Ontology Engineering and the FAIR principles: A Gap Analysis*

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Abstract

Ontologies and vocabularies play a key role when standardising, organizing and integrating data from heterogeneous data sources into Knowledge Graphs. In order to develop ontologies, different engineering methodologies have been proposed throughout the years, whose application resulted in thousands of semantic artefacts (taxonomies, vocabularies and ontologies) in a wide range of domains. But how to ensure that ontologies follow the Findable, Accessible, Interoperable and Reusable principles (FAIR) from their inception? In this paper, we review existing guidelines to help make ontologies FAIR and map them to the ontology development lifecycle activities. Our analysis outlines the current gaps, where no guidelines exist for ontologies to become **FAIRbyDesign**.

Keywords

Ontology Engineering, FAIR principles, Semantic Artifacts, Ontologies, Vocabularies

1. Introduction

Ontologies and vocabularies play a key role in data integration by defining the structure, guiding the construction, and validating Knowledge Graphs. Ontologies are widely used in multiple domains, ranging from Bioinformatics [1] and Astrophysics [2] to Smart Cities [3] or Web content annotation [4].

A number of ontology engineering methodologies have been proposed by researchers through the years in order to build ontologies [5] [6] [7] [8] [9] [10] [11] [12] [13]. These methodologies define the steps and activities needed to gather ontology requirements, discuss with domain experts, reuse existing vocabularies, validate the results, etc. Among them, Linked Open Terms

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(LOT) [13] is the only one addressing an online publication and maintenance activity, key for sustaining the obtained results.

With the growing adoption of the Findable, Accessible, Interoperable and Reusable (FAIR) principles for data [14], different efforts have proposed guidelines to apply FAIR in ontologies and vocabularies [15] [16] [17] [18] [19]. However, no alignment between ontology development methodologies and the guidelines/recommendations for FAIR ontologies has been developed so far. In practice, the compliance with the FAIR guidelines is usually validated at the end of the ontology development processes without being integrated in the ontology development life-cycle.

In this paper we explore this challenge by mapping existing guidelines for developing FAIR ontologies and vocabularies to the different stages of the ontology engineering development process. For each stage, we identify the gaps of the current good practices and discuss potential solutions to address them. With this work, we aim to pave the way towards a **FAIRbyDesign** ontology engineering methodology.

The rest of the paper is structured as follows. Section 2 introduces state of the art methodologies and FAIR guidelines. Section 3 describes the method we followed to map together existing FAIR guidelines against the LOT methodology and the obtained results, while Section 4 discusses the main gaps outlined in our analysis. Section 5 concludes the paper.

2. Related Work

Ontology engineering has attracted the interest of researchers during decades, and as a consequence, a number of methodologies have been proposed to develop ontologies (e.g, Gruninger & Fox [5], METHONTOLOGY [6], Ontology Development 101 [7], On-To-Knowledge [8], Diligent[9], NeOn [10], eXtreme Design with ODP [11], SAMOD [12], Linked Open Terms (LOT) [13]). While these methodologies propose different lifecycles and activities, they usually start with ontology requirement specification, then ontology implementation, optionally including a previous conceptualisation activity, finalizing with ontology evaluation.

From these methodologies, LOT is the first one that considered the ontology publication phase, including their registration in public repositories, which is vital to increase the ontology's FAIRness level. In addition, LOT also considered the ontology reuse phase, addressing 'R' from FAIR. Thus, LOT was the first ontology engineering methodology addressing the FAIR principles. This is the case because most other methodologies were developed prior to the publication of the FAIR principles. Considering this, we selected LOT as basis for our study.

