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## M4.3 - Specification of semantic artefact description

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► **To cite this version:**

Alejandra Gonzalez-Beltran, Antony Wilson, Biswanath Dutta, Daniel Garijo, Clement Jonquet, et al.. M4.3 - Specification of semantic artefact description. MS4.3, FAIR-IMPACT. 2024. hal-04493123

**HAL Id: hal-04493123**

**<https://hal.science/hal-04493123>**

Submitted on 6 Mar 2024

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|                       |   |
|-----------------------|---|
| Project Title         | Expanding FAIR solutions across EOSC                          |
| Project Acronym       | FAIR-IMPACT   |
| Grant Agreement No.   | 101057344   |
| Start Date of Project | 2022-06-01  |
| Duration of Project   | 36 months   |
| Project Website       | <a href="https://fair-impact.eu/">https://fair-impact.eu/</a> |

## 1 M4.3 - Specification of semantic artefact description

|                              |   |
|------------------------------|---|
| Work Package                 | <b>WP 4, Metadata and Ontologies</b>  |
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| Due Date                     | <b>2024-02-29</b>   |
| Date                         | <b>2024-02-29</b>   |
| Version                      | <b>V1.0</b>   |
| DOI                          | <b>10.5281/zenodo.10725304</b>  |

### Dissemination Level

|                                     |  |
|-------------------------------------|--|
| <input checked="" type="checkbox"/> | PU: Public   |
| <input type="checkbox"/>            | PP: Restricted to other programme participants (including the Commission)        |
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| <input type="checkbox"/>            | CO: Confidential, only for members of the consortium (including the Commission)  |

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## 2 Versioning and contribution history

| Version | Date         | Author   | Notes   |
|---------|--------------|--|---|
| 0.0     | 2022-2023    | Participants in task T4.2.3  | Contributions to work on T4.2.3 that are summarised in this milestone, as documented in meeting notes and GitHub repositories |
| 0.1     | Jan-Feb 2024 | Alejandra Gonzalez-Beltran, Antony Wilson  | Document outline and first draft of sections  |
| 0.3     | Feb-2024     | Biswanath Dutta, Daniel Garijo, Clement Jonquet, Yan Le Franc, María Poveda-Villazón | Contributions to the document and review of all the content   |
| 1.0     | Feb 2024     | Alejandra Gonzalez-Beltran, Antony Wilson  | Final review addressing comments/feedback   |

### Disclaimer

FAIR-IMPACT has received funding from the European Commission’s Horizon Europe funding programme for research and innovation programme under the Grant Agreement no. 101057344. The content of this document does not represent the opinion of the European Commission, and the European Commission is not responsible for any use that might be made of such content.

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## Terminology

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| Terminology/Acronym | Description                                       |
|---------------------|---|
| API                 | Application Programming Interface                 |
| DCAT                | Data Catalogue Vocabulary                         |
| EOSC                | European Open Science Cloud                       |
| FAIR                | Findable Accessible Interoperable and Reusable    |
| RDA                 | Research Data Alliance                            |
| RDF                 | Resource Description Framework                    |
| LOT                 | Linked Open Terms                                 |
| MOD                 | Metadata for Ontology Description and Publication |
| OWL                 | Web Ontology Language                             |
| SA                  | Semantic Artefact                                 |
| SKOS                | Simple Knowledge Organization System              |
| SSSOM               | Simple Standard for Sharing Ontology Mappings     |
| TTL                 | Terse RDF Triple Language                         |
| VSSIG               | Vocabulary and Semantic Services Interest Group   |
| WP                  | Work Package                                      |

## 4 Introduction

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Semantic artefacts (SA) are key for the description of data and for making data FAIR (findable, accessible, interoperable and reusable) [1]. SA is a broader term to include ontologies, terminologies, taxonomies, thesauri, vocabularies, metadata schemas and semantic standards. Describing SAs is fundamental to make them FAIR themselves. The Metadata for Ontology Description and Publication (MOD<sup>8</sup>) was developed to provide the vocabulary required to describe ontologies, and Semantic Artefacts in general. The Data Catalogue Vocabulary (DCAT<sup>9</sup>) [2] was designed to describe datasets and resources that can be catalogued.

This milestone presents a DCAT-based standard for description of Semantic Artefacts and their catalogues, building on the MOD vocabulary as well as recommendations and outcomes from the FAIRsFAIR project<sup>10</sup> and the Research Data Alliance Vocabulary and Semantic Services Interest Group (RDA VSSIG<sup>11</sup>). This milestone also makes a distinction between the MOD specification and a series of mappings with other vocabularies, presented in a machine-actionable way. Last but not least, we describe a methodology for MOD profiles and how to formalise them in a machine-actionable and composable way.

The next step (deliverable D4.3) related to this milestone will be to specify a common Application Programming Interface (API) for interoperability of SA catalogues in the European Open Science Cloud (EOSC) ecosystem and beyond, building from MOD descriptions of SAs. The API for SA-catalogues will enable interoperability and unified access to their content, enabling seamless querying and use by stakeholders independent of domain. The API will be adopted by FAIR-IMPACT T4.2's use case SA-catalogues and it will be publicly available for other catalogues to deploy; via the API, other registries could consume content from multiple SA-catalogues. The implementation of this API will be the topic of an upcoming FAIR-IMPACT Open Call.

## 5 Description of the Milestone

---

This milestone presents a first version of a specification for Semantic Artefacts descriptions, relying on a new version of the Metadata for Ontology Description and Publication Ontology (MOD) (version 3.0).

The milestone emphasises on the importance of Semantic Artefacts descriptions in the context of producing data that follows the FAIR guiding principles, and presents an historical perspective of the evolution of the MOD vocabulary, which has been originally developed [3] in a convergence approach considering three aspects: by exploring existing vocabularies that

<sup>8</sup> MOD: <https://github.com/FAIR-IMPACT/MOD>

<sup>9</sup> DCAT version 3: <https://www.w3.org/TR/vocab-dcat-3/>

<sup>10</sup> FAIRsFAIR project: <https://fairsfair.eu/>

<sup>11</sup> RDA VSSIG: <https://www.rd-alliance.org/groups/vocabulary-services-interest-group.html>

are useful to describe SAs, by analysing existing SAs descriptions and by studying the description properties offered by SA-catalogues

Here we present the latest design decisions that lead to MOD version 3.0, which has also been complemented with a set of mappings to other vocabularies and representation of MOD profiles.

