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A Maturity Model towards FAIR Data in FAIR Enabling Repositories (D4.6)

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Disclaimer

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Abbreviations and Acronyms

CapMat	Capability and Maturity
DMP	Data Management Plan
EOSC	European Open Science Cloud
FAIR	Findable, Accessible, Interoperable, Reusable
LTDP	Long-Term Digital Preservation
RDA	Research Data Alliance
TDR	Trustworthy Digital Repository

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Executive Summary

The *CoreTrustSeal+FAIRenabling Capability Maturity (CapMat)* model aligns the CoreTrustSeal Requirements with the FAIR Data Principles, allowing repositories to self-assess their practice and associated evidence with a view to their development and improvement.

The FAIR Data Principles define the expectation that digital objects should be findable, accessible, interoperable and re-usable. Repositories provide the organisational context for enabling FAIR data. Trustworthy digital repositories (TDR), such as those certified to the CoreTrustSeal, offer long-term digital preservation services that can ensure digital assets remain FAIR over time. This text describes the alignment between the 15 FAIR Principles and the 16 CoreTrustSeal Requirements so that repositories can self assess their trustworthiness and FAIR enabling status together. The associated capability-maturity model measures the repository in terms of the policies and procedures used to deliver (meta)data services.

FAIR enabling trustworthy digital repositories are acknowledged as key nodes in the research data lifecycle and in networks of federated data infrastructures, including the European Open Science Cloud (EOSC). The community development of indicators, metrics and automated systems for assessing compliance with the FAIR Principles is ongoing and to date, no formal standard, process and governance structure is in place to certify FAIR objects or FAIR enabling repositories. The *CoreTrustSeal+FAIRenabling CapMat* self-assessment can be used immediately by repositories seeking to to identify current levels of capability and to plan for increased maturity. Applying this approach supports the readiness of a repository for formal CoreTrustSeal certification. Other types of data service can also use it to prepare for future assessments of FAIR enabling capability.

Development of the *CoreTrustSeal+FAIRenabling CapMat* model within FAIRsFAIR has benefited from a range of internal perspectives including policy administration, data services, repository support, registry developments, and guidance and testing for object FAIRness. Iterations of the model have been improved through engaged and informed public feedback.

This paper presents guidance for those applying the *CoreTrustSeal+FAIRenabling CapMat* model and provides detailed alignment of the CoreTrustSeal Requirements, FAIR Principles and Capability-Maturity levels. Concluding remarks reflect on the next steps for FAIRenabling TDRs, trustworthy data services and FAIR certification.

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Introduction

Repositories are acknowledged as vital nodes in the network of federated data infrastructures. Improvements in the provision of FAIR enabling trustworthy repository data services have immediate benefits for the full research lifecycle of research. A number of project outcomes and reports acknowledge that the process of achieving both *Trust* and *FAIR* may be likened to a journey[1]. This ongoing journey towards achieving FAIR digital objects in FAIR enabling TDRs is the key challenge to delivering a unified, formal certification standard and process. Ongoing improvement of (meta)data objects and the data services that care for them are necessary to meet these evolving expectations. There is a practical awareness that formal FAIR-related certification (of objects and/or data services) should not be a 'gatekeeper' to engagement with the European Open Science Cloud (EOSC[2]).

The content presented here can be applied immediately by repositories seeking to demonstrate their trustworthiness and FAIR enabling practice. It can also provide valuable insights to a wider range of data services, infrastructure providers, funding bodies and policy makers seeking to define, evaluate and reward FAIR enabling practice that ensure objects remain FAIR in the long term. Providing ongoing support to a range of data services, including repositories, will be the key to success.

This report presents the final outcomes of the task *Capability Maturity models towards FAIR Certification* (T4.1) of the *FAIR Certification* work package (WP4) of the FAIRsFAIR[3] project. The main body of the text provides the v01.00[4] release of the *CoreTrustSeal+FAIRenabling Capability-Maturity (CapMat)* model including guidance on implementation.

The work to date has benefited from a wide range of source materials[5], cooperative actions and periods of public feedback over three years. The FAIRsFAIR project plan was informed by the *Turning FAIR into Reality* report[6] which underlined the critical role of trustworthy digital

[1] E.g. Recommendations on certifying services required to enable FAIR within EOSC, Genova, F.(editor), Publications Office, 2021, https://data.europa.eu/doi/10.2777/127253

[2] https://eosc.eu/

[3] https://www.fairsfair.eu/

[4] See Appendix 1: *Change Log - CoreTrustSeal to FAIR & CapMat*.