However, when considering the FAIR principles applied to semantic artefacts, and more precisely ontologies, a number of guidelines have been proposed in the last years. During 2020, ten guidelines for publishing FAIR vocabularies were proposed covering the design of accessible ontology URIs, the generation of reusable documentation and the correct publication of the ontology code and human oriented documentation by Garijo and Poveda-Villalón [15]. Later, in 2021, Cox *et al* [16] presented ten rules for publishing FAIR vocabularies focusing on the transformation of legacy vocabularies into semantic artefacts as SKOS[1] terminologies or OWL ontologies. In 2022. Le-Franc *et al.* [17] published a list of 17 recommendations about identifiers,

[1] https://www.w3.org/TR/skos-reference/

metadata and repositories in the context of the FAIRsFAIR project. In the same year, Amdouni *et al.* [18] proposed a list of 61 questions for ontology FAIRness assessment. Finally, in 2023, Xu *et. al* [19] presented a list of 11 features, related to identifiers, metadata and publication, that a FAIR vocabulary should have.

These efforts on ontology development methodologies and guidelines for improving ontology FAIRness have so far evolved independently. In this work, we align these approaches to LOT, hence proposing the first steps towards a **FAIRbyDesign** methodology for building ontologies.

3. Methodology and Results

This section describes the process we followed to identify gaps and alignments between different existing FAIR good practices for ontologies and the LOT methodology.

Figure 1 shows an overview of LOT methodology. LOT is is organised in four phases, which are split in specific activities. As the activities in "Ontology requirements specification" and "Ontology maintenance" phases are too detailed to be mapped to the FAIR Principles, we decided to map the FAIR principles at the phase level. For the "Ontology implementation" and "Ontology publication" phases, the FAIR Principles are mapped at activity level as the activities in these phases are more technical. The "Propose release candidate" activity is not considered in this exercise, as it is not a technical activity. In summary, from now we will refer to the selected phases or activities as "activity". We considered the following activities for our analysis: requirements specification, reuse, conceptualization, encoding, evaluation, documentation, publication and maintenance.

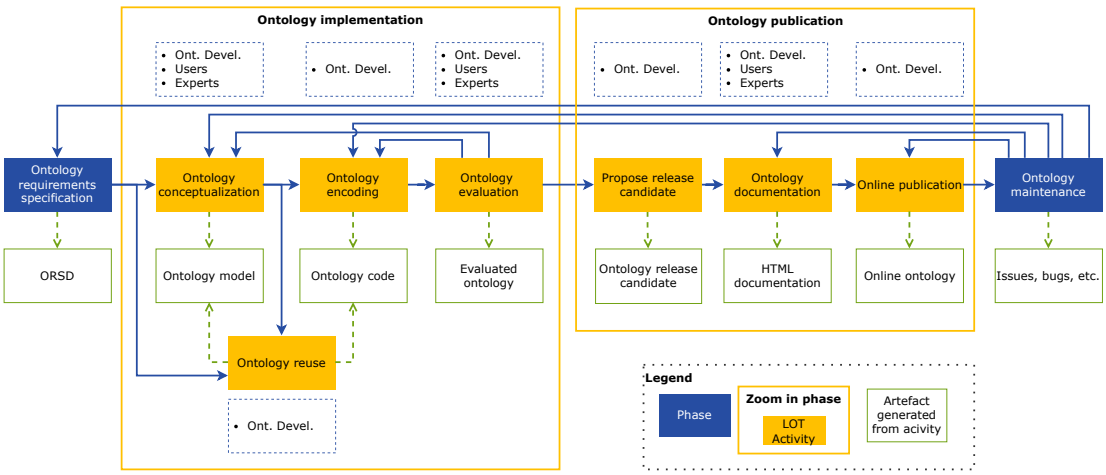

Figure 1: Excerpt of the LOT methodology phases and activities.