There are other tasks and their milestones/deliverables within the FAIR-IMPACT project that are related to this work, as follows:

- M4.2 Processes and tools to engineer FAIR Semantic Artefacts [3];
- M5.3 Semantic Artefact assessment methodology [5]
- Upcoming D4.5 Guidelines and methodology to create, document and share mappings and crosswalks
- Upcoming D4.3 Specification of shared metadata description of Semantic Artefacts and their catalogues, including common reference API

## ***5.1 Role of the milestone***

This milestone has been driven by three objectives:

- i) specify a new version of the MOD vocabulary as an extension of the DCAT vocabulary by addressing outstanding design issues,
- ii) a clear identification between MOD elements and mappings to other vocabularies, by representing the mappings using the SSSOM standard,
- iii) present a machine-actionable representation of an MOD profile.

### ***5.1.1 Means of verification***

The required means of verification for this milestone is the publication of this report together with the artefacts presented in the related GitHub repositories:

- i) MOD repository: <https://github.com/FAIR-IMPACT/MOD>
- ii) MOD mappings: <https://github.com/FAIR-IMPACT/MOD-mappings>
- iii) An MOD profile: <https://github.com/FAIR-IMPACT/MOD-FAIRsFAIR-profile>



## 6 FAIR Semantic Artefacts

This milestone relies on the definition of Semantic Artefact historically proposed by the H2020 FAIRsFAIR project<sup>12</sup>, and endorsed by the EOSC Interoperability Framework [6], as follows: *“Semantic Artefact is defined as a machine-actionable and readable formalisation of a conceptualisation enabling sharing and reuse by humans and machines. These artefacts may have a broad range of formalisation, from loose set of terms, taxonomies, thesauri to higher-order logics, and include the concepts/terms/classes constituting these. Moreover, Semantic Artefacts are serialised using a variety of digital representation formats, e.g., RDF Turtle, OWL- RDF, XML, JSON-LD”* [7].

The description of SAs is an important element required to make a Semantic Artefact FAIR, following the findability F2 principle “Data are described with rich metadata” and reusability R1 principle “(Meta)data are richly described with a plurality of accurate and relevant attributes”.

The FAIRsFAIR project work on FAIR Semantic Artefacts [7], [8], [9] focused on providing practical recommendations on how to make SAs FAIR, and these best practices and recommendations were discussed extensively with the community. To implement one of the recommendations (P-Rec 3 “A common minimum metadata schema must be used to describe semantic artefacts and their content”), FAIRsFAIR also developed and presented a minimal schema for describing Semantic Artefacts [6][10]. In addition, the project presented a service architecture for harmonising SA repositories metadata with this minimum metadata schema and published the resulting harmonised metadata in a FAIR Data Point. This service architecture, called FAIRCat, has been developed from the Federated FAIR Data Space technology, developed in EOSC Pillar [11]. This work has been done in collaboration with a dedicated discussion group with the RDA Vocabulary and Semantic Service Interest Group. During a dedicated final workshop, the model based on DCAT and MOD2.0 was presented to the various communities and was evaluated according to a simple use-case i.e. searching and retrieving ontologies. Based on this use-case, the 70+ participants from 17 communities identified the metadata elements of the model which should be mandatory, recommended and optional. The mandatory set of fields representing the minimum metadata model. Based on voting results, we created two machine actionable descriptions of the minimum metadata schema, an OWL version and a SHACL version. These machine actionable versions were used to aggregate 5 different SA repositories with the FAIRCat platform and to publish the harmonised metadata into a FAIR Data Point<sup>13</sup>. In this milestone, we present the FAIRsFAIR work<sup>14</sup> as a profile for the MOD specification (see Section 7.3).

Other initiatives also worked on recommendations on making SAs FAIR [12], [13], [14], [15] and tools [16], [17] to verify their FAIRness.

<sup>12</sup> <https://fairsfair.eu/>

<sup>13</sup> <https://fdp-semdcat-app.vps.esciencedatafactory.com/>

<sup>14</sup> <https://github.com/FAIRsFAIR/SemanticDCAT-AP/>

Within the FAIR-IMPACT project, we are working on different aspects of Semantic Artefacts building on previous work:

- This work (M4.3) focuses on a specification for describing Semantic Artefacts, a presentation of a couple of profiles of such specification, and mappings between the specification and other relevant vocabularies
- M4.2 [4] proposes a FAIR-by-design methodology for developing vocabularies and ontologies (formalised in the RDF/RDFS and OWL representation languages) that can be extended to address other types of SAs.
- M5.3 [5] presents a generic methodology for assessing the FAIRness of Semantic Artefacts that groups categories of tests consistently; this is achieved by building on the Linked Open Terms (LOT) [18] methodology, which splits the assessment into smaller parts, considering code, content, metadata and a new module on FAIR assessment.

## 7 The Metadata for Ontology Description and Publication (MOD) Ontology

### 7.1 MOD Previous Work

In this section, we present a historical view on how MOD was developed. The initial version (MOD 1.0<sup>15</sup>) was presented at the Dublin Core conference in 2015 [19]. It introduced the Metadata for Ontology Description and publication (MOD) analysing the need for a controlled vocabulary for cataloguing ontologies, its design principles and methodology. The article reported the survey results of ontology users, which consisted of ontology researchers and practitioners with diverse educational backgrounds, their search behaviour, search criteria and parameters. It also reported on the metadata vocabulary usage by the thirteen ontology libraries (now called Semantic Artefact catalogues in EOSC), such as BioPortal<sup>16</sup>, EBI OLS<sup>17</sup>, AberOWL,<sup>18</sup> LOV<sup>19</sup>, etc. for ontology description.