[5] See Bibliography for a full list of relevant source materials

[6] TFiR: European Commission (2018) Turning FAIR into Reality: Final Report and Action Plan from the European Commission Expert Group on FAIR Data. https://doi.org/10.2777/1524

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repositories (TDR)[7] in ensuring the adoption and growth of the FAIR Data Principles[8]. Examples of TDRs include repositories certified to the CoreTrustSeal[9] Requirements[10]. The work undertaken to date has been facilitated by the FAIRsFAIR Synchronisation Force[11], which ensured an ongoing engagement with the wide range of EOSC and FAIR-related projects.

During this period the RDA FAIR Data Maturity Model Working Group[12] began work to define more specific indicators for the principles that data should be *findable*, *accessible*, *interoperable* and *reusable*. Their final report[13] provides these indicators to enable the development of assessable metrics against which testing systems can be developed. One such system is the F-UJI tool[14] which was developed as part of FAIRsFAIR Task 4.5[15]. Work on these indicators, metrics and tests demonstrated that the evaluation of digital objects for FAIRness is dependent on an understanding of their environmental context (e.g. the repository or other data service(s) that care for them). The FAIRsFAIR work to align the CoreTrustSeal Requirements with the FAIR Principles uses the term 'FAIR enabling' for the steps taken by repositories to ensure digital objects become and remain FAIR. The critical function of a TDR, in addition to those provided by other types of data services, is the provision of long-term digital preservation (LTDP) for a designated community[16] of users. A TDR ensures technical continuity through file format migration or emulation, and maintains data and metadata so that it remains understandable to their defined community of users[17]. Together these steps ensure data and metadata remain FAIR over time.

---

[7] Specifically TFiR Recommendations: Rec. 9: Develop assessment frameworks to certify FAIR services, Rec. 13: Develop metrics to certify FAIR services, Rec. 20: Deposit in Trusted Digital Repositories.

[8] The FAIR Guiding Principles for scientific data management and stewardship https://doi.org/10.1038/sdata.2016.18

[9] https://www.coretrustseal.org

[10] CoreTrustSeal Trustworthy Data Repositories Requirements: Extended Guidance 2020–2022 https://doi.org/10.5281/zenodo.3632533

[11] https://www.fairsfair.eu/advisory-board/synchronisation-force/

[12] https://www.rd-alliance.org/groups/fair-data-maturity-model-wg

[13] FAIR Data Maturity Model Working Group (2020): *FAIR Data Maturity Model. Specification and Guidelines*. https://doi.org/10.15497/rda00050

[14] https://www.fairsfair.eu/f-uji-automated-fair-data-assessment-tool

[15] *D4.5 Report on FAIR Data Assessment Toolset and Badging Scheme* https://doi.org/10.5281/zenodo.5336159

[16] 'Designated Community' as defined by the *OAIS Reference Model* https://public.ccsds.org/Pubs/650x0m2.pdf and adopted by the *CoreTrustSeal Glossary* https://doi.org/10.5281/zenodo.3632563

[17] Explored in depth in the *FAIR+Time: Preservation for a Designated Community* Paperhttps://doi.org/10.5281/zenodo.5797776

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Continuing evolution of FAIR indicators, metrics and tests[18] is required to reach a number of goals, including clear definitions for disciplinary FAIR practice, and the machine-actionable evaluation of FAIR digital objects' and/or FAIR enabling status of repositories. Some of these developments will be directly addressed through ongoing standards development and assessment processes for digital objects[19]. The CoreTrustSeal Requirements are subject to periodic community revision during 2022. Other developments will depend on progress being made in defining the wider interactions[20] between the digital objects, software, services and people that characterise the full research data lifecycle. Progress has already been made on addressing the characteristics that data services, beyond those of digital repositories, should display[21].