We followed three main steps in our analysis:

- **Step 1. Identify the needs**: Ontology developers and experts were asked to identify any relationship between the considered LOT activities and the FAIR principles. That is,

FAIR Principle	F1	F2	F3	F4	A1	A1.1	A1.2	A2	I1	I2	I3	R1	R1.1	R1.2	R1.3
Ontology Requirements Specification	X	X			X	X			X			X	X		X
Ontology Reuse		X			X				X	X	X	X	X	X	X
Ontology Conceptualization									X	X	X	X		X	X
Ontology Encoding	X	X	X		X			X	X	X	X	X	X	X	X
Ontology Evaluation												X	X	X	
Ontology Documentation	X	X	X		X				X	X	X	X	X	X	X
Ontology Publication	X		X	X	X	X	X	X	X				X	X	X
Ontology Maintenance	X			X				X			X				

Table 1: Matrix of identified needs for each FAIR principle (columns) and ontology development activities. Cells with "X" represent that the ontology development activity execution could have an impact in the built ontology FAIRness level regarding the corresponding FAIR principle.

whether the answer to "*Is there something to be done while carrying out the ACTIVITY_X that could affect the FAIRness level of the final ontology with respect to FAIR_principle_Y*?" is "Yes". In that case, a "X" is included in the cell relating the ACTIVITY_X with the FAIR_principle_Y? in Table 1. This process was carried out following a brainstorming session (online and offline). The resulting output is presented in Table 1 which identifies the needs for best practices for each activity and each FAIR Principle regardless whether potential guidelines exist or not. Such needs are represented with "X".

- **Step 2. Map activities to existing guidelines**: The recommendations for increasing ontology FAIRness level described in Section 2 were mapped to the LOT activities and the FAIR principles addressed by the guidelines (only in case it was not already mapped in the original work). This process has been carried out in collaboration with the authors of the corresponding best practices. The output of this activity is a matrix of existing best practices for each LOT activity and each FAIR Principle represented in Tables 2 and 3. The best practices are identified by the following codes (a summary of all referenced best practices is included in Appendix A):
  - FVF-*X*: FAIR Vocabulary Feature (FVF-) *X* defined by Xu et al. [19]
  - G&P-*X*: Guideline for publishing FAIR vocabulary *X* defined by Garijo and Poveda-Villalón [15]
  - F*Y*Q*X*: Question *X* for FAIR Principle *Y* defined in (Amdouni, E. et al. [18]
  - P-Rec-*X*: Preliminary Recommendation *X* defined by Le Franc et al. [17]
  - Rule-*X*: Rule *X* for FAIR vocabularies defined by Cox, et al. [16]

FAIR principle	F1	F2	F3	F4	A1	A1.1	A1.2	A2
O. Req. Spec.								
Ontology Reuse					FVF-3 A1Q1 A1Q2 A1Q3			
Ontology Conceptualization								
Ontology Encoding	FVF-1 G&P-1 G&P-5 F1Q1 P-Rec1 Rule-5	FVF-2 G&P-6 P-Rec3 Rule-7	G&P-6 F3Q1 F3Q2 F3Q3		G&P-1 G&P-2 G&P-3 G&P-4			FVF-6 G&P-9 G&P-10 P-Rec8
Ontology Evaluation								
Ontology Documentation	F1Q3 F1Q4	FVF-2 G&P-6 F2Q1 F2Q2 F2Q3 P-Rec3 Rule-7	G&P-6		FVF-3 A1Q1 A1Q2 A1Q3			
Ontology Publication	FVF-1 G&P-5 F1Q2 P-Rec2		P-Rec2	FVF-4 G&P-10 F4Q1 F4Q2 F4Q3 P-Rec 4 P-Rec 5 Rule-8	FVF-5 G&P-1 G&P-2 G&P-4 A1Q4 P-Rec 5 Rule-9	FVF-5 G&P-9 A1.1Q1 A1.1Q2 A1.1Q3 P-Rec 5	FVF-5 A1.2Q1 A1.2Q2 P-Rec7	FVF-6 G&P-10
Ontology Maintenance								FVF-6 A2Q1 A2Q2 A2Q3 A2Q4 P-Rec8

Table 2: Mapping a. Mappings between existing guidelines, ontology development activities during which they guidelines should be applied and corresponding FAIR principles (Findable and Accesible).