MOD 1.2 [3] revised the previous version by considering 23 existing metadata vocabularies with relevant properties for describing Semantic Artefacts, as well as studied metadata usage analytics within ontologies and ontology repositories from three different perspectives: analysis of existing metadata vocabularies to describe ontologies; analysis of present use of metadata vocabularies for ontology descriptions (more in section 8.3); and analysis of metadata representation within ontology repositories. This new version of MOD (1.2) proposed 88 properties intended as a vocabulary for the annotation and description of semantic artefacts to be used by ontology engineers and ontology libraries. The article

<sup>15</sup> <https://www.isibang.ac.in/ns/mod/1.0/>

<sup>16</sup> <https://bioportal.bioontology.org/>

<sup>17</sup> [www.ebi.ac.uk/ols](http://www.ebi.ac.uk/ols)

<sup>18</sup> <http://aber-owl.net>

<sup>19</sup> <https://lov.linkeddata.es>

documented the selection criteria for inclusion of terms from other existing vocabularies to MOD.

At the time, discussions with the RDA VSSIG started to consider a community-driven standardisation effort, collaborative design and adoption of MOD future versions. In addition, AgroPortal [20] implemented MOD 1.2 and identified other properties not already available in that version of MOD [21]. MOD 1.4<sup>20</sup> was produced by incorporating the new properties identified by the AgroPortal work bringing MOD's list of description properties to 127.

In 2020, as part of the RDA VSSIG and FAIRsFAIR work, a proposition for MOD 2.0 was made that considered relating MOD classes to the DCAT vocabulary for description of data catalogues and catalogues of resources, from DCAT version 2.0. This work was presented and discussed in multiple RDA and FAIRsFAIR meetings<sup>21</sup> in 2020 and 2021 then later described in [10]. Initial versions of MOD defined the *mod:Ontology* class that was later replaced by *mod:SemanticArtefact*. In MOD 2.0, the properties from the other vocabularies not maintained any more by their original creators (*i.e.* OMV, DOOR and VOF) were redefined within the MOD namespace, which since MOD 2.0 relies on the W3ID platform for persistent identifiers (<https://w3id.org/mod>).

## 7.2 MOD Version 3.0

In this section, we describe how the new version of MOD (version 3.0)<sup>22</sup> was designed and implemented, by formalising MOD relationship with the DCAT vocabulary for resource catalogues and clearly distinguishing between the elements that are part of the MOD vocabulary definition and additional terms from other ontologies that were mapped to MOD, in order to facilitate:

- i) the specification of a new version of the MOD vocabulary as an extension of the DCAT vocabulary by addressing outstanding design issues,
- ii) a clear identification between MOD elements and mappings to other vocabularies, by representing the mappings using the SSSOM standard,
- iii) present machine-actionable representations of MOD 3.0 profiles.

### 7.2.1 Design Decisions

The WP4 members involved in this task met on multiple occasions to reach consensus on the approach to be taken around multiple design issues, which were documented in the open GitHub repository using the Discussions feature<sup>23</sup>. This section describes each of the design issues and the decisions taken.

<sup>20</sup> MOD versions: <https://github.com/FAIR-IMPACT/MOD/tree/main/versions>

<sup>21</sup> <https://fr.slideshare.net/jonquet/presentation-fairsfair-workshop-june-2021>

<sup>22</sup> <https://github.com/FAIR-IMPACT/MOD/>

<sup>23</sup> MOD Design Discussions: <https://github.com/FAIR-IMPACT/MOD/discussions>

### 7.2.1.1 What class of DCAT does *mod:SemanticArtefact* specialise?

The discussion on this designed issue was captured online<sup>24</sup> and determines what is the DCAT class that *mod:SemanticArtefact* should specialise. Two DCAT classes were identified as possible parent classes of the *mod:SemanticArtefact*, the *dcat:Resource* and *dcat:Dataset*. A *dcat:Resource* is “something that can be catalogued” and a *dcat:Dataset* is a “collection of data”.

We had multiple discussions on this design issue (FAIR-IMPACT project meetings related to T4.2.3), the discussion above, as well as discussion in the DCAT issue [w3c/dxwg#1576](https://www.w3.org/2018/07/18-dcat-dxwg#1576)<sup>25</sup>.

While some team members, who considered Semantic Artefact as a collection of concepts and relations, were happy with deriving *mod:SemanticArtefact* from *dcat:Dataset*, others preferred to distinguish between a dataset and a Semantic Artefact, so preferred to derive from *dcat:Resource* that is DCAT's extension point.

However, for Semantic Artefacts, we still want to take advantage of the dichotomy between abstract entity and distribution provided by the DCAT modelling, so the suggestion was to still use the *dcat:distribution* property for Semantic Artefacts. In effect, it was decided to explicitly specialise *dcat:Resource*, but using *dcat:distribution* implies that *dcat:SemanticArtefact* can be inferred as a *dcat:Dataset* in the current interpretation of DCAT. This seemed to be a good compromise with those who disagree to make the subclass explicit, while we wait for a resolution on the discussion with the DCAT group.

Thus, we represented:

```

mod:SemanticArtefact
  a rdfs:Class ;
  a owl:Class ;
  rdfs:subClassOf dcat:Resource ;
  
```

and still use the distribution predicate to refer to multiple representations of the Semantic Artefact. This representation is available in MOD 3.0.

### 7.2.1.2 How to capture the notion of distribution?

The discussion on this designed issue was captured online<sup>26</sup>. Three different proposals were made.

#### Distribution - Proposition 1

- *mod:SemanticArtefact* specialises *dcat:Resource* only
- *mod:SemanticArtefactDistribution* is defined independently of *dcat:Distribution*

<sup>24</sup> Design issue #1: <https://github.com/FAIR-IMPACT/MOD/discussions/34>

<sup>25</sup> <https://github.com/w3c/dxwg/issues/1576>

<sup>26</sup> Design issue #2: <https://github.com/FAIR-IMPACT/MOD/discussions/35>

- If one connects other objects (e.g., *schema:Dataset*, *void:Dataset*) to *dcat:Dataset* then a *mod:SemanticArtefact* can not benefit from their properties.