In the context of evolving standards, digital objects and repository practice, it is critically important that repositories are able to self-assess their current capabilities and overall maturity status as part of planning a journey towards improvement. Capability-maturity models[22], such as CMMI[23], help organisations monitor their current status and plan for future progress in different 'areas of focus'. The project has used the FAIR Principles, aligned with the CoreTrustSeal Requirements as the areas of focus for assessing capability-maturity (See diagram 3 below)[24]. Repositories self-assess their capability for each area at one of 5 levels: initial, managed, defined, quantitatively managed, and optimising. A capability at level **2. managed** for each requirement is proposed as the minimum expectation for CoreTrustSeal compliance. Once a repository is achieving 'defined' (level 3) levels of capability across the requirements, it becomes more meaningful to refer to overall organisational maturity. 'Defined' implies that policy and practice are integrated and maintained across the wider organisation; from here the repository can focus on 'quantitative management' (data-driven

[18] Further explored by the FAIRsFAIR project team in *FAIR Principles: Baseline Comments* https://doi.org/10.5281/zenodo.3728130
[19] Examined by FAIRsFAIR in *D4.5 Report on FAIR Data Assessment Toolset and Badging Scheme* https://doi.org/10.5281/zenodo.5336159
[20] Further explored by the FAIRsFAIR Project Team in *FAIR Ecosystem Components: Vision* https://doi.org/10.5281/zenodo.3734273
[21] Addressed by the FAIRsFAIR Work Package 2 team in *D2.7 Framework for assessing FAIR Services* https://doi.org/10.5281/zenodo.5336233
[22] For an overview of current repository Capability-Maturity models, see CoreTrustSeal+FAIR Landscape of Capability Maturity Modeling - A FAIRsFAIR Discussion Paper https://doi.org/10.5281/zenodo.3862587
[23] Capability Maturity Model Integration (CMMI) Levels of Capability and Performance, https://cmmiinstitute.com/learning/appraisals/levels
[24] Explored in detail by Evaluation of Current CoreTrustSeal Guidelines and Extended Guidance to Consider their Implications for Maturity Modelling (FAIRsFAIR M4.1) https://doi.org/10.5281/zenodo.3735030

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measurements and controls) and may progress to 'optimising' for continuous improvement. The capability-maturity levels and associated community engagement tiers (used for Requirement 06: Expert Guidance) were the result of an initial FAIRsFAIR design[25]and engagement with Science Europe work on maturity matrices[26]

Many elements of the CoreTrustSeal, across organisational infrastructure, digital object management and technology/security, are essential to FAIR enabling and there are multiple possible alignments between the CTS Requirements and FAIR Principles. The *CoreTrustSeal+FAIRenabling CapMat* provides a single *Requirement*-to-*Principle* mapping with the explicit intention of assisting repositories in assessing their current FAIR enabling status, alongside their overall TDR capability-maturity. This crosswalk aligns with the CoreTrustSeal review process that seeks clear and honest self-assessment statements supported by links to (ideally public) evidence.

The capability levels for each united 'area of focus' (Requirements and mapped Principles) focus on the repository ability to demonstrate compliant practice and supporting evidence.

The *CoreTrustSeal+FAIRenabling CapMat* approach has benefited from multiple iterations[27] of public feedback from the wider repository community, from the FAIRsFAIR supported repositories[28] and through repository support carried out on other EOSC projects[29, 30]. The CoreTrustSeal Board has publicly expressed their support[31], though any changes to the CoreTrustSeal standard and process are dependent on their periodic community revision of requirements .

CoreTrustSeal+FAIRenabling CapMat is immediately applicable to repositories seeking to be both trustworthy and FAIR enabling. The main content of this document presents the CoreTrustSeal Requirements to FAIR Principles alignment and their associated capability maturity levels, preceded by implementation guidance. This is followed by some concluding thoughts on the current and future status of the work, including sustainability and ongoing

[25] Capability Maturity & Community Engagement Design Statement https://doi.org/10.5281/zenodo.4705235
[26] https://scienceeurope.org/our-resources/practical-guide-to-sustainable-research-data/
[27] See Appendix 1 for a Change Log
[28] https://www.fairsfair.eu/application-results-open-call-data-repositories
[29] SSHOC D8.2 Certification plan for SSHOC repositories, https://doi.org/10.5281/zenodo.4558303
[30] EOSC-Nordic D4.1 An assessment of FAIR-uptake among regional digital repositories https://doi.org/10.5281/zenodo.4045402
[31] https://www.coretrustseal.org/why-certification/coretrustsealfair-statement-of-cooperation-support/

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change management. Appendices provide a change log of the steps taken to reach this point and a supporting bibliography.