- **Step 3. Identify gaps**: In this step the matrix from step 1 (needs) is compared to the matrix from step 2 (existing guidelines) in order to identify gaps for those activities for which a need has been identified but have no recommendations to date. These results are shown in Table 4 in which for each activity and FAIR principle it is shown whether a need was detected (content taken from Table 1 marked with "X") and whether there are existing guidelines covering it (represented by a "Y" in the cell in case at least one guideline was mapped for that cell in Table 2 or 3) or whether there is an identified gap (represented by "gap" in the cell in case no guideline was mapped for that cell in Tables 2 and 3).

FAIR principle	I1	I2	I3	R1	R1.1	R1.2	R1.3
O. Req. Spec.							
Ontology Reuse		I2Q1 I2Q2 I2Q3 I2Q4 I2Q5 I2Q7	FVF-8 P-Rec15	I2Q2	FVF-10 G&P-6 Rule-2	P-Rec15	
Ontology Conceptu alization	I1Q1 I1Q2	I2Q6 P-Rec14		R1Q5 Rule-3		G&P-6 G&P-8	FVF-11
Ontology Encoding	FVF-7 I1Q3 I1Q4 I1Q5 P-Rec9 P-Rec10 P-Rec11 P-Rec12 Rule-6	P-Rec10 P-Rec14	FVF-8 I3Q1 I3Q2 I3Q3 P-Rec10 P-Rec12	FVF-2 FVF-9 G&P-6 R1Q6	G&P-6	P-Rec3 P-Rec17 Rule-7	P-Rec3 P-Rec12
Ontology Evaluation				R1Q1 R1Q2 R1Q3 R1Q4			
Ontology Documen tation			FVF-8 P-Rec15	FVF-9 G&P-8	FVF-10 G&P-6 R1.1Q1 R1.1Q2 R1.1Q3 P-Rec3 P-Rec16	R1.2Q1 R1.2Q2 R1.2Q3 R1.2Q4 R1.2Q5 R1.2Q6 R1.2Q7 R1.2Q8 P-Rec3 P-Rec15 P-Rec17 Rule-7	R1.3Q1 R1.3Q2 P-Rec3
Ontology Publication	G&P-9 P-Rec9				FVF-10 G&P-6	FVF-6 P-Rec13	R1.3Q3 P-Rec13
Ontology Mainte nance			Rule-10				

Table 3: Mapping b. Mappings between existing guidelines, ontology development activities during which they guidelines should be applied and corresponding FAIR principles (Interoperable and Reusable).

4. Discussion

As shown in Tables 2, 3 and 4, there is a high availability of guidelines and recommendations for ontology encoding, documentation and publication activities. This situation is expected considering that the guidelines analyzed focus on ontologies and vocabularies based on semantic web technologies and this community has been driven by best practices for publishing code and human oriented documentation by applying content negotiation mechanisms[2]. Despite

[2]Seehttps://www.w3.org/TR/swbp-vocab-pub/

FAIR principle	F1	F2	F3	F4	A1	A1.1	A1.2	A2	I1	I2	I3	R1	R1.1	R1.2	R1.3
O. Req. Spec.	**X gap**	**X gap**			**X gap**	**X gap**			**X gap**			**X gap**	**X gap**		**X gap**
Ontology Reuse		**X gap**			X Y				X Y	X Y	X Y	X Y	X Y	X Y	**X gap**
Ontology Conceptua									X Y	X Y	**X gap**	X Y		X Y	X Y
Ontology Encoding	X Y	X Y	X Y		X Y			X Y	X Y	X Y	X Y	X Y	X Y	X Y	X Y
Ontology Evaluation												X Y	**X gap**	**X gap**	
Ontology Documen	X Y	X Y	X Y		X Y				**X gap**	**X gap**	X Y	X Y	X Y	X Y	X Y
Ontology Publi	X Y		X Y	X Y	X Y	X Y	X Y	X Y	X Y				X Y	X Y	X Y
Ontology Mainten.	**X gap**			**X gap**				X Y			X Y				

Table 4: Gaps identified between ontology development activities and current guidelines for improving ontologies FAIRness level. "X" are taken from Tables 1, "Y" are taken from Table 2 and 3. "gap" indicates that a need "X" was identified for the corresponding activity and FAIR principle but no guideline is currently developed. This information is also highlighted in red cells.

this situation, ontology FAIRness may be improved during the ontology documentation activity by providing metadata and provenance information about the documentation itself, that is applying FAIR principles I1 and I2 to the documentation resources (e.g. HTML pages, diagrams, etc.)