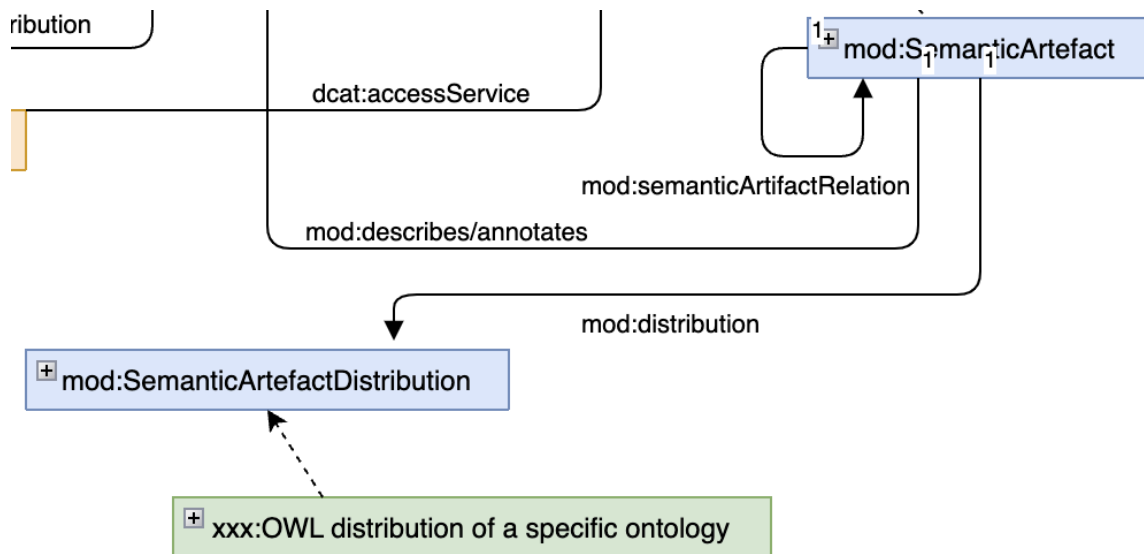


Diagram 1. Distribution - Proposition 1

### Distribution - Proposition 2

- SA becomes a subclass of *dcat:Dataset* and thus *SADistribution* becomes a subclass of *dcat:Distribution*
- The idea of keeping the distribution is still there but is a SA a dataset ?
- If we connect *schema:Dataset* to *dcat:Dataset* then a SA can still benefit from the properties
- We probably do not need the *mod:distribution* property anymore

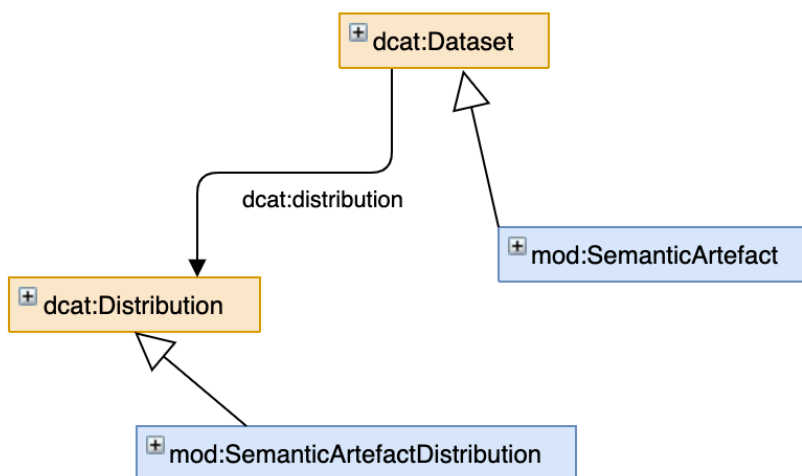


Diagram 2. Distribution - Proposition 2

For this proposition, the properties for *mod:SemanticArtefactDistribution* need to be considered (see Diagram 3 listing those properties).

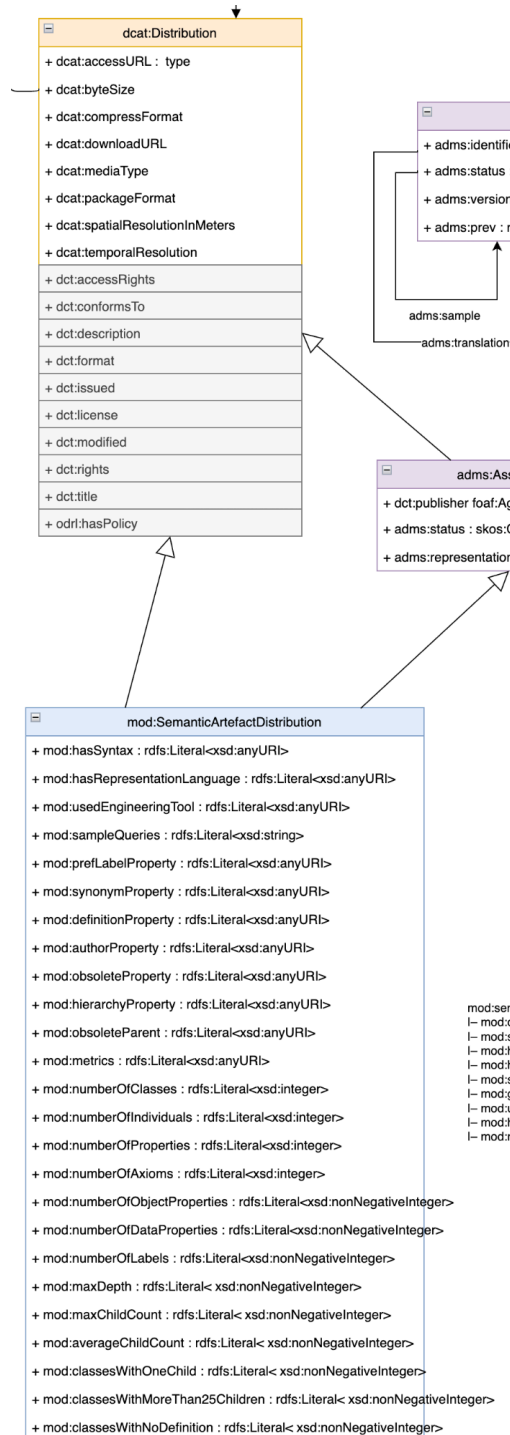


Diagram 3. Distribution - List of Properties

### Distribution - Proposition 3

- Get rid of *SemanticArtefactDistribution* completely, but then it does not make sense to follow DCAT anymore.

