ONTO COMMONS
ONTOLOGY-DRIVEN DATA DOCUMENTATION FOR INDUSTRY COMMONS

Report D5.2
"Specification of initial cases"

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Report D5.2
"Specification of initial cases"

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Task	T5.2 | Definition of requirements upon tools and ontologies and specification of 11 initial cases
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2.0	14.07.2022	Nadja Adamovic (TU Wien, coordinator)	Final approval and submission

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Disclaimer

Executive Summary

This deliverable provides detailed specification of initial demonstrator cases. Specifically, building on OntoCommons D5.1, we describe detailed state of the art of the eleven initial demonstrators of the project, addressing the relevant to the project needs, state of the affairs in the usage of ontologies and ontology tools, Technology Readiness Levels, and also the state of the FAIRness for the data in the demonstrators. Also, the demonstrator needs, aims and expectations from the project have been analysed, and Key Performance Indicators (KPIs) have been defined. The elaborated demonstrator descriptions and requirements have been collected with extended surveys and through individual meetings with the demonstrators, dedicated to the specification of initial cases. Representatives of OntoCommons technical work-packages have provided the inputs to surveys and been taking part in the meetings, to understand the specification and requirements better. Further, we provide conclusions and outline our future work.

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1. Introduction

The OntoCommons project has 11 initial demonstrators that allow the project partners to foster the development of initial guidelines and best practices driven by common requirements with regards to ontologies and tools. The initial demonstrators are mainly from Materials, Manufacturing and Procurement domains. Each demonstrator provides a use case. In the previous deliverable D5.1, we provided a set of requirements collected from the initial demonstrators. This deliverable presents each use case in more detail, particularly focusing on detailed main scenarios, FAIRness assessment, domain-specific requirements for ontology development and KPIs to measure the success of the demonstrator with regards to the results of OntoCommons project. The main purpose of this deliverable is on the one hand to help technical work-packages such as WP3 and WP4 to understand the use cases better, on the other hand to identify the metrics and their calculation functions for laying the ground for the future validation activities.

For the specifications, we have conducted structured interviews with each over the course of several weeks. The interviews were conducted jointly with WP3 for supporting domain level ontology engineering from bottom-up. The demonstrators received the interview questions in advance and answered them in preparation to the interview. The interviews with each demonstrator took between 30-60 minutes with at least one WP5 member present and in many cases joined by the members of WP3 and any other interested/related OntoCommons partners. During the interviews, the given answers have been discussed and elaborated. The deliverable presents the answers given by demonstrators to the interview questions.

The deliverable is structured as follows. Sections 2 to 12 correspond to the interview results from use cases 1 to 11. Each interview has been elaborated by WP5 task leaders, and has the same structure (see the Appendix), but the content of some sections are personalized per use case (e.g., initial FAIR assessment of each use case was provided for reference as part of the interview questions). First, a brief description of the use case is provided (although this is already done in D5.1, the same information has been repeated for the sake of completeness). Then a detailed description of the use case is given. This description contains an overall description of the goals and any figures that give an overview to the use case (again taken from D5.1), the pre-conditions, post-conditions and actors of the use case. The detailed descriptions are followed by the presentation of the main scenario that includes the steps of the main scenario including the ontologies (Top-Level, Mid-Level and Domain Ontologies) and tools involved at each step, data sources used and the expected impact of OntoCommons. The main scenario section also includes a question about the most common terms in their domain from the perspective of each demonstrator, which is used by WP3 as input. After introducing the main scenario, we give a rough implementation plan for the use case. The last three sections for each interview are dedicated to FAIRness assessment, Technology Readiness Level (TRL) and Key Performance Indicators (KPIs) for the use case. The FAIRness assessment section aims to identify any changes in comparison to the baseline established in the beginning of the project. Technology Readiness Level section asks the same question in terms of TRL from the perspective of overall use case and the ontologies used in the use case. Finally, the KPIs section identifies metrics and measurement functions for each use case in order to enable the validation at a further stage of the project. The deliverable is finally concluded with a summary, lessons learned and indicators for the future work.

2. UC1: IRIS - IndustRIal Co-design Support

AIRBUS is a European aerospace corporation, registered in the Netherlands and trading shares in France, Germany and Spain. It designs, manufactures and sells large civil and military aerospace products worldwide, and manufactures in the European Union and various other countries. The company has three divisions: Commercial Aircraft, Defense and Space, Helicopters. **Error! Reference source not found.**Table 2.1 gives a summary of the use case.

Use case owner:	Airbus
Involved partner:	University of Oslo
Technology Readiness Level:	TRL4
Data sources used:	Historical system design data Design requirements and KPIs
Ontologies considered:	IOF Core QU4LITY Ontology GRACE Ontology Z-BRE4K Ontology
Main Challenges:	• High-complexity of the system makes it hard to model and populate a comprehensive ontology • Lack of process-oriented ontologies to be reused • Lack of unified tools to integrate design requirements to process data for simulation

Table 2.1 - Overview of UC1 as given in D5.1

2.1 Detailed Description

The primary goal of the use case is to increase the interoperability and improve the communication between aircraft assembly and the industrial system design. Airbus aims to use ontologies to support trade-off decision making, represent domain and process knowledge explicitly and improve traceability of the decisions made during the design and assembly processes. The use case aims to demonstrate:

- decreased development time via automatized decision making and improved re-usability,
- improved reliability via traceability,
- improved communication between assembly and design experts via data integration and increased domain knowledge interoperability.

This will be demonstrated with an illustrative case of product aircraft design and its orbital joint process design. This use case will be based on the output of a relevant project (QU4LITY) pilot. An application ontology corresponding to this scenario is underdevelopment. The main knowledge sources for that ontology are documented historical system specifications and experts' feedback.

In OntoCommons the application ontology will be further improved by collecting information and knowledge from more stakeholders and take reference from other application or domain ontologies in the OntoCommons ecosystem if available. Another objective is to improve the interoperability by aligning the application ontology to the top level ontology or top reference ontology which are expected output of OntoCommons. An overview of the use case is shown in Figure 2.1.

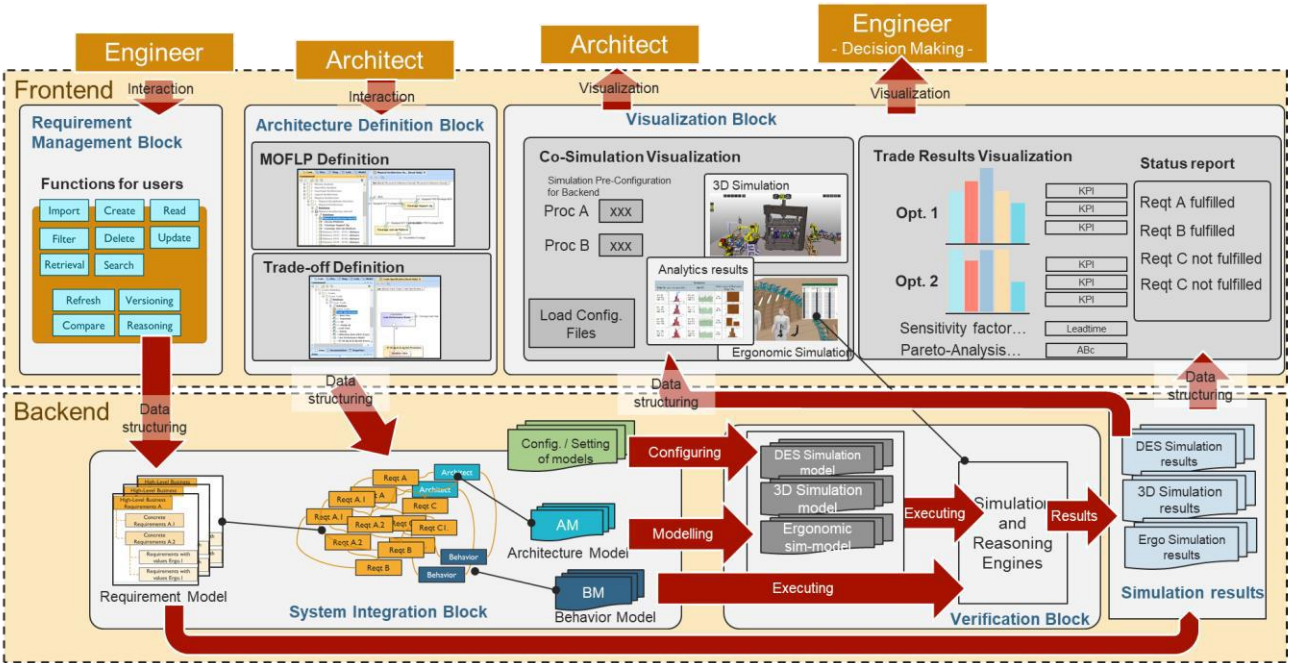


Figure 2.1 - UC1 Overview as given in D5.1

What are the pre-conditions of your use case? In which state the system should be in before the scenario starts?

This use case focuses on the R&D phase of a new industrial system. Pre-conditions include:

1) There are public historical data available from similar industrial systems of relevant aircraft products;
2) There are domain experts involved from the case owner who are familiar with ontology and semantic engineering;
3) An application ontology has been developed during previous research projects which refers to standardized middle level ontology (IOF-Core) and to level ontology (BFO). It provides starting points for this case in OntoCommons.

What are the post-conditions of your use case? What is the expected state of the system after the scenario is completed?

The system is expected to support decision-makings during aircraft industrial system design. Some expected benefits include:

1) Predict behavior, explore architectural alternatives early in the development process, and perform trade studies to assess which design choices make the most sense for manufacturing performance.
2) Develop a cognitive twin based on captured domain knowledge, models and simulations.
3) Perform a business transformation that includes new organizations and new roles to develop the models and to perform manufacturing engineering activities.

Who are the actors involved? (List of all actors mentioned in the scenario steps)

1) Knowledge scientist
2) System engineering expert
3) Assembly process engineer
4) Simulation engineer

2.2 Main Scenario

No	Description	TLO	MLO	DO	Tools
1	Knowledge capturing by Knowledge scientists	BFO	IOF-Core	QU4LITY Domain Ontology (under development)	Protégé
2	Process design by System engineering expert and Assembly process engineer	-	-	-	-
3	Architecture models by systems engineering expert and Assembly process engineer	BFO	IOF-Core	IOF-MBSE ontology	MetaGraph 2.0
4	Simulations models development supported by ontology by System engineering expert and Knowledge scientists	-	-	-	Neo4j
5	Simulation and visualization by Simulation engineer	-	-	-	-

6	Optimize Ontology according to application feedbacks	-	-	-	Protégé Neo4j
7	Update and maintain Ontology according to new versions of MLO	BFO	IOF-Core	-	Protégé

Which data sources are used? (Please cross-reference with the steps of the main scenario)

- Public and representative historical system design data – Step 1
- Public Design requirements and KPIs – Step 2,3,4

What are the major (expected) contributions of OntoCommons to the use case?

1) Improve the interoperability and scalability of the application ontology by adapting to the OntoCommons ecosystem.
2) Obtain possible extra domain knowledge from relevant use cases and ontologies.

Name the most important 20 terms for the domain of your use case. If available, please add any diagrams illustrating these terms (e.g. UML diagram, ER diagram)

The levels correspond to a hierarchical relationship between terms (Level 1 is the most generic term)

Level 1	Level 2	Level 3
Product		
	Manufactured Product	
Resource		
	Human Resource	
	Material Resource	
		Manufacturing Resource
	Intangible Resource	
Process		
	Assembly Process	
	Business Process	
	Manufacturing Operation	
Requirement		

Descriptive Information Content Entity		
	System Model	
Directive Information Content Entity		
	Plan Specification	
		Manufacturing Process Plan
Material		
	Manufacturing Material	
Quality		

2.3 Implementation Time Plan

Scenario steps		**Expected finish time**	**Status**
1	Knowledge capturing and ontology development by Knowledge scientists	April-2022	A draft version of the ontology is developed. It will be optimized according to more feedbacks from experts and application results
2	Apply ontology to support Process design by System engineering expert and Assembly process engineer	April-2022	These three steps will be conducted in parallel supported by the application ontology.
3	Architecture model development using ontology from System engineering expert and Knowledge scientists		
4	Simulation model development supported by ontology by System engineering expert and Knowledge scientists		
5	Simulation and visualization by Simulation engineer		

6	Optimize Ontology according to application feedbacks	Nov.-2023	Feedbacks may include simulation results and extended knowledge sources etc.
7	Update and maintain Ontology according to new versions of MLO	Nov.-2023	Adapt ontology to fit new versions of IOF-Core and integrate to OntoCommons ecosystem

2.4 FAIR Plan

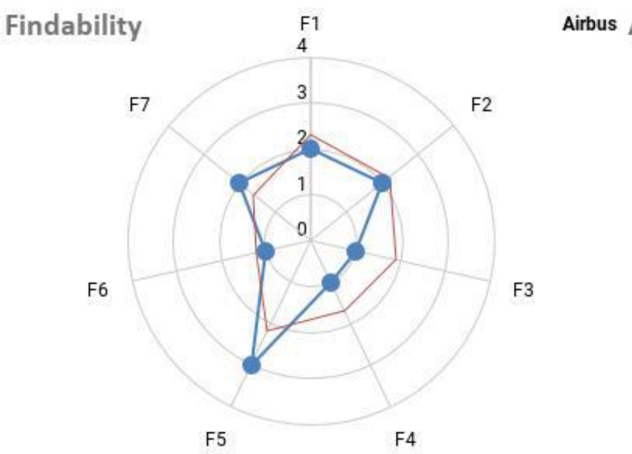
Results of the initial FAIRness evaluation:

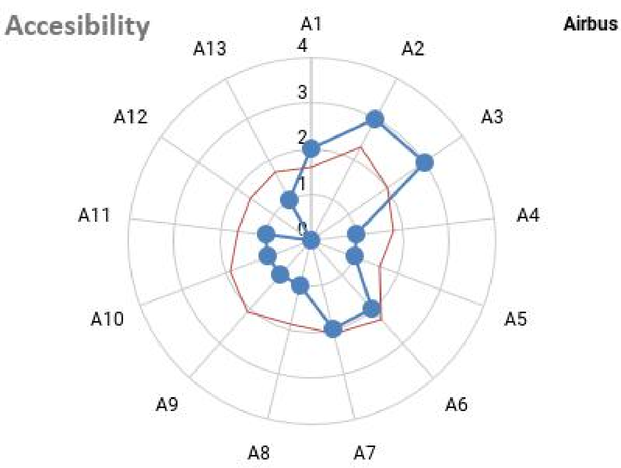
In the Findability dimension the use case is close to the average of the initial use cases. All dimensions are deemed to be applicable, and one principle (rich metadata is provided to allow discovery) is already in the implementation phase. The principles regarding persistent identifiers for metadata and data are also in the planning phase.

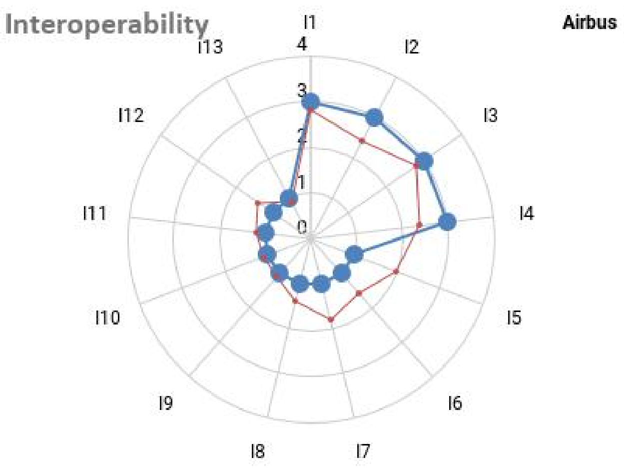
Almost all principles for the Accessibility dimension are applicable. There are already principles regarding manual access to the data and metadata being implemented. Publication of data and metadata over a standardized protocol is in the planning phase.

Interoperability is arguably the strongest dimension in this use case with four principles already in the implementation phase. This situation indicates that both metadata and data are represented with standardized and machine-understandable metadata formats.

At the Reusability front, the use case is still at an early stage as none of the principles have not even been considered yet.







What evolved from that time until now? Please answer per dimension:

Findable: The application ontology classes and individuals based on an exemplary pseudo-dataset have been stored in a cloud server making it findable by authorized users manually or via automated agents (RDA-F4-01M).

Accessible: Owning to the above action, the pseudo dataset is accessible to authorized users via a standard protocol (HTTP and Neo4j Cypher).

Interoperable: None

Reusable: None

What are the future steps to improve FAIRness? What does the demonstrator want to improve? If there are no/little improvement made and/or foreseen, motivate why. If there is an interest to progress here, what are the roadblocks?

Due to the regulations of the owner of use case, a major part of the data related to the detailed application scenario cannot be shared publicly. However, some common knowledge including the ontology and the system framework will be published through workshop/conference papers, which will be available in the following months.

Another step could be releasing the desensitized version of the application ontology by removing the detailed individuals and specific classes that are unique to the use case owner. In this way, the ontology with domain common knowledge can be shared on public repositories (Github, WebProtégé, etc.), while the complete version of the ontology remains available only to authorized users.

2.5 Technologies Readiness Level (TRL)

Using the standard definition[1]**:**

- **for different scenario steps,**
- **for TLOs employment,**

[1] https://en.wikipedia.org/wiki/Technology_readiness_level

- for MLOs employment,
- for DOs employment,
- for tools deployment.

How they evolved since spring 2021 (last half a year)? How are the TRLs expected to evolve in the next months?

During the year 2021, this use case has evolved from internally defined MVP2 (Simple trade-off scenario simulation) to MVP4 (Global semantic integration). From the Ontology perspective, the application ontology has been adapted to comply with the MLO IOF-Core ontology which adopts BFO itself.

In the next months, the TRLs are expected to reach TRL4 by April 2022. The ontology will be integrated with requirement management, architecture design, simulation and visualization functional blocks, and to be verified through extended version of experiments and simulations.

2.6 Key Performance Indicators (KPIs)

KPI	Metric	Function	Range
TRL improvement	• TRL change	– 0.33 – *1/1+(TRL_end 4-TRL_start 2)*	(0,1]
FAIR improvement	• average score in each FAIR dimension	– For each dimension, average based on final surveys	[0,4] for each dimension
Avoidance of physical testing	• Percentage of avoided physical testing	– TBD	(0,1]
CO2 emission – improved architecture	• Percentage of reduced CO2 emission	– TBD	(0,1]
Automation level	• Percentage of increased automation level	– TBD	(0,1]
Lead Time: e.g. in production, in ontology modelling	• Time spent	– Hours	Not fixed
Optimised performance	• Percentage of the performance improvement	– TBD	(0,1]

3. UC2: SeDIM: Semantic Data Integration for Manufacturing

The Bosch Group is a leading global supplier of technology and services with 394,500 associates worldwide (as of December 31, 2020). Its operations are divided into four business sectors: Mobility Solutions, Industrial Technology, Consumer Good s, Energy and Building Technology. As a leading IoT provider, Bosch offers innovative solutions for smart homes, Industry 4.0, and connected mobility. Bosch is pursuing a vision of mobility that is sustainable, safe, and exciting. It uses its expertise in sensor technology, software, and services, as well as its own IoT cloud, to offer its customers connected, cross-domain solutions from a single source. The Bosch Group's strategic objective is to facilitate connected living with products and solutions that either contain artificial intelligence (AI) or have been developed or manufactured with its help. The summary of the use case at the beginning of the project is given in Table 3.1.

Use case owner:	Bosch
Involved partner:	Bosch, University of Oslo
Technology Readiness Level:	TRL5
Data sources used:	• Manufacturing • Simulated laboratory data
Ontologies considered:	Bosch Ontology (developed in-house)
Main Challenges:	• Cost of ontology development • Lack of standards and guidelines

Table 3.1 - Overview of UC2 as given in D5.1

3.1 Detailed Description

The main goal of this use case is to foster scalable development of Machine Learning (ML) pipelines for condition monitoring of industrial equipment. The use case aims to improve the reusability of existing ML pipelines for similar processes of tasks. The company aims to achieve the adaptation of ML pipelines with affordable, minimal modifications in the existing pipelines.

The core of the use case relies on the semantic technologies by representing domain knowledge both for manufacturing processes and ML pipelines explicitly with ontologies. A reasoner is then able to derive feature groups from the annotated data and selects the suitable ML algorithms. This knowledge-based approach also improves explainability as both the selected features and ML models are explicitly annotated.

