
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronics Engineers
IMC	Intelligent Manufacturing Custodian
IoT	Internet of Things
ISO	International Standardisation Organisation
ITU	International Telecommunication Union
KPI	Key Performance Indicator
LLM	Large Language Model
MaaS	Manufacturing as a Service
MESA	Manufacturing Enterprise Solution Association
ML	Machine Learning

Mx	Month x
MSx	Milestone x
NIST	National Institute for Standardisation and Technology
OMG	Object Management Group
OPC	Open Platform Communication
OPC UA	OPC Unified Architecture
SCOR	Supply Chain Reference Model
SMN	Smart Manufacturing Network
TX.Y	Task X.Y
UN/CEFACT	United Nations Centre for Trade Facilitation and Electronic Business
W3C	World Wide Web Consortium

EXECUTIVE SUMMARY

The NARRATE project focuses on developing next-generation integrated sustainability manufacturing services to enable agile and resilient supply chains. These supply chains aim to adapt to disruptions, ensure European economic security, and maintain technological leadership. A key emphasis of the project is on seamless interoperability across diverse product domains and regional economies, which necessitates the adoption and development of standards.

The main objectives of Task 7.5 include several key points. First, it aims to identify and address standardisation needs for NARRATE assets and functions. Second, it focuses on collaborating with relevant standardisation organisations to influence and adopt standards. Third, it seeks to leverage existing standards in production control, supply chain management, and data exchange. Finally, it aims to contribute to new standardisation activities in areas such as Artificial Intelligence and data spaces.

To achieve those objectives, NARRATE adopts the ISO 11354 Enterprise Interoperability Framework, tailored to its specific needs. This framework includes a functional frame for the management and planning of circular value chains, an organisational frame for role assignments among ecosystem partners, and a technology frame encompassing core NARRATE methodologies like digital twins, data models, and analytics services.

The document recommends several major activities. These include the application of widely accepted standards for security infrastructure, IT governance, policy management, identity and access management, data storage, and data carriers. Additionally, there is a focus on contributing to ISO TC 184 standards for digital twins and interoperability, as well as data standards maintained by the Industrial Digital Twin Association. Lastly, it suggests analysing and adapting existing standards to ensure cross-sectoral application and future-proof technologies, particularly in the context of data modelling methods.

NARRATE can influence existing and emerging standards by demonstrating, through its IMC-driven Smart Manufacturing Network architecture, how interoperable data models, blueprint-based orchestration, and AI-enabled resilience mechanisms can be formalized into repeatable, standardized practices.

By validating these concepts in real industrial pilots, NARRATE provides concrete reference models and technical specifications that can inform and shape current and future standards in digital manufacturing, supply-chain interoperability, sustainability assessment, and Manufacturing-as-a-Service.

1. INTRODUCTION

NARRATE is working on next generation of integrated sustainability manufacturing services along supply chains and facilitate circular ecosystems. Under that premises different enterprises in dynamic roles (e.g. supplier, integrator, original manufacturer, customers and even repairer) must collaborate across different product domains by interacting between different regional economies. The functioning of those next generation services requires seamless interoperability which demands standards. In the frame of NARRATE there are long time existing standards, especially in production control, supply chain management and data exchange. But also new standardisation activities in emergent topics like Artificial Intelligence (e.g. CEN CLC JTC 21) or data spaces (e.g. CEN CLC JTC 25) are started already. But there are others to come. Based on that consideration and to make the achievement of NARRATE relevant in the respective ecosystems, NARRATE needs a footprint into standardisation in terms of:

- Identification of standardisation needs in the context of NARRATE assets and functions
- Identification of standardisation bodies, where NARRATE can contribute to
- Identification of existing standards to be taken into account for NARRATE
- Identification of current standardisation activities, where NARRATE can influence
- Identification of future activities, where NARRATE achievements can be useful

NARRATE should identify were new or existing work Items have to be created in standardisation or were the NARRATE assets (e.g. the executable environments) should be compliant with existing relevant standards coming from several sources, mandated international ones (e.g. ISO or CEN), de facto like OMG (**¡Error! No se encuentra el origen de la referencia.**).

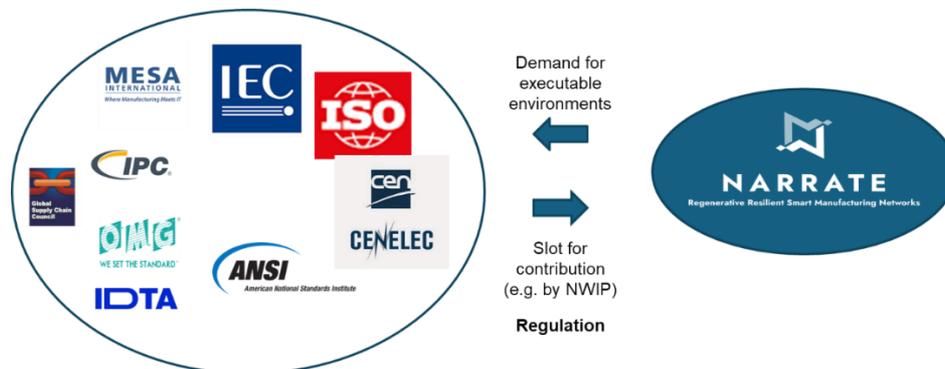


FIGURE 1 RELATIONSHIP BETWEEN NARRATE AND STANDARDISATION

1.1. PURPOSE OF THE DOCUMENT

The document has the aim to connect the scientific-technical work of NARRATE to available, developing and even future standards. This mapping envisages to purposes:

- Guidance of further development work in NARRATE to motivate the application of available standards in order to be compliant with existing industrial eco-systems as well to reduce research and implementation efforts

- Road mapping of possible standardisation work in ongoing and future standardisation activities.

For achieving that, the document focusing the Identification of standardisation bodies, existing standards, standardisation activities and needs for future standardisation in the frame of NARRATE assets and function.

1.2. DOCUMENT STRUCTURE

The document is organized according to the following major structure

1. Introduction

The introduction is setting up the purpose of the document, the related work package and the objectives of the task.

2. Context of Global Standardisation Related to NARRATE

Because of the huge variety of standardisation bodies and activities in the context of NARRATE, first a framework considering NARRATE's methodological and technological assets will be described in way, that they can be considered for mapping to standards. Further on, existing standardisation frameworks are analysed, selected and adjusted for the purpose of mapping. A collection and assignment of related official and de facto-standardisation bodies is completing the standardisation framework.

3. Evaluation of Standards for Engagement

Based on the standardisation framework, the related standards for the purpose of NARRATE were identified, selected and evaluated. This is based on a scheme in order to select standards for being used in the project work, to contribute with the achievements coming out of NARRATE for revision and set-up new standards

4. Stakeholder Engagement

The chapter provides a guideline, how NARRATE experts can be involved into standardisation activities to maximise the impact of the research work.

5. Conclusion

1.3. TIME FRAME

Task 7.4 Standardisation in Smart Manufacturing Networks

Milestone: Month 24.

1.4. OBJECTIVES

The objective of this document is to identify specific initiatives that can be useful to include in the project. NARRATE is developing artefacts covering a wide area of possible standardisation activities, e.g.:

- Industry 4.0 - frameworks for smart manufacturing that includes cyber-physical systems, the Internet of Things (IoT), and cloud computing,
- Industrial Digital Twin - Developing standards and best practices for digital twins in manufacturing, healthcare, and other industries
- AI based decision management systems to support resilience of production towards complete cross-organisational value-chains.
- Environments and Protocols for industrial communication and automation that allows different systems to exchange data.

Based on this consideration, the first objective is to provide a framework for a comprehensive collection of standardisation organisations and its completed, current and future standardisation activities in the field of NARRATE. The second objective is to identify the most relevant standards which NARRATE should follow, influence or even should initiate. The third objective is to explain, how NARRATE partner can take part on standardisation activities.

2. CONTEXT OF GLOBAL STANDARDISATION RELATED TO NARRATE

2.1. STANDARDISATION FRAMEWORK FOR SMN

2.1.1. Introduction into NARRATE assets and functions to be considered for standardisation

Narrate is addressing the aim to enable more agile and resilient supply chains - which possess the ability to deal with adversity, recover quickly from unexpected events, withstand shocks and continuously adapt and accelerate as disruptions arise overtime - are essential for European economic security, and technological leadership.

The main asset of NARRATE project is the Intelligent Manufacturing Custodian (IMC) – that allows for end-to-end visibility and control over supply chain operations. The IMC employs advanced AI capabilities coupled with reliable models, simulators, digital twins, decision making and planning technologies. will conduct cutting edge research that integrates effectively recent advances in foundational digital technologies that include Artificial Intelligence (AI) and Machine Learning (ML), Big-Data, IoT, and Digital Twins (DT) – that allows for end-to-end visibility and control over supply chain operations. The IMC leverages data from various data sources, such as product, production and relevant supply-chain data, and data from machines, sensors, and IoT devices, to enable proactive decision-making and act as a nerve centre for a supply-chain network, providing real-time monitoring and coordination of intelligent production processes, and logistics. Based on the requirements framework elaborated in Deliverable 1.1 “Project Requirements” and the building blocks of the NARRATE architecture as defined in Deliverable 1.3 “Architecture requirements”, the following frames of standardisation can be derived for NARRATE.

Function Frame (Requirements)		Organisation Frame			Technology Assets Frame		
		Supplier	Own Organisation	Customer	Language	Models	System Functions
Management	Sustainability	Resilience, Sustainability & Circularity Testing Tool Supplier and Risk Assessment Tool Resilience Strategy Tool Risk Identification and Monitoring Tool			Digital Twin Language Blueprint Frames Annotation	Digital Twin Models Digital Twin Configuration	MaaS Digital Twin Orchestration Interfaces (IoT) Digital Twin Data Storage
	Performance						
	Improvements						
	Capacity Management						
	Cost						
Planning	Plan	Resilience, Sustainability & Circularity Testing Tool End-to-End Visibility & Advance Decision Tool Intelligent Logistics and Warehousing Production Planning and Process Routing Tool Production and (Re-) Planning LLM System for supporting Production Planning MaaS Orchestration					
	Schedule						
	Control						
	Sustainability	Risk Identification & Monitoring Tool					

TABLE 1 NARRATE FRAME FOR STANDARDISATION (FUNCTIONS, ORGANISATION, TECHNOLOGY)

The first frame is the Functional Frame for Management and Planning of entire circular value chains, the second is the Organisation Frame, where the respective roles of partners are assigned. The third frame is related to the core methodology assets of the Blueprint Management System, based on Languages, the related Models and the surrounding system functions. In **¡Error! No se encuentra el origen de la referencia.** those three frames are related to each other and the specific solutions, envisaged by NARRATE are assigned to.