According to the results shown in Table 4 (gaps), it is clear that the ontology requirement specification activity has been largely neglected by existing guidelines and recommendations about FAIR ontologies. This might be due to the fact that, even though requirements are the basis for any ontology development project, their management and maintenance is usually relegated once the ontology is built. Making sure ontology requirements are available online with a persistent identifier and maintained (versioned) after each ontology release may help explain ontology design decisions and provenance, as well as incorporating new changes in consistently in future releases.

Similarly, it can be observed that ontology evaluation has not been addressed in general by existing guidelines for FAIR ontologies. Ontology evaluation reports and tests, like ontology requirements, have not been considered first-class citizen during the ontology development process. Guidelines for documenting, annotating and sharing tests and results are needed. For example, authors tend to mention in their publications whether an evaluation/ FAIR assessment tool was used to improve an ontology, but the assessment report is usually not included in the corresponding ontology documentation.

Regarding the ontology reuse activity, main recommendations about using standard languages, checking the FAIRness level and licences of reused ontologies are already considered. However, there is a lack of guidance about how to describe the type of ontology reuse and provenance using metadata.

Current approaches to increase the FAIRness level of ontologies consist in assessing them once an ontology is built and published. Automated tools like FOOPS! [20] or O'FAIRE [21] help identifying issues which have to be addressed by ontology developers by hand. However, according to results shown in Table 1 it is clear than increasing the FAIRness level of an ontology should be addressed along its whole development lifecycle (e.g., carefully documenting design decisions and requirements, including ontology metadata in the conceptualization phase, etc.) and not just at the end.

5. Conclusions and future work

In this paper we have aligned the main guidelines for developing FAIR ontologies with the LOT ontology development methodology, with the goal of paving the way for a FAIRbyDesign methodology for building ontologies.

In addition, main gaps to be addressed by the complete FAIRbyDesign methodology have been identified. In general, further recommendations are needed for ontology development activities producing resources other than the main ontology code, as it has been observed that most of the recommendations focus mainly on the ontology code and the associated metadata, but no other resources like ontology requirements or tests.

During the analysis it has been observed the different granularity levels provided by existing guidelines. For example, P-Rec3 [17] suggest to use minimum metadata to describe the semantic artefact or ontology including pointers to a number of recommendations for potential metadata to be used, while the O'FAIRE questions [18] refer to MIRO must and should metadata, include questions about how the metadata is provided and propose other questions about specific metadata fields. Other guidelines like [15] propose a set of metadata fields suggesting to include them in the ontology header.

The presented work is being extended by producing recommendations and guidelines to increase the FAIRness level of ontologies for those activities where gaps have been identified. In addition, tools for helping during each activity will be suggested to ease the development process as much as possible.

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A. Existing guidelines for FAIR ontologies

G&P-X: Guideline for publishing FAIR vocabulary X defined by Garijo and Poveda-Villalón [15]

- G&P-1: Design ontology name and prefix
- G&P-2: Decide between hash or slash URIs
- G&P-3: Decide whether to use opaque URIs
- G&P-4: Define an ontology versioning strategy
- G&P-5: Use of permanent URIs
- G&P-6: Generate ontology metadata
- G&P-7: Generate HMTL documentation
- G&P-8: Generate diagrams
- G&P-9: Provide the ontology online in multiple formats (HTML and ontology serializations)
- G&P-10: Make the ontology findable on the Web

- Rule-1: Determine the governance arrangements and custodian of the legacy vocabulary
- Rule-2: Verify that the legacy-vocabulary license allows repurposing, and agree on the license for the FAIR vocabulary
- Rule-3: Check term and definition completeness and consistency in the legacy vocabulary
- Rule-4: Establish a traceable maintenance-environment for the FAIR vocabulary content
- Rule-5: Assign a unique and persistent identifier to (a) the vocabulary and (b) each term in the vocabulary