What are the pre-conditions of your use case? In which state the system should be in before the scenario starts?

For the welding process, one of the typical manufacturing processes, the data of this use case are collected from three typical sources: the production plants at OEMs[2], the laboratories for process development, and simulation in research center for a better understanding of the process. The dataset size, i.e., number of welding spots, ranges from 10 to around 3000.

What are the post-conditions of your use case? What is the expected state of the system after the scenario is completed?

By annotating data with uniformly defined structures and feature names from ontologies, data collected from different conditions, sources or even different processes with similarity can be integrated into a Uniform Data Format[3]. The relational database data in Uniform Data Format will migrate to a triple store in knowledge graph whose knowledge graph schema will integrate the core ontology and domain ontology involved in this use case (welding process).

Who are the actors involved? (List of all actors mentioned in the scenario steps)

- process experts
- measurement expert
- managers
- data managers
- data scientists

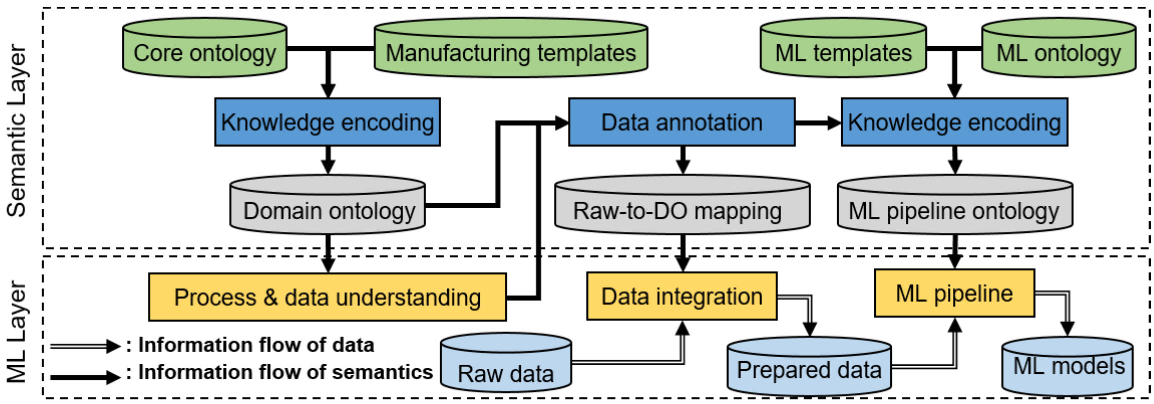


Figure 3.1 - UC2 overview as given in D5.1

[2] Original Equipment Manufacturer

[3] **Uniform Data Format**: after data are transformed into unified file formats, their feature names need to be changed to unified feature names. The resulting data with unified feature names in unified file formats are named as Uniform Data Format (UDF) in UC2. This is essential for allowing any algorithms of data visualisation, data pre-processing or ML modelling in the subsequent steps to access the features in a uniform manner. Applies to the later.

3.2 Main Scenario

No	Description	TLO	MLO	DO	Tools
1	Data acquisition from three sources	-	-	-	
2	Task negotiation, to define feasible and economic tasks	-	-	-	an ontology-based software system: SemML
3	Data integration, to integrate data from different conditions and factories	-	QMM-Core Ontology [4]	QMM-Domain Ontology[5]	an ontology-based software system: SemML
4	Data analysis, ML model development	-	QMM-ML Ontology [6]	ML Pipeline Ontology[7]	an ontology-based software system: SemML

[4] **QMM-Core Ontology**: the middle-level ontology for quality monitoring in manufacturing, encoding general knowledge of manufacturing. QMM-Core Ontology has been developed through a series of workshops, taking inputs from various Bosch experts of engineering and machine learning. It reflects the consensus terminology for a common base of discussion. QMM-Core Ontology is an OWL 2 ontology. With its 1170 axioms, which define 95 classes, 70 object properties and 122 datatype properties, it models the processes of discrete manufacturing with an emphasis on quality analysis. Classes and properties of the QMM-Core Ontology define the key modelling patterns for the domain ontologies of different manufacturing processes. Patterns capture repetitive structures in the linked classes and their associated properties and can be instantiated via the ontology templates.

[5] **QMM-Domain Ontology** focuses on particularities of a specific manufacturing process, e.g., welding.

[6] **QMM-ML Ontology**: the task ontology for machine learning that powers the ML components of the system. QMM-ML Ontology has classes to categorise features as qmm-ml: FeatureGroups: time series, categorical features, identifiers, etc. It also encodes various preprocessing, feature engineering, and ML algorithms. It contains 62 classes, 4 object properties, 2 datatype properties as well as 210 axioms and 122 annotation assertions. QMM-ML Ontology is used to enhance the dataset described in the Domain Knowledge Annotator with the ML-relevant information on the feature level. This is done via reasoning and the reasoning results are stored as Data-to-FG mappings store qmm-ml:FeatureGroups for all columns in the prepared data.

[7] **ML Pipeline Ontologies** contain concrete ML solutions for specific datasets. The selected ML pipeline ontology from the ML Pipeline Catalogue by the user will be adjusted to the dataset by SemML. An ML Pipeline Ontology is an executable description of a concrete ML pipeline configuration. It adopts a layer-wise structure, which always starts from the qmm-ml:PreparedDataLayer, goes a series of qmm-ml:FeatureProcessingLayer, ends qmm-ml: MLModellingLayer. These are the three types of layers. The layers are connected with the object property qmm-ml: hasNextLayer. Each qmm-ml:FeatureProcessingLayer or qmm-ml:MLModellingLayer has a structure of qmm-ml:Input, qmm-ml:Algorithm, and qmm-ml:Output.

Which data sources are used? (Please crossreference with the steps of the main scenario)

- the production plants at OEMs
- the laboratories for process development
- simulation in research center for a better understanding of the process

What are the major (expected) contributions of OntoCommons to the use case?

Our use case combines the ontologies from domain experts and data scientists. OntoCommons will provide intra-and cross-domain interoperability of ontologies that will allow for data integration and interoperability. OntoCommons will provide top level ontologies regarding manufacturing process and machine learning.

Name the most important 20 terms for the domain of your use case. If available, please add any diagrams illustrating these terms (e.g. UML diagram, ER diagram)

- RSWOperation
- WeldingProgram
- WeldingMachine
- WeldingControl
- ControlModule
- MeasurementModule
- MonitorModule
- OperationCurveCurrent
- ReferenceCurceCurrent
- SheetCombination
- WorkSheetBottom
- WeldingSpot
- QValueSetPoint
- Q-Value[8]
- AdhesiveType
- ChassisPart
- WorkSheetTop
- SpotDiameter
- WearCount
- DressCount

3.3 Implementation Plan

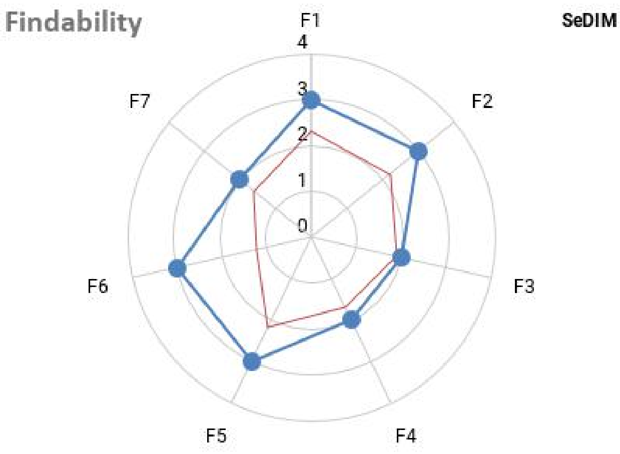
TBD

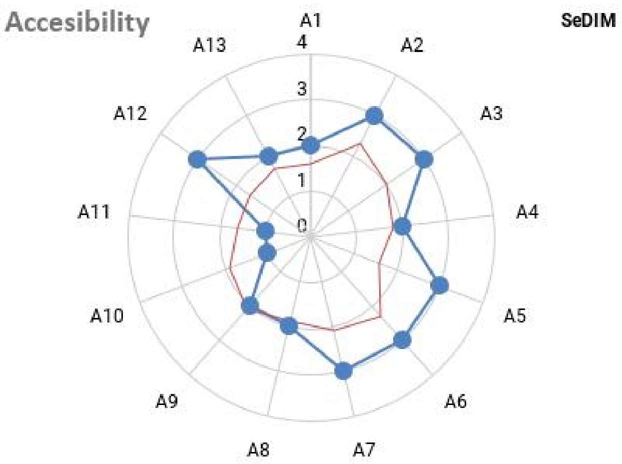
[8] **Q-Value**: one type of quality indicator for welding, developed by Bosch Rexroth through engineering know-how and long-time experience, is calculated after each welding operation, based on statistic features (e.g., mean, maximum) from sensor data. The optimal Q-Value is one and any value that deviates from one indicates quality deterioration or inefficiency. In dataset evaluation, an overview of the general information (e.g., #welding operations, #welding programs), and the behaviour of Q-Value should be presented to the users (e.g., process experts, data scientists), to identify potential problematic welding machines. Q-Value is especially important and will be used as the criteria in this use case for identifying conspicuities.

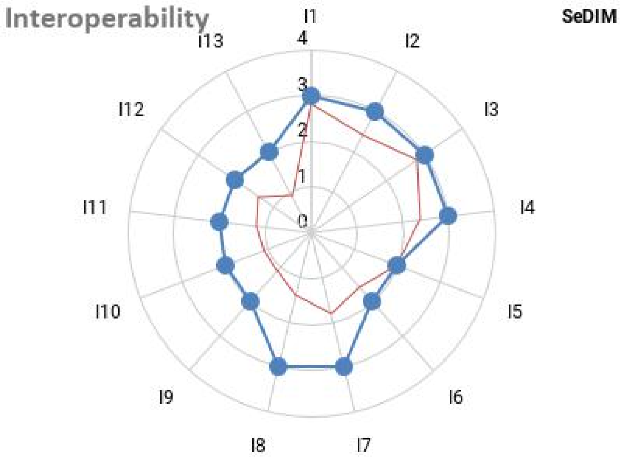
3.4 FAIR Plan

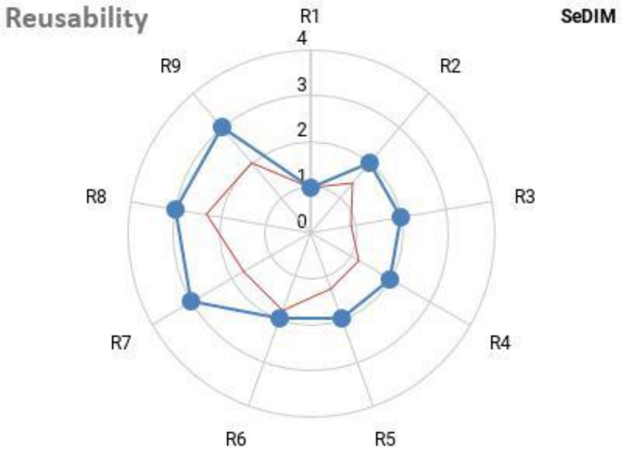
Results of the initial FAIRness evaluation:

In terms of adherence to FAIR principles, the use case is more mature than the average of the initial demonstrators. Most of the principles in each dimension are either in the implementation phase or in the planning phase, which creates an opportunity for OntoCommons best practices for ontologies and tools to influence the developments towards the implementation of these principles.









What evolved from that time until now? Please answer per dimension:

The system that collects the data has been automatized and has improved the Findability, Accessibility, Interoperability, and Reusability of the data by the members of the organization.

Findable: Due to data privacy no actions have been made to improve findability for other users.

Accessible: Due to data privacy no actions have been made to improve accessibility for other users.

Interoperable: Ontologies integration has started to enhance data interoperability. Terms (e.g., spot diameter, adhesive type, etc.) used for knowledge graph schema selected.

Reusable: Ontologies integration has started, in order to enhance data and machine learning model data pipeline reusability.

What are the future steps to improve FAIRness? What does the demonstrator want to improve? If there are no/little improvement made and/or foreseen, motivate why. If there is an interest to progress here, what are the roadblocks?

The demonstrator needs to improve the FAIRness of the metadata, so information about the data can be discovered. The data of the use case are not to be shared with third-party, so actions taken should regard the improvement of Findability, Accessibility, Interoperability, and Reusability among in the organization level.

3.5 Technology Readiness Levels (TRL)

Using the standard definition[9]:

- **for different scenario steps,**
- **for TLOs employment,**
- **for MLOs employment,**
- **for DOs employment,**
- **for tools deployment.**

How have they evolved since spring 2021 (last half a year)? How are the TRLs expected to evolve in the next months?

For UC2 we developed ontologies of 3 types: Core Ontology that captures middle level welding knowledge, Domain Ontology that focuses on particularities of RSW or other specific welding processes, and ML Ontology that captures ML aspects such as feature groups and ML algorithms.

1. **MLOs**: The Middle level ontologies used for the Use Case have been decided.
   - QMM-ML Ontology
   - QMM-Core Ontology
2. **for DOs employment:** The DOs that will be used for our Use Case have been determined:
   - QMM-Domain Ontology
   - ML Pipeline Ontology
3. **for tools deployment:** we developed a system, called **SemML**, that extends the conventional ML workflow with four semantic components: Ontology extender, Domain knowledge annotator, Machine learning annotator, Ontology interpreter. These components rely on ontologies, ontology templates, and reasoning. Indeed, **SemML** exploits upper-level and concrete domain ontologies and the ML-ontology that captures machine learning tasks.

[9] https://en.wikipedia.org/wiki/Technology_readiness_level

3.6 Key Performance Indicators (KPI)

KPI	Metric	Function	Range
TRL improvement	• TRL change	– 1/1+(TRL_end - TRL_start)	(0,1]
FAIR improvement	• average score in each FAIR dimension	– For each dimension, average based on final surveys	[0,4] for each dimension
Cost reduction of the machine learning data pipeline process. (target 20%)	• working hours needed to complete data analysis of an experiment	– Calculation of the percentage cost reduction	[0,100]
Cost reduction of maintenance (target 30%)	• Financial Cost of *maintenance in a specified period*	– Calculation of the percentage of cost reduction	[0,100]
Quality control Improvement (target 10%)	• Improvement of the Q-Value	– Calculation of the percentage improvement in the Q-Value	[0,100]

4. UC3: Engineering for Procurement

Aibel is a service company within the oil, gas and offshore wind industries. The company has 4000 employees and uses semantic technologies in their data-driven solutions since 2015. Table 4.1 provides a summary of the use case as specified in the beginning of OntoCommons activities.

Use case owner:	Aibel
Involved partner:	University of Oslo
Technology Readiness Level:	TRL5
Data sources used:	• Regulatory requirements • Product/Material specification • Production or purchase orders • Product certificate • Design codes • Material standards
Ontologies considered:	ISO 15926-14 Material-Core (In-house development) Standards Ontology (In-house development) ChEBI SKOS
Main Challenges	• Scalability of ontology development • Overcoming the learning barriers for semantic technologies in the industry • Dealing with Intellectual Property (IP) protected content

Table 4.1 - Overview of UC3 as given in D5.1

4.1 Detailed Description

The main goal of the use case is to describe data from various sources within the Aibel organization, semantically, in order to

- improve the reusability of data and processes,
- find inconsistencies via reasoning in terms of specific requirements,
- improve interoperability between departments/organizations, and
- improve interoperability between applications.

The use case will be built on top of the existing ontologies used in the company. The ontologies will be extended in the scope of the use case. The ontologies will be used for semantic modelling of material properties and chemical composition. Existing standards will be converted into ontologies via OTTR templates. Figure 4.1 gives an overview of the use case.

What are the pre-conditions of your use case? In which state the system should be in before the scenario starts?

The system / infrastructure is operational at Aibel.

What are the post-conditions of your use case? What is the expected state of the system after the scenario is completed?

Accessible ontologies with templates and documentation

Who are the actors involved? (List of all actors mentioned in the scenario steps)

- Ontology experts
- IT operation
- Subject Matter experts, material technology

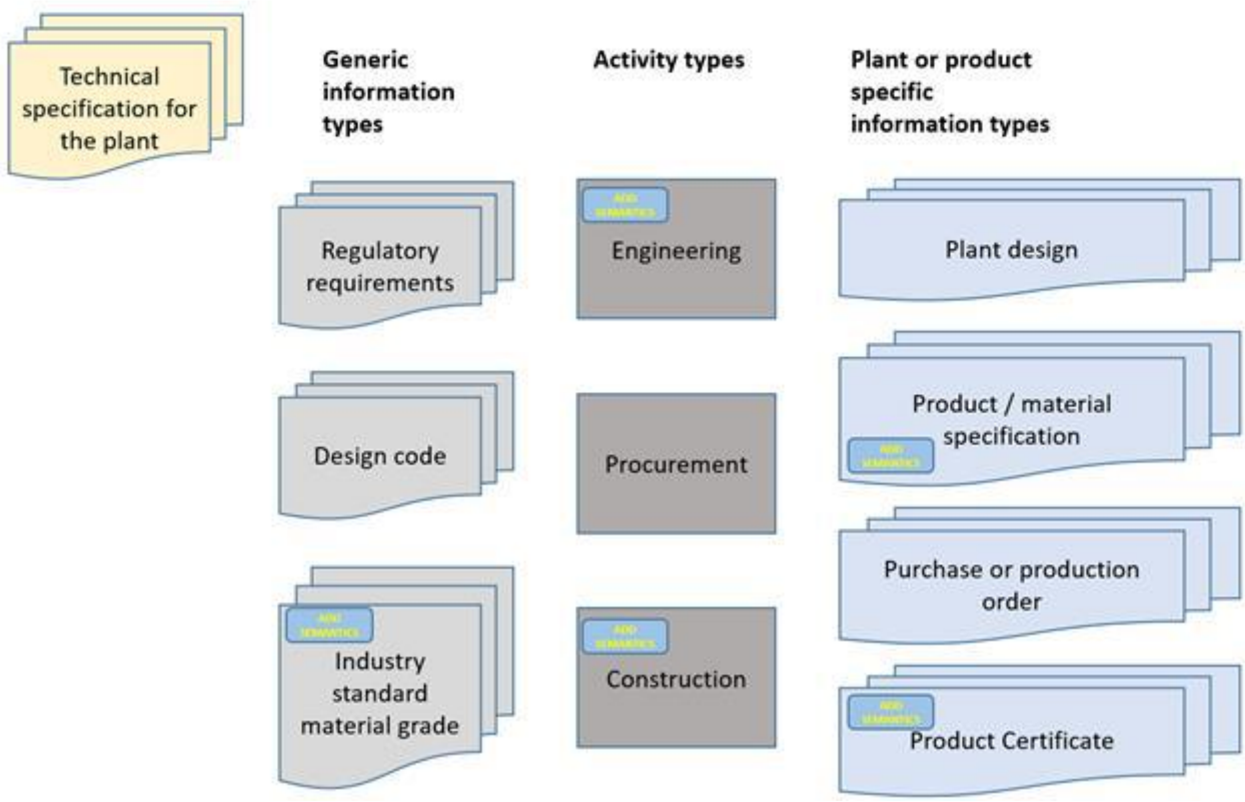


Figure 4.1 - An overview of UC3 as given in D5.1

4.2 Main Scenario

No	Description	TLO	MLO	DO	Tools
1	Specify use case				Document processors
2	Develop modelling patterns and templates be developed.				OTTR template
3	Tabular input has been provided by Subject matter experts. Industry standards				Tabular data
4	Define ontology imports				Internal PPR
5	Create Ontologies				OTTR
6	Demonstrate				Hermit reasoner
7	Report				

Which data sources are used? (Please cross-reference with the steps of the main scenario)

ISO 15926-14 to ontology, and Aibel MMD material ontologies

What are the major (expected) contributions of OntoCommons to the use case?

Material property and chemical composition semantics added to material grade ontologies. Demonstration of how such addition is industrially relevant.

Name the most important 20 terms for the domain of your use case. If available, please add any diagrams illustrating these terms (e.g. UML diagram, ER diagram)

Examples in OWL2 terminology;

Annotation property types; 'hasRevisionPremise', hasQualityFactor, hasENSteelNumber, hasDocumentRevision; Design article record rule: material, Created by, Created with, Created on

Object property types; createdBy, hasPart, hasFeature; hasTestCertificate

Classes; Compound, InanimatePhysicalObject, Steel, Copper, Titanium, Austenitic stainless steel, Austenitic-Ferritic stainless steel

4.3 Implementation Time Plan

Please provide a rough time plan for your implementation.