CoreTrustSeal+FAIRenabling Capability Maturity

Implementation Guide

To ensure that the value of digital assets is maintained, it is desirable that trustworthy digital repositories (TDRs) enable the deposit, curation and preservation of data that is FAIR for the long term. The CoreTrustSeal provides our reference for TDR standards:

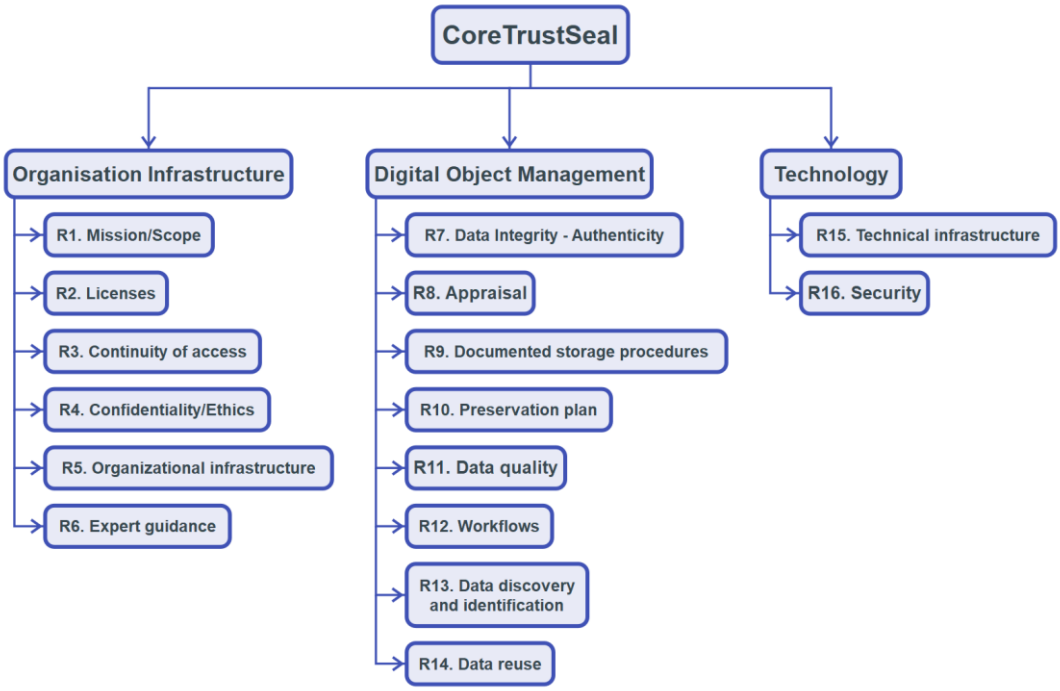

Diagram 1: CoreTrustSeal Requirements

The primary reference for CoreTrustSeal is the Extended Guidance[32] document (currently at version 2.0), this should be used alongside the CoreTrustSeal Glossary[33].

All of the CoreTrustSeal Requirements are necessary to achieve TDR status. Though many of the CoreTrustSeal Requirements contribute to enabling FAIR data, each FAIR Principle is

[32] https://doi.org/10.5281/zenodo.3632533

[33] https://doi.org/10.5281/zenodo.3632563

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aligned with a single CoreTrustSeal Requirement to streamline the preparation of self-assessment statements and supporting evidence.

Diagram 2 below presents mappings from the FAIR Principles to the CoreTrustSeal Requirements. A diagram presenting the converse CoreTrustSeal to FAIR mapping is included in Appendix 2 and parts of that diagram are presented under the subsections *Organisational Infrastructure*, *Digital Object Management* and *Technology* below. Together these provide all the context necessary for a repository to self-assess as a CoreTrustSeal TDR that enables FAIR data.