- Rule-6: Create machine readable representations of the vocabulary terms
- Rule-7: Add vocabulary metadata
- Rule-8: Register the vocabulary
- Rule-9: Make the vocabulary accessible for humans and machines
- Rule-10: Implement a process for publishing revisions of the FAIR vocabulary

FYQX: Question X for FAIR Principle Y defined in (Amdouni, E. et al. [18]

- F1Q1: Does the ontology have a ”local” identifier, i.e., a globally unique and potentially permanent identifier assigned by the developer (or developing organization)?
- F1Q2: Does the ontology provide an additional “external” identifier, i.e., a guarantee globally unique and persistent identifier assigned by an accredited body? If yes, is the external identifier a DOI?
- F1Q3: Are the ontology metadata clearly identified either by the same identifier than the ontology (if included in the ontology file) or with its own globally unique and persistent identifier?
- F1Q4: Does the ontology provide a version-specific URI, and is this URI resolvable?
- F2Q1: Is the ontology described with additional ’MIRO must’ metadata properties?
- F2Q2: Is the ontology described with additional ’MIRO should’ or ’optional’ metadata properties?
- F2Q3: Is the ontology described with another metadata property with no explicit corresponding MIRO requirement?
- F3Q1: Are the ontology metadata included and maintained in the ontology file?
- F3Q2: If not, are the ontology metadata described in an external file?
- F3Q3: Does that external file explicitly link to the ontology and vice-versa?
- F4Q1: Is the ontology registered in multiple ontology ’libraries’?
- F4Q2: Is the ontology registered in multiple open ontology ’repositories’?
- F4Q3: Are the ontology ’libraries’ or ’repositories’ properly indexed by Web search engines?
- A1Q1: Do the ontology URI and other identifiers, if they exist, resolve to the ontology?
- A1Q2: Does the ontology URI (if metadata are included in the ontology file) or the external metadata URI resolve to the metadata record?
- A1Q3: Do the ontology URI and the external metadata URI (if the metadata are not included in the ontology file), support content negotiation?
- A1Q4: Are the ontology and its metadata accessible through another standard protocol such as SPARQL?
- A1.1Q1: Is the ontology relying on HTTP/URIs for its identification and access mechanisms?
- A1.1Q2: Is the ontology access protocol open, free, and universally implementable?
- A1.1Q3: If the ontology and metadata are accessible through another protocol, is that protocol open, free, and universally implementable?
- A1.2Q1: Is the ontology accessible through a protocol that supports authentication and authorization?

- A1.2Q2: Are the ontology metadata accessible through a protocol that supports authentication and authorization?
- A2Q1: Is the ontology accessible in a repository that supports versioning?
- A2Q2: Are the ontology metadata of each version available?
- A2Q3: Are the ontology metadata accessible even if no more versions of the ontology are available?
- A2Q4: Is the status of the ontology clearly informed?
- I1Q1: What is the representation language used for the ontology and ontology metadata?
- I1Q2: Is the representation language used in a W3C Recommendation?
- I1Q3: Is the syntax of the ontology informed?
- I1Q4: Is the formality level of the ontology informed?
- I1Q5: Is the availability of other syntaxes/formats informed?
- I2Q1: Does the ontology import other FAIR vocabularies?
- I2Q2: Does the ontology reuse terms from other FAIR vocabularies (URIs)?
- I2Q3: If yes, does it include the minimum information for those terms?
- I2Q4: Is the ontology aligned to other FAIR vocabularies?
- I2Q5: If yes, are those alignments well represented and to unambiguous entities? If yes, are those alignments curated?
- I2Q6: Does the ontology provide information about the relation to or influence of other FAIR vocabularies?
- I2Q7: Does the ontology reuse standard and FAIR metadata vocabularies to describe its metadata?
- I3Q1: Does the ontology provide qualified cross-references to external resources/-databases?
- I3Q2: If yes, are those cross-references well represented and to unambiguous entities?
- I3Q3: Does the ontology use valid URIs to encode some metadata values?
- R1Q1: Does the ontology provide information about how classes or concepts are defined?
- R1Q2: Does the ontology provide metadata information about its hierarchy?
- R1Q3: How much of the ontology objects are described with labels?
- R1Q4: How much of the ontology objects are defined using a text description?
- R1Q5: How much ontology objects are defined using a property restriction or an equivalent class?
- R1Q6: How much ontology objects provide provenance information with annotation properties (e.g., author, date)?
- R1.1Q1: Is the ontology license clearly specified, with an URI that is resolvable and supports content negotiation?
- R1.1Q2: Are the ontology access rights specified and permissions documented?
- R1.1Q3: Are the ontology usage guidelines and copyright holder documented?
- R1.2Q1: Does the ontology provide information about the actors involved in its development?
- R1.2Q2: Does the ontology provide information about its general provenance?