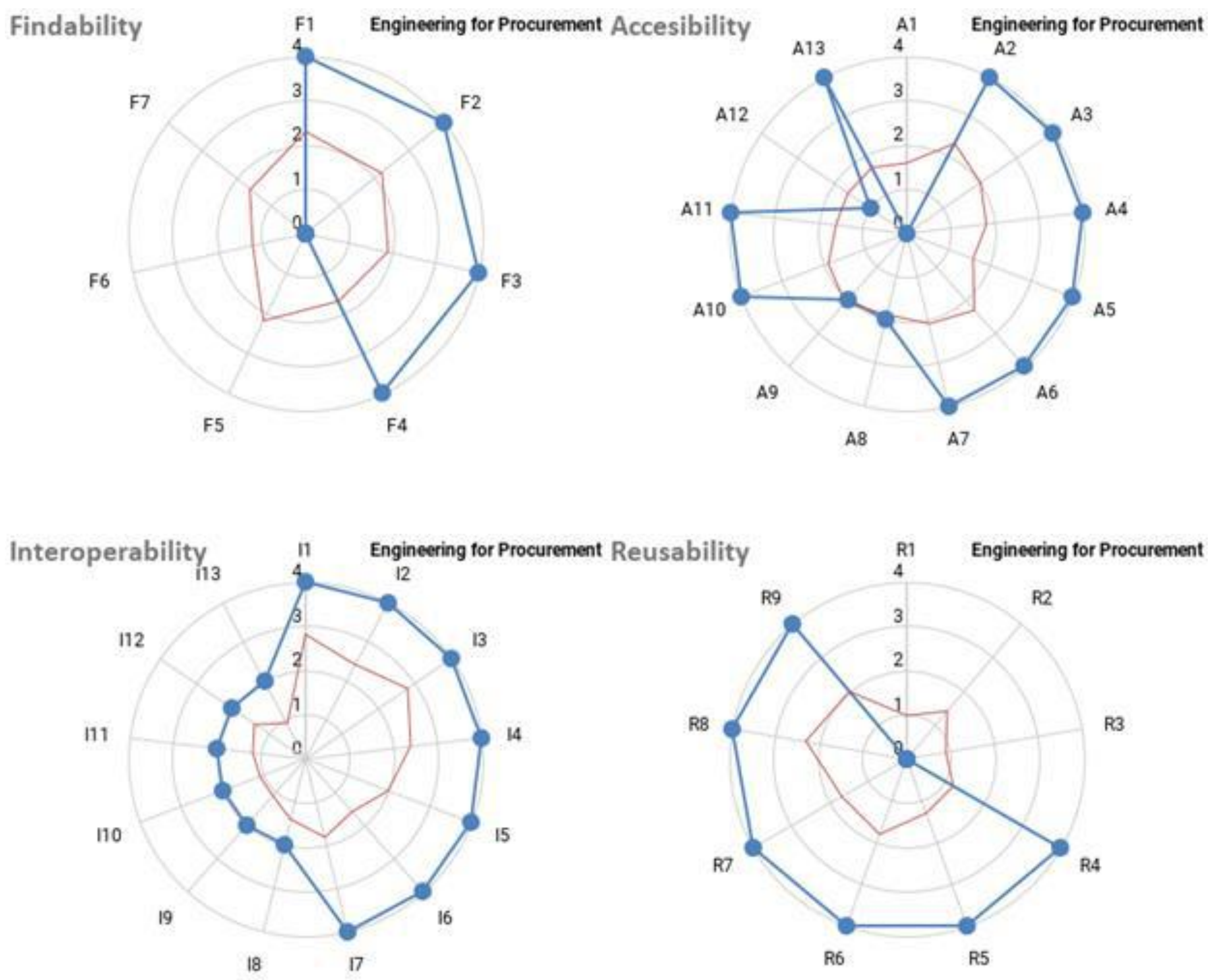
Particularly, list the milestones or scenario steps - by when what will be developed.

Plan and schedule must be aligned / agreed with UiO SIRIUS.

4.4 FAIR Plan

Results of the initial FAIRness evaluation:

Although there are many non-applicable principles, Aibel has already implemented many principles in every FAIR dimensions. OntoCommons can benefit from the experience gained from Aibel's use case while developing its best practices and the developed best practices can influence the adoption of further principles that are in the planning or implementation phase.



Is there already any development since the first survey towards improving FAIRness?
No change

What evolved from that time until now? Please Answer per dimension:

Findable: No change

Accessible: No change

Interoperable: No change

Reusable: No change

What are the future steps to improve FAIRness? What does the demonstrator want to improve? If there are no/little improvement made and/or foreseen, motivate why. If there is an interest to progress here, what are the roadblocks?

No particular plan so far.

4.5 Technology Readiness Levels (TRL)

Using the standard definition[10]:

- **for different scenario steps,**
- **for TLOs employment,**
- **for MLOs employment,**
- **for DOs employment,**
- **for tools deployment.**

How they evolved since spring 2021 (last half a year)? How are the TRLs expected to evolve in the next months?

TRL – Current 3 target aim 5

4.6 Key Performance Indicators (KPI)

KPI	Metric	Function	Range
TRL improvement	TRL change	1/1+(TRL_end - TRL_start)	(0,1]
FAIR improvement	average score in each FAIR dimension	For each dimension, average based on final surveys	[0,4] for each dimension

[10] https://en.wikipedia.org/wiki/Technology_readiness_level

Reduced man-hours comparing specification against stock product properties (target 60%)	• Time per product record	• Calculation of percentage decrease in man-hours	[0,100]

https://en.wikipedia.org/wiki/Technology_readiness_level

5. UC4: Materials' Tribological characterization

Tekniker is a research and development centre located in Spain. They have over 40 years of experience in applied research, especially in manufacturing. Table 5.1 highlights the key data about the use case provided in the beginning of the project.

Use case owner:	Tekniker
Involved partner:	Tekniker
Technology Readiness Level:	TRL4
Data sources used:	i-Tribomat DB
Ontologies considered:	EMMO / EMMC TribAIn[11] VAR Ontology
Main Challenges:	• Uncertainty regarding whether currently used ontologies cover all the use case requirements

Table 5.1 - Overview of UC4 as given in D5.1

The primary goal of the use case is to reduce the number and size of, and time required for experiments, for identifying the behaviour of a material or combination of them (e.g., metal, coating, lubricant) with respect to specific operation conditions. The goal is planned to be achieved via:

- better representation of material experiments,
- enriching existing data with additional background knowledge,
- easing data retrieval and navigation through related resources.

The use case will provide ontology-based access to a materials' tribological[12] related information in order to abstract from underlying data structures. Figure 5.1 provides an overview of the use case.

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[11] Kügler P, Marian M, Schleich B, Tremmel S, Wartzack S. tribAIn—Towards an Explicit Specification of Shared Tribological Understanding. *Applied Sciences*. 2020; 10(13):4421. https://doi.org/10.3390/app10134421

[12] https://en.wikipedia.org/wiki/Tribology

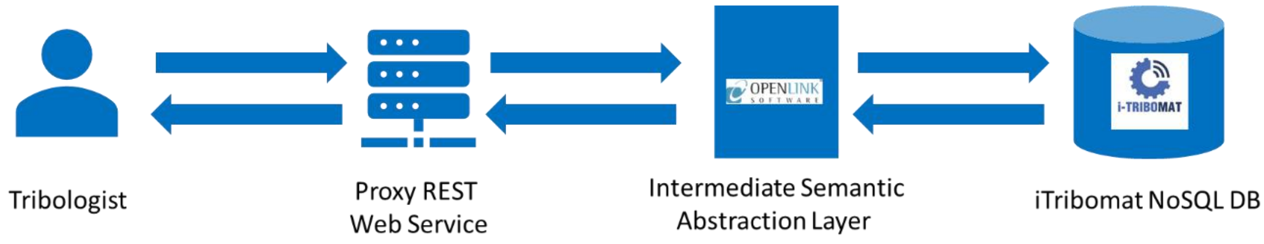


Figure 5.1 - An overview of UC4 as given in D5.1

5.1 Detailed Description

The primary goal of the use case is to reduce the number and size of, and time required for experiments, for identifying the behavior of a material or combination of them (e.g., metal, coating, lubricant) with respect to specific operation conditions. The goal is planned to be achieved via

- a common representation of material tribological experiments,
- enriching existing data with additional background knowledge,
- easing data retrieval and navigation through related resources.

The use case will provide ontology-based access to a materials' tribological[13] related information in order to abstract from underlying data structures.

What are the pre-conditions of your use case? In which state the system should be in before the scenario starts?

We should have access to at least one Database containing information of tribological experiments

What are the post-conditions of your use case? What is the expected state of the system after the scenario is completed?

We should be able to have an API to query the information of experiments. The information would be represented with adequate ontology terms, but the API would abstract end-user from the necessary underlying SPARQL queries.

Who are the actors involved? (List of all actors mentioned in the scenario steps)

- Tribological expert
- Ontology engineer/Semantic technologies expert
- Software developer

[13] https://en.wikipedia.org/wiki/Tribology

5.2 Main Scenario

No	Description	TLO	MLO	DO	Tools
1	Identify requirements of tribological experiment representation			TribAIn	
2	Extend TribAIn to cover new requirements			TribAIn extended with material related concepts	
3	Automate the instantiation of the new ontology with information of experiments stored in the DB			newOntology (TribAIn 2.0)	Protègè/OnTop or Apache Jena for ontology instantiation Virtuoso/Stardog for storing data (if necessary)
4	API for abstracting from parameterized SPARQL queries				Java or Python
5	Validation				

Some general questions that need to be answered are:

- TribAIn does not cover all the aspects that one might expect to describe all tribological aspect (horizontal extension).
- Do we need to align TribAIn with MLO in material science?

Which data sources are used? (Please cross-reference with the steps of the main scenario)

- Tribological Database (PostgreSQL)
- Virtuoso/Stardog where experiments represented with ontological terms may be accessible

What are the major (expected) contributions of OntoCommons to the use case?

Extension of the TribAIn ontology for covering the description of tribological experiments from a materials-oriented perspective.

Name the most important 20 terms for the domain of your use case. If available, please add any diagrams illustrating these terms (e.g. UML diagram, ER diagram)

Figure 5.2 and Figure 5.3 are provided.

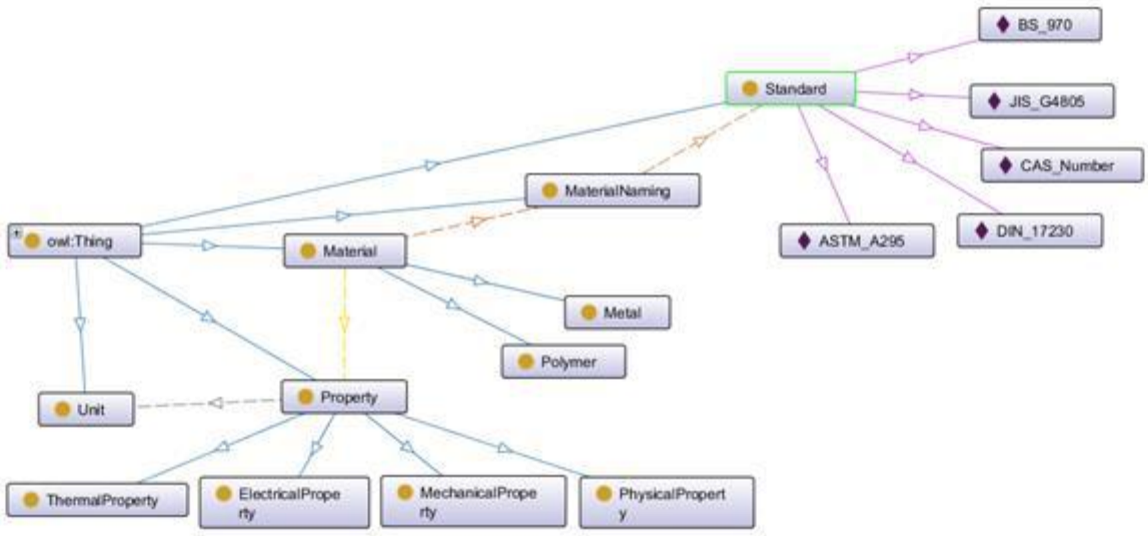


Figure 5.2 - Classes already including some of the extension terms. Current status of this set concepts are included here but set of most important 20 terms is not yet complete, will be done in the next implementation phases

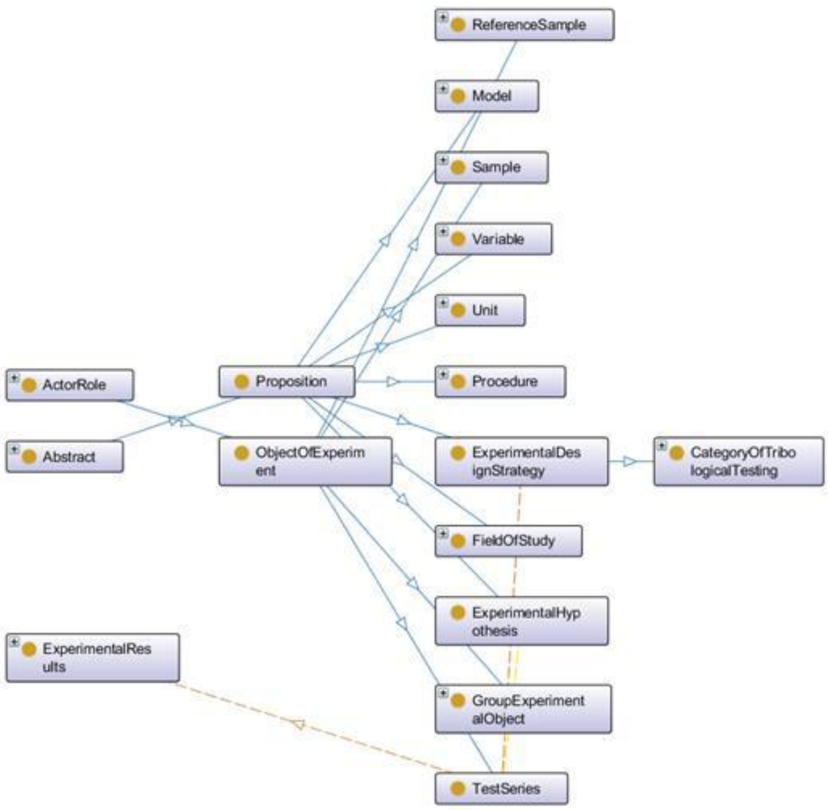


Figure 5.3 - Classes from the TribAIn ontology

TribAIn ontology: https://eref.uni-bayreuth.de/60510/

TribAin does not cover material related data, therefore the extension needs to be done
The goal in the end of the Demonstrator is to have a (new/updated) ontology and a tool that will use this ontology to go over the experiments information of a new project (saved in a database) and can instantiate the ontology with the experiments information, or rather annotate the information with the ontology terms. Go from a relational database to ontology related/annotated data.

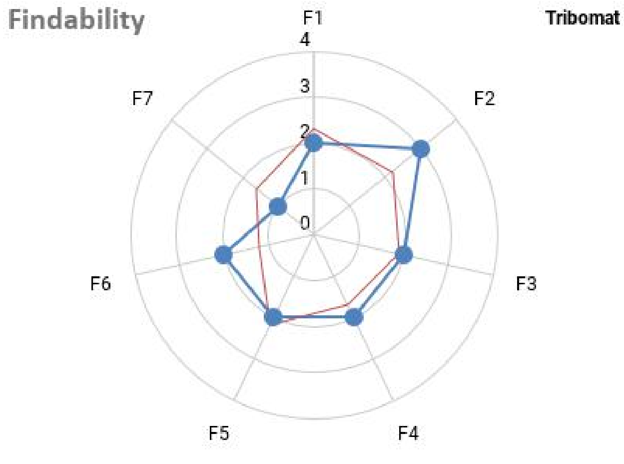
5.3 Implementation time plan

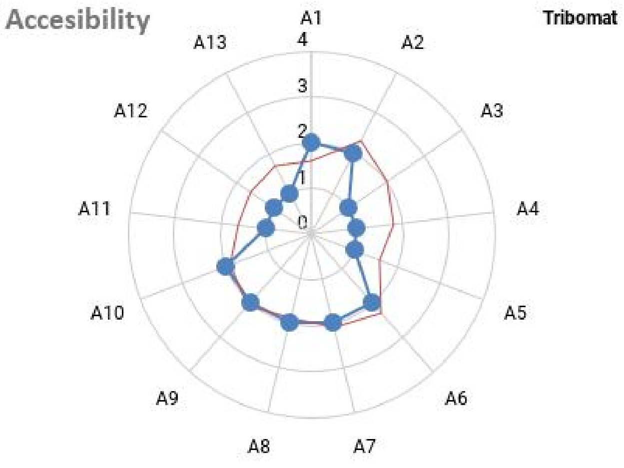
No	Description	When
1	Identify requirements of tribological experiment representation	October 2021 (M12)
2	Extend TribAIn to cover new requirements	April 2022 (M18)
3	Automate the instantiation of the new ontology with information of experiments stored in the DB	June 2022 (M20)
4	API for abstracting from parameterized SPARQL queries	October 2022 (M24)
5	Validation	July 2023 (M33)

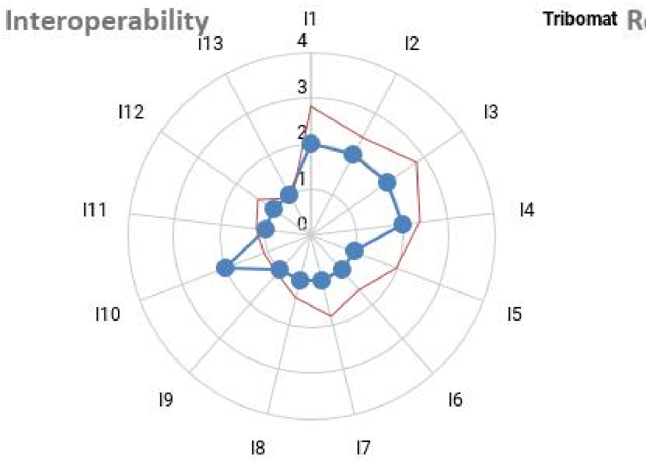
5.4 FAIR Plan

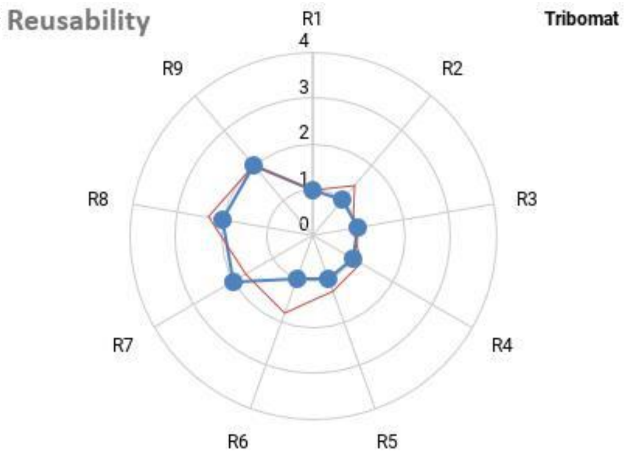
Results of the initial FAIRness evaluation:

The use case is overall well-rounded in all dimensions comparing to the average adherence to FAIR principles. In the Findability dimension, the majority of the principles are in planning phase which has a good potential to be improved with the outcomes of OntoCommons. Same goes for the Accessibility dimension, as 7 out of 13 principles are in the planning phase. Interoperability and Reusability dimensions are less mature than the other two. But the overall large number of principles in the planning or implementation phase indicate a good potential for application of best practices produced by OntoCommons to improve their adherence to the FAIR principles.









Nothing has evolved in terms of FAIRness, since we only identified requirements and we did not reach to the implementation phase.

What are the future steps to improve FAIRness? What does the demonstrator want to improve? If there are no/little improvement made and/or foreseen, motivate why. If there is an interest to progress here, what are the roadblocks?

The aim is to improve in all the four categories of the FAIRness thanks to the use of ontologies (Accessibility to the generated data is not sure)

5.5 Technology Readiness Levels (TRL)

Using the standard definition[14]:

- **for different scenario steps,**
- **for TLOs employment,**

[14] https://en.wikipedia.org/wiki/Technology_readiness_level

- **for MLOs employment,**
- **for DOs employment,**
- **for tools deployment.**

How they evolved since spring 2021 (last half a year)? How are the TRLs expected to evolve in the next months?