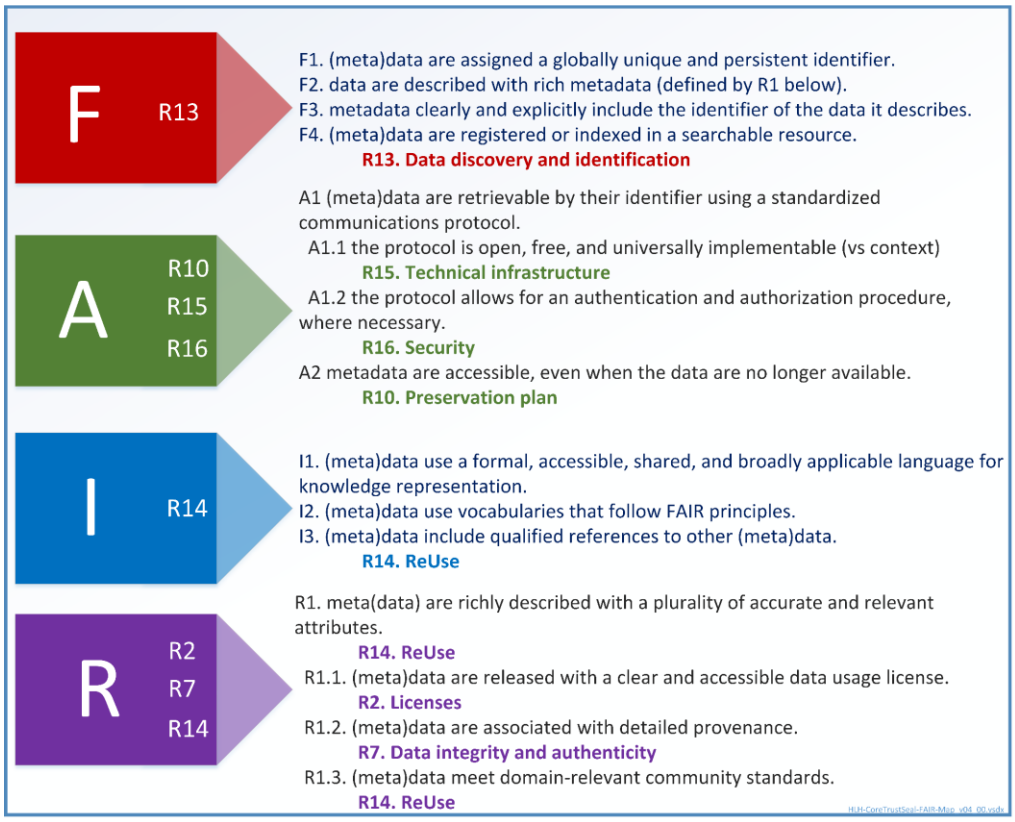

Diagram 2: FAIR Principles to CoreTrustSeal Alignment v1.0

The capability maturity levels provided allow repositories to assess their current status and to plan for, and monitor progress towards, being FAIR enabling TDRs.

Demonstrating compliance with standards depends on a framework of policies, procedures and other business information[34] in different areas of focus[35]. The first three levels of the

[34] See Appendix: Capability-Maturity & Policy-Evidence Frameworks.

[35] See explanatory diagram in Appendix: Capability-Maturity & Policy-Evidence Frameworks

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CoreTrustSeal+FAIRenabling CapMat are built around the preparation and implementation of appropriate evidence as follows[36]:

1. Initial	**Aware** of the scope and issue within the area of focus (Requirement/Principle). Lists of all items relevant to the area of focus exist.
2. Managed	Processes, procedures and other implementation measures are **in place** for all items on the lists.
3. Defined	Managed areas of focus (Requirement/Principle) are further **integrated** and **maintained** at the wider organisational level (policy and practice).

The authors recommendation[37] is that a capability level of **2. Managed** across all Requirements should be sufficient to demonstrate CoreTrustSeal compliance and FAIR enabling. Neither the CoreTrustSeal, nor the FAIR Principles specify a need for evidence of practice to be integrated and maintained at the wider organisational level (**3. Defined**). Note that CoreTrustSeal always prefers publicly available evidence to support self-assessment statements. Evidence may be made public at any level of capability-maturity, but we would suggest that assigning a **3. Defined** level should depend on making appropriately managed documentation (evidence) publicly available. Once compliance with Requirements/Principles reaches a capability level of **3. Defined** it becomes more meaningful to talk about the overall maturity of an organisation or service. Further progress can be made by achieving level **4. Quantitatively Managed** or **5. Optimising**.

[36] See Appendix: Capability-Maturity and Community Engagement Descriptions, for formal definitions.