As it can be seen, there are no specific product related assets mentioned (e.g. furniture). They are out of scope, because NARRATE is cross-domain oriented, even the pilots are assigned to specific products.

2.1.2. Existing Standardisation frameworks for interoperability

To cover both perspectives for the purpose of standardisation a common framework seems to be suitable. In order to select a suitable framework, generic and application

specific frameworks can be identified. A candidate for a generic framework is the ISO 11354 Enterprise Interoperability Framework. Options for specific frameworks are supply-chain ones like the SCOR-Model or IT-System specification ones like the C4ISR (Command, Control, Communications, Computers, Intelligence, Surveillance, and Reconnaissance), which comes from defense perspective. Specific framework models are mostly limited in their scope (e.g. SCOR is not addressing infrastructure and technologies). To cover the entire solution space of NARRATE, several specific framework models must be combined, which leads to unforeseen complexity. Generic framework models come with the risk not being specific enough. Because of the complexity issue of specific framework models a strategy were taken to apply one generic framework model and specialize, if necessary, for the purpose of covering aspects for the NARRATE project. For enterprise interoperability there are two standard frameworks considered. The first one is the European Interoperability Framework (EIF) and the second is the already mentioned ISO 11354 Enterprise Interoperability Framework. The European Interoperability Framework consist on two major parts:

- Underlying interoperability principles (e.g. Underlying principle 11: preservation of information and assigned recommendation, e.g. Formulate a long-term preservation policy for information related to)
- Layers and assigned recommendations (e.g. Ensure holistic governance of interoperability activities across administrative levels and sectors.)
 - Legal Interoperability
 - Organisational Interoperability
 - Semantic Interoperability
 - Technical Interoperability
 - and across the core layers the “Integrated Public Service Governance”

The EIF do not address any technology aspects, which is required for covering NARRATE artefacts for standardisation. A specialization of EIF for that would lead to the problem of overlapping of one technology to several layers' and principles. This would create redundant and complexity.

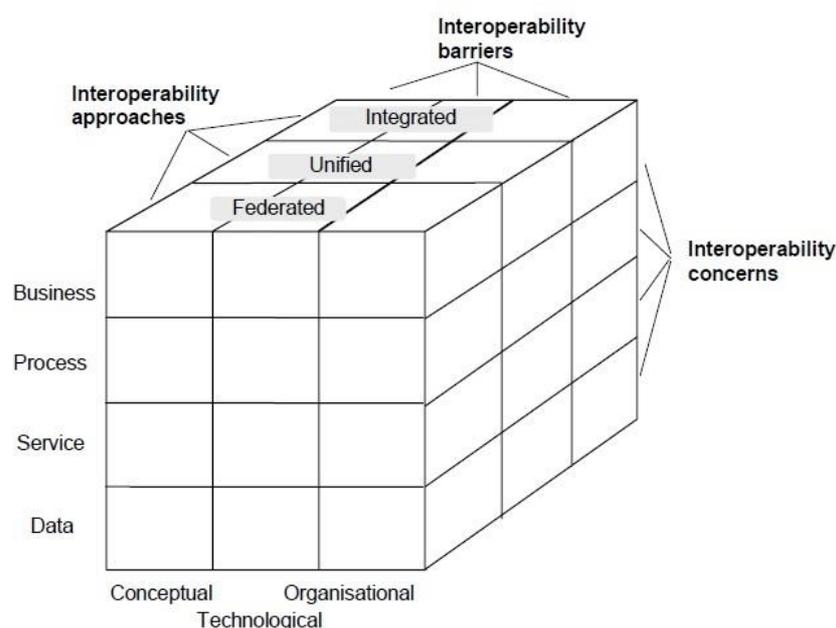


FIGURE 2 ISO 11354 ENTERPRISE INTEROPERABILITY FRAMEWORK

The ISO 11354 Enterprise Interoperability Framework is more technical orientated and is addressing Interoperability concerns, barriers and approaches (Figure 2).

The separation of standards into the different interoperability barriers (conceptual, technological and organisational) is not relevant for the purpose of just taking technical standards. A similar issue can be seen with the interoperability approaches. Because NARRATE is following mainly a federated approach, so unified and integrated ones can be left aside. The Interoperability Concerns dimension seems to be too general and lacks on the perspective of identification and governance issues.

2.1.3. Standardisation Framework for NARRATE

The ISO 11354 was first time revised and specialized for CEN CLC JTC 24 DPP Framework. Based on that a resulting framework for NARRATE is adapted and visualized in Figure 3.

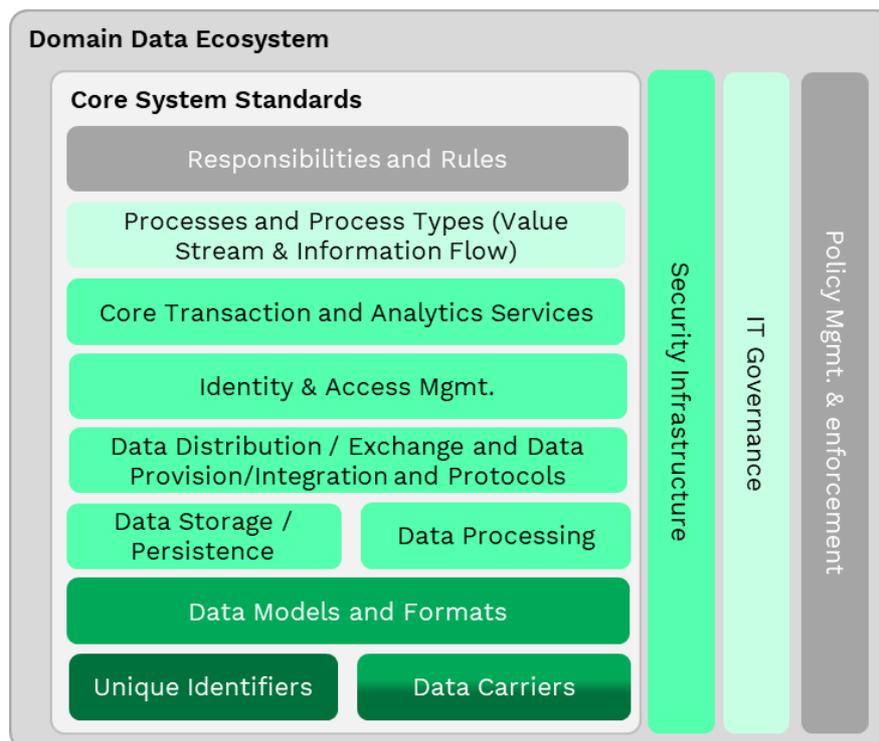


FIGURE 3 ENTERPRISE INTEROPERABILITY FRAMEWORK ADAPTED FOR NARRATE

In the following subchapters, the elements of the framework are described briefly.

2.2. DOMAIN DATA ECOSYSTEM

The domain data ecosystem describes the totality of DPP relevant data, in this case it is about manufacturing, and their relationships to each other. Within this ecosystem, several important aspects converge to enable a holistic understanding. This covers the following sub-elements:

- Product Semantics as it is addressed in sector specific standards like in funSTEP (ISO 10303-236).
- Production Semantics of assets, like machines, procedures and processes in a given sector and in addition cross-sectoral, as it is covered by SCOR for core supply chain management semantics.

2.3. CORE SYSTEM STANDARDS – RESPONSIBILITIES AND RULES

The responsibility describes the participation by various roles in completing tasks or deliverables for a project or business process. A business rule defines or constrains some aspect of a business. It may be expressed to specify an action to be taken when certain conditions are true or may be phrased so it can only resolve to either true or false. Business rules are intended to assert business structure or to control or influence the behaviour of the business. Both are fundamental aspects of business interoperability to clarify duties of different partners in an ecosystem. The responsibilities and rules are a basis for the policy management and enforcement component.

2.3.1. Core System Standards – Processes, Process Types, Object and Object Types

A process is a “set of interrelated or interacting activities” that can be executed to realize one or more given objectives of an enterprise, a network, or a part of an enterprise to achieve some desired end result. Typically, there are management, value stream, support, as well as data and information flow processes.

The core value processes relate to the upstream and downstream processes along the value chain in intelligent manufacturing. To understand the characteristics of the processes contributing to the overall system, we cover the specific aspects as well. Support processes involve the operations of technical and organisational resources required for the operation of the Intelligent Manufacturing System. Additionally, we separate the data and information flow processes that traverse and interconnect the management, core value, and support processes.

- **Management Processes:** The major management processes for the Intelligent Manufacturing System include resource management, business continuity management, performance management, as well as risk, safety, and change management related to technical standards. Especially the control processes executed by the IMC Services are located.
- **Core Value Processes:** These processes always involve materials and physical goods. Here, types of processes can be categorized into flow, batch, and discrete processes. Discrete processes can be further divided into mass, configured, individual, and one-of-a-kind processes. Common process definitions and output specifications across sectors will help define the property systematics of the passport, which are necessary for data analytics, auditing, and validation and verification of data (e.g., for logical verification). Here the interfaces to the IMC services and control processes have to be specified.
- **Support Processes:** For intelligent manufacturing, these processes address the operations of the relevant IT systems (Data and Information Flow Processes: These processes involve observation, classification, analysis, control, feedback, transformation, and aggregation. Here the data management and execution processes as have to be executed by the IMC Services are assigned.

2.3.2. Core System Standards - Core Transaction and Analytics Services

Core IMC software service components are assigned. Here the planned services to address the Management and Planning Function Frame according along the Organisation frame as mentioned in **¡Error! No se encuentra el origen de la referencia.** a

re relevant. Very important is the connection of those services to the upper and lower components of the standardisation framework.

2.3.3. Core System Standards – Identity and Access Management

Identity and access management is a framework of business processes, policies and technologies that facilitates the management of digital identities and ensures that the right actors and stakeholders have the appropriate access to services and data assets.

The relevant actors and stakeholders in a decentralised ecosystem shall be identified and granted access to information in line with their respective access rights specified in upcoming delegated acts by the European Commission. Since, the IMC is envisaged to be an collaborative system connecting different organisations with even ad-hoc interaction Identity management shall ensure that organisations, individuals, machines and services are provided with acknowledged identities. Identified standards shall define clear rules and requirements related to access control measures to regulate the access to restricted product passport information. Access rights management shall be attribute-based and domain specific rules. The standard(s) shall also address to third-party service providers, to natural persons operating as employees of the before mentioned legal entities as well as legal persons.

2.3.4. Data integration, distribution, exchange and protocols

Data integration, distribution, exchange and protocols refer to the different ways that systems use to collect and exchange data between different stakeholders and software components. There are e.g. APIs, file sharing platforms and many others. In the following, we will focus on aspects of the technical interoperability in data exchange via APIs.