The discussion around this design issue is related to the previous design issue, where *mod:SemanticArtefact* is now represented as a subclass of *dcat:Resource*, and not *dcat:Dataset* explicitly, even though the use of the property *dcat:distribution* is still encouraged (and with the current DCAT representation, this implies that *mod:SemanticArtefact* will be inferred as a *dcat:Dataset*).

The group agreed that it is important for MOD to follow the approach of DCAT and distinguish between SA and SADistribution, thus *mod:SemanticArtefactDistribution* will extend *dcat:Distribution*.

The properties listed for *mod:SemanticArtefactDistribution* were analysed to make sure they make sense at the distribution level. The property *dcat:distribution* will be used, and there is no need for a *mod:distribution* property. Thus, Proposition 2 was accepted.

#### 7.2.1.3 What other classes (not in DCAT) can *mod:SemanticArtefact* specialise?

The discussion on this designed issue was captured online<sup>27</sup>

### Semantic Artefact Specialisation - Proposition 1

- SA specialises all the pre-existing semantic objects (e.g., *owl:Ontology*) as it was done in MOD1.4 with the object *mod:Ontology*. Then, all the properties of all the objects are available.

<sup>27</sup> Design issue #3: <https://github.com/FAIR-IMPACT/MOD/discussions/36>

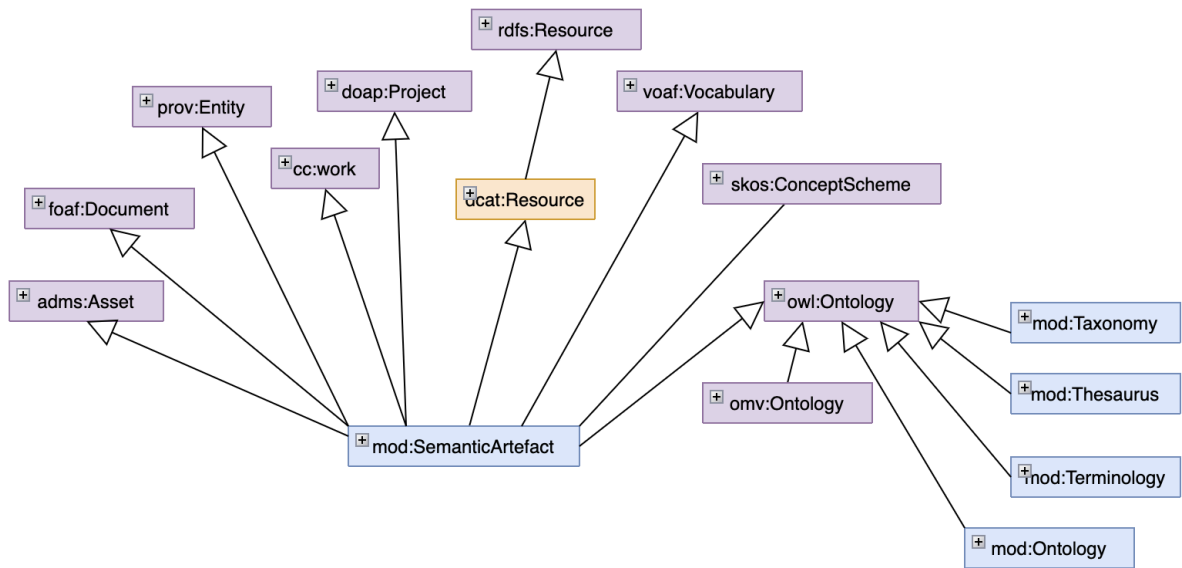


Diagram 4. Semantic Artefact Specialisation - Proposition 1

**Semantic Artefact Specialisation - Proposition 2**

- SA specialises even more pre-existing semantic objects but not the pre-existing ones that were representing a type of SA (*owl:Ontology*, *skos:ConceptScheme*, *voaf:Vocabulary*)

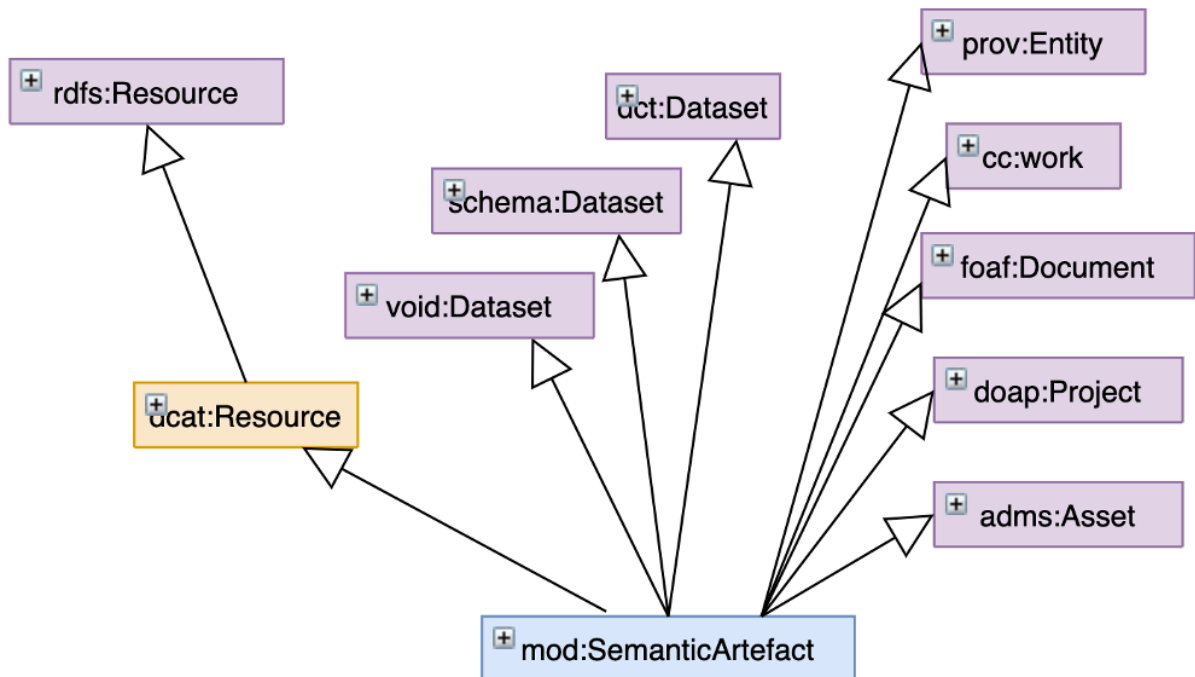


Diagram 5. Semantic Artefact Specialisation - Proposition 2



### Semantic Artefact Specialisation - Proposition 2-bis

- The same as proposition 2 but SA supersedes the pre-existing ones.