[37] NB: feedback on this point will be sought through the CoreTrustSeal Board

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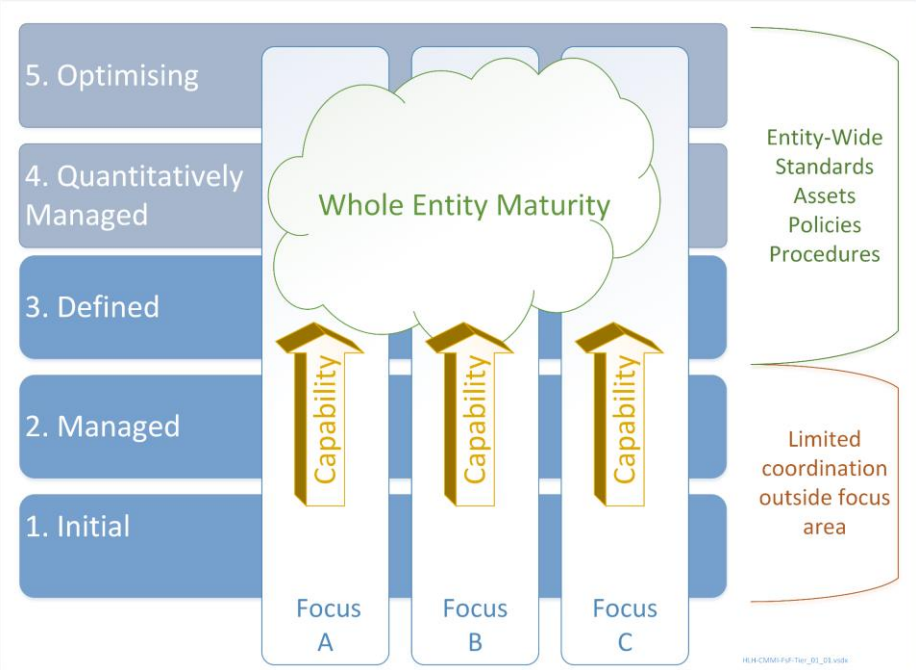

Diagram 3: How *capability* within areas of focus can combine into overall *maturity*

Self-Assessment at Levels *4. Quantitatively Managed* and *5. Optimising*

Once repositories reach level **2. Defined** practice across the Requirements and Principles they may choose to seek higher levels of capability and maturity in one or more areas of focus. The details of reaching and maintaining these more challenging levels will differ between repositories, but there are some generally applicable considerations and some specific issues related to CoreTrustSeal Requirements.

Some methodology for 'counting' performance (level **4. Quantitatively Managed**) is a dependency if repositories want to periodically review their progress with a view to reaching level **5. Optimising**. Risks to data services and the digital objects they care for are of course minimised with continuous improvement (**5. Optimising**) but quantitative management has an administrative overhead and repositories may choose to prioritise the areas they want to measure and optimise. In the context of FAIR and CoreTrustSeal, some areas of continuous improvement will be delivered through regular reviews, identification of community needs and timely updates to new standards.

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For a mission statement (R1) to be level **4. Quantitatively Managed** it would need to be linked to functions and activities that ensure it is delivered to defined levels e.g. KPIs (Key Performance Indicators). These would permit level **5. Optimising**.

Quantitative management and optimisation for R2. Licences would be more practical if rights were described using a structured or machine-actionable standard (e.g. Open Digital Rights Language-ODRL[38]).

Quantitative management of organisational infrastructure (R5) would equate to monitoring of both time and costs against repository functions with metrics (e.g. KPIs) in place. **5. Optimising** would involve the continuous improvement of governance processes and resource management to maximise service levels and minimise costs.

Preservation planning (R10) is a wide topic that has dependencies in many other CoreTrustSeal Requirements. For this reason the proposed capability-maturity levels focus on preservation *actions*. The fact that preservation is the central focus of repository data services could suggest that 'defined' should be the minimum level necessary for CoreTrustSeal, though some repositories, particularly those that are hosted by larger organisations may find it hard to deliver preservation planning that is fully integrated with their wider organisational practice.

Ideally preservation planning would be both quantitatively managed (prioritisation based on quantified demand from the community and quantified risk from technology watch) and optimising (continuous improvement and agile responses to opportunity and the need for change).

But reaching this ideal of digital preservation partially depends on wider community agreement about minimum standards, and is likely to require targeted investment in repositories as part of research infrastructure uplift.