It is expected to go from a TRL3 to a TRL6 (for 4. and 5.)

5.6 Key Performance Indicators (KPI)

KPI	Metric	Function	Range
TRL improvement	TRL change	1/1+(TRL_end - TRL_start)	(0,1]
FAIR improvement	average score in each FAIR dimension	For each dimension, average based on final surveys	[0,4] for each dimension
		• F1: +2 • F2: +1 • F3: +2 • F4: +2 • F5: +2 • F6: +2 • F7: +0	
–Reduction in time of the design of materials (20%)	Time taken to design new material	Calculation of the percentage reduction in time	
–Reduction in costs of the design of materials (20%)	Costs to design new material	Calculation of the percentage reduction in time	

6. UC5: EVMF - European Virtual Marketplace Framework

The UK Research and Innovation (UKRI) agency is a non-departmental public body. It brings together the seven disciplinary research councils, Research England, and Innovate UK. The Science and Technology Facilities Council (STFC) is a multi-disciplinary science institution whose field of activity includes astronomy, particle physics, space science, nuclear physics, as well as the provision and operation of research facilities for all areas of activity of UKRI.

Goldbeck Consulting Ltd (GCL), based in Cambridge (UK), aims to bridge existing gaps in the materials modelling ecosystem, connecting communities, supporting the validation and technology transfer of academic developments to industry, translating industrial needs into impactful materials modelling projects and researching the pathways and barriers to economic impact. Table 6.1 gives an overview of the use case as described in D5.1.

Use case owner:	UKRI/STFC and GCL
Involved partner:	UKRI/STFC and GCL
Technology Readiness Level:	TRL3-TRL4
Data sources used:	Not specified
Ontologies considered:	VIMMP Ontologies EMMO SWO

Table 6.1 - Overview of UC5 as given in D5.1

6.1 Detailed Description

The main goal of this use case is to extend and improve the VIMMP (Virtual Materials Marketplace Project) Ontologies[15] [Horsch et al., 2020][16] which are in the core of the VIMMP platform that aims to support interoperability between different services and marketplaces in NMBP domains.

The use case will provide a concrete implementation for the VIMMP platform and will improve it based on the input from the OntoCommons ecosystem and a wider community. It will also create a basis for alignment of EMMO top-level ontology with various domain ontologies in materials domain. An example simple scenario would be: providing a description of a Materials modelling software tool for inclusion in a virtual marketplace.

[15] https://emmc.info/taxonda/vimmp-ontologies/

[16] Horsch, M.T., Chiacchiera, S., Seaton, M.A. *et al.* Ontologies for the Virtual Materials Marketplace. *Künstl Intell* **34,** 423–428 (2020). https://doi.org/10.1007/s13218-020-00648-9

What are the pre-conditions of your use case? In which state the system should be in before the scenario starts?

A certain software tool is not present on the given virtual marketplace (VIMMP).

What are the post-conditions of your use case? What is the expected state of the system after the scenario is completed?

A certain software tool is present on the given marketplace (VIMMP) and its key aspects (capabilities, requirements, i.e., libraries and operating systems, licensing) are presented in a way that is helpful and satisfactory for both users and providers.

Who are the actors involved? (List of all actors mentioned in the scenario steps)

MM Software developer/distributor, MM software user, industrial end-user, modeling expert ("translator").

6.2 Main Scenario

1	Description of a MM software tool	EMMO		VISO, OSMO, SWO	Zontal Space platform (where the VIMMP marketplace is implemented). Owlready2 Python package

Which data sources are used? (Please cross-reference with the steps of the main scenario)

RoMM [RoMM (Review of Materials Modeling): A.F. De Baas (ed.), What makes a material function?, EU Publications Office, Luxembourg, Let me compute the ways, 2017.], MODA [CEN-CENELEC Management Center, Materials modeling: terminology, classification and metadata. CEN workshop agreement 17284, Brussels, Belgium, 2018.], knowledge and services from VIMMP partners and perspective marketplace providers/users (where with "data" we intend both the terminology used and the concrete assertions made).

What are the major (expected) contributions of OntoCommons to the use case?

- Help to discuss and improve the proposed framework, also via interactions with similar initiatives
- Discuss the alignment to EMMO of applied domain ontologies (as those in the use case, that address prototypical needs from digital marketplaces and similar NMBP platforms)

Name the most important 20 terms for the domain of your use case. If available, please add any diagrams illustrating these terms (e.g. UML diagram, ER diagram)

1. Software
2. (Software tool) Feature
3. License
4. Physical equation
5. Programming language
6. Distributor
7. Version identifier
8. (Software) Manual
9. Software interface
10. Solver
11. Model
12. Electronic
13. Atomistic-Mesoscopic
14. Continuum
15. Material
16. MM Topic

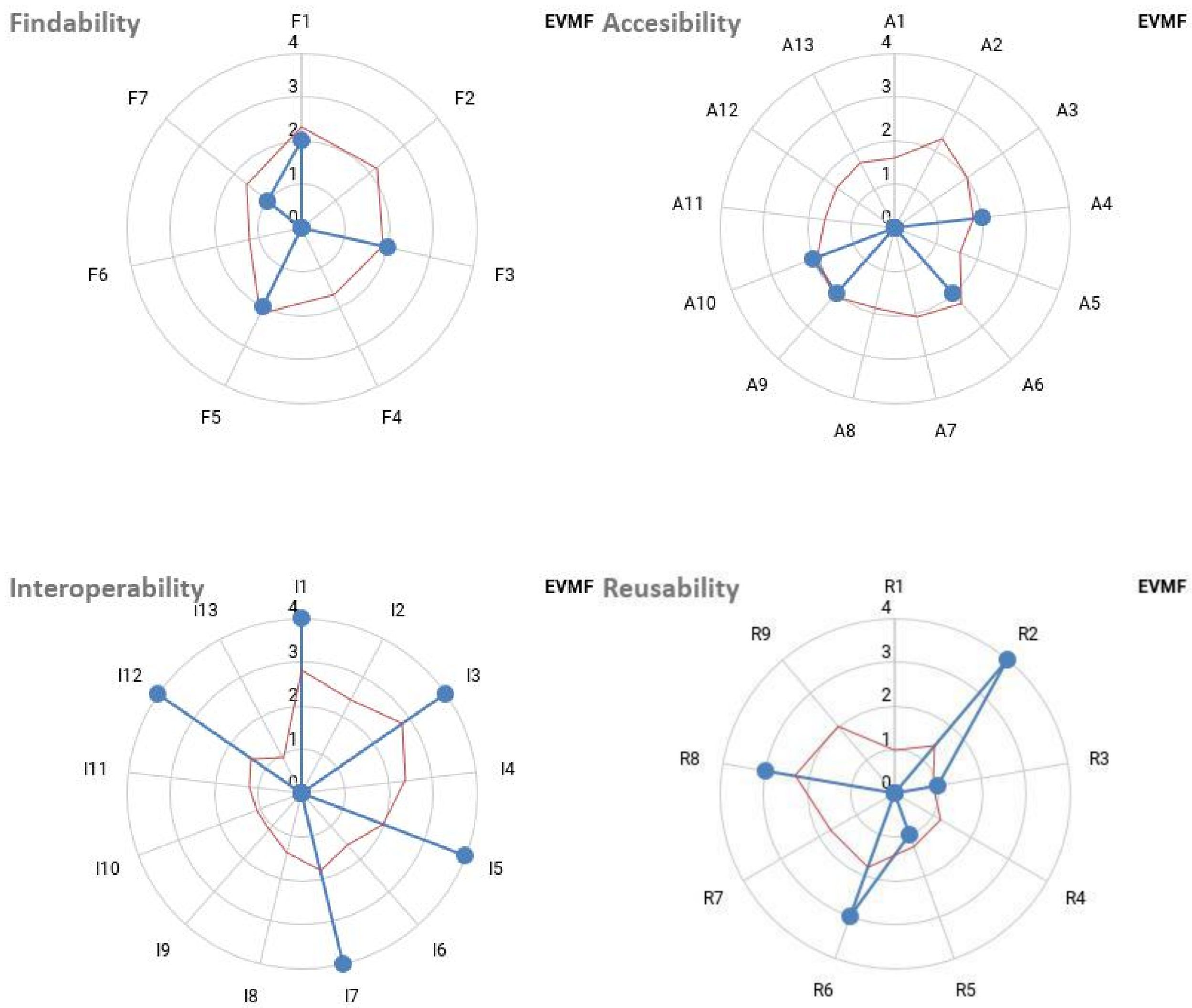
6.3 Implementation Time Plan

The implementation is ongoing: currently there is a version implemented internally in VIMMP. The project has been extended, will end in June 2022, by then this scenario will be consolidated

6.4 FAIR Plan

Results of the initial FAIRness evaluation:

The use case has many non-applicable principles at this stage, because there are still some Intellectual Property (IP) issues to be resolved. Nevertheless, it is already mature from the perspective of Interoperability (which is expected due to the nature of the use case) and the other dimensions are mostly in the planning phase, which opens up a nice path for OntoCommons project results to influence the FAIR compatibility of the data and metadata of the use case.



Is there already any development since the first survey towards improving FAIRness?

Yes, all VIMMP Ontologies are more findable and accessible: now they are available on a GitLab page (https://gitlab.com/vimmp-semantics/vimmp-ontologies/), where the development has been recently moved, and they have also been uploaded on MatPortal (https://matportal.org/ontologies/VIMMP_ONTOLOGIES). Both tools are free, users only need to register to contribute and/or make suggestions: this enables all interested parties to participate in the development and to track discussions.

Findable: Yes, findability has increased (two web locations added, one for development and one for main releases only)

Accessible: Yes, accessibility has increased (before the ontologies files were also available, but only in correspondence of releases and were mostly provided as attachments to papers/reports)

Interoperable: None

Reusable: None

What are the future steps to improve FAIRness? What does the demonstrator want to improve? If there are no/little improvement made and/or foreseen, motivate why. If there is an interest to progress here, what are the roadblocks?

We could have persistent identifiers: we need to discuss that within the VIMMP project (the currently used, https://purl.vimmp.eu/semantics/, is not resolvable).

6.5 Technology Readiness Levels (TRL)

DO: Recent changes and probably coming up ones will concern aspects related to the user interface. In particular, the creation of appropriate SKOS lists for drop-down menus in Zontal. E.g., a recent one concerned having pref-labels for the "software tool feature" entries to include extra information (e.g., parent class) so to be easily readable as a single flat list (see also GitLab repository).

Currently no significant update on the TRL level in the framework. Domain ontologies have reached to TRL 5. (they have been validated in the VIMMP environment).

6.6 Key Performance Indicators

KPI	**Metric**	**Function**	**Range**
TRL improvement	• TRL change	– 1/1+(TRL_end - TRL_start)	(0,1]
FAIR improvement	• average score in each FAIR dimension	– For each dimension, average based on final surveys	[0,4] for each dimension
Described Software Tools	• Number of software tools that is described	– Counting	[0,..)
Adoption....	• Number of initiatives/projects adopting our approach	– Counting	[0,...)

7. UC6: OAS

OAS AG is a privately owned SME based in Bremen, Germany. It has 250 employees in 5 subsidiaries over Germany. The company specialize in turn-key solutions for process control in food, concrete, chemical and other process industries; process control and visualization systems for highly-automated processes; yard management solutions and weighing data processing systems. Table 7.1 provides an overview of the initial stage of the use case.

Use case owner:	OAS AG
Involved partner:	ATB Bremen, OAS AG
Technology Readiness Level:	TRL4-TRL5
Data sources used:	Internal data sources regarding yard management and logistics Internal data sources containing data about process control system for yard logistic objects and devices
Ontologies considered:	Product Service System (PSS) Ontology IOF Core Ontology Material Ontology (reuse existing) Logistic Ontology (reuse existing) Supply Chain Ontology (reuse existing)
Main challenges:	• Easy definitions of rules to support decisions within configuration • Challenge is to allow for flexibility in the definition of rules and take dependencies of rules into account (e.g., flexibility in definition of rules of sequence/prioritization of lorries entrance to yard based on diverse aspects: materials, lorry types, parking availability). Allowing (on mid-term) that services may self-learn and adapt to site- specific dynamically- changing conditions. • Collaborative aspects – ontology to allow for effective work together with the customers and their clients to find

	the best definition of workflow and rules (common terminology and rules) • Ontologies should support standardization of yard management services; yard sites do differ from each other leading to very individual solution for each site • Ontologies from different domains need to be used and work together harmonized • Different hardware/software systems need to be able to process the ontologies used • Hardware components used possibly with low processing capabilities • Actors with different skills (e.g., software engineers, hardware maintenance experts, project managers, etc.) or domain expertise (e.g., logistics, machine or material manufacturing, business management/administration etc.) need to be able to use the ontology

Table 7.1 - Overview of UC6 as given in D5.1

7.1 Detailed description

The main goal of the use case is to improve the automation of yard management starting with the setup/configuration of a site/yard. Yard management, plant logistics, and dispatch automation covers the planning, organization, control, processing, and supervision of the entire flow of materials and goods. The use case will make use of semantic technologies to assist the decision-making process regarding the yard management, for example inferring the next action of a lorry in the yard given various logistics data and ontologies describing that data.

The demonstrator within OntoCommons aims at improving effectiveness and responsiveness of decision-making in logistics control systems based on data sharing built around big volume data streams semantically described by dedicated PSS ontologies

What are the pre-conditions of your use case? In which state the system should be in before the scenario starts?

The preconditions for the setup phase of the use case are: devices in Yard installed, signals for Yard defined, the configuration tool integrated with ontologies and rules,

What are the post-conditions of your use case? What is the expected state of the system after the scenario is completed?

OAS aims to standardize as many processes devices and communications among devices as possible and to have a strong semantic model behind. To that extent, the OAS systems will automatically retrieve (trigger) and use the ontology in order to call the necessary process (e.g. truck identification or weighting process) or to perform a necessary action (e.g. open a terminal barrier, display a message in a terminal, inform the next terminal in sequence). The workflow of the actions and processes triggered depend on the types of vehicles involved and the materials carried by the vehicles.

Be more interoperable, use ontologies when doing site configuration and yard management.

Who are the actors involved? (List of all actors mentioned in the scenario steps)

For the OAS the following actors are being involved:

- Service Designer (yard designer, project manager in OAS):

The service designer (SERVICE DESIGNER) needs to create a new service (SERVICE) (e.g., site configuration for yard management and logistics on warehouse, good/material transportation and fleet monitoring, automation opportunity for e.g. access control of a vehicle) for the OAS systems "Login" and "Pylod" and yard automation hardware solutions (PRODUCT, EQUIPMENT). The Login and Pylod are the software systems for yard management complementing OAS yard automation hardware solutions featuring the logistic terminals and traffic routing systems and weighing systems.

- Software designer

The software designer is responsible for adjusting the software of a new instance of the yard management system, based on the SERVICE designed by the service designer. The adjusted software components need to comply with the infrastructure available in the customer site.

- Customers (and their clients implicitly)

The customers define the existed infrastructure (software & hardware) used in the site, as well as the types of vehicles and materials need to be taken into consideration for the definition of the yard management workflow. They are responsible, in cooperation with the service and the software designers, to define the workflow for the yard management systems to reflect on the needs of their operations.

7.2 Main Scenario

The OAS scenario has 2 sets of steps:

- Setup set of steps. One that is to be done in the setup phase, primarily now in the scope of OntoCommons, and is related to the creation/update of use case relevant ontologies as well as preparation of the used SW within the demonstrator to use said ontologies. This set of steps will be revisited seldom at runtime.
- Runtime set of steps. The second set is the one that relates to the use of the SW and ontologies at runtime in the scope of a yard/site configuration. This will be prepared, tested and evaluated within OntoCommons and will be further exploited within OAS further work.

No	Description	TLO	MLO	DO	Tools
Steps to be done in scope of setup phase to configure the OAS SW					
1.1	Study PSS Ontology and update if needed for OAS purposes	BFO	IOF	PSS Ontology	Protége
1.2	Study Supply chain and Logistics Ontology and update if needed for OAS purposes	BFO	IOF	SC and LOGO Ontology	Protégé
1.3	Study relation with Material Ontology for special treatments of loads				
1.4	HW Data Input & Ontology Compliance Check				
1.5	Study currently used data sources (see below for details) and semantically enhance the data sources				
1.6	Define generic Rules that are not dependent on the possible instances of the Yard configuration				
1.7	Adapt the OAS SW used for the yard configuration and management to the updated semantic data sources				
Steps to be done in the runtime phase at the time of site configuration (for each client)					
2.1	Service Workflow Configuration Based on the Ontology for a particular site/yard	BFO	IOF	PSS Ontology Supply Chain and Logistics ontology	
2.1.1	Services are Yard management, and logistic process definition services				
2.2	Definition / update of Rules based on the Ontology for the specific site				Rule engine that can handle rules such as:

					- If we have a ramp then we need a light and a gate - Rule with the sequence of HW points
2.3	OAS System Operation Based on defined Workflow and Rules.				

Which data sources are used? (Please cross reference with the steps of the main scenario)

Currently used data sources are:

- Internal data sources regarding yard management and logistics
- Internal data sources containing data about process control system for yard logistic objects and devices

Both data sources are to be enhanced by the use of ontologies in steps.

What are the major (expected) contributions of OntoCommons to the use case?

OAS aims to standardize as many processes devices and communications among devices as possible and to have a strong semantic model behind. To that extent, the OAS systems will automatically retrieve (trigger) and use the ontology in order to call the necessary process (e.g. truck identification or weighting process) or to perform a necessary action (e.g. open a terminal barrier, display a message in a terminal, inform the next terminal in sequence). The workflow of the actions and processes triggered depend on the types of vehicles involved and the materials carried by the vehicles.

Main contribution expected from OntoCommons in the described scenario is support in the creation/modification of existing ontologies for use in the OAS operation, as well as guidelines to introduce rules in ontology.