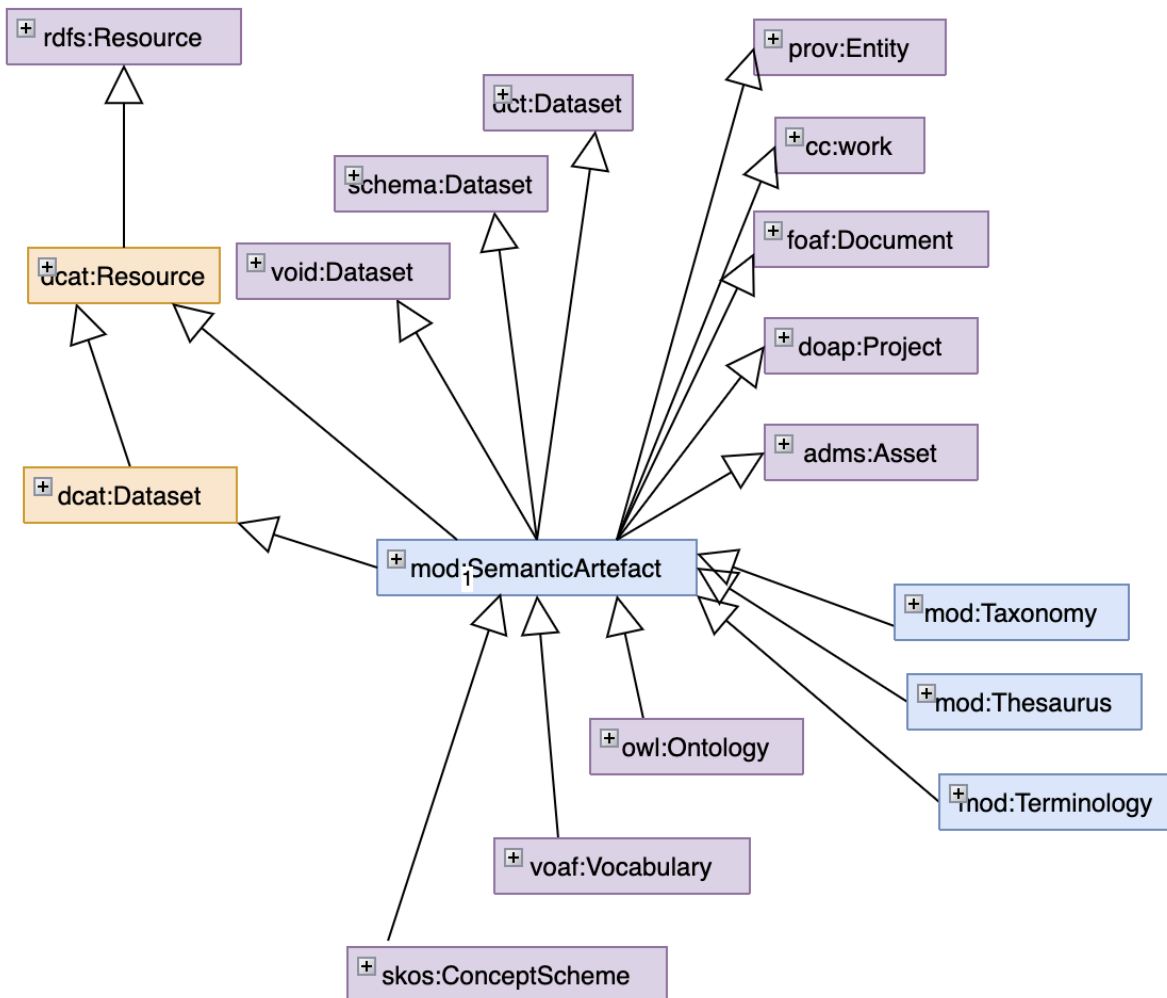


Diagram 6. Semantic Artefact Specialisation - Proposition 2-bis

The conclusion around this design issue considered:

- *mod:SemanticArtefact* must not specialise *owl:Ontology* or *rdfs:Resource*
- Any other specialisation, when considering other vocabularies, should be discussed as part of an MOD profile and/or MOD mappings with other vocabularies, rather than being part of MOD definitions.

### 7.2.2 Implementation

The new MOD version 3.0 was developed and hosted in the GitHub repository: <https://github.com/FAIR-IMPACT/MOD>

The pre-release for MOD version 3.0 is available at: <https://github.com/FAIR-IMPACT/MOD/releases/tag/v3.0>

It is available using the turtle format as default syntax, incorporating all the conclusions from the design issues discussion.

### 7.3 MOD Profiles

We adopted the definition of profiles by the Profiles Vocabulary [22], which refers to "A [data/application] specification that constrains, extends, combines, or provides guidance or explanation about the usage of other [data/application] specifications".

Here we consider MOD as a specification, "A basis for comparison; a reference point against which other things can be evaluated." [22], and we have defined a profile to demonstrate how to use the Open Geospatial Consortium (OGC) building blocks approach<sup>28,29</sup>.

The OGC building blocks approach has its foundation on the reusability of a set of requirements, so that they can be applicable to other contexts. The basic principles are<sup>30</sup>: i) a building block a standard or a part of a standard, ii) one or more building blocks can be integrated into new applications, iii) each building block represents a testable interface component.

To demonstrate this approach with profiles, we produced a FAIRsFAIR MOD profile, which is defined by considering the results in the vote organised within a FAIRsFAIR workshop for the endorsement level mandatory-recommended-optional for each property to describe a semantic artefact, as reported in [10]. The article refers to Consensus as:

*consensus = (0.333 + percentage of votes for the winning option (mandatory, recommended or optional) – sum of percentages of the non-winning options) / 1.333*

To create the FAIRsFAIR MOD profile<sup>31</sup>, we considered as required those properties that have consensus > 50%, for the mod:SemanticArtefact class, as no properties had consensus >50% for mod:SemanticArtefactDistribution.