Similarly, quality (R11) is a challenging concept to define and apply without further context[39] and community consensus. Quality and quality assurance depend on the selection or development of appropriate standards (implied across CoreTrustSeal) and workflows (R12) to curate for, and check for expected levels of quality. **4. Quantitatively Managed** depends on an agreed scale and evaluation process for quality. **5. Optimising** depends on an active strategy to increase quality over time.

[38] https://www.w3.org/TR/odrl-model/
[39] e.g. Bruce & Hillman (2004 The Continuum of Metadata Quality: Defining, Expressing, Exploiting

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Repositories seeking to achieve higher levels of capability-maturity should apply their local contexts to the evaluation and contribute to wider community discussion about how a TDR should be quantitatively managed and optimising.

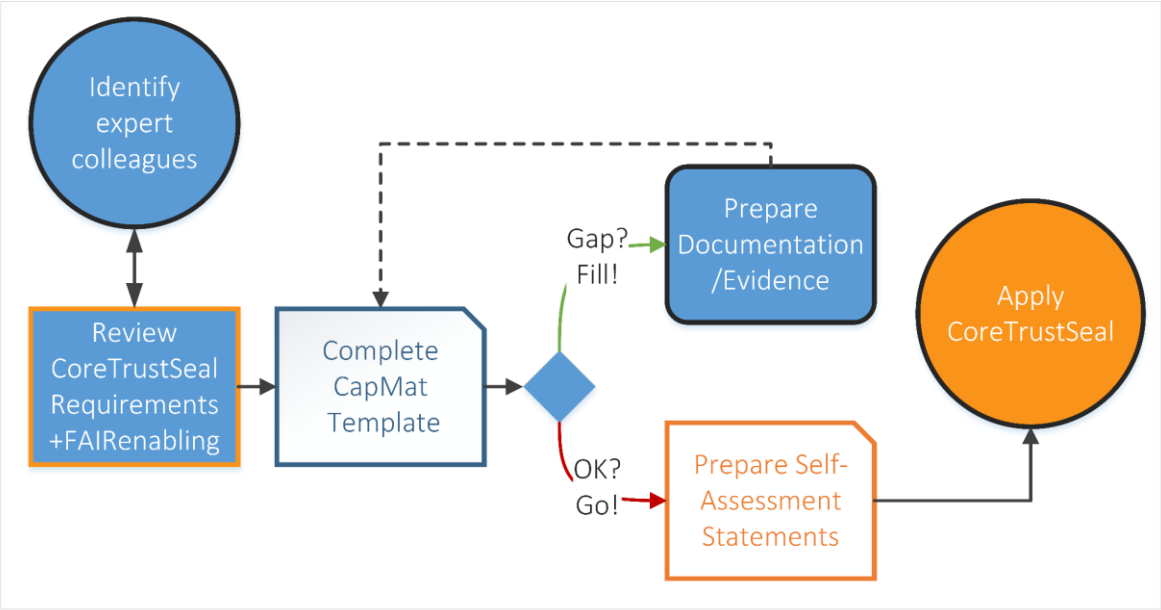
Capturing an Initial Self-Assessment of Capability-Maturity

Though CoreTrustSeal applications require completion of prose evidence statements with links to supporting evidence, an initial self-assessment of *CoreTrustSeal+FAIRenabling CapMat* should be completed in tabular form. This document is accompanied by a *FAIR enabling TDR CapMat Self-Assessment template*[40] using the following structure.

CoreTrustSeal Requirement	FAIR Principle	Evidence Links	CapMat Assessment Level	CapMat Target	Notes
R01					
etc.					

Figure 1: Example of *CoreTrustSeal+FAIRenabling CapMat* Self-Assessment Template

It is suggested that repositories approach the completion of this template by following the workflow below:



[40] FAIR-Enabling-TD-Repositories-CapMat-SelfAssess-Template https://doi.org/10.5281/zenodo.6090389

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Diagram 4: Suggested Capability-Maturity Self-Assessment Workflow

- Identify expert colleagues and review the CoreTrustSeal Requirements and the +FAIRenabling alignment (below). You may choose to add additional team members including digital object managers, organisational administrators, and technical and security staff[41].
- Complete a first version of the template, assigning a CapMat level to each Requirement/Principle, and adding links to available documentation (internal or public) that could provide evidence.
    - R06 Expert Guidance assigns an additional level for *Community Engagement*.