Name the most important 20 terms for the domain of your use case. If available, please add any diagrams illustrating these terms (e.g. UML diagram, ER diagram)

- Product
- Service: Yard Management, logistic process definition
- Product Service System
- Supply Chain
- Resources: Device, Sensors, Control System,...
- Information: Vehicle Load Description, Access Timestamp
- Agent: Vehicle Driver, Access Manager
- Vehicle

- Material (of the vehicle load)
- …

7.3 Implementation time Plan

Action	**Deadline**	**OntoCommons support/comments**
Study PSS Ontology and update if needed for OAS purposes	March 2022	Support in updating and harmonization of PSS ontology with other ontologies (Use of the LOT methodology to analyse the current sources of data)
Study Supply chain and Logistics Ontology and update if needed for OAS purposes	March 2022	Support in selecting and using ontologies (Use of the LOT methodology to analyse the current sources of data)
Material ontology	March 2022	Support in selecting and using ontologies
HW Data Input & Ontology Compliance Check	May 2022	
Study currently used data sources (see below for details) and semantically enhance the data sources	May 2022	
Define generic Rules that are not dependent on the possible instances of the Yard configuration	June 2022	Support in method to be applied for the definitions of rules in ontology
Adapt the OAS SW used for the yard configuration and management to the updated semantic data sources	October 2022	
Service Workflow Configuration Based on the Ontology for a particular site/yard	December 2022	
Services are Yard management, and logistic process definition services	May 2023	

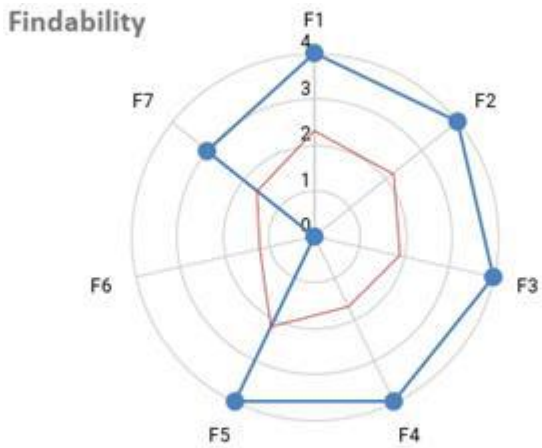
Definition / update of Rules based on the Ontology for the specific site	May 2023	Support in method to be applied for the definitions of rules in ontology
OAS System Operation Based on defined Workflow and Rules.	September 2023	

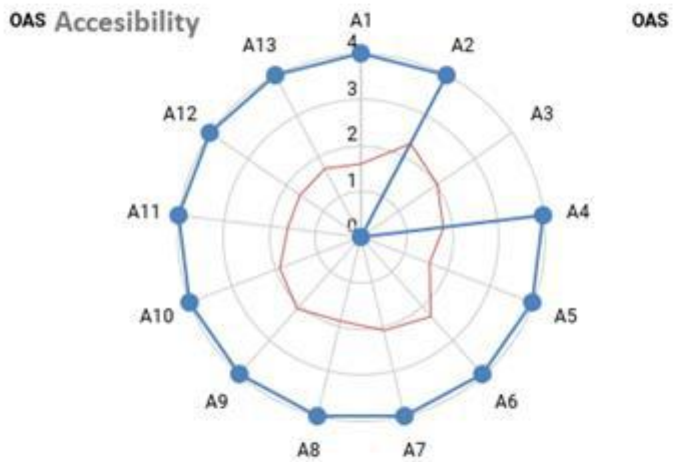
7.4 FAIR Plan

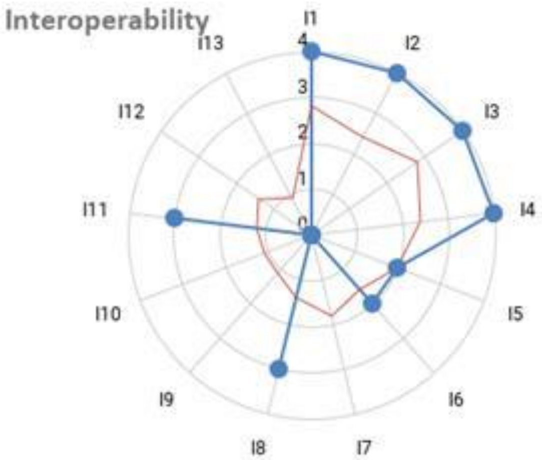
Results of the initial FAIRness evaluation:

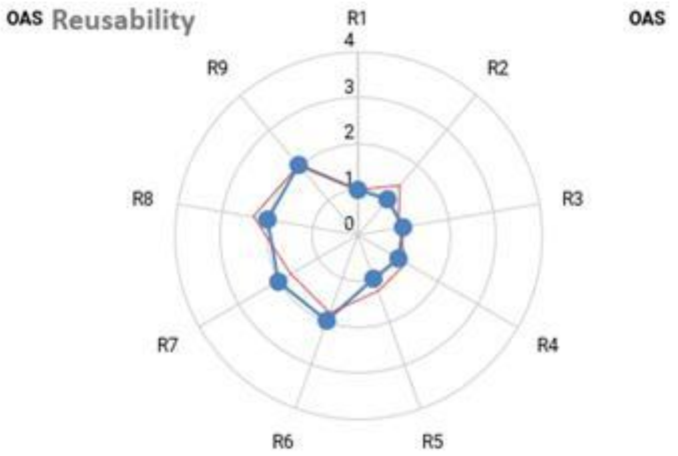
The OAS use case is already at a quite mature state in terms of FAIRness, especially for the Accessibility dimension, with all applicable principles already in a fully implemented stage. Findability principles are also followed in a similar fashion. There is certainly a room for improvement regarding Interoperability and especially Reusability dimensions. The use case can benefit from the OntoCommons best practices and OntoCommons project can analyse the mature dimensions while building best-practices for ontologies and tools.

Below you see radar charts drawn for each dimension for your use case based on the initial survey in the first six months of the project.









What evolved from that time until now?

Findable: Working on the step where "Metadata is offered in such a way that it can be harvested and indexed"

Accessible: Fully implemented (as far as the steps are applicable)

Interoperable: Presently working on the step to have "Data include references to other data"

Reusable: Working on "Metadata and Data is expressed in compliance with a machine-understandable community standard (e.g. an ontology)"

Otherwise no further evolution up to now as the use case activities are still only starting now.

What are the future steps to improve FAIRness? What does the demonstrator want to improve? If there are no/little improvement made and/or foreseen, motivate why. If there is an interest to progress here, what are the roadblocks?

The main step is the introduction of ontologies in the yard management and site design processes. In particular:

- Use OntoCommons LOT methodology and other recommended OntoCommons tools to refine and extend the PSS ontology that will form the metadata basis of the Yard Management ecosystem data
- Using ontologies to facilitate both
  - interoperability (by using qualified references to other metadata) and
  - Reusability (by expressing metadata and data with community standards)

7.5 Technology Readiness Levels (TRL)

The TRL has not evolved significantly in the last half year as the development is still in its initial steps.

The primary goal of the use case is to reduce the number and size of, and time required for experiments, for identifying the behaviour of a material or combination of them (e.g., metal, coating, lubricant) with respect to specific operation conditions. The goal is planned to be achieved via

- a common representation of material tribological experiments,
- enriching existing data with additional background knowledge,
- easing data retrieval and navigation through related resources.

The use case will provide ontology-based access to a materials' tribologicalrelated information in order to abstract from underlying data structures.

7.6 Key Performance Indicators (KPI)

KPI	Metric	Function	Range
TRL improvement	TRL change	1/1+(TRL4-TRL5)	
FAIR improvement	average score in each FAIR dimension		
Shorten time to make a new yard configuration for a new client/ site/ domain	% of time spent in new site configuration	Calculation of the percentage of improvement	[0,100]
Shorten time to make decisions in the Yard configuration	TBD	TBD	TBD
Time to identify errors in the process (e.g. vehicle with specific load missing, or sent to a wrong lane, vehicle load not the expected, driver not authorized to enter, etc.)	Average Time need to identify error in the process		[0,...)
Ontologies should support standardization of yard management services; yard sites do differ from each other leading to very individual solution for each site	% of standardized components	Calculation of increase in the standardized components	[0, 100]
Security management of the yard	TBD	TBD	TBD

8. UC7: Feedstock Quality Assurance

The Fraunhofer-Institute for Manufacturing Technology and Advanced Materials is one of 72 institutes of the non-profit research organization Fraunhofer-Gesellschaft zur Förderung der Angewandten Forschung e.V..The Powder Technology department of Fraunhofer IFAM has experience in processing techniques and material development. New materials and processes are being developed in the areas of additive manufacturing, functional printing, powder technology, production technology, and lightweight construction. The materials range includes metals, alloys, ceramics, composites and bio-polymers. Table 8.1 gives a summary of the use case as it is initially defined.

Use case owner:	Fraunhofer IFAM
Involved partner:	Fraunhofer IFAM
Technology Readiness Level:	TRL3
Data sources used:	Source material data Machine Data (torque, time, temperature)
Ontologies considered:	EMMO

Main challenges:	• data integration of different devices/machines for the mixing process
	  ○ machines from different companies without standardized interfaces for data transfer from one to another
	  ○ data formats and structure (e.g. it is not always known in detail when the data will be recorded or requested)
	• data correlation for decision making is not yet done in the mixing process
	• vendor information on material (e.g. metal powder and binder material) mainly on paper or as PDF
	• some machines only provide log-files that are accessible after the process (no data stream, no interaction during operation)
	• limited possibilities for machine settings to adjust the process (lack of device-setting-customization options)

Table 8.1 - Overview of UC7 as given in D5.1

8.1 Detailed description

The main focus of this use case is improving feedstock quality assurance. The mixing of metal powders and polymeric binder components (feedstock) is a crucial part of the metal injection molding process, as well as for the production of parts via extrusion. The process depends on the source materials (chemical composition, quantity of the components, shape and size of the metal powder particles). The quality (homogeneity, reproducibility,..) of the feedstock not only influences the following production steps, but also have a strong influence on the produced parts (e.g. dimensions, homogeneity, mechanical properties). So far, the quality of feedstock is not objectively quantifiable. A shared formal specification like an ontology could help to identify the main process and material parameters that allow describing the quality in an objective way.

What are the pre-conditions of your use case? In which state the system should be in before the scenario starts?

- Material defined (quality and quantity)
- Data integration of different devices/machines for the mixing process
- Appropriate information on the materials used (from supplier or from own measurements)
- Appropriate information on produced parts (from own measurements)
- Appropriate process data to correlate mixing process to “quality”
- TLO and MLO are defined

What are the post-conditions of your use case? What is the expected state of the system after the scenario is completed?

- Case 1 (basis)
    - Determination of parameters that influences part quality
- Case 2 (must)
    - Correlation of mixing parameters with produced parts
- Case 3 (future)
    - Live self-regulating mixing process to ensure part quality

Who are the actors involved? (List of all actors mentioned in the scenario steps)

- Material scientist
- Process operator

8.2 Main scenario

The use case will be demonstrated on a decision support system, where a feedstock developer feeds the relevant data and the ontology (describing material characteristics and the mixing process) to the system and an upon triggering by an operator, the system will decide on the proper mixing process configuration and measure the conditions of the mixing process. The main expected benefits are:

- digital representation of the entire mixing process,
- recognition of previously unknown correlations,
- deciding on adjustable process parameters,
- consistent quality of feedstock.

The use case has the following workflow (Figure 8.1).

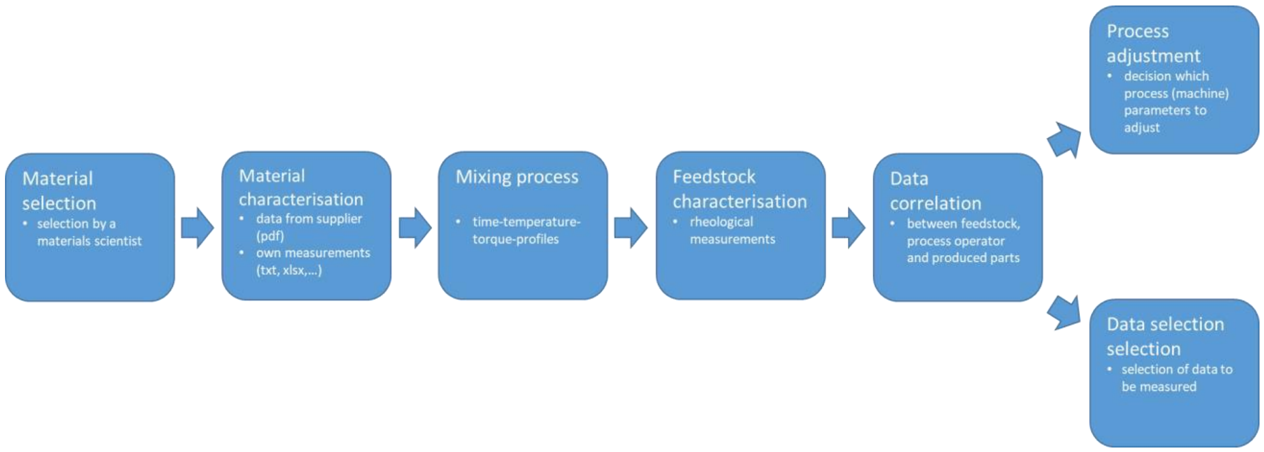


Figure 8.1 - An overview of UC7 as given in D5.1

No	Description	TLO	MLO	DO	Tools
	Reasoning over sensor data			Semantic Sensor Network - to represent sensor data	Pellet reasoner Purpose: OWL DL reasoning
1	Material selection		Material parameters and properties	Material parameters and properties	
2	Material characterization		Analytical methods	Analytical methods	
3	Mixing process			Process data, equipment	
4	Feedstock characterization		Analytical methods	Analytical methods	
5	Data correlation		Software		Software: e.g. Python
6	Data selection: application of ontology				Software
7 (future)	(Live process adjustment: application of ontology)				Software: AI

Which data sources are used? (Please cross-reference with the steps of the main scenario)

- Data of supplier
- Data of analytical analysis

- Sensor data
- Input from operator

What are the major (expected) contributions of OntoCommons to the use case?

- Definition of TLO and MLO
- Digital implementation of combining ontology and raw data
- Harmonization of individual ontology levels
- Support in the selection/implementation of a software for the correlation of quality and mixing process

Name the most important 20 terms for the domain of your use case. If available, please add any diagrams illustrating these terms (e.g. UML diagram, ER diagram)

- Material
  - Metal
  - Polymer
  - Feedstock
  - Powder
- Physical properties
  - Material properties
  - Particle size distribution
  - Particle shape
  - Rheological data
  - Density
- Mixing properties
  - Torque
  - Temperature
  - Mixing time
- Part properties
  - Part density
  - Shrinkage
  - Dimensional accuracy
  - Strength
- Material identifiers
  - CAS (Chemical Abstracts Service Registry Number, international labeling standard for chemical substances)
  - Experiment ID (identification no. of the Experiment, e.g. number of the analysis or of the trial)
  - LOT Number
- Process
  - Blades
  - Mixer
  - Operator

8.3 Implementation time Plan

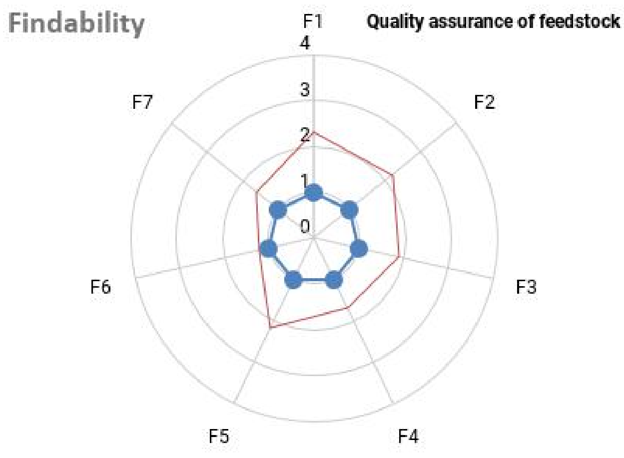
	11/2021	12/2021	01/2022	02/2022	03/2022	04/2022
Adaption of the BFO						
Adaption of the BWMD						
Development of Domain Ontology						
Structured mixing data generation						
Development of software for correlation of Mixing and Quality						

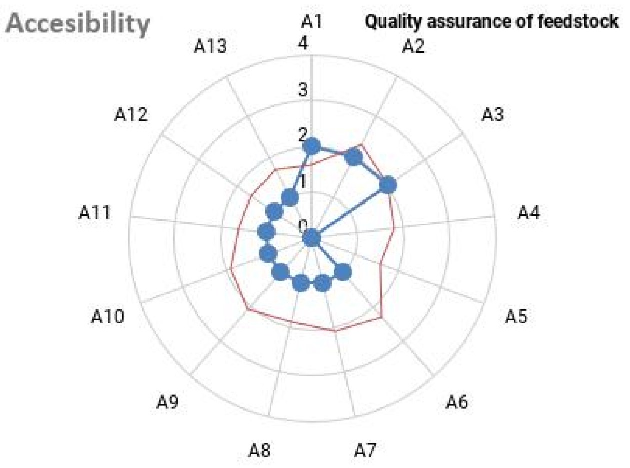
8.4 FAIR Plan

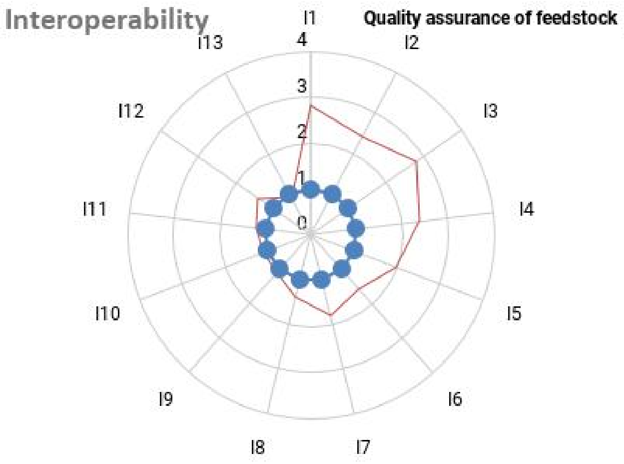
Results of the initial FAIRness evaluation:

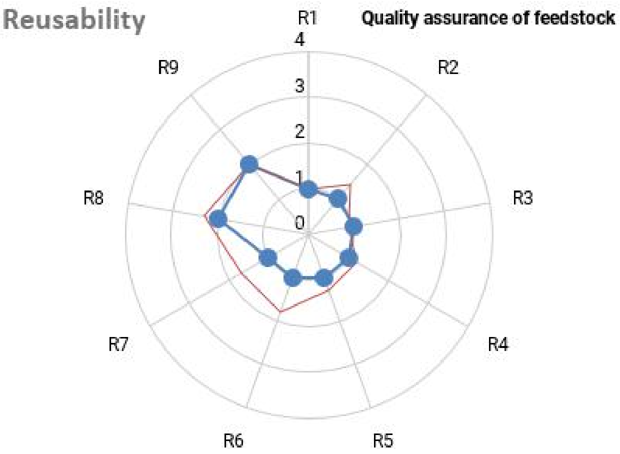
The use case currently has a very limited adoption of FAIR principles with only a few principles are in planning phase in Accessibility and Reusability dimensions. OntoCommons results may initiate an effort towards implementing some of the principles that are not being considered at the moment.

Below you see radar charts drawn for each dimension for your use case based on the initial survey in the first six months of the project.









What evolved from that time until now? Please Answer per dimension:

- After selection of TLO and MLO ontology, the FAIR principles increase to “in implementation phase” (Level 3) or higher, since the FAIR principles highly dependent on the used ontologies
- BFO and BWMD ontology fulfill FAIR principles

Findable:

- For TLO and MLO ontology: when using BWMD/BFOincrease to “in implementation phase” (Level 3) or higher
- For domain: “under consideration or in planning phase”

Accessible:

- For TLO and MLO ontology: when using BWMD/BFO increase to “in implementation phase” (Level 3) or higher
- For domain: “under consideration or in planning phase”

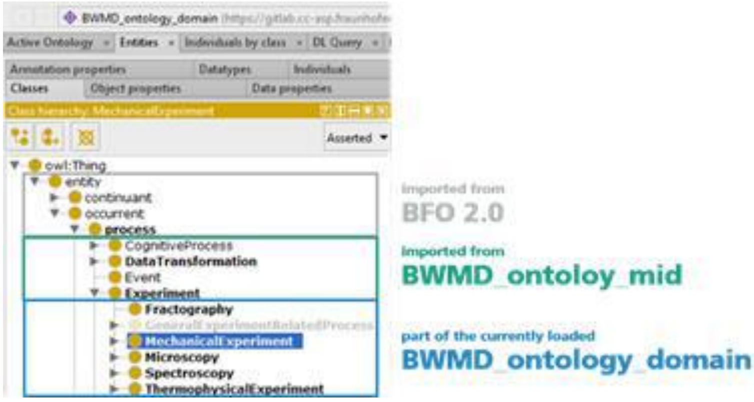
Interoperable:

- For TLO and MLO ontology: when using BWMD/BFO increase to “in implementation phase” (Level 3) or higher
- For domain: “under consideration or in planning phase”

Reusable:

- For TLO and MLO ontology: when using BWMD/BFO increase to “in implementation phase” (Level 3) or higher
- For domain: “under consideration or in planning phase”

8.5 Technology Readiness Levels (TRL)



Ontology by level	TRL	Info
Top-level ontology: BFO 2.0	4	Already implemented
Mid-Level ontology: BWMD_ontology	4	Already implemented with other domains for material experiments
Domain ontology	3	Planning phase: following the instructions from BWMD-ontology for development of domain ontology, integration of the scenarios steps

8.6 Key Performance Indicators (KPI)

KPI	**Metric**	**Function**	**Range**
TRL improvement	TRL change	1/1+(TRL_end - TRL_start)	(0,1]
FAIR improvement	average score in each FAIR dimension	For each dimension, average based on final surveys	[0,4] for each dimension
Time Reduction for processing high quality feedstock	Reduced and adapted mixing time	TBD	TBD
Cost saving	Shorter mixing time operator is not used so often	TBD	TBD
No misproduction	No waste of materials Reliable production	TBD	TBD

9. UC8: Nanomaterials Characterization

Innovation in Research & Engineering Solutions (IRES) was established in 2015, bridging the gap between academia and industry with TRL transition. The key company activities include data science and digitization in material science applications, health, risk and safety management and activities in environment, sustainability and circular economy. Table 9.1 provides an overview for the initial state of the use case.