For future work, we will continue to explore this approach, and look to implement other potential MOD profiles<sup>32</sup>, and explore ways to combine them. We will also explore the connection with previous work, such as the FAIRsFAIR SemanticDCAT-AP<sup>33</sup> work.

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<sup>28</sup> <https://blocks.ogc.org/>

<sup>29</sup> <https://github.com/opengeospatial/bblock-template>

<sup>30</sup> <https://blocks.ogc.org/>

<sup>31</sup> <https://github.com/FAIR-IMPACT/MOD-FAIRsFAIR-profile>

<sup>32</sup> <https://github.com/FAIR-IMPACT/MOD/discussions/56>

<sup>33</sup> <https://github.com/FAIRsFAIR/SemanticDCAT-AP/>

## 8 MOD Mappings

### 8.1 Introduction

Work has been undertaken to produce machine-readable mappings which will enable users to map ontology metadata properties from existing metadata vocabularies and standards to MOD (see more details in [Section 7](#)), formalising previous mappings that were part of previous versions of MOD and doing an additional analysis.

As part of previous work, a TTL description of MOD included more than 200 mappings from MOD properties to other properties. Note that in most of the cases, the property suggested by MOD is not declared within the MOD namespace, so the mappings are representing MOD point of view on which properties could be used to encode an information. See [Section 8.2](#) for a description of how these mappings were formalised.

For example, the *mod:status*, declared in the MOD namespace is proposed by MOD to encode the “The status of the current version of the ontology (alpha, beta, production, retired).” We identified 3 equivalent properties: *adms:status*, *idot:status* and *omv:status* respectively from the ADMS vocabulary, IDOT vocabulary and the historical OMV ontology. We thus have to represent 3 mappings each of them with a source property within the MOD namespace.

On the other hand, MOD suggests to use the *dcterms:creator* property to encode the “An entity primarily responsible for making the resource.” and does not declare any new property in the MOD namespace. We identified 7 equivalent properties: *doap:maintainer*, *foaf:maker*, *omv:hasCreator*, *pav:authoredBy*, *pav:createdBy*, *prov:wasAttributedTo* and *schema:author* from multiple various metadata vocabularies. We thus have to represent 7 mappings but none of them are with a source property in the MOD namespace. In other words, MOD proposes these mappings that we believe are relevant in the context of semantic artefact descriptions; but might not be relevant in any other context.

As part of M5.3, Daniel Garijo carried out an audit of ontology metadata [5]. Subsequently, as part of this work, over 600 properties were mapped to MOD [23]. See [Section 8.3](#) for more details on the analysis of ontology metadata and mappings.

Mappings from these two sources have been combined to produce a single set of mappings, which in turn has been converted into a machine-readable format, see [Section 8.4](#). These mappings were to MOD 2.0 terms, as MOD 3.0 was still under development. As part of the ongoing development, the mappings will be updated to point to MOD 3.0 terms.

### 8.2 Existing MOD Mappings

Previously, as part of MOD version 1.4 then 2.0, a turtle (TTL) file was created that included 200+ mappings.<sup>34</sup> In fact, counting the suggested 127 properties, and all the mappings MOD2 included 346 properties that a system could use to manage ontology metadata

<sup>34</sup> [https://github.com/FAIR-IMPACT/MOD/blob/main/mod-v2.0\\_profile.ttl](https://github.com/FAIR-IMPACT/MOD/blob/main/mod-v2.0_profile.ttl)

descriptions. This enabled, for instance, AgroPortal to recognize 346 properties in semantic artefact source files and map them to the metadata model based on the 127 MOD1.4 properties [21].

The mappings existing in the file (MOD ttl<sup>35</sup>) have been analysed and combined with the ontology metadata audit (see next section) and represented using a machine-readable representation of mappings (see Section 8.4).

### 8.3 Ontology Metadata Audit

As part of the methodology for FAIR semantic artefact assessment [5], a metadata landscape analysis was performed over 1961 unique OWL and RDFS ontologies and 587 SKOS vocabularies in order to determine common metadata practices across different semantic artefacts. This analysis extends the work done by [21] with 805 ontologies taken from different sources (AgroPortal, BioPortal, MMI ORR and miscellaneous online servers).

The analysis retrieved semantic artefacts from popular community catalogues and repositories: Linked Open Vocabularies (1495 ontology and vocabulary versions were found),<sup>36</sup> Archivo (1750),<sup>37</sup> BioPortal (976),<sup>38</sup> EcoPortal (23),<sup>39</sup> IndustryPortal (45),<sup>40</sup> and MedPortal (54).<sup>41</sup> Additional ontologies were found, and subsequently downloaded, by searching in w3id.org (687)<sup>42</sup> and OnToology (160).<sup>43</sup> Since many semantic artefacts were present in more than one registry (e.g., Archivo incorporates many LOV ontologies), the final set consisted of 2784 *files* (with their corresponding metadata). After removing artefacts with duplicate identifiers, the final number of semantic artefacts was reduced to **1961 OWL ontologies and 587 SKOS vocabularies** [5].

Next, we performed a metadata audit on the downloaded resources. We counted the number of occurrences of each metadata property per semantic artefact. For example, if an ontology defines three authors, the “author” property would only be counted once, in order to avoid over-representation. The results of this step resulted in a list of 622 unique properties, including properties with typos (e.g., misspelt) or referencing non-resolving vocabularies.

- All properties were manually aligned to MOD 2.0 by three different human annotators, linking all properties (when possible) to the existing MOD property (which itself included mappings to other properties, as explained in previous Section) [23]. Disagreements in the annotation process were resolved by iterating discussion until an agreement was reached. This human-readable mapping is available online:

<sup>35</sup> [https://raw.githubusercontent.com/FAIR-IMPACT/MOD/main/mod-v2.0\\_profile.ttl](https://raw.githubusercontent.com/FAIR-IMPACT/MOD/main/mod-v2.0_profile.ttl)

<sup>36</sup> <https://lov.linkeddata.es/dataset/lov/>

<sup>37</sup> <https://archivo.dbpedia.org>

<sup>38</sup> <https://bioportal.bioontology.org/>

<sup>39</sup> <https://ecportal.lifewatch.eu/>

<sup>40</sup> <http://industryportal.enit.fr/>

<sup>41</sup> <https://medportal.bmicc.cn/>

<sup>42</sup> <https://github.com/perma-id/w3id.org>

<sup>43</sup> <https://ontology.linkeddata.es/>

<https://github.com/FAIR-IMPACT/MOD-mappings> and was used to generate the SSSOM mappings described in Section 8.4.