In order to have the right impact of IMC, all information included in IMC environment shall be based on open standards and be in an interoperable format, transferable through an open interoperable data exchange network without vendor lock-in, machine-readable, structured and searchable" and "IMC" shall be fully interoperable with other environment by Union law concerning eco-design". This does affect several APIs connecting the Blueprint Service Management to other ecosystems Standard(s) shall define rules to exchange data between two or more parties as well as processes to introduce, modify, and update information in the Digital Twins of the Blueprints.

The standard(s) aim at harmonising the APIs for automating the management of the digital Twins throughout its life cycle and serving remote queries as required by the numerous envisaged services on management and planning side (e.g. Resilience, Sustainability & Circularity Testing Tool).

2.3.5. Core System Standards – Data Storage and Persistence

Data persistence is the ability of data to survive beyond the current runtime or session. It involves storing data in a way that allows it to be retrieved and used even after the application or system that created it has been shut down. Data persistence is crucial for applications that need to store user preferences, application state, or other types of data for later use. Data storage and persistence refer to the concept of retaining digital information in a way that it can be accessed and retrieved later. This is a crucial aspect of computing and information management, as it allows data to be stored beyond the duration of a single session or use. Data storage ensures that valuable information is not lost when a computer or device is turned off or restarted. Data Storage and Persistence is mostly relevant for storing Digital Twin Models, Digital Twin Configuration and the Digital

Twin Data Storage as assigned in the Technology Assets Frame in **¡Error! No se encuentra el origen de la referencia..**

2.3.6. Core System Standards – Data Processing

Data processing refers to the transformation of data into meaningful and useful information through a series of operations, computations, and manipulations. It involves collecting, organising, analysing and converting data into a structured format that can be interpreted and used for various purposes, such as decision-making, reporting, and generating insights. Importantly, this process must adhere to data privacy principles to protect the confidentiality and integrity of the data being handled. This includes ensuring compliance with relevant data protection regulations, securing personal and sensitive information, and implementing measures to prevent unauthorised access or disclosure. Data processing can encompass a wide range of activities, including data entry, validation, verification, cleaning, aggregation, calculation, and visualisation. The ultimate goal of data processing is to extract valuable insights, patterns, or knowledge from the data to support informed decision-making and improve business processes.

In the context of NARRATE all services as mentioned in the Functional and Technology Frame (Figure 3) have to follow a harmonized set of widely accepted existing rules for secure data processing including the standards of data access and validation and verification.

2.3.7. Core System Standards –Data Model and Data Formats

A data model is a structured and organised representation of data that defines the relationships, attributes, constraints, and semantics of various elements within a system or domain. It provides a blueprint for how data should be organised, stored, and manipulated, enabling a clear understanding of the data's structure and meaning. Data models serve as a bridge between the real-world entities and the digital representation of those entities, facilitating effective communication, analysis, and management of data. They are used in fields such as database design, software development, information systems, and more, to ensure consistency, accuracy, and meaningful interpretation of data.

In NARRATE, Data Models and Formats are referring to the core technology Assets Frame, specifically to the Digital Twin Language, the Blueprint Frames and its Annotations. They have to be applied in a harmonized way for all Management and Planning Services for supporting IMC in the Organisation Frame (see **¡Error! No se encuentra el origen de la referencia.**).

2.3.8. Core System Standards – Unique Identifier

A unique identifier is a series of characters, which is guaranteed to be unique within a given space. When such an identifier is assigned to an object, it allows that single object to be individually referenced within the space, and in the case of linked data allows for references and relationships between objects to be maintained.

NARRATE has to address different object levels for being identified as unique:

- Product
- Legal Entity (Company)
- Personal Entity (Person)

- Facility
- Production and Logistics Device (e.g. a machine)
- IMC Software Services to be applied

2.3.9. Core System Standards – Data Carrier

A data carrier, in the context of information technology and data management, is a medium or device used to store, transport, or transmit data. Data carriers come in various forms and technologies (e.g. Data Matrix code, QR code, NFC Tag) and they serve as containers for digital information.

NARRATE should support data carrier application in case, there is a physical representation of an object, needs to be identified for being used of the IMC Service set. This is relevant for all objects as mentioned in the Unique Identifier subchapter except the software services.

2.3.10. Cross System Standards – Security Infrastructure

Security infrastructure refers to the way security is implemented and maintained within a system. It typically includes aspects of access control, application security, behavioural analytics, firewalls, virtual private networks, vulnerability management, intrusion detection and prevention, virus protection, security and integrity monitoring.

2.3.11. Cross System Standards - Policy management and enforcement

Policies are used to represent permitted and prohibited actions over a certain asset, as well as the obligations required to be met by actors and stakeholders. In a data exchange context, policy management and enforcement refer to the way terms and conditions related to data access and usage are expressed and operationalised. Typically, this includes using specific policy management tools or frameworks, languages or processes to ensure that policies can be defined, evaluated, enforced and monitored consistently. It shall also ensure data sovereignty to data providers, especially in decentralised global data space environments

2.3.12. Cross System Standards - IT governance

IT governance, or information technology governance, refers to the framework and processes used to ensure that an organisation's IT resources are effectively managed and aligned with its strategic goals and objectives. It involves defining and implementing policies, procedures, and decision-making structures to oversee and control IT-related activities within an organisation

2.3.13. Mapping of adapted Enterprise Interoperability Framework and NARRATE Standardisation Frames

In the following figure a mapping between the NARRATE Frames the adapted Interoperability Standardisation framework can be seen. There are two kinds of relationship identified. First, when NARRATE research work is not performed at a certain standard element. Then NARRATE has to check for a suitable adoption of existing technology standards (e.g. for unique identifier). Second, were NARRATE is performing

research. Here both, adoption of existing standards and contribution to new or adapted standards have to be considered.

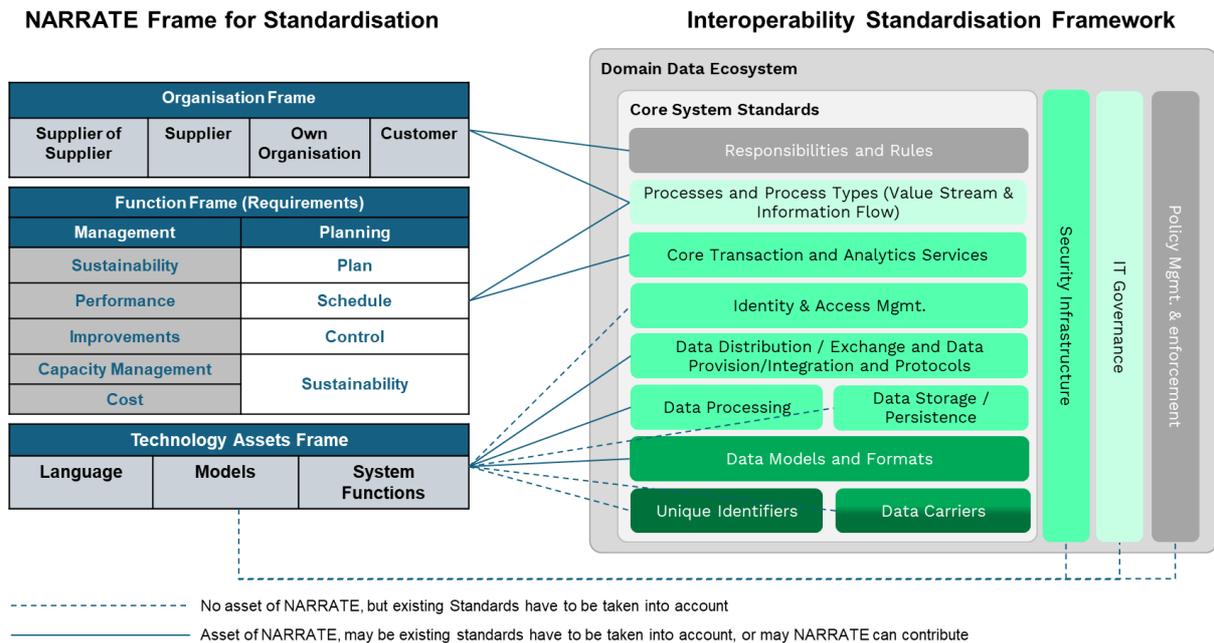


FIGURE 4 MAPPING, HOW PLANNED NARRATE ASSETS ARE RELATED TO INTEROPERABILITY ISSUES

The mentioned mapping will be used for the assignment of existing standardisation initiatives coming from official and de facto-standardisation organisations.

2.4. ASSIGNMENT OF STANDARDISATION INITIATIVES AND COMMITTEES TO THE FRAMEWORK

For NARRATE, official and de facto standardisation organisations are relevant. Official standardisation organisations are typically mandated through various processes and actors. Here are the main ways in which this occurs:

- Government Mandates:** In many countries, standardisation organisations are recognized and mandated by the government or through national laws. This can occur through specific legislation or the assignment of responsibilities.
- National and International Agreements:** Standardisation organisations can be mandated through international agreements or treaties, such as trade agreements, which emphasize the need for standards to promote trade and Security Infrastructure Cooperation.
- Industry Initiatives:** Companies and industry associations may commission official organisations to develop standards to address specific requirements or challenges within their sector.
- Stakeholder Engagement:** The involvement of stakeholders, including businesses, consumers, scientists, and governments, in the standardisation process can lead to organisations being mandated to represent the interests of these groups.

5. **Global Organisations:** Global entities like the International Organisation for Standardisation (ISO) receive mandates from their member countries to develop and promote international standards.

These mandates enable standardisation organisations to carry out their work in a structured and focused manner, meeting the needs of society and the economy. E.g. in Europe there are only three official European Standardisation Organisations listed (CEN, CENELEC and ETSI, see Table below).

Organisation	Internationality	Industry
ISO (International Organisation for Standardisation)	Global	Cross-industry
IEC (International Electrotechnical Commission)	Global	Electrotechnics
ITU (International Telecommunication Union)	Global	Telecommunications
CEN (European Committee for Standardisation)	Europe	Cross-industry
CENELEC (European Committee for Electrotechnical Standardisation)	Europe	Electrotechnics
ETSI (European Telecommunications Standards Institute)	Europe	Telecommunications
DIN (Deutsches Institut für Normung)	National (Germany)	Cross-industry
BSI (British Standards Institution)	National (UK)	Cross-industry
ANSI (American National Standards Institute)	National (USA)	Cross-industry
NIST (national Institute for Standardisation and Technology)	National (USA)	National (USA)

TABLE 2 OFFICIAL STANDARDISATION ORGANISATIONS, POTENTIALLY RELEVANT FOR NARRATE

National, Regional and Global standardisation organisations are closely linked to each other. E.g. ETSI standards are very often transferred to ITU and vice versa.