Use case owner:	IRES
Involved partner:	IRES
Technology Readiness Level:	TRL4
Data sources used:	Emission / Exposure Measurement Instruments Data extraction from Nanoindentation Instrument 3D Printer Slicer
Ontologies considered:	EMMO
Main Challenges:	• Scarcity of available data • Knowledge gaps towards detailed correlation between the nanomechanical properties and Nanosafety domain. • Domain ontologies of interest are based on different Top Level Ontologies • Ontologies used for the use case may need further development

Table 9.1 - Overview of UC8 as given in D5.1

9.1 Detailed Description

The main goal of the use case is to bridge the gaps between material characterization and nanosafety domains. In the use case, the data collected from exposure and emission measurement devices collected by a risk analyst and the experimental data collected by a nanoindentation engineer will be integrated via domain ontologies and top-level ontologies like EMMO in a tripe store with reasoning capabilities. Afterward, the potential causal relationships between the nanomaterial characterization process and safety risks will be analyzed via inference and querying. An overview is given in Figure 9.1.

What are the pre-conditions of your use case? In which state the system should be in before the scenario starts?

This Use Case collects data coming from a nanoindentation instrument, exposure measurements and additive manufacturing. The data are stored in a relational database through an automated system. This system consists of a task scheduler that gathers data uploaded to Dropbox through Dropbox API and a restful API.

What are the post-conditions of your use case? What is the expected state of the system after the scenario is completed?

The relational database data will migrate to a triple store whose schema will integrate the 3 domain ontologies involved in this use case (material science, additive manufacturing, safety exposure).

What are the post-conditions of your use case? What is the expected state of the system after the scenario is completed?

The relational database data will migrate to a triple store whose schema will integrate the 3 domain ontologies involved in this use case (material science, additive manufacturing, safety exposure).

Who are the actors involved? (List of all actors mentioned in the scenario steps)

- Material scientist (Step 1, 7)
- Risk analyst (Step 1, 7)
- Exposure measurement operator (Step 1)
- Nanoindenter operator (Step 1)
- Data scientist (Step 3,4,5,6)

9.2 Main Scenario

No	Description	TLO	MLO	DO	Tools
1	Data collection from By Risk analyst from all instruments: From nanoindenter: hardness, elastic modulus From 3D printer: temperature: particle concentration Material scientist is involved step 1	-	-	-	3D Printer Software, 3D Printer Software, Nanoindenter Software

2	Data Processing and storage Saved in Dropbox as CSV and text files Scripts process the files to extract information data is then stored in a relational database	-	-	-	Python scripts, Automated software system
3	Material characterization Data Integration	EMMO	-	OYSTER Mechanical Testing Ontology	Nanoindenter Software
4	3D Printing Data Integration	BFO	-	Additive Manufacturing Ontology	3D Printer Software
5	Printed Object characterization Data Integration	EMMO	-	OYSTER Mechanical Testing Ontology	Nanoindenter Software
6	3D Printing Emission Data Integration	EMMO	-	eNanoMapper	Exposure measurement instruments
7	Reasoning over data Finds rule-based or ontology based relations between the collected measurements and characteristics and impact on the safety	-	-	-	Protege plug-in reasoners Triplestore with reasoning support

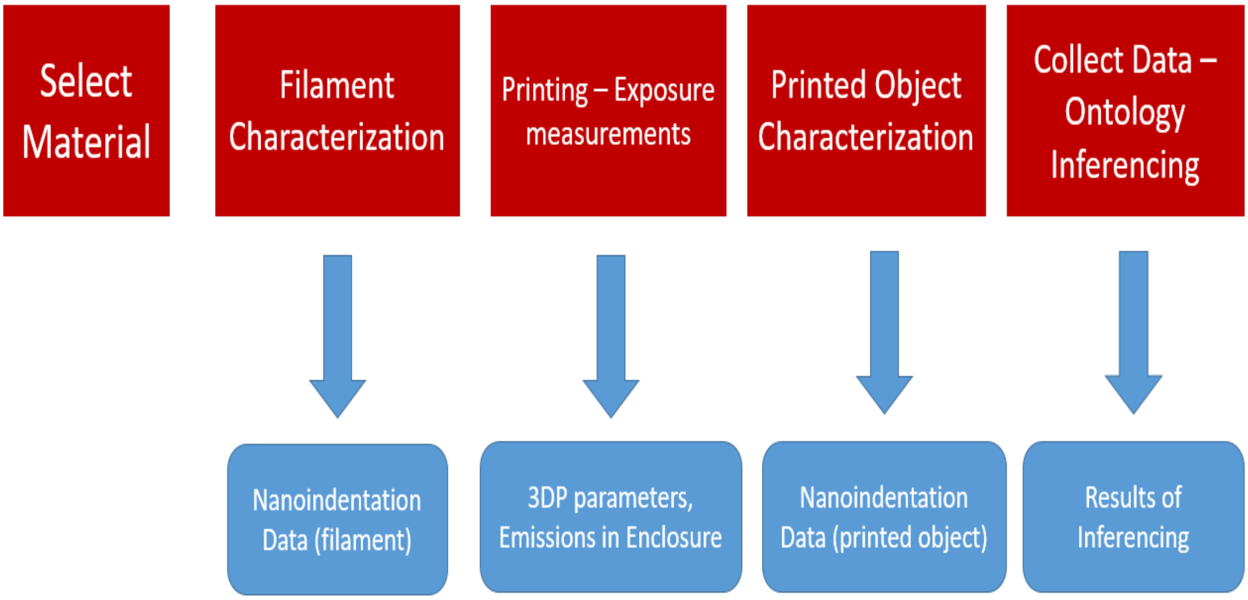


Figure 9.1 - Overview of UC8 as given in D5.1

Which data sources are used? (Please cross-reference with the steps of the main scenario)

- Emission / Exposure Measurement Instruments – Data Acquisition Software
- Software for data extraction from Nanoindentation Instrument
- 3D Printer Slicer

What are the major (expected) contributions of OntoCommons to the use case?

The use case combines data that come from materials science domain, safety exposure domain and additive manufacturing domain. OntoCommons will provide intra- and cross-domain interoperability of ontologies that will allow for data integration and interoperability.

3d-printing nanoparticle emissions: not all classes are found in the existing ontologies.

Name the most important 20 terms for the domain of your use case. If available, please add any diagrams illustrating these terms (e.g. UML diagram, ER diagram)

- Material
- specimen
- Nanoparticle
- Particle size
- Filament
- PLA - Polylactic acid
- Particle concentration
- Elastic modulus
- Hardness
- Temperature
- 3D-Printing
- Nozzle

- Filter
- Nanoindenter
- Exposure measurement instrument
- Cleaning agent
- Slicer (software)

9.3 Implementation Time Plan

M14 – Finalize terminology from DO/MLO/TLOs used

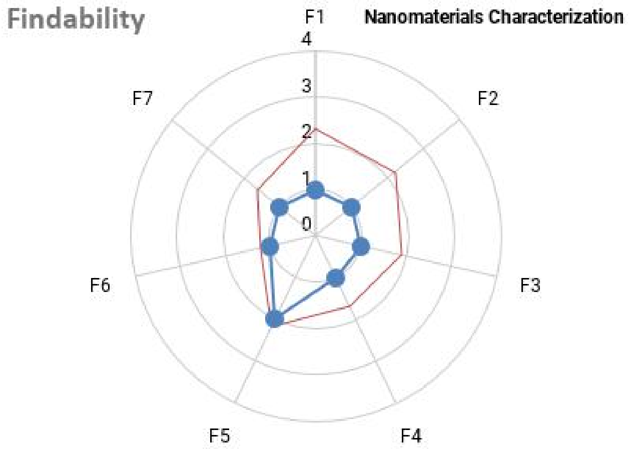
M18 – Ontologies harmonization and data integration

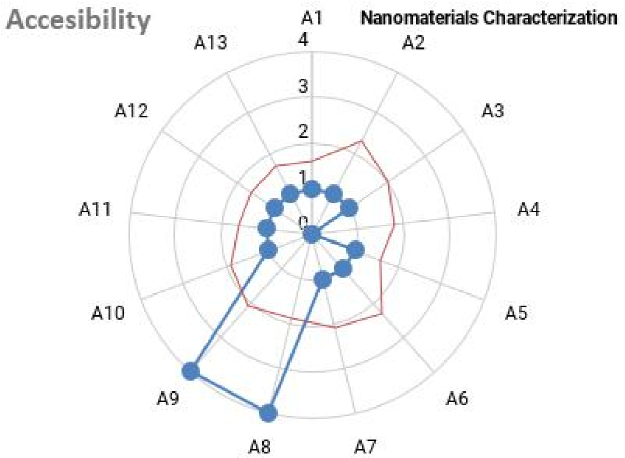
Till M24 – Triple store deployment and reasoning

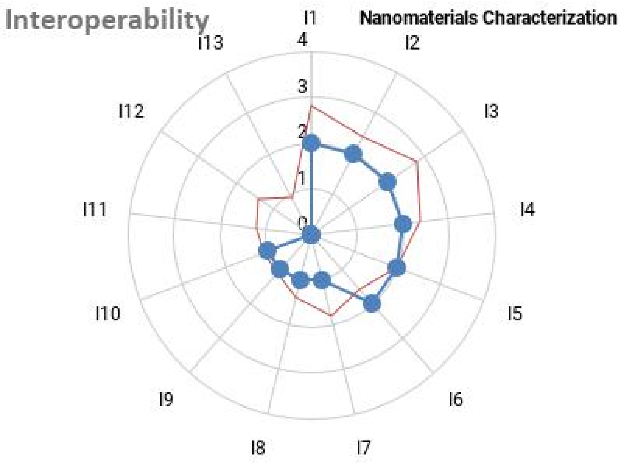
9.4 FAIR Plan

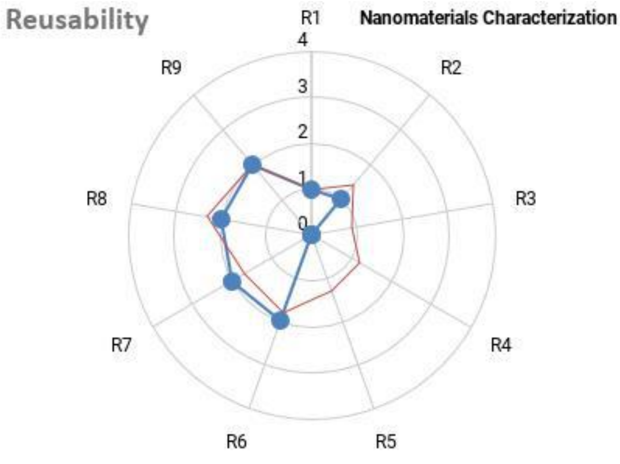
Results of the initial FAIRness evaluation:

The use case has already implemented the principles regarding machine-accessible metadata and data. Several other principles in Interoperability and Reusability dimensions are in the planning phase. The OntoCommons best practices can influence the further development of these principles in the use case.









What evolved from that time until now? Please Answer per dimension:

The system that collects the data has been automatized and has improved the accessibility, findability, interoperability and reusability of the data by the members of the organization.

Findable: Due to data privacy no actions have been made to improve findability for other users.

Accessible: Due to data privacy no actions have been made to improve accessibility for other users.

Interoperable: Ontologies integration has started in order to enhance data interoperability. Terms (e.g. nanoparticle concentration, nozzle temperature, etc.) used for triple store schema selected.

Reusable: : Ontologies integration has started in order to enhance data reusability.

What are the future steps to improve FAIRness? What does the demonstrator want to improve? If there are no/little improvement made and/or foreseen, motivate why. If there is an interest to progress here, what are the roadblocks?

The demonstrator needs to improve the FAIRness of the metadata, so information about the data can be discovered. The data of the use case are not to be shared with third-party, so actions taken should regard the improvement of findability, accessibility, interoperability and reusability among in the organization level.

9.5 Technology Readiness Level (TRL)

1. **TLOs:** The Top level ontologies used for the Use Case have been decided

- BFO
- EMMO

(TRL 4 – TLOs are utilized as an extension of the Dos. No further updates will be made in the TLOs employment)

2. **for DOs employment:** The DOs that will be used for our Use Case have been determined:

- OYSTER Mechanical Testing Ontology
- Additive Manufacturing Ontology
- eNanoMapper

In addition, we have decided upon the terms from these ontologies that are relevant to our use case. The development of the ontology that contains these terms has initiated (TRL 4). The TRL level will get updated in the next months, with the development of the ontology and its integration to a graph database (TRL4 à TRL 6)

3. **for tools deployment:** The system that collects and integrates data to a database has been automated with the use of python scripts (TRL 6 - the system has been updated and verified).

9.6 Key Performance Indicators (KPIs)

KPI	Metric	Function	Range
TRL improvement	• TRL change	– 1/1+(TRL_end - TRL_start)	(0,1]
FAIR improvement	• average score in each FAIR dimension	– For each dimension, average based on final surveys	[0,4] for each dimension
Cost reduction of the manufacturing process.	• working hours needed to complete data analysis of an experiment	• Calculation of the percentage of cost reduction	[0,100]

10. UC9: Ontology-based Maintenance

Adige S.p.A. is an Italian company and part of the BLM Group, an industrial group specialised in designing, producing, selling and maintaining industrial equipment for working on metal tubes and profiles. BLM Group is a global partner for the whole tube processing life-cycle, from laser cutting to cold saw, bending, end-forming, and measurement, with a world wide presence. This wide range of solutions is manufactured in dedicated production sites, with highest expertise and skill levels, established in more than 50 years work and experience in the tube processing technology, with thousands of applications all over the world. Within the BLM Group, Adige produces laser cutting systems and machines for disc-cutting tubes, solid pieces and sections. Adige develops internally also the software suite deployed with its machines. Table 10.1 provides a summary of the initial stage of the use case.

Use case owner:	Adige SpA
Involved partner:	CNR/ISTC
Technology Readiness Level:	TRL3
Data sources used:	Technical design data from CAD Machine documentation Instructional media (e.g., videos)
Ontologies considered:	DOLCE
Main challenges:	• Data are collected in different formats and channels (natural language text, forms with open/closed entries, phone calls, data sensors, machine logs) • Data may refer to different views: machinery structure, machinery function, machinery behaviour. • Experts' knowledge is often implicit in data generation

Table 10.1 - Overview of UC9 as given in D5.1

10.1 Detailed description

The main goal of the use case is to create a common formal terminology for diagnosis and repair of the machines manufactured by Adige SpA. To that end, an ontology that covers part of the machine technical information, possible malfunctions' reasons and diagnosis, as well as maintenance processes and their relationships will be developed in the scope of the use case. This ontology will be then used to annotate samples of malfunction reports from clients, their possible reasons and machine parts relevant to the malfunction will be listed. Such a formal report can be also used for purposes like semi-automated analysis of malfunctions and their comparison.

What are the pre-conditions of your use case? In which state the system should be in before the scenario starts?

The initial scenario consists in the reception of a communication (phone call/email/texting) from a client to the Adige maintenance service about a laser cutting machine malfunctioning. The precondition of the scenario is the integration in the Adige information system of an ontology-based knowledge base suitable to search malfunctioning information in the Adige database and to classify and store incoming malfunctioning data.

What are the post-conditions of your use case? What is the expected state of the system after the scenario is completed?

At the end of the scenario the Adige knowledge base should include the data about the occurred malfunctioning and how it was repaired. The new data should be semi-automatically extracted from the technicians' report about the malfunctioning using the ontology.

Who are the actors involved? (List of all actors mentioned in the scenario steps)

- The client owning the faulty machine
- The technician of the company tasked with assisting the client remotely
- The technician of the company tasked with repairing the machine

10.2 Main Scenario

No	Description	TLO	MLO	DO	Tools
1	Client reports malfunction to Adige maintenance service	NO (only unstructured data)	NO (only unstructured data)	NO (only unstructured data)	Phone, email, apps
2	If necessary, the technician searches for information about similar malfunctions, in order to better diagnose the relevant issues	DOLCE	NO (possibly considered in future)	DO, to be developed and aligned with DOLCE, about machine functions, structures and malfunctioning, here used for its ability to encode malfunctions	An ad choc search engine developed by a third party for Adige spa. An early prototype uses Protégé.

3	If the malfunctioning could not be solved remotely, an on-field intervention is scheduled and a list of spare parts that could be used to replace (possible) faulty components is selected	DOLCE	NO (possibly considered in future)	The above DO ontology used to suggest the list of faulty components	As above plus Adige spa existing software
4	The intervention is carried out and the exact malfunction is determined and solved.	NO (unstructured data)	NO (unstructured data)	NO (unstructured data)	
5	The spare parts used are charged on the client and the others are returned. A report of the activity is filled out by the technician.	DOLCE	NO (possibly considered in future)	The above DO ontology is updated with the malfunction data	An ad-hoc interface, developed by a third party for Adige spa, used to insert the data in the ontology.

Which data sources are used? (Please cross-reference with the steps of the main scenario)

In Step 2 a database with machine data and previous known malfunctions and repairing services is queried.

What are the major (expected) contributions of OntoCommons to the use case?

The ontology-based organization of a vocabulary for maintenance. The alignment of the vocabulary to the DOLCE top level ontology. A list of criteria and a modeling comparison for ontological modeling of machine structure and maintenance information.

Name the most important 20 terms for the domain of your use case. If available, please add any diagrams illustrating these terms (e.g. UML diagram, ER diagram)

1. Machine
2. Component
3. Laser Source
4. Cutting
5. Cutting Head
6. Cutting parameters
7. Spindle
8. Steady Rest
9. Loader
10. Maintenance
11. Diagnosis
12. Failure
13. Failure Cause
14. Failure Effect
15. Failure Mode
16. Failure Mechanism
17. Compliance
18. Replacement
19. Service
20. Repairing