- R1.2Q3: Are the accrual methods and policy of the ontology documented?
- R1.2Q4: Is the ontology clearly versioned with version information and links to previous versions?
- R1.2Q5: Are the ontology latest changes documented?
- R1.2Q6: Are the methodology and tools used to build the ontology documented?
- R1.2Q7: Is the ontology rationale documented?
- R1.2Q8: Does the ontology inform about its funding organization?
- R1.3Q1: Does the ontology provide information about projects using or organizations endorsing?
- R1.3Q2: Is the ontology included in a specific community set or group?
- R1.3Q3: Is the ontology openly and freely available?

P-Rec-X: Preliminary Recommendation X defined by Le Franc et al. [17]

- P-Rec1: Globally Unique, Persistent and Resolvable Identifiers must be used for Semantics Artefacts, their content (terms/concepts/classes and relations) and their versions
- P-Rec2: Globally Unique, Persistent and Resolvable Identifiers must be used for Semantic Artefact Metadata Records. Metadata and data must be published separately, even if it is managed jointly
- P-Rec3: A common minimum metadata schema must be used to describe semantic artefacts and their content
- P-Rec4: Semantic Artefact and its content should be published in an appropriate semantic repository
- P-Rec5: Semantic repositories must offer a common API to access semantic artefacts and their content in various serialisations for both use/reuse and indexation by search engines
- P-Rec6: Build semantic artefact search engines that operate across different semantic repositories
- P-Rec7: Repository should offer a secure protocol and user access control functionalities
- P-Rec8: Human and machine-readable persistence policies for semantic artefacts metadata and data must be defined
- P-Rec9: Semantic artefacts must be made available as a minimum portfolio of common serialisation formats
- P-Rec10: Foundational Ontologies may be used to align semantic artefacts
- P-Rec11: A standardised language should be used for describing high expressivity semantic artefacts

Rule-X: Rule X for FAIR vocabularies defined by Cox, et al. [16]
FVF-X: FAIR Vocabulary Feature (FVF-) X defined by Xu et al. [19]

- FVF-1: Vocabulary and their terms are assigned globally unique and persistent identifiers.
- FVF-2: Vocabularies and their terms have rich metadata.
- FVF-3: Vocabularies and their terms can be accessed using the identifiers, preferably by both human and machine.

- FVF-4: Vocabularies and their terms are registered or indexed in a searchable engine or a resource.
- FVF-5: Vocabularies and their terms are retrievable using a standardised communications protocol, preferably open, free and universally implementable protocols. and allows for authentication and authorisation, where necessary.
- FVF-6: Vocabularies and their terms are persistent over time and are appropriately versioned
- FVF-7: Vocabularies and their terms use a formal, accessible and broadly applicable, and preferably machine-understandable language for knowledge representation.
- FVF-8: Vocabularies and terms use qualified references to other vocabularies.
- FVF-9: Vocabularies and terms are described with a plurality of accurate and relevant attributes.
- FVF-10: Vocabularies are released with a standard data usage licence, preferably machine-readable licence.
- FVF-11: Vocabularies meet domain relevant community standards