Next to the mentioned official standardisation organisations, there exist numerous de facto-standardisation organisations, which might be relevant for NARRATE as well. They are normally sector specific and most of them have established relationships to official standardisation organisations. In the table below, there are those de facto-standardisation organisations listed, which have a potential relevance to the standardisation framework as mentioned in the chapter above:

Organisation	Internationality	Industry	Key Standards
IETF - Internet Engineering Task Force	Global	Internet	RFC 791 (IPv4), RFC 2616 (HTTP/1.1)
W3C World Wide Web Consortium	Global	Web Technologies	HTML, CSS, SVG
OASIS Organisation for the Advancement of	Global	Information Technology	XML, UBL (Universal Business Language)

Organisation	Internationality	Industry	Key Standards
Structured Information Standards			
GS1 Global Standards 1	Global	Commerce, Logistics	GS1-128, EPCglobal, EPCIS
IEEE - Institute of Electrical and Electronics Engineers	Global	IT, Electrotechnics	IEEE 802.11 (Wi-Fi), IEEE 754 (Floating Point)
OMG Object Management Group	Global	Software	UML (Unified Modeling Language), BPMN (Business Process Model and Notation)
APICS Association for Supply Chain Management	Global	Supply Chain Management	CPIM (Certified in Production and Inventory Management), CSCP (Certified Supply Chain Professional)
SCOR Supply Chain Operations Reference	Global	Supply Chain Management	SCOR Model
UN/CEFACT - United Nations Centre for Trade Facilitation and Electronic Business	Global	Trade Facilitation	UN/CEFACT XML, UN/EDIFACT
OPC Foundation	Global	Manufacturing Control	OPC UA
AIAG Automotive Industry Action Group	Global	Automotive, Supply Chain	AIAG Quality Standards, APQP (Advanced Product Quality Planning)
IPC - Global Electronics Association	Global	Electronics	Manufacture, Inspection, & Testing of Electronics

TABLE 3 STANDARDISATION ORGANISATIONS, POTENTIALLY RELEVANT FOR NARRATE

Most of the organisations are product group agnostic. The only exception is the AIAG (automotive), because of their advanced requirements in supply chain management due to the fact of very high demands (e.g. just in sequence delivery) this standardisation organisation was selected to be relevant for NARRATE as well.

3. EVALUATION OF STANDARDS FOR ENGAGEMENT

3.1. EVALUATION SCHEMA

The evaluation scheme is following the objectives of Task 7.4 to identify and evaluate how given standards can be used for the NARRATE technologies and how NARRATE can contribute to existing and upcoming standardisation activities. Moreover, this consideration is depending on the focus of NARRATE, considering, that not every component of the Intelligent Manufacturing Custodian (IMC) will be developed from scratch and in not every topic NARRATE is performing research (compare to **Error! No se e**

ncuentra el origen de la referencia.). In the following **¡Error! No se encuentra el origen de la referencia.**, the evaluation scheme is illustrated. Based on the status of standardisation and the relevance for NARRATE research activities, the action types are defined (e.g. Compare, use and check possible improvements for research topics in NARRATE and Mature Standards in use).

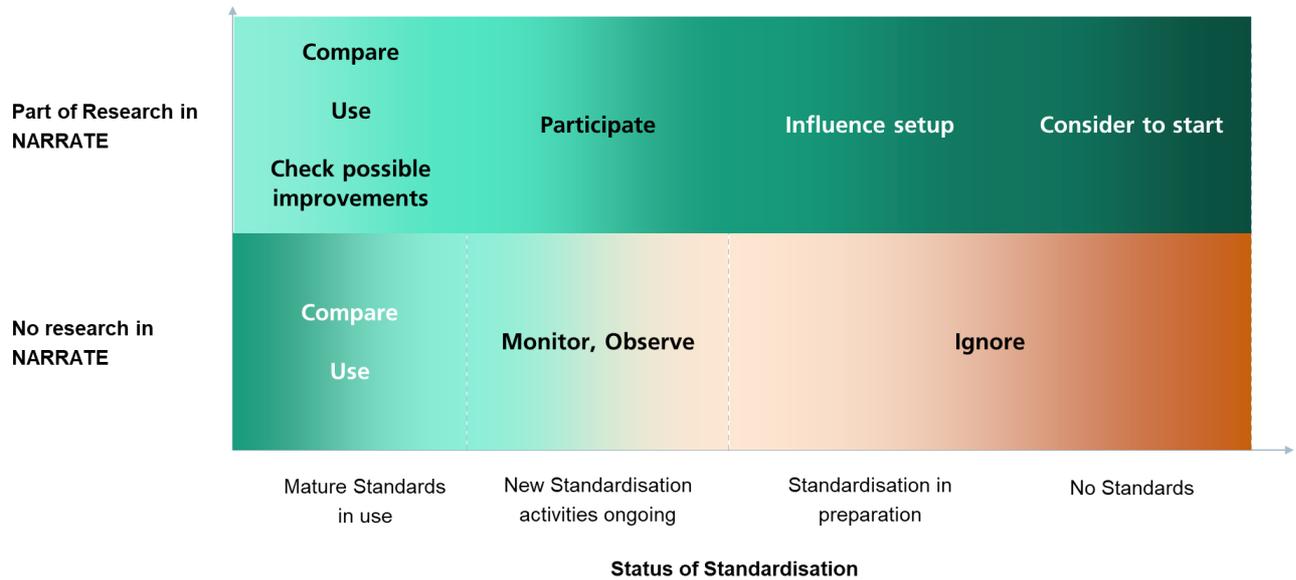


FIGURE 5 STANDARDS EVALUATION SCHEME

In the following sections the standards are listed according to the framework as defined in section 2.1. However, existing standards do not follow the framework exactly. Therefore, some standards are assigned to several elements of the framework, e.g. JSON appears in “Data Distribution / Exchange and Data Provision / Integration and Protocols” and Data Models and Formats.

Further on, standards coming from mandated global/ international standardisation organisations like ISO, IEC are listed by their reference identification number and the name without their complete reference. Based on this reference and the typical portals like *nautos* (nautos.org) or the original those standards can be easily accessed. For standards, coming from de facto-standardisation organisation like OPC Foundation, typically a link to the respective sources will be provided, directly in the document, e.g. <https://opcfoundation.org/about/opc-technologies/opc-ua/> for OPC UA.

3.2. TO BE APPLIED STANDARDS FOR NARRATE PROJECT WITHOUT RESEARCH FOCUS

As indicated in **¡Error! No se encuentra el origen de la referencia.** and following **¡Error! No se encuentra el origen de la referencia.**, the following components have to be considered for comparison for pure application in the NARRATE project. These are:

- Security infrastructure
- IT Governance
- Policy Management and Enforcement
- Identify & Access Management
- Data Storage / Persistence

- Unique Identifiers and
- Data Carriers

Those standards will be listed in the following subchapters.

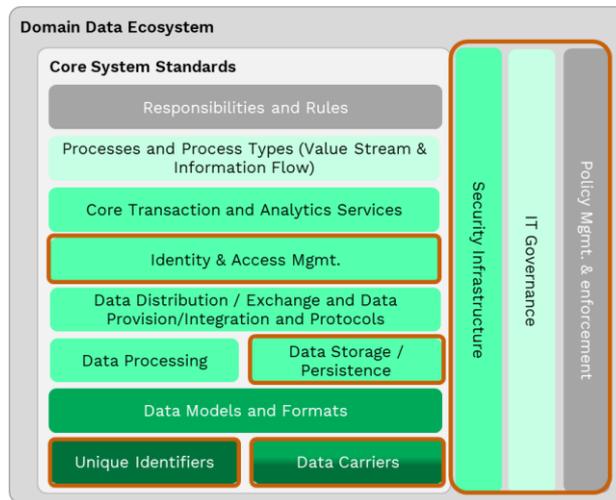


FIGURE 6 TO BE APPLIED STANDARDS FOR NARRATE

3.2.1. Security Infrastructure

Standard and Title	Classification L: Level, Sc: Scope, St: Status	Originator	Short Description in Context to NARRATE
ISA/IEC 62443 Series of Standards - The World's Only Consensus-Based Automation and Control Systems Cybersecurity Standards	L: Global, De Facto Sc: General St: Widely Applied	IEC	The ISA/IEC 62443 series of standards define requirements and processes for implementing and maintaining electronically secure industrial automation and control systems (IACS).

TABLE 4 RELEVANT STANDARD FOR SECURITY INFRASTRUCTURE

The before mentioned table shows the well-accepted standard IEC 62443 for establishing security infrastructure. It has also been the foundation for the IDSA certification schemes. The major concepts to be taken into account in NARRATE are security levels, access control and security mechanisms. Regarding mechanisms, e.g. the security protocols are mostly relevant, like TLS (Transport Layer Security) in accordance to the Security Levels.

3.2.2. IT Governance

Standard and Title	Classification L: Level, Sc: Scope, St: Status	Originator	Short Description in Context to NARRATE
COBIT (Control Objectives for	L: Global, De Facto Sc: General St: Widely Applied	ISACA	IT governance framework focusing on aligning IT with business objectives,

Standard and Title	Classification L: Level, Sc: Scope, St: Status	Originator	Short Description in Context to NARRATE
Information and Related Technologies)			ensuring risk management, and maintaining control over IT processes
ISO/IEC 38500:2015 - Information technology - governance of IT for the organisation	L: Global, ISO Sc: General St: Widely Applied	ISO/IEC	ISO/IEC 38500:2015 provides principles and guidelines for corporate governance of IT
ITIL (Information Technology Infrastructure Library)	L: Global, De Facto Sc: General St: Widely Applied	Axelos	ITIL is a set of best practices for IT service management (ITSM)
ISO/IEC 20000	L: Global, ISO Sc: General St: Widely Applied	ISO/IEC	ISO/IEC 20000 specifies requirements for an IT service management system (ITSM), helping organisations deliver quality IT services that align with business requirement
ISO/IEC 27001:2022 - Information security, cybersecurity and privacy protection	L: Global, ISO Sc: General St: Widely Applied	ISO/IEC	While it primarily addresses security, it plays a crucial role in IT governance by ensuring that information assets are protected and aligned with business objectives

TABLE 5 RELEVANT STANDARDS FOR IT GOVERNANCE

All of the mentioned standards are widely accepted. COBIT and ISO/IEC 38500:20215 are dealing with IT Governance from a methodology perspective, whilst ITIL and ISO/IEC are focussing on the implementation and application perspective of IT Governance in the frame of IT-Service. In the application guideline of solutions coming from NARRATE the specifications of these standards have to be considered. ISO/IEC 27000:2022 is focussing on IT Security, which must be fulfilled by the critical solutions of IMC, especially when transferring and processing sensitive data.