See also Figure 10.1 - Adige top terms used for a detailed ER diagram

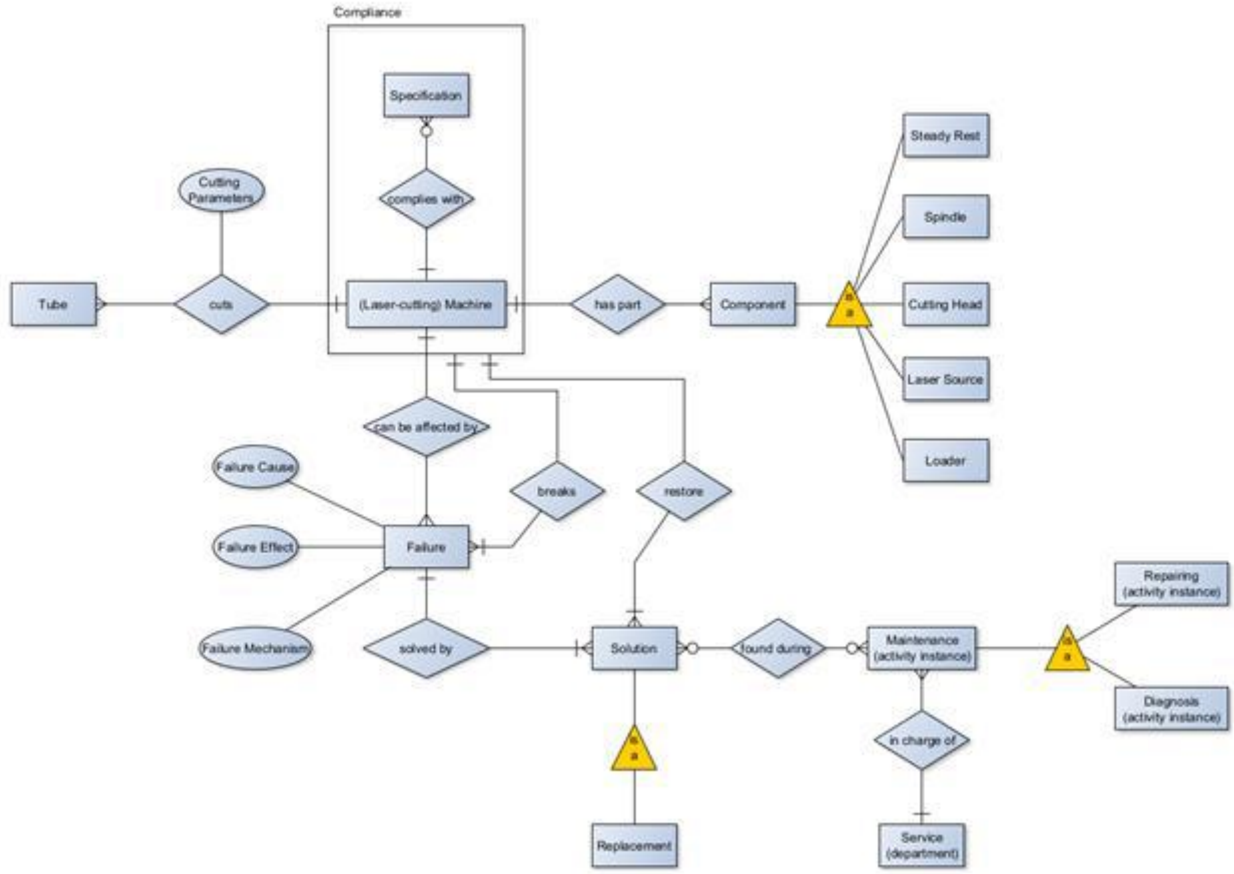


Figure 10.1 - Adige top terms used

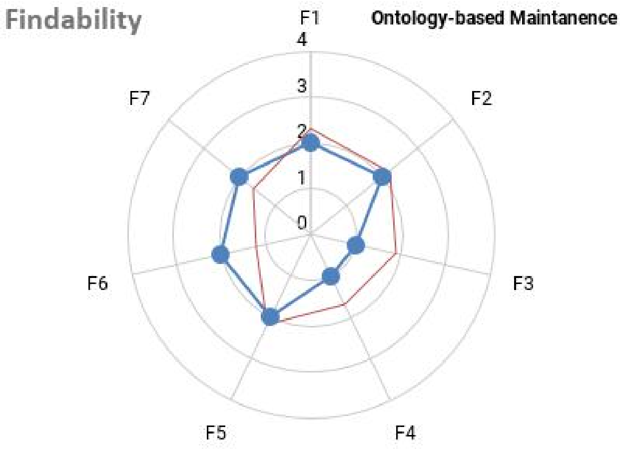
10.3 Implementation time Plan

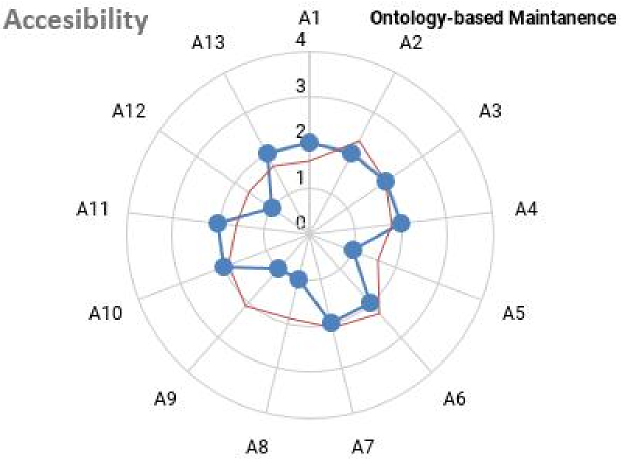
1. Machine vocabulary development (M1-18)
2. Function vocabulary development (M12-24)
3. Data collection reorganization to use the vocabulary (M18-36)
4. Testing of the vocabulary with data (M24-36)

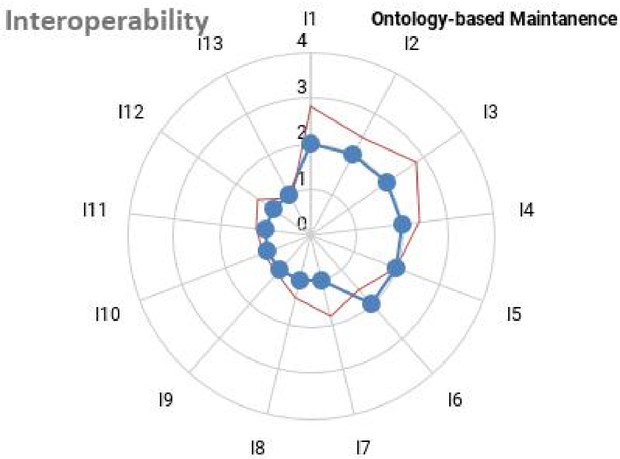
10.4 FAIR Plan

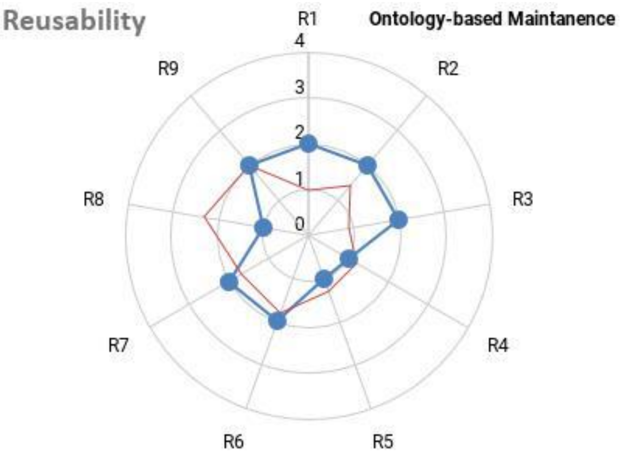
Results of the initial FAIRness evaluation:

The use case is around the average of all use cases in terms of FAIR adherence. Most of the principles are in the planning phase which can benefit from the OntoCommons best practices. Below you see radar charts drawn for each dimension for your use case based on the initial survey in the first six months of the project.









What evolved from that time until now? Please Answer per dimension:

Findable: n.a.

Accessible: Indexes I8, I11 are being developed (level 2)

Interoperable: n.a.

Reusable: n.a.

What are the future steps to improve FAIRness? What does the demonstrator want to improve? If there are no/little improvement made and/or foreseen, motivate why. If there is an interest to progress here, what are the roadblocks?

Future steps: Introduction of ontology-based FAIRness-compliant vocabulary to describe data and relations between data (I2, I4, I6 indexes should therefore move to levels 3-4 due to introduction of a formalized vocabulary. Moreover, indexes I8 and I11 should also reach level 3-4 due to the use of ontology-specified relations between data.)

Finally, the development of an ontology (also) in OWL language will change R7 and R9 to level 3-4.

Demonstrators wants to improve: Terminology used in the company (terms should be unique and should be language-independent, the company aims to develop a 'multilingual glossary'). 'Richness' of data in order to simplify their search and comparison.

Roadblocks: The demonstrator is currently moving to a new information system. No change in the data structure is possible until after the transition will have taken place. This could take several months. Also, solutions w.r.t. FAIRness improvement need to meet business related concerns which may have an impact on the final FAIRness levels.

10.5 Technology Readiness Levels (TRL)

How they evolved since spring 2021 (last half a year)? How are the TRLs expected to evolve in the next months?

- for different scenario steps: n/a
- for TLOs employment: 8/9 (no change foreseen)
- for MLOs employment: n/a
- for DOs employment: from 1 to 3 compared to spring 2021; expected 3/4 in the near future
- for tools deployment: from 1 to 2 compared to spring 2021; expected 3 in the near future

10.6 Key Performance Indicators (KPI)

KPI	Metric	Function	Range
TRL improvement	TRL change	For each case above: TRL_end - TRL_start	Integer
FAIR improvement	average score in each FAIR dimension	For each dimension, average based on final surveys	[0,4] for each dimension
Ontology-based application acceptance	Evaluations obtained from questionnaire/interviews of the end-users of the ontology-based application to be developed. Interviews could ask about different dimensions e.g. the usefulness of the application, its ease of use, etc.	For each dimension, average based on questionnaire/interviews	Qualitative range e.g. [1,5] where 1 stands for useless (difficult/...), and 5 stands for extremely useful (extremely clear/...)
Time for ticket resolution	Change in average time used by service technicians to close a client issued ticket	Difference between the averages before and after the introduction of the	A temporal value

		ontology-based application	
Returned spare parts	Change in average number of spare parts sent to a field intervention for a repair and not used	Difference between the averages before and after the introduction of the ontology-based application	A rational number

11. UC10: Data Integration and Interoperability in Manufacturing

Halcor is the copper tubes division of ElvalHalcor S.A. and has a dynamic commercial presence across European and global markets with a tube production capacity of approximately 80,000 tons. Halcor has been offering solutions in fields, such as plumbing, HVAC&R, renewable energy, architecture, engineering and industrial production. Table 11.1 provides a summary of the initial stage of the use case.

Use case owner:	ElvalHalcor S.A.
Involved partner:	University of Oslo
Technology Readiness Level:	TRL3
Data sources used:	ERP MES SCADA Energy Management Waste Management Traceability systems and hardware.
Ontologies considered:	None
Main Challenges:	• Data format too diverse • Disconnected or poorly connected Information Systems • Semantic data relations missing

Table 11.1 - Overview of UC10 as given in D5.1

11.1 Detailed description

Name: UC10: Data Integration and Interoperability in Manufacturing

The use case focuses on development of ontologies to empower a decision support system for procurement of raw materials (billets) for tube production plants. The ontologies that will be developed for the use case aims to unify the data from different departments involved in the procurement process and help the data integration and interoperability. The ontologies will describe data about manufacturing execution, traceability systems and product specifications. An overview of the use case is given in Figure 11.1.

What are the pre-conditions of your use case? In which state the system should be in before the scenario starts?

During OntoCommons project in parallel is running the design and installation of MES (Manufacturing Execution System) in the extrusion process of Tubes Plant.

What are the post-conditions of your use case? What is the expected state of the system after the scenario is completed?

During the designing phase of the application ontology and the representation of real-world processes in Information Flow diagrams, it is important to identify the possibilities of reducing human intervention (referring to mobile and e-mail communication) in the procurement process and the future changes in the processes caused by the installation of MES.

Who are the actors involved? (List of all actors mentioned in the scenario steps)

Some of the actors involved in the procurement process based on Halcor's Tubes Plant are:

- Production Supervisor and Foreman – responsible for making the raw material order to Foundry and reporting billet inventory
- Production Planning Department – responsible for calculating monthly production target in line with Sales Department
- Supervisors and Foreman of Finishing lines – responsible for making orders of semifinal products to Extrusion Process Department
- Production Operators – responsible for operating machines and recording daily production
- Product Specification Department – responsible for creating and updating BOM (Bill of Materials)
- Gate and Production Vehicles Operators – responsible for checking and transporting incoming billets inside Tubes Plant
- Information Systems in Extrusion Work Center

Likewise, some of the actors based on Halcor's Foundry are:

- Production Department – responsible for monitoring billet production and inventory
- Weighing platform Operator – responsible for raw material measurement aimed for billet production
- Quality Control Department – responsible for billet Sample Testing and Quality Control
- Truck Driver and Gate – responsible for billet check and transport to Tubes Plant
- Forklift truck Operator – responsible for raw material and billet transport inside Foundry
- Information Systems in Foundry's Production Process

11.2 Main Scenario

The use case focuses on development of ontologies to empower a decision support system for design and procurement of raw materials (billets) for tube production plants. The ontologies that will be developed for the use case aims to unify the data from different departments involved in the design and procurement process and help the data integration and interoperability. The ontologies will describe data about energy monitoring, manufacturing execution, traceability systems and waste management. The main expected benefit is the development of an ontology-based procurement system for billets interconnected with the process ontologies is expected to contribute in developing a Smart Decision System in order to optimize product quality, reduce manufacturing costs and environmental footprint.

Halcor as a 3rd party participant shall contribute to OntoCommons project in the design and evaluation phase of Application Ontology. For this purpose, Halcor shall provide information about organization's procurement process, in terms of people/ departments that get involved, also places, documents, data etc. and represent how these things are related to each other using diagrams. To fulfil this scenario the following steps should be included:

Step 1) Specification of Actors

Step 2) Specification of Procurement Process

Step 3) Visualization of Procurement Process in Information Flow Diagram

Step 4) Inclusion of specified actors and inputs in each step/ action of diagram

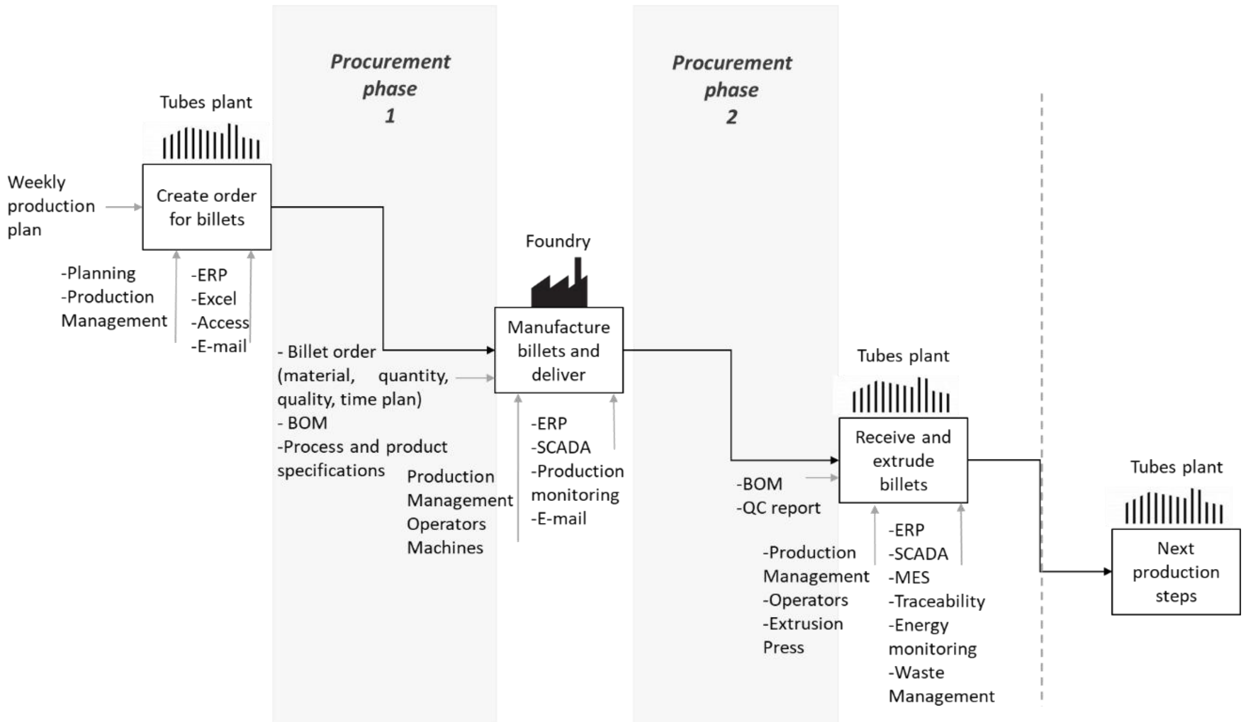


Figure 11.1 - Overview of UC10 as given in D5.1

Which data sources are used? (Please cross-reference with the steps of the main scenario)

- PLC and SCADA – data acquisition
- Traceability System
- Manufacturing Execution System – integration in progress

- PME – Energy Consumption Monitoring

What are the major (expected) contributions of OntoCommons to the use case?

1. Data Mapping - enrich data with context and semantics, optimize reference data management for better classification and categorization of master and operational data
2. Data Interoperability – real-time data availability and accessibility to all business units
3. Communication Improvement between business units
4. Productivity Improvement – increase the timeliness and empower decision-making processes

Name the most important 20 terms for the domain of your use case. If available, please add any diagrams illustrating these terms (e.g. UML diagram, ER diagram)

The detailed diagram shown in the meeting is confidential. For this reason it will be prepared a new one high-level for the attachment in deliverable.

11.3 Implementation time Plan

Step 1) Specification of Actors, till 11/2021

Step 2) Specification of Procurement Process

Step 3) Visualization of Procurement Process in Information Flow Diagram, till 12/2022

Step 4) Inclusion of specified actors and inputs in each step/ action of diagram, till 01/2022

11.4 FAIR Plan

Results of the initial FAIRness evaluation:

ElvalHalcor's use case is at the very beginning of implementing FAIR principles in their data and metadata therefore all principles can be considered as "not being considered yet", but they aim to gain traction towards adopting FAIR principles throughout the project.

Is there already any development since the first survey towards improving FAIRness?

What evolved from that time until now? Please Answer per dimension:

Findable:

Accessible:

Interoperable:

Reusable:

What are the future steps to improve FAIRness? What does the demonstrator want to improve? If there are no/little improvement made and/or foreseen, motivate why. If there is an interest to progress here, what are the roadblocks?

This answer is in progress.

11.5 Technology Readiness Levels (TRL)

TRL4 is the current overall status of the demonstrator in terms of TRL.

11.6 Key Performance Indicators (KPI)

KPI	Metric	Function	Range
TRL improvement	TRL change	1/1+(TRL_end - TRL_start)	(0,1]
FAIR improvement	average score in each FAIR dimension	For each dimension, average based on final surveys	[0,4] for each dimension
Delivery Time	average time for billet delivery	TBD	TBD
....			

12. UC11: Digital Manufacturing / Automation Engineering

Siemens provides products and services in various industrial domains such as healthcare, digital infrastructure and mobility, and energy. Table 12.1 - Overview of UC11 as given in D5.1gives an overview of the use case at the beginning of the project.

Use case owner:	Siemens
Involved partner:	University of Oslo
Technology Readiness Level:	TRL5
Data sources used:	Physical engineering system Functional engineering system Electrical Engineering System Sensors Actuators Control Systems Asset Management System Operations Monitoring System Weather Forecast Service
Ontologies considered:	ISO 15936 QuED SSN UMATI eClass OPC-UA (in-house transformation from the standard) CFIHOS

Main Challenges	Different data format (PDF, TXT, emf…), storage structure and locations (unit systems) No material data request possible (knowledge hidden in individual experts' minds) Waste of productive hours duplicate tests, delays and uncertainties Legal liabilities (e.g., access to IP protected data and metadata)

Table 12.1 - Overview of UC11 as given in D5.1

The main goal of the use case is to provide a data layer as part of the IOT platforms of Siemens that reduces application/customer-specific data provisioning and integration costs. To that end, Siemens will develop an ontology library that covers various relevant domain ontologies as well an ontology transformations of various industrial standards. The worldwide-distributed, heterogeneous data sources of Siemens will be mapped to the ontologies in this library and stored in the data layer. Applications from various departments of Siemens will have access to the integrated and curated data via this data layer (Figure 12.1). The main expected benefits are

- Overview of existing industry ontologies with relevance for Siemens, potential for becoming part of library:
  - Material data models
  - Equipment / O&G data models (e.g. CFIHOS)
  - Building data models (e.g. BIM)
  - Energy data models (e.g. CIM)
  - Automation data models (e.g. AutomationML, OPC-UA Companion Standards, etc.)
- Best practice for data model governance as well as modelling tools (also for domain experts)
- Guidelines and best practices for modelling, modularization and maintenance
- Training material for developers and other stakeholders.