## 8.4 Production of MOD mappings with SSSOM

The SSSOM<sup>44</sup> representation language and format has been recommended by FAIR-IMPACT T4.4 to represent the mappings.

“The Simple Standard for Sharing Ontology Mappings (SSSOM) [24] is an initiative to provide a minimal and standard set of elements for the dissemination of mappings between ontology terms, to ensure a reliable interpretation of generated mappings and to enable sharing and data integration between people and applications”<sup>45</sup>.

The main items of the data model are `subject_id`, `subject_label`, `predicate_id`, `object_id`, `object_label` and `mapping_justification`. In addition there are provenance fields for the individual mappings, `author_id`, `reviewer_id` and `mapping_provider`.

SSSOM has very few required fields and many optional fields. Only a limited number of the optional fields were used when producing the MOD mapping. One of the outputs of T4.4 will be a list of recommended fields that should be included in SSSOM mappings.

### 8.4.1 Mappings From the MOD *ttl*

The mappings from the MOD2.0 *ttl* file<sup>46</sup> were extracted and put into a spreadsheet. Because aligning multiple metadata vocabularies where properties are explicitly defined differently (`rdf:property`, `owl:AnnotationProperty`, `owl:DataProperty` or `owl:ObjectProperty`) with mixed domains and ranges, MOD authors decided to choose a semantically loose relationship to encode those “mappings”. Indeed, the initial relationship used was “`dcterms:relation`”. We have now decided to require a more specific relationship. Assigning new relationships was a manual process. The properties, on either side of the relationship, were resolved and any descriptions of the property terms read, before assigning a new relationship. The relationships used were taken from Simple Knowledge Organization System (SKOS):

- `skos:relatedMatch`
- `skos:closeMatch`
- `skos:exactMatch`
- `skos:narrowMatch`
- `skos:broadMatch`

There were 207 mappings extracted from the MOD2.0 *ttl* file. The relationships can be broken down as follows:

47 `skos:relatedMatch`  
 60 `skos:closeMatch`

<sup>44</sup> SSSOM: <https://mapping-commons.github.io/sssom/home/>

<sup>45</sup> SSSOM specification: <https://mapping-commons.github.io/sssom/spec/>

<sup>46</sup> [https://github.com/FAIR-IMPACT/MOD/blob/main/mod-v2.0\\_profile.ttl](https://github.com/FAIR-IMPACT/MOD/blob/main/mod-v2.0_profile.ttl)

89 skos:exactMatch  
 11 skos:narrowMatch

### 8.4.2 Mappings for the Ontology Audit

The output from the ontology audit included mappings of the properties identified in the source files to MOD 2.0 properties, although the relationship was not defined for the mappings. In this phase 255 mappings from the ontology metadata audit were added to the spreadsheet produced from the MOD *ttl* mappings ([Section 8.4.1](#)). From this 37 duplicates were removed. Where there were conflicts the mappings from the MOD 2 *ttl* were used. The relationships between the remaining properties were then assigned to one of the SKOS relationships listed above.

It should be noted that many of the metadata properties taken from the ontology source files had errors including URI's that did not resolve, properties not present in the ontologies or vocabularies. For a number of these it was easy to spot errors in their URI's, for example including “#” when it should not be there or using a property that is not even in the vocabulary, e.g., in Dublin Core we found “author”, rather than “creator”. For this phase we mapped properties where it was easy to determine what the property should have been. This still left over 200 terms that have not been mapped. By including erroneous properties in the mappings, we provide a means to use these erroneous properties.

We are showing 2 examples of incorrect URIs in use in ontology source files below. The first one has an incorrect namespace (including “#”), and the second one uses “author” instead of “creator”:

- <http://purl.org/dc/terms/#license>
- <http://purl.org/dc/terms/author>

### 8.4.3 Producing a SSSOM Mapping

The SSSOM cookie cutter<sup>47</sup> was used to set up a GitHub repository , MOD-mappings<sup>48</sup>, to host the mappings. This repository includes tools to generate a SSSOM file from a tsv file and validate the generated SSSOM file.

The workflow is as follows:

- Production of the mappings is done in a spreadsheet, we have used a Google Sheet.
- The data is exported as a *tsv* file, *mod\_mappings.tsv*, which is put in the *sources* directory in the *MOD-mappings* GitHub project. Also in this directory is the *YAML* file *mod\_mappings\_metadata.yml*, which contains the curie map.
- A new mappings file, *mappings/mod\_mappings.sssom.tsv*, is generated using “sh odk.sh make mappings”
- The new mappings file is then validated by running “sh odk.sh make test”

<sup>47</sup> <https://github.com/mapping-commons/mapping-commons-cookiecutter>

<sup>48</sup> <https://github.com/FAIR-IMPACT/MOD-mappings>

Included in the repository are Git Hooks to run the validation when a new mapping file is committed.

The outcome of this process is a validated SSSOM file that can be used by other applications.

#### **8.4.4. Future Mapping Work**

The main product of this milestone is a collection of mappings to MOD 2.0 terms. With the release of MOD 3.0 these mappings will be updated to use MOD 3.0 terms. In addition, we need to follow the outcomes of T4.4 in terms of the metadata that should be included with the SSSOM mapping.

## **9 Conclusions and next steps**

This milestone is about a specification for describing semantic artefacts based on the MOD vocabulary.

The main outcomes from this milestone are:

- i) specify a new version of the MOD vocabulary as an extension of the DCAT vocabulary by addressing outstanding design issues,
- ii) a clear identification between MOD elements and mappings to other vocabularies, by representing the mappings using the SSSOM standard,
- iii) present machine-actionable representations of MOD profiles.

For the next steps, we will continue to refine the MOD specification, and we will produce an Application Programming Interface for semantic artefact catalogues. This will be described in a deliverable extending this milestone.

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