3.2.3. Policy Management and enforcement

Standard and Title	Classification L: Level, Sc: Scope, St: Status	Originator	Short Description in Context to NARRATE
ISO/IEC 29146:2016 - Security techniques (Link)	L: Global, ISO Sc: General St: Widely Applied	ISO/IEC	A framework for access management
W3C ODRL – ODRL Model (Link)	L: Global, De Facto Sc: General St: Widely Applied	W3C	Open Digital Rights Language (ODRL) is a flexible and interoperable

Standard and Title	Classification L: Level, Sc: Scope, St: Status	Originator	Short Description in Context to NARRATE
			policy expression language.
XACML v3 (Link)	L: Global, De Facto Sc: General St: Widely Applied	OASIS	The eXtensible Access Control Markup Language (XACML) is an XML-based standard markup language for specifying access control policies (used in Catena-X).
Dataspace Protocol v 1.0 (Link)	L: Global, De Facto Sc: General St: Upcoming	IDSA	The Dataspace Protocol is a set of specifications designed to facilitate interoperable data sharing between entities governed by usage control and based on web technologies.

TABLE 6 RELEVANT STANDARD FOR POLICY MANAGEMENT AND ENFORCEMENT

The W3C ODRL model is a suitable concept for machine readable policy expressions, relevant for NARRATE to support access and data security in the very sensitive business environments of NARRATE solutions.

3.2.4. Identity and Access Management

Standard and Title	Classification L: Level, Sc: Scope, St: Status	Originator	Short Description in Context to NARRATE
ISO/IEC 24760-1:2019 - IT Security and Privacy (Link)	L: Global, ISO Sc: General St: Widely Applied	ISO/IEC	A framework for identity management.
ISO/IEC 29146:2016 - Security techniques (Link)	L: Global, ISO Sc: General St: Widely Applied	ISO/IEC	A framework for access management.
W3C DID Decentralised identifiers (Link)	L: Global, de Facto Sc: General St: Widely Applied	W3C	Decentralised Identifiers (DID) are a new type of identifier that enables verifiable, decentralised digital identities.
W3C VC Verifiable Credentials (Link)	L: Global, de Facto Sc: General St: Widely Applied	W3C	Verifiable Credentials (VC), a mechanism to express credentials on the web in a way that is cryptographically secure, privacy respecting, and machine verifiable.
W3C VP Verifiable Presentations (Link)	L: Global, De Facto Sc: General St: Widely Applied	W3C	Verifiable Presentations (VP), can express data from multiple Verifiable Credentials and contain

Standard and Title	Classification L: Level, Sc: Scope, St: Status	Originator	Short Description in Context to NARRATE
			arbitrary additional data encoded as JSON-LD.
W3C DID Decentralised identifiers (Link)	L: Global, de Facto Sc: General St: Widely Applied	W3C	Decentralised Identifiers (DID) are a new type of identifier that enables verifiable, decentralised digital identities.
eIDAS Regulation (Link)	L: Europe, de Facto Sc: General St: Widely Applied	EU regulation	eIDAS stands for electronic identification, authentication and trust services. It is a European regulation that created one single framework for electronic identification (eID) and trust services, making it more straightforward to deliver services across the European Union.
Open ID Connect (Link)	L: Global, De Facto Sc: General St: Widely Applied	OpenID Foundation	OpenID Connect is an interoperable authentication protocol based on the OAuth 2.0 framework of specifications.
OID4VCI OpenID for Verifiable Credential Issuance (Link)	L: Global, De Facto Sc: General St: Widely Applied	OpenID Foundation	Defines an API for the issuance of Verifiable Credentials.
OID4VP OpenID for Verifiable Credentials (Link)	L: Global, De Facto Sc: General St: Widely Applied	OpenID Foundation	Defines a mechanism on top of OAuth 2.0 to allow presentation of claims in the form of Verifiable Credentials
Gaia-X Trust Framework (Link)	L: Europe, de Facto Sc: General St: Upcoming	Gaia-X AISBL	The Gaia-X Trust Framework is the set of rules that define the minimum baseline to be part of the Gaia-X Ecosystem. Those rules provide a common governance and the basic level of interoperability across individual ecosystems while letting the users remain in full control of their choices.
EUDI Wallet (Link)	L: Europe, Companies, Persons, St: in distribution	European Commission	Every EU Member State will offer its own wallet app, built to the same specifications, to all citizens, residents and businesses in the next few years.

TABLE 7 RELEVANT STANDARDS FOR IDENTITY AND ACCESS MANAGEMENT

To conclude, ISO/IEC 24760-1:2019 and ISO/IEC 29146:2016 providing the foundation of the identity and access management system to be followed. For the implementation it is

important to consider identity and access management not only for persons and organisations, machines and artificial assets need to be considered as well. Under that assumption either the W3C or OpenId standards should be used.

3.2.5.Data Storage/ Persistence

Standard and Title	Classification L: Level, Sc: Scope, St: Status	Originator	Short Description in Context to NARRATE
ISO/IEC 27040:2015(en) Information technology — Security techniques — Storage security	L: Global, ISO/IEC Sc: General St: Widely Applied	ISO/IEC	Focus on securing of data storage
Several Specifications of SNIA "Storage Networking Industry Association"	L: Global, De facto Sc: General St: Widely Applied	https://www.snia.org	Standards for various storage systems

TABLE 8 RELEVANT STANDARDS FOR DATA STORAGE AND PERSISTENCE

The NARRATE solutions shall consider the specifications of ISO/IEC 27040:2015, especially the guidelines for design and implementation of storage security as defined in chapter 7 of that standards. The SNIA specification can be used as implementation support, e.g. the Computational Storage Architecture and Programming Model ([Link](#))

3.2.6.Unique Identifier

In the framework of NARRATE the solutions have to manage unique identifiers on all artefacts for products, machines, logistic elements, persons and organisations on item level. For unique identifiers on all artefacts exist parallel solutions for schemes. Some of them are very long in the market, some requires membership fees or even fees per identifier and some are freely available.

Standard and Title	Classification L: Level, Sc: Scope, St: Status	Originator	Short Description in Context to NARRATE
ISO/IEC 9834-8:2014: Generation of universally unique identifiers (UUIDs) and their use in object identifiers (Link)	L: Global, ISO Sc: General St: Widely Applied	ISO/IEC	A UUID is a globally unique identifier which requires no central registration process.
Uniform Resource Names (URNs) (Link)	L: Global, De Facto Sc: General St: Widely Applied	IETF	A Uniform Resource Name is a persistent, location-independent resource identifier using a well-defined syntax
Universally Unique Identifier URN Namespace (Link)	L: Global, De Facto Sc: General St: Widely Applied	IETF	The defined syntax and grammar for the URN namespace can be used to map existing proprietary identifiers as URNs

Standard and Title	Classification L: Level, Sc: Scope, St: Status	Originator	Short Description in Context to NARRATE
ISO/IEC 15459:2014	L: Global, ISO Sc: General St: Widely Applied	ISO/IEC	ISO/IEC 15459:2014 specifies a unique string of characters for the identification of individual transport units
Decentralised Identifiers (DIDs) (Link)	L: Global, De Facto Sc: General St: Upcoming	W3C (World Wide Web Consortium)	The DID scheme is designed to enable organisations to generate their own identifiers using systems they trust.
Economic Operators Registration and Identification number (Link)	L: Europe, De-Jure Sc: General St: Widely Applied	Regulation of the European Parliament (EC) No 648/2005	EORI is an identifier for businesses which undertake the import or export of goods into or out of the EU.
ISO 26324:2025, Information and documentation — Digital object identifier system	L: Global, De-Jure Sc: General St: Widely Applied	ISO/IEC	Specifies the requirements for the digital object identifier (DOI) system, which provides a framework for the identification, management, and retrieval of digital content across various platforms and applications.
ISO/IEC 6523-1:2023, Information technology — Structure for the identification of organisations and organisation parts	L: Global, De-Jure Sc: General St: Widely Applied	ISO/IEC	structure for the identification of organisations and their related entities through the use of a coding system, facilitating interoperability and data exchange in electronic commerce and information systems.
IEC 61406 Identification Link	L: Global, De-Jure Sc: industrial Assets St: partially Applied	IEC TC 65	Sets minimum requirements for a globally unique identification of physical objects, which also represents a link to the associated digital information
ISO 26324 Digital Object Identifier	L: Global, De-Jure Sc: Documents St: partially Applied	ISO/TC 46	Specifies the syntax, description and resolution functional components of the digital object identifier system. It is normally used for documents but can be used for all object types as well.

TABLE 9 RELEVANT STANDARDS FOR UNIQUE IDENTIFIER

For NARRATE for each artefact a standard for unique identifier has to be selected and followed. Because of the research mode it is recommended to use a standard without obligation of paying fees.

3.2.7. Data Carrier

Standard and Title	Classification L: Level, Sc: Scope, St: Status	Originator	Short Description in Context to NARRATE
ISO/IEC 18004:2015	L: Global, ISO Sc: General St: Widely Applied	ISO/IEC	ISO/IEC 18004:2015 defines the requirements for QR codes
IEC 63365: Digital Nameplate	L: Global, IEC Sc: General St: Upcoming	IEC	Concept and requirements for the digital nameplate
ISO/IEC 22603-1: Information technology - Digital representation of product information	L: Global, ISO Sc: General St: Widely Applied	ISO/IEC	ISO/IEC 22603-1 defines the general requirements for electronic product labelling
ISO/IEC 21471: Information technology - Automatic identification and data capture techniques	L: Global, ISO Sc: General St: Widely Applied	ISO/IEC	Extended rectangular Data Matrix (DMRE) bar code symbology specification
ISO/IEC 18000 series, Information technology — Radio frequency identification for item management	L: Global, ISO Sc: General St: Widely Applied	ISO/IEC	The ISO 18000 series comprises international standards that specify the air interface and communication protocols for radio frequency identification (RFID) devices used in various applications, enhancing interoperability and efficiency in data exchange.

TABLE 10 RELEVANT STANDARDS FOR DATA CARRIER

Data Carrier have to be applied in the context of the application conditions and the acceptance in the different sectors. So e.g. RFID (ISO 18000 series) standards can be applied when scanning is possible in the environment. Because NARRATE has a research attitude and no ambition to develop Data Carrier technologies further, the simplest, most known and easiest to be applicable technologies and standards should be applied

independent from achieved level of automation. A suggestion would be QR Code ISO/IEC 18004.

3.3. TO BE APPLIED STANDARDS FOR NARRATE WITH RESEARCH INFLUENCE

The following collection the standard elements are shown were NARRATE can contribute to (Figure 7).

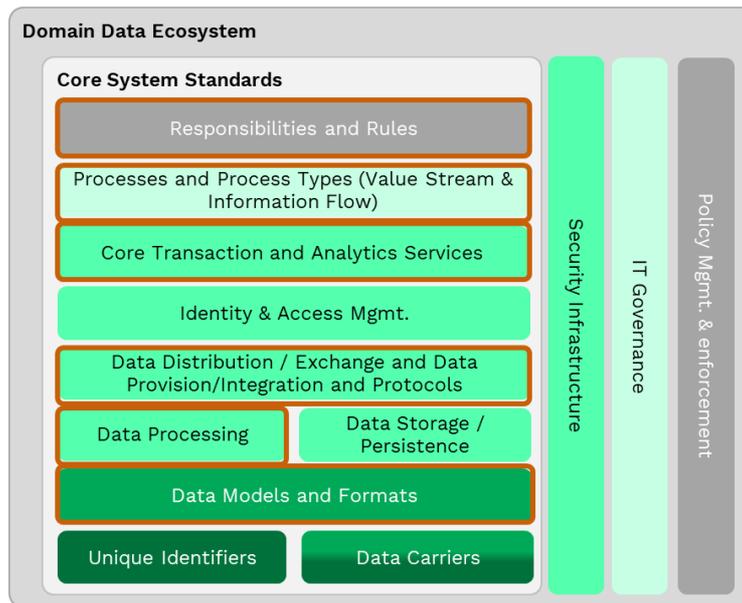


FIGURE 7 STANDARD ELEMENTS WITH RESEARCH INFLUENCE OF NARRATE

For those elements it is important, to develop solutions based on the analysis of given standards, to identify standards contradictions and gaps.

3.3.1. Responsibilities and Rules

For the application of the IMC it is important to have a machine-readable specification of responsibilities and application rules.

Standard	Classification L: Level, Sc: Scope, St: Status	Originator	Short Description in Context to NARRATE
RACI Matrics for Responsibility definition in Projects and Processes	L: Global, De Facto Sc: General St: Widely Applied	Not yet accessible	Classification Scheme and of Responsibilities
eXtensible Access Control Markup Language (XACML)	L: Global, De Facto Sc: General St: partially applied	OASIS	Declarative markup language for rule specification and access control

TABLE 11 RELEVANT STANDARDS FOR RESPONSIBILITIES AND RULES

Both standards are applied only for long time. In the Frame of NERRATE there is a potential need for standardisation of dynamic responsibilities and its formal specification. Because

in ISO it seems there is no opportunity for contributing. So just the application for eXtensible Access Control Markup Language (XACML) is recommended.

3.3.2. Core Transaction and Analytics Services

Core Transaction Services and analytics services are essential aspects of the work in NARRATE. Whilst transaction services are normally independent from purpose of analytics they will be separated.

Core Transaction Services

The standard specifications as listed below are addressing the concepts for production processes in general and its control principles. They are independent from the purpose of optimization, even some of the standards are including specific aspects, like MESA for energy optimization.

Standard	Classification L: Level, Sc: Scope, St: Status	Originator	Short Description in Context to NARRATE
ISO/IEC 20000-1 Service management system requirements	L: Global, ISO Sc: General St: Widely Applied	ISO/IEC	Process definitions and the outcomes for IT service management
eTOM Process Framework	L: Global, De Facto Sc: General St: Widely Applied	TM Forum	Library of processes for IT services including a data model.
MESA model	L: Global, De Facto Sc: Manufacturing St: Widely Applied	MESA International	Specifications for manufacturing and manufacturing management
ISO / IEC 62264 series of standards for Enterprise-control system integration (ISA95)	L: Global, ISO Sc: Manufacturing St: Widely Applied	ISO/IEC and original from ANSI	General value stream processes and its control mechanisms as well as data exchange specifications on all levels of production for discrete manufacturing
ISO/IEC 61512 series of standards for Batch control (ISA 88)	L: Global, ISO Sc: Manufacturing St: Widely Applied	ISO/IEC and original from ANSI	Same as ISO / IEC 62264, but specialized for Batch Control

TABLE 12 RELEVANT STANDARDS FOR TRANSACTION SERVICE

The principles, vocabulary and interface definitions of ISO/IEC 61512 and 62264 should be the base for NARRATE definitions.

All standards are missing dynamics in production and production control regarding re-routing, ad-hoc processes and process generation. Here is a need for further

standardisation. Currently there is no activity ongoing. NARRATE should investigate in ISO TC 184, how dynamics can be established based on the achievements.

Analytics Services

Analytic services are distributed into several branches. For analytics services there exist different kind of standards:

- Frameworks for clustering activities and tasks for improvement regarding different objectives (e.g. ISO 9001 for Quality). Normally they do not provide specific services, but terminologies and principles to be followed for analysis
- Methods and Technologies for analytics, those methods are specific to the purpose. According to the functions frame of NARRATE

Standard	Classification L: Level, Sc: Scope, St: Status	Originator	Short Description in Context to NARRATE
ISO 9001 Quality Management Systems	L: Global, ISO Sc: General St: Widely Applied	ISO TC 176	Addresses continuous improvements in processes.
ISO 14001 Environmental Management Systems	L: Global, ISO Sc: General St: Widely Applied	ISO TC 207	Framework for improving environmental performance
ISO 55000 ff. Asset Management	L: Global, ISO Sc: General St: Widely Applied	ISO TC 251	Guidelines for effective asset management to optimize performance.
ISO 50001 Energy Management Systems	L: Global, ISO Sc: General St: Widely applied	ISO TC 242	A framework for improving energy efficiency and managing consumption in organisations
SCOR Model Supply Chain Operations Reference (Link)	L: Global, ISO Sc: Supply Chain St: Widely Applied	Supply Chain Council as part of ASCM	Framework for evaluating and improving supply chain performance.

TABLE 13 RELEVANT STANDARDS FOR GENERAL FRAMEWORKS OF ANALYTICS SERVICES

All standards are very general and provide a frame for analysis rather than specific methods for analysis. Except the SCOR model, to some extent the standards are demanded to implement by government and customers. Even risk management is in the focus of planned improvements, there cannot be seen new activities in the standardisation for risk analysis yet. In the frame of NARRATE those standards can be combined and to framing the to be applied analysis functions. Because of the general notion of the standards there is no necessity to contribute to those standards coming from NARRATE.

Analytics Services for Risk and Resilience Management

In the standards, the methods for risk and resilience management are quite similar, because in the following list standards, applicable for both are mentioned.

Standards	Classification L: Level, Sc: Scope, St: Status	Originator	Short Description in Context to NARRATE
ISO 31010 - Risk Management - Risk Assessment Techniques	L: Global, ISO Sc: Risk Management St: not yet assessable	ISO/TC 262	Explains fundamental principles for Risks assessment
NIST SP 800-30 (Link)	L: Regional, US Sc: Risk Management St: not yet assessable	NIST	Explains fundamental principles and procedures for Risks assessment
ISO 22301 Security and Resilience – Business Continuity Management System	L: Global, ISO Sc: Risk Management St: not yet assessable	ISO/TC 292	Explains the structure and requirements for implementing and maintaining a Business Continuity Management System. It includes principles of risk analysis, and it impacts.
ISO/IEC 27005:2018 - Information Security Risk Management	L: Global, ISO Sc: Risk Management in IT St: not yet assessable.	ISO/IEC JTC 1/SC 27	Defines Procedures and Rules for Cyber Security. It includes analysis steps and functions for risk identification, evaluation and managing.

TABLE 14 RELEVANT STANDARDS ANALYTICS SERVICES REGARDING RISKS AND RESILIENCE

All the standards providing mainly principles and procedures for risk management rather than specific analytical assessment methods. Based on the work in ISO TC 262 in ISO 31010 - Risk Management - Risk Assessment Techniques the other standards can complete the guideline for NARRATE. An updated guideline is currently developed in ISO TC 262 under the base standard ISO 31000 is currently in the finalization. After the publication new achievements have to be analysed. Other NWIP are not seen in the relevant standardisation committees. In the same stage is the standard ISO/WD 28018.2 on Security and resilience — Security management systems — Guidelines for the application and implementation of ISO 28000 in the supply chain under the responsibility of ISO TC 292.

Services for implementing and operation of industrial digital Twins

As digital twin is a major concept of the core concept of NARRATE IMC solution. In the following list the standards are mentioned which has an impact to industrial digital twins.

Standard	Classification L: Level, Sc: Scope, St: Status	Originator	Short Description in Context to NARRATE
ISO 23247 Digital Twin Technology	L: Global, ISO Sc: Production St: Partly adopted	ISO TC 184	Standards for implementing digital twins to enhance analytics in production.
IEC 62890 Lifecycle Management of Assets	L: Global, ISO Sc: General St: partly	IEC TC 65	Addresses asset lifecycle management to optimize performance and decision-making.

ANSI/ISA-95 Enterprise-Control System Integration	L: Global Sc: Production Control St: Applied	ANSI	Provides guidelines for integrating enterprise systems with control systems.
IEEE 1516 Modeling and Simulation in Distributed Interactive Systems	L: Global Sc: Systems Engineering St: Applied	IEEE	Focuses on modelling and simulation to support decision-making in production.
ETSI GS CIM 009 NGSI-LD (Link)	L: Global, ISO Sc: Systems Engineering St: Applied	ETSI/ITU	Specifies a data model and API framework for managing context information in smart city applications, enabling the interoperability and integration of diverse data sources through a linked data approach.

TABLE 15 INDUSTRIAL DIGITAL TWINS

By looking into the listed standards, three major parallel technologies for digital twins can be identified: ISO TC 184 with core series of ISO 23247, IEC TC 65 with the standards on Asset Administration Shell (ASS) and the ETSI NGSI-LD specifications. In the following Table 16, a more detailed analysis on standard for digital twins is provided.

Criteria	ISO 23247	IEC 62890	NGSI-LD
Industrial Application	Focused on digital twin technology in industrial applications, enhancing interoperability and data exchange.	Primarily addresses the lifecycle management of assets in industrial environments, including monitoring and control.	Aimed at smart cities and IoT applications, facilitating the integration of diverse data sources and services.
Base Technology	Utilizes digital twin frameworks, emphasizing the representation of physical assets in the digital realm.	Based on asset management principles, incorporating standards for data models and communication protocols.	Built on linked data principles, leveraging semantic web technologies for data interoperability and integration.
Openness	Generally, promotes openness through interoperability but may have proprietary elements in implementation.	Focuses on standardisation to ensure compatibility, but specific implementations may vary in openness.	Highly open, based on open standards and protocols, promoting data sharing and integration across platforms.

Criteria	ISO 23247	IEC 62890	NGSI-LD
Advantages	<ul style="list-style-type: none"> - Enhances collaboration and data sharing. - Supports advanced analytics and simulations. - Facilitates integration with IoT devices. 	<ul style="list-style-type: none"> - Provides a structured approach to asset management. - Ensures compliance with industry standards. - Promotes efficient lifecycle management. - increasing application in industry 	<ul style="list-style-type: none"> - Enables seamless integration of heterogeneous data sources. - Supports real-time data access and sharing. - Facilitates interoperability across different platforms and systems.
Disadvantages	<ul style="list-style-type: none"> - Implementation may be complex and resource-intensive. - May require significant upfront investment in technology and training. 	<ul style="list-style-type: none"> - Can be rigid, making adaptation to new technologies challenging. - Potentially limited flexibility in implementation. 	<ul style="list-style-type: none"> - May require specialized knowledge of semantic web technologies. - Can be perceived as less mature compared to traditional standards. - Limited application rate

TABLE 16 DETAILED ANALYSIS ON CORE STANDARDS FOR DIGITAL TWINS

Based on the analysis above it can be stated, that the ISO specifications are more comprehensive whilst the level of application rate and the impact of NARRATE can be made better with AAS. On top NGSI-LD seems to be more flexible and adaptable than the other ones. Because the scope of ISO TC 184 is broader than IEC TC 65 it is recommended to contribute to current activities in ISO TC 184. Currently the elaboration of a draft international standard is performed on very important aspects of NARRATE work:

- Automation systems and integration — Digital twin framework for manufacturing — Part 5: Digital thread for digital twin ISO/DIS 23247-6 [Under development]
- Automation systems and integration — Digital twin framework for manufacturing — Part 6: Digital twin composition
- Automation systems and integration — Industrial digital twin interface architecture ISO/AWI TS 25271

It is strongly recommended to participate to that activities for knowing the state of the art and to contribute with NARRATE achievements.

Analysis with Artificial Intelligence

Standard	Classification L: Level, Sc: Scope, St: Status	Originator	Short Description in Context to NARRATE
ISO/IEC TR 24029 - Artificial Intelligence	L: Global, ISO Sc: General	ISO/IEC JTC 1	Background about existing methods to assess

- Use Cases in Decision Making	St: not yet assessible		the robustness of neural networks
IEEE P7000 - Model Process for Addressing Ethical Issues in AI Systems	L: Global, ISO Sc: Engineering St: partly	IEEE	framework to identify, analyse, and mitigate ethical risks by integrating values into the design.
NIST Special Publication 1270 - A Taxonomy and Framework for Artificial Intelligence (Link)	L: Global, ISO Sc: General St: not yet assessible	National Institute of Standards and Technology (NIST)	Describes the stakes and challenge of bias in artificial intelligence
ISO/IEC 23894 - Artificial Intelligence - Guidelines for the Ethical and Responsible Use	L: Global, ISO Sc: General St: Partly adopted	ISO/IEC JTC 1	Procedures and rules for managing risk specifically related to AI

TABLE 17 NARRATE RELATED STANDARDS FOR AI

In the standards there is no guideline to develop AI solutions, mostly like ISO/IEC 23894 are dealing with ethical issues and risk management. The recommendation is, to follow the standards along the development phase to ensure ethical requirements and avoid risks for application.

Analysis for Circularity and Sustainability

Standard	Classification L: Level, Sc: Scope, St: Status	Originator	Short Description in Context to NARRATE
ISO 14044:2006 - Life Cycle Assessment - Requirement and Guidelines	L: Global, ISO Sc: General St: Partly adopted	ISO/TC 207	Methodological Framework for LCA and Reporting
ISO 20400:2017 - Sustainable Procurement - Guidance	L: Global, ISO Sc: General St: not yet assessible	ISO/PC 277	Guidance to organisations on integrating sustainability within procurement,
EN 45552:2020 - General method for assessing the recyclability of electrical and electronic equipment	L: Regional, CEN Sc: General St: not yet assessible	CEN/TC 111	Parameters and methods as a framework in order to assess the durability of Electrical Products
ISO 59000 Family of standards	L: Global Sc: General St: not yet assessible	ISO/TC 323	Provides a comprehensive set of specifications for Vocabulary, Business Models, measuring circularity and traceability and recovery of secondary materials

TABLE 18 NARRATE RELEVANT STANDARDS FOR CIRCULARITY

ISO 14044:2006 and ISO 20400:2017 are covering management specifications and therefore are just applicable for being used as a frame for methods to be incorporated into the IMC. Further on definitions and terms can be reused as well, in order to facilitate the application of IMC functions in other environments. Because of the objectives of NARRATE, there is no subject, that NARRATE can contribute to these standards. This is different to the ISO 59000 standard family. In ISO/TC 323, most of the ISO 59000 Family are not finished and in the respected mirror committee on CEN level work is currently performed, e.g. as newly established project, like ISO/AWI 59010. Especially the ISO 59010 "Organizing a value network towards circularity" can be an anchor-point for NARRATE to influence the standardisation with newly defined blue-prints.

Analysis for Supply Chain Visibility

Standard	Classification L: Level, Sc: Scope, St: Status	Originator	Short Description in Context to NARRATE
ISO 28001:2020 - Security management systems for the supply chain - Guidelines for implementing ISO 28000	L: Global Sc: General St: not yet assessable	ISO/TC 8	Comprehensive Framework for SC-Security incl. a questionnaire for assessing readiness
ISO 22301:2019 - Business Continuity Management Systems (BCMS)	L: Global Sc: General St: not yet assessable	ISO/TC 292	Provides a structured framework that encompasses the planning, implementation, monitoring, and continuous improvement of a BCMS.
UN/CEFACT Core Component Technical Specification (Link)	L: Global Sc: General St: not yet assessable	United Nations Centre for Trade Facilitation and Electronic Business (UN/CEFACT)	Defines a complete framework and components for data objects to be exchanged between different business management systems across organisations
Supply Chain Reference Data Model (Link)	L: Global Sc: General St: Widely applied	United Nations Centre for Trade Facilitation and Electronic Business (UN/CEFACT)	Reference data model based on the UN/CEFACT Core Component Library (CCL)
AIAG Inventory Visibility and Interoperability (IV&I) (Ive07)	L: Global Sc: Automotive Industry St: partially applied	AIAG	Provides data sets data models for inventory visibility in the context of eKanban application for automotive industry
SCOR Performance Metrics (Link)	L: Global Sc: General St: widely applied	Association for Supply Chain Management	Defines the terms and definitions of measurement criteria of supply chains

Standard	Classification L: Level, Sc: Scope, St: Status	Originator	Short Description in Context to NARRATE
SCOR Version 12.0 - Supply Chain Operations Reference Model	L: Global Sc: General St: widely applied	Association for Supply Chain Management (ASCM)	Defines the fundamental of Supply Chain Management with comprehensive analysis, design and implementation methods. Includes circularity issues as well.

TABLE 19 NARRATE RELATED SUPPLY CHAIN VISIBILITY STANDARDS

Since more than 20 years, the ASCM is maintaining the SCOR models and even increased the scope towards sustainability. Whilst major industry sectors are following the specifications and tools exist, for NARRATE it is envisaged to take into account the elaborated standards, especially the SCOR Reference Model. From the perspective of data exchange objects, the UN/CEFACT Core Component Technical Specification (CCTS) should be reviewed to consider the specifications as core data object specifications. Those objects are used for the exchange between different business IT systems. Both standards are very much industry oriented. For further input, especially ASCM are quite open, but membership fees have to be paid.

3.3.3. Data Distribution / Exchange and Data Provision / Integration and Protocols

Because of the integration between the data distribution and the comprehensiveness of solutions there are some overlaps between the listed standards as mentioned below in Table 20 and the others in the standard stack. This has e.g. happened for the AAS in TC 65. On the other hand, some of the standards are connected to other elements, like EPCIS within the GS1 identification standards in ISO/IEC 15459. Further on the wide application of OPC UA including its application-oriented companion specs made them very useful even for the implementation and operation of industrial communication between assets and business systems along supply chains.

Standard	Classification L: Level, Sc: Scope, St: Status	Originator	Short Description
ISO/IEC 19987:2017 - EPC Information Services (EPCIS) Standard (Link)	L: Global, IEC Sc: General St: Widely Applied	ISO/IEC JTC 1	EPCIS enables disparate applications to create and share visibility event data, both within and across enterprises.
OPC UA (Link)	L: Global Sc: control St: Widely Applied	OPC Foundation	Provides a unified architecture incl. a protocol for industrial communication between different kind of assets.

Standard	Classification L: Level, Sc: Scope, St: Status	Originator	Short Description
W3C Web of Things (Link)	L: Global, De Facto Sc: General St: Widely Applied	W3C	The Web of Things (WoT) seeks to counter the fragmentation of the IoT by using and extending existing, standardised web technologies.
IEC 63278-1 and series - Specification of the Asset Administration Shell Part 2: Application Programming Interfaces (Link)	L: Global, IEC Sc: General St: Widely Applied	IEC TC 65	Specifies the interfaces as well as the APIs in selected technologies for the Asset Administration Shells and its sub-models.
ETSI NGSI-LD API (Link)	L: Europe, De Facto Sc: General St: Widely Applied	ETSI	NGSI-LD is an information model and API for publishing, querying and subscribing to context information.
PEPPOL eDelivery (Link)	L: Europe, De Facto Sc: General St: Widely Applied	PEPPOL	eDelivery provides technical specifications and standards, installable software and ancillary services to allow projects to create a network of nodes for secure digital data exchange.
REST API (Link)	L: Global, De Facto Sc: General St: Widely Applied	Not yet Assessable	REST API is a general API style for accessing, send, update and delete of data.
IETF HTTP(S) Hypertext Transfer Protocol (Link)	L: Global, De Facto Sc: General St: Widely Applied	IETF	The Hypertext Transfer Protocol (HTTP) is a stateless application-level protocol for distributed, collaborative, hypertext information systems.

Standard	Classification L: Level, Sc: Scope, St: Status	Originator	Short Description
			Hypertext Transfer Protocol Secure (HTTPS) is an extension of the Hypertext Transfer Protocol (HTTP).
IETF TCP/IP (Link)	L: Global, De Facto Sc: General St: Widely Applied	IETF	The internet protocol suite, commonly known as TCP/IP, is a framework for organising the set of communication protocols used in the internet and similar computer networks according to functional criteria.
IPC-2591 (CFX) Connected Factory Exchange	L: Global, De Facto Sc: Electronics St: Widely Applied		Universal language and data exchange protocol for manufacturing equipment, software, and systems
ISO/IEC 21778:2017 JSON (Link)	L: Global, ISO Sc: General St: Widely Applied	ISO/IEC JTC 1/SC 22	Is a data format for data exchange between different applications.
W3C JSON-LD (Link)	L: Global, De Facto Sc: General St: Widely Applied	W3C	JSON-LD 1.1 is a JSON-based format to serialise linked data.

TABLE 20 RELEVANT STANDARDS FOR DATA DISTRIBUTION / EXCHANGE AND DATA PROVISION / INTEGRATION AND PROTOCOLS

IPC-2591 (CFX) Connected Factory Exchange is applied in NARRATE by providing standardised types of messages using JSON LD for semantics annotation in the Federated Data Integration Framework (FDIF). Because the Standardisation is already going on in all relevant committees (IEC TC65, in ISO TC 184, in ETSI for NGSI-LD). Here is a need for consolidation and alignment. A NARRATE demonstration to have different semantics interoperable in one federated case would convince the standardisation of a common federated framework.

Because of the existence of a huge number of actual standards and considering the schema as defined in **¡Error! No se encuentra el origen de la referencia.**, NARRATE should perform an analysis first to use the most suitable approach to adopt. It should be avoided to strongly linked standards, like ISO 15459 and EPCIS. This would support the wide application of NARRATE solutions.

3.3.4. Data Processing

As Data Processing standards are mainly referred to specific data points, coming from industrial sectors like it is the case for ISO/IEC 62264-1 Enterprise- control system integration in industrial automation. Here specifications for data objects and functions to proceeds are defined.

Standard	Classification L: Level, Sc: Scope, St: Status	Originator	Short Description
ISO/IEC 62264-Enterprise-control system integration, initially established by ISA (ISA 95)	L: Global, ISO Sc: General St: Widely Applied	ISO/TC 184/SC 5	Guidelines and best practices for integrating various aspects of control systems and manufacturing operations into a cohesive whole.
IEC 62890-1 Industrial-process measurement, control and automation - Life-cycle-management for systems and components	L: Global, ISO Sc: General St: Widely Applied	ISO/TC 184/SC 5	Definitions and reference models related to the life cycle of a product type and the lifetime of a product instance. It defines a consistent set of generic reference models and terms.
ISO/IEC 22123-1 Information technology – Cloud computing	L: Global, ISO Sc: General St: Widely Applied	ISO/IEC JTC 1/SC 38	Reference for cloud computing, providing a consolidated cloud computing vocabulary consisting of terms, terminology and definitions.

TABLE 21 RELEVANT DATA PROCESSING STANDARDS FOR NARRATE

Based on the scope of the work NARRATE should consider all standards and combine except the ISO/IEC 22123, which is mainly for information about terminology.

3.3.5. Data Models and Formats

Based on the scope of the work NARRATE will consider the application of a certain data modelling methodology and must apply or extent existing data models for covering the supply-chain issues across different organisations. Therefore both, modelling methodologies and concrete reference models are addressed. In some of the standards both aspects are integrated.

Standard	Classification L: Level, Sc: Scope, St: Status	Originator	Short Description
Data Modelling Method and Data Model			
UN/CEFACT Core Component Technical Specification (Link)	L: Global Sc: General St: widely applied	United Nations Centre for Trade Facilitation and Electronic Business (UN/CEFACT)	Core business component to facilitate the data exchange between business software
IDTA Sub-model Template and Sub-models (Link)	L: Global Sc: General St: increasing application	Industrial Digital Twin Association	Provides the core method for the specification of DT Models and more than 100 sub-models for different industries
Specific Data Model			
Supply Chain Reference Data Model (Link)	L: Global Sc: General St: widely applied	United Nations Centre for Trade Facilitation and Electronic Business (UN/CEFACT)	Reference data model based on the UN/CEFACT Core Component Library (CCL)
AIAG Inventory Visibility and Interoperability (IV&I) (Link)	L: Global Sc: Automotive St: Not assessable	AIAG	Provides data sets data models for inventory visibility in the context of eKanban application for automotive industry
Data Modelling Method			
Resource Description Framework (RDF) (Link)	L: Global, De Facto Sc: General St: Widely Applied	W3C (World Wide Web Consortium)	RDF has sufficient mapping power to allow platform-independent semantic data models and ontologies to be described.
Model Driven Architecture (MDA) (Link)	L: Global, De Facto Sc: General St: Widely Applied	OMG (Object Management Group)	MDA is an approach to software design and development that focuses on using models. The concept describes platform independent models that can be transformed into platform specific models.

Standard	Classification L: Level, Sc: Scope, St: Status	Originator	Short Description
Meta-Object Facility (MOF) (Link)	L: Global, De Facto Sc: General St: Widely Applied	OMG (Object Management Group)	MOF provides a set of standards for developing and representing meta models in a standardised way. It is linked to MDA.
ISO/IEC 21778:2017 Java Script Object Notation JSON	L: Global, De Facto Sc: General St: Widely Applied	ISO IEC SC22	JSON is a compact data format that allows serialisation of structured data based on a defined schema described with JSON-Schema notation.
Java Script Object Notation – Linked Data (Link)	L: Global, De Facto Sc: General St: Widely Applied	W3C	JSON-LD supports the concept of linked data. It can be used as serialisation of RDF.
IEC 63278-1: Asset Administration Shell (AAS)	L: Europe, IEC Sc: General St: Upcoming	IEC	Meta model to represent semantic data models for digital twins by composition of sub-models. A possible serialisation format for AAS models is JSON.
Next Generation Service Interface – Linked Data NGSI-LD (Link)	L: Europe, De Facto Sc: General St: Upcoming	ETSI	NGSI-LD uses semantic data models based on JSON-LD which could be considered as an alternative platform specific semantic model that can be transformed from RDF. Domain-specific semantic models will be presented as Smart Data Models.

TABLE 22 RELEVANT DATA FORMAT AND DATA MODEL STANDARDS FOR NARRATE

The existing technologies for modelling methodologies intents to have suitable concepts and solutions for the purpose of NARRATE. In the past, a lot of specific data models were developed, which can be reused for NARRATE. Those models are often called as Reference Ontologies, e.g. for manufacturing and were developed in numerous research projects. Some examples are:

- MASON (Lem06)
- Flexinet Ontology (Pal16)

- TOVE (Kim95)

Regarding Standardisation, until now, all of them went not into a formalized standardisation project with a sufficient output. To start a new approach on international level just from the NARRATE perspective is not recommended yet.

On of the major developments were done in the IDTA. Here a possibility to apply current models and to contribute with NARRATE models.

3.4. OPTIONS FOR ADAPTATION OF EXISTING STANDARDS

Based on the current development status of NARRATE a candidate for extension / revision of existing standards could be the committees in IEC TC 64 or ISO TC 184. Here some investigation should be performed. The first investigation would be approaching national mirror committees

3.5. CONCLUSION ON RECOMMENDED ACTIVITIES

It is recommended to apply the specifications of the existing standards for the following standard elements:

- Security Infrastructure
- IT Governance
- Policy Management and Enforcement
- Identity & Access Management
- Data Storage/ Persistence
- Unique Identifiers and Data Carriers

by using free available standards without paying membership or licensing fees.

Based on the achievement in NARRATE and the current options because of open standardisation activities below there are possible contributions listed:

- Dynamics in Transaction Services in ISO TC 184 SC5
- Integrate analytics for digital TWIN in ISO TC 184 SC4
- Propose a federated data framework based on the IPC-2591 application in one of the major international standardisation organisations, namely IEC TC65 or ISO TC 184.
- Adapt existing submodels or create new models in the IDTA from achievements created by NARRATE

Currently it is not seen, that from NARRATE complete new standardisation committees should be created.

4. HOW TO BE INVOLVED INTO STANDARDISATION BODIES

As it is identified, that NARRATE contribution can be concentrated to ISO TC 184 in SC4 and SC5, below there is a brief guideline, how the contribution can be made.

1. **Identify the Role:** Check the expertise as required for contribution in the focus areas of TC 184 SC4 (Industrial Data) and SC5 (Interoperability).
2. **Contact the National Standards Body:** Reach out to the country's national standards organisation to express the interest in joining SC4 or SC5. They are facilitating your membership. Normally they assign persons to a national mirror committee. E.g. this is the case in Germany by the association VDMA.
3. **Attend Meetings:** Participate in committee meetings and workshops. Engaging in discussions will allow to share insights from NARRATE experiences and learn from others.
4. **Review Draft Standards:** Actively review and provide feedback on draft standards.
5. **Promote the Standards:** Advocate for the adoption and understanding of the standards developed by SC4 and SC5 within the professional community.

For the involvement into industrial standardisation like into IDTA it is slightly different. Here a membership has to be achieved, and several industrial partners convinced to standardise specific data models.

5. CONCLUSION

the major research asset of NARRATE, the IMC is facing to a huge number of standardisation categories across different standardisation bodies with interdependent and even conflicting standards, having different approaches and time-lines. More than 200 relevant standards were found to be taken into account.

For all addressed standards, which seen be suitable to follow and to be applied by NARRATE it is recommended to perform an analysis for the application of standards according to the following criteria:

- Wideness of Applications in different sectors – ensure cross-sectorial application which have a widespread in the market
- Future proof of technologies – take into account mature and up-to-date standards
- Genericity of concepts – follow core solution, which can be easily specialized

For those standards, were NARRATE can contribute, the prioritization to standards, were NARRATE can contribute, is essential for creating impact of NARRATEs achievements. These are mainly the ISO TC 184 standards on digital twins for products and production assets and the existing and future data standards for digital twins, as there are maintained in the IDTA. Here the NARRATE stakeholder should engage into actual standardisation activities. For all the other standardisation elements as elaborated in the NARRATE standard stack, the selection and adoption of suitable existing ones should be focused. This will enable effective research activities and maximum reuse of existing sources. Further on the blue-prints of NARRATE seems to be worth for considering into IDTA. This requires an interoperability to the specification templates of the AAS.

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REST API	https://en.wikipedia.org/wiki/REST
RFC 8141	https://datatracker.ietf.org/wg/urn/about/
SCOR Model Supply Chain Operations Reference	apics.org/scor

SCOR Performance Metrics	https://www.apics.org/apics-for-business/benchmarking/scormark-process/scor-metrics?iOS=
Supply Chain Reference Data Model	https://unece.org/trade/documents/2024/08/standards/supply-chain-reference-data-model-d22a#:~:text=The%20UN/CEFACT%20Supply%20Chain%20Reference%20Data%20Model,more%20*%20Construct%20Business%20Data%20Exchange%20Structures
UN/CEFACT Core Component Technical Specification	https://unece.org/sites/default/files/2025-03/CCTS-Version3.pdf Universally Unique Identifier URN Namespace. Available at: https://datatracker.ietf.org/doc/html/rfc4122
W3C JSON-LD	https://www.w3.org/TR/json-ld11/
W3C ODRL – ODRL Model	https://www.w3.org/TR/odrl-model/
W3C VC Verifiable Credentials Available	https://www.w3.org/TR/vc-data-model/
W3C VP Verifiable Presentations	https://www.w3.org/TR/vc-data-model/#presentations
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