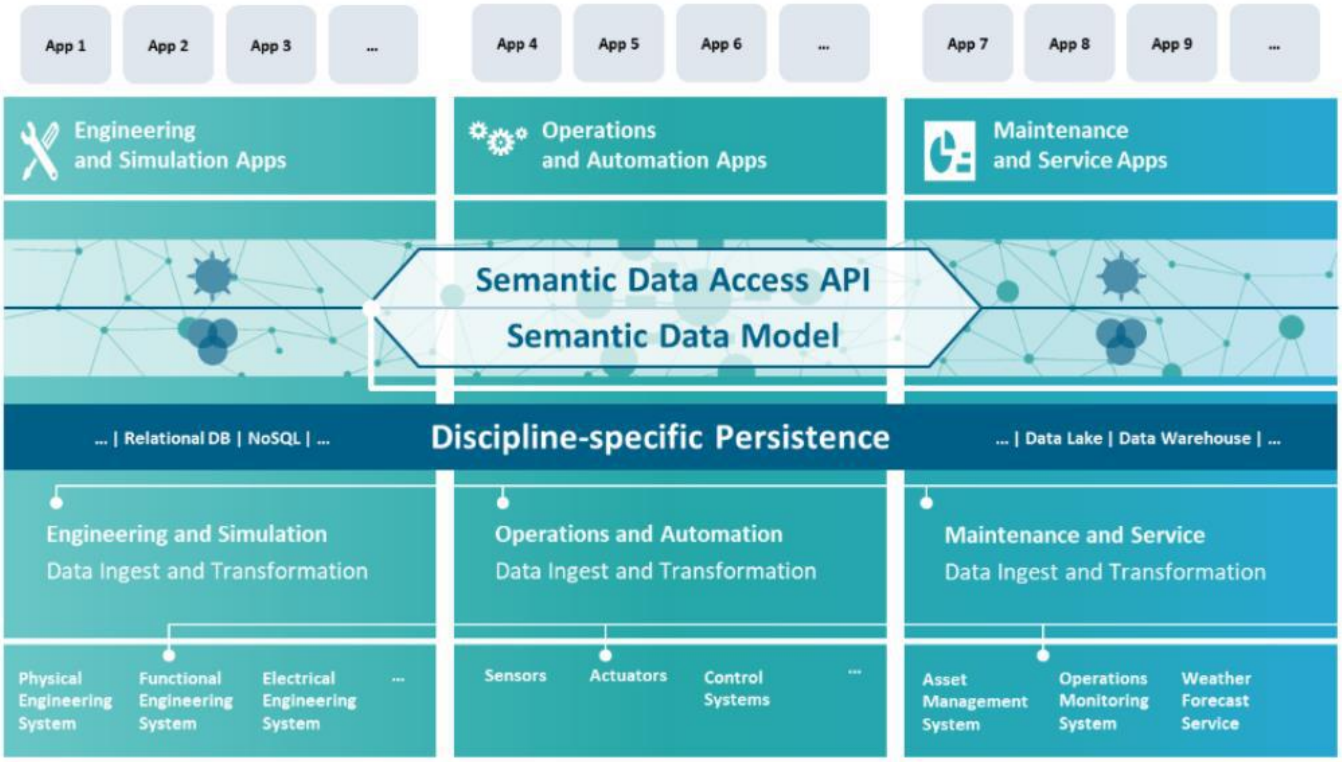


Figure 12.1 - An overview of UC11 as given in D5.1

12.1 Detailed description

The main goal of the use case is to realize a seamless integration of automation engineering data when building up complex manufacturing equipment. Our main objective is to address scenarios of reducing the efforts of factory automation engineers for accessing engineering data from various disciplines, such as electrical engineering, mechanical engineering or automation software. To that end, Siemens will develop an ontology library that covers various relevant domain ontologies as well as ontology transformations of various industrial standards. In particular, this library will cover models for assets in the domains of manufacturing and automation engineering. Based on these models, Siemens will showcase a demonstrator for the integrated access to various otherwise disparate automation engineering artifacts that are combined in a scenario in which integrated automation engineering data is being made accessible to technical users in order to ease their daily work in a heterogeneous landscape of engineering tools.

What are the pre-conditions of your use case? In which state the system should be in before the scenario starts?

- Availability of automation engineering data from industrial scenarios within Siemens business units.
- Access to tools/APIs that provide automation engineering data not available in form of files

What are the post-conditions of your use case? What is the expected state of the system after the scenario is completed?

- Best practice ontology guidelines (naming, versioning, metadata) are published
- Top layer ontology is defined
- Middle layer ontologies are defined and domain/subdomain structure for Siemens ontologies is defined
- Siemens Ontologies are published internally (documentation + source files)
- Published Ontologies are validated against best practice guidelines
- Specific schemas for automation engineering are instantiated with data from real projects and scenarios
- A demonstrator accessing this data in an integrated way is being realized by querying these schemas

Who are the actors involved? (List of all actors mentioned in the scenario steps)

- Ontology (Knowledge engineering) experts
- Domain experts (Automation Engineering, Manufacturing Equipment)

12.2 Main Scenario

No	Description	TLO	MLO	DO	Tools
	Contribution Process to Siemens Ontology Library		ISO 15926-14 SOSA/SSN QUDT	Automation engineering	SHACL for validation
	Connecting an engineering tool data source for integration		ISO 15926-14	tool-specific	e.g. RML for mapping
	Querying over integrated schemas		ISO 15926-14	Automation SW, electrical engineering, etc.	Triple store infrastructure, SPARQL processor
	Displaying/Browsing integrated engineering content		ISO 15926-14	Automation SW, electrical engineering, etc.	Possibly a UI component for graph visualization

Which data sources are used? (Please cross-reference with the steps of the main scenario)

- Standards for guiding the development of schemas
    - Automation ML (IEC 62714)
    - Possibly ISA'95 for manufacturing equipment
    - others
- E.g. TIA Portal for automation software data
- E.g. EPlan for electrical engineering data
- Others for other disciplines

What are the major (expected) contributions of OntoCommons to the use case?

Guidelines and middle level ontologies, in particular a generic technical asset and IoT ontology that are aligned with external standards and Siemens portfolio

Typical patterns of usage for upper and mid-level ontologies that apply to the Siemens scenarios

A somewhat complete and consistent system of upper-level and mid-level ontologies with a good coverage for Siemens-relevant domains

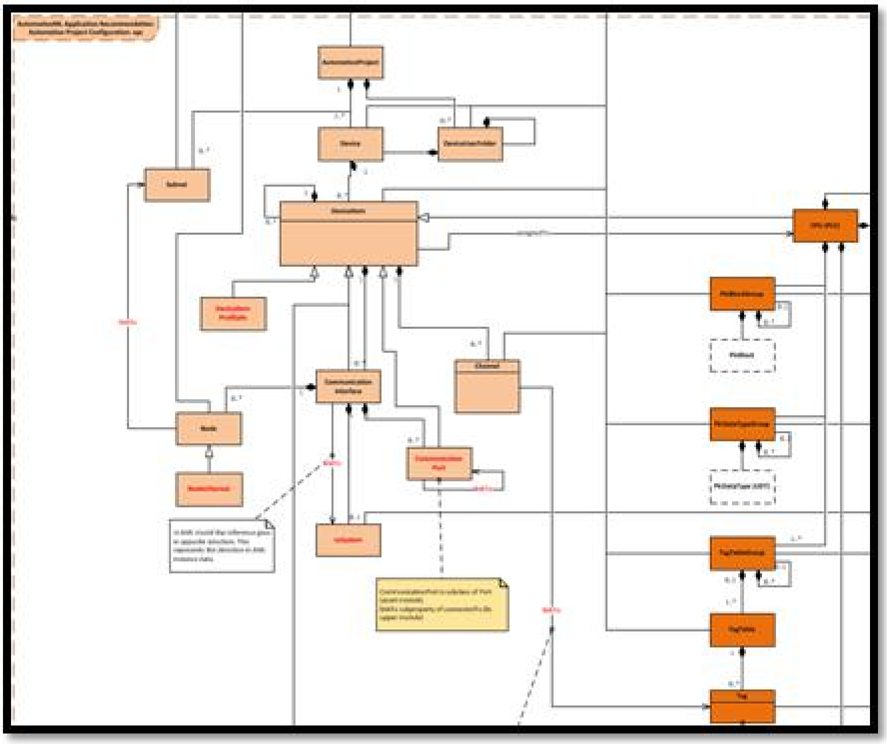
Name the most important 20 terms for the domain of your use case. If available, please add any diagrams illustrating these terms (e.g. UML diagram, ER diagram)

There is no single domain, but several ones we consider. The domains relevant for this use case come mainly from the production and automation engineering domains.

For automation engineering:

Device, PLC (programmable logic controller), Function (SW), Variable (SW), CommunicationInterface, …

See Figure 12.2 for details.



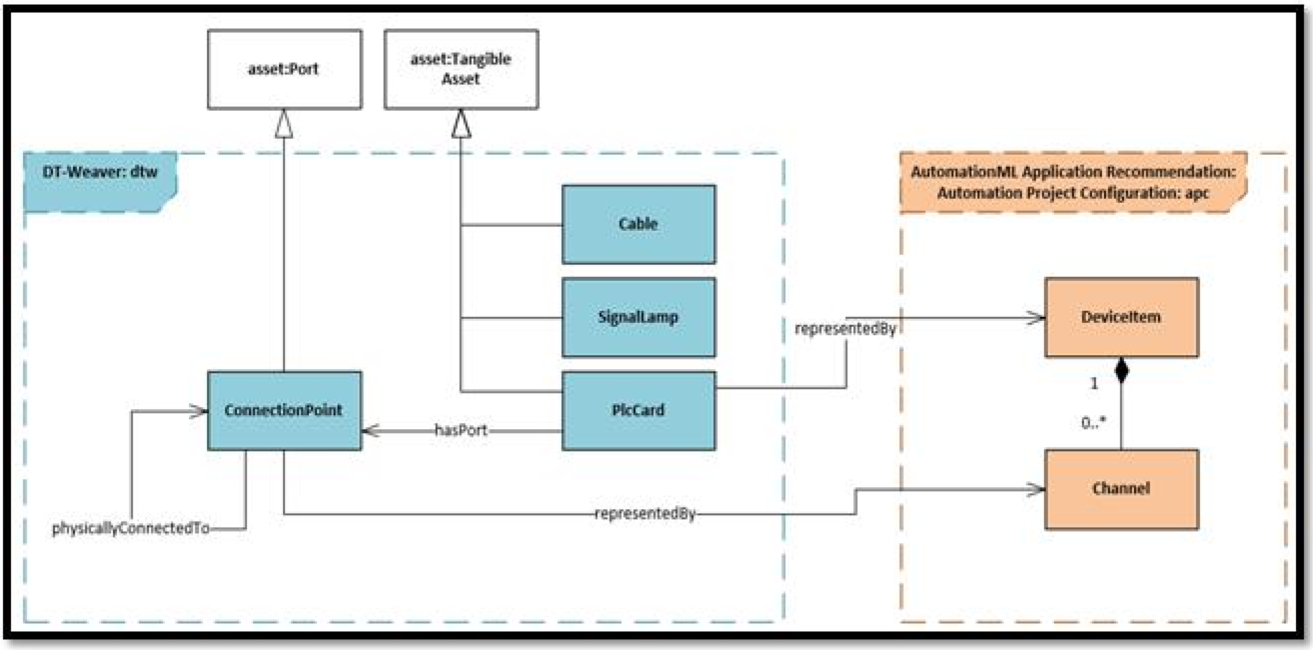


Figure 12.2 - Integrated Schemas for Automation Software and Electrical Engineering

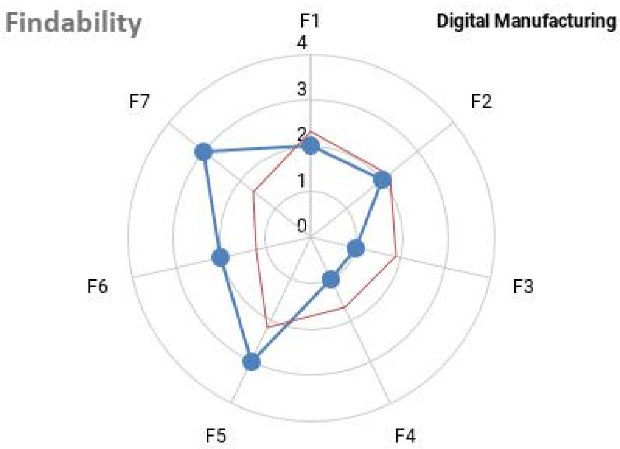
12.3 Implementation Time Plan

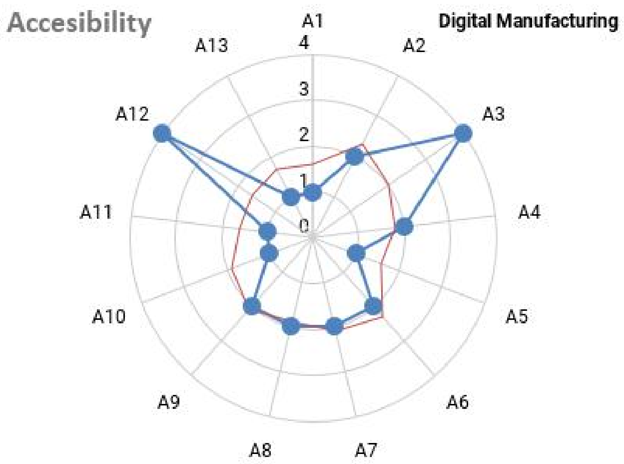
TBD

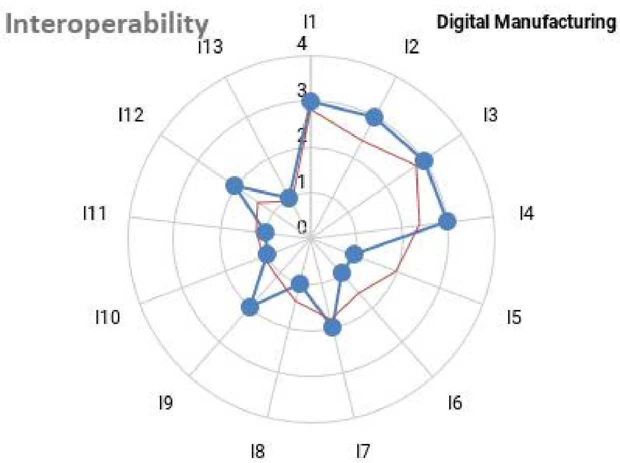
12.4 FAIR Plan

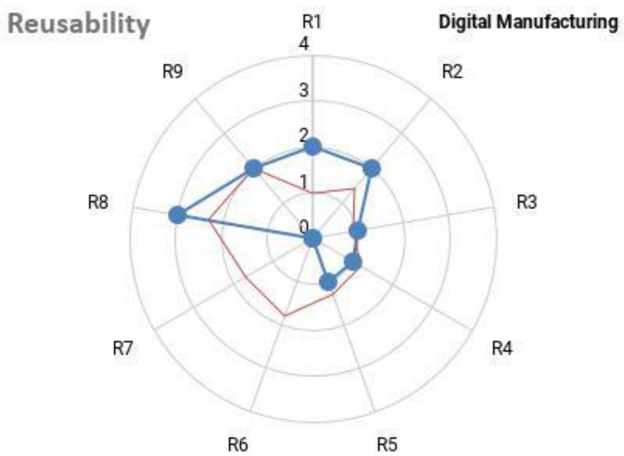
Results of the initial FAIRness evaluation:

The use case is around or better than the overall demonstrator average in terms FAIR principles adoption. The use case already uses machine-understandable and linked metadata. Several accessibility and Interoperability principles are currently being implemented or in the design phase.









What evolved from that time until now? Please Answer per dimension:

Findable: no change

Accessible: no change

Interoperable: no change

Reusable: no change

What are the future steps to improve FAIRness? What does the demonstrator want to improve? If there are no/little improvement made and/or foreseen, motivate why. If there is an interest to progress here, what are the roadblocks?

Currently, various Siemens divisions have their own repositories for ontology development and some of them have their own publication platforms. Within this use case we work on bringing them together under one joint publication platform, while still enabling distributed development. This will lead to better findability and accessibility of domain independent ontologies that were developed by single Siemens divisions and enable re-use by other divisions.

For automation engineering data, the current situation is that engineers have an enormous manual effort in handling/searching data in heterogeneous tools from the different disciplines due to e lack of integration. An ontology-based integration of engineering data aims at improving all the above points (FAIR dimensions), saving time in the engineer's daily work for accessing and connecting engineering data artifacts.

12.5 Technology Readiness Levels (TRL)

Using the standard definition:

- **for different scenario steps,**
- **for TLOs employment,**
- **for MLOs employment,**
- **for DOs employment,**
- **for tools deployment.**

How they evolved since spring 2021 (last half a year)? How are the TRLs expected to evolve in the next months?

TBD

12.6 Key Performance Indicators (KPI)

KPI	Metric	Function	Range
TRL improvement	• TRL change	• 1/1+(TRL_end - TRL_start)	(0,1]
FAIR improvement	• average score in each FAIR dimension	• For each dimension, average based on final surveys	[0,4] for each dimension
Quantity	• *Number of ontologies hosted*		
Coverage	• Number of domains (e.g. production, automation software, etc) + number of tools (e.g. TIA portal)		
Adoption	• Number of users/contributors for OL		

13. Conclusion and Future Work

In this deliverable, we have presented the specification of initial use cases. With extension of our initial questionnaire (from D5.1) and conduction of further interviews, we have gained more insight of the details of each case, and recorded explicitly the aims of the use case, and the targeted KPIs. Also, we have started to trace how the use cases are evolving in practice e.g. which works are being done in which manner. It has been visible that each demonstrator has been evolving in a different manner. The progress updates are serving as an input to the work-packages of the projects working on ontologies and tools, and also will be delivering a relevant input to the project roadmap, in terms of identifying best practices for ontology adoption.

Note that not every aspect of the survey was answered by every demonstrator. Some of the questions, particularly about certain KPIs, implementation plan and the adoption FAIR principles are not answered at this stage (marked as TBD). This is mostly due to the nature and the level of maturity of the use cases at the initial stage. The following work in the WP5 such as the progress monitoring (D5.4) will address most of these questions again.

Our future work will comprise working with the existing demonstrators on the ontology and ontology tools adoption, and also starting the same work with further demonstrators, that have joined the project as a result of an open call in autumn 2021. The selection of new demonstrators took place according to the set criteria in D5.1, and we have managed to extend the pool of the demonstrators and particularly to make this pool more representative, and covering more of possible scenarios within the domain scope of OntoCommons.

Together with other work-packages of the OntoCommons project and with the demonstrators, the work will be coordinated towards addressing of the requirements and targeted KPIs, and improving of the state of the development of the demonstrators in general, for example on the aspects such as raising of the demonstrator's TRLs and making their data more FAIR.

The next deliverables of this WP will comprise initial specification of the further demonstrators (M18 of the project), which will gather the specifications from the demonstrators who have joined the project as a result of an open call in autumn 2021, and description of initial cases results and initial validation – early feedback (M18), which will be showing further evolution of the initial use cases, as well as the first feedback and validation outcomes.

Appendix

OntoCommons Demonstrator Use Case Specification Interview

The purpose of this interview is to specify use cases from different aspects in order to create a basis for the development of best practices for top-level, mid-level and domain ontologies. Moreover, at aims to create baselines and measures for evaluation of OntoCommons' impact.

We kindly ask you to go through and answer these interview questions before your arranged interview. We will then discuss and elaborate on your answers during the online interviews.

1. Use Case Specification

Please specify at least one scenario/goal for your use case. We already provided some information such as the name and short description for your use case, based on the initial requirement collection. Please read and the provided information and comment if the scenario or goal has had changes since spring 2021.

Name:

Add name

Short Description:

Add description

What are the pre-conditions of your use case? In which state the system should be in before the scenario starts?

What are the post-conditions of your use case? What is the expected state of the system after the scenario is completed?

Who are the actors involved? (List of all actors mentioned in the scenario steps)

What are the steps of the main scenario?

Please add one row for each step in your scenario. If a step involves with an ontology or a tool, please specify its name and purpose at this step. If some of types of ontologies (Top Level Ontology, Mid-Level Ontology, Domain Ontology are not used, explain why). Also include intentions for future development plans.

No	Description	TLO	MLO	DO	Tools
	Reasoning over sensor data			Semantic Sensor Network - to represent sensor data	Pellet reasoner Purpose: OWL DL reasoning

Which data sources are used? (Please crossreference with the steps of the main scenario)

What are the major (expected) contributions of OntoCommons to the use case?

Name the most important 20 terms for the domain of your use case. If available, please add any diagrams illustrating these terms (e.g. UML diagram, ER diagram)

2. Implementation Time Plan

Please provide a rough time plan for your implementation.

Particularly, list the milestones or scenario steps - by when what will be developed.

3. FAIR Plan

Is there already any development since the first survey towards improving FAIRness?

Below you see radar charts drawn for each dimension for your use case based on the initial survey in the first six months of the project.

Add charts

What evolved from that time until now? Please Answer per dimension:

Findable:

Accessible:

Interoperable:

Reusable:

What are the future steps to improve FAIRness? What does the demonstrator want to improve? If there are no/little improvement made and/or foreseen, motivate why. If there is an interest to progress here, what are the roadblocks?

4. Technology Readiness Levels (TRL)

Using the standard definition[17]:

- **for different scenario steps,**
- **for TLOs employment,**
- **for MLOs employment,**
- **for DOs employment,**
- **for tools deployment.**

[17] https://en.wikipedia.org/wiki/Technology_readiness_level

How they evolved since spring 2021 (last half a year)? How are the TRLs expected to evolve in the next months?

5. Key Performance Indicators (KPI)

Please add KPIs specific to your use case, particularly focusing on the KPIs related to evaluating ontology usage in you use case. You can take the generic KPIs below as example and extend table with your use cases specific ones.

KPI	**Metric**	**Function**	**Range**
TRL improvement	• TRL change	– 1/1+(TRL_end - TRL_start)	(0,1]
FAIR improvement	• average score in each FAIR dimension	– For each dimension, average based on final surveys	[0,4] for each dimension
Use case specific KPI - 1	•	–	
….	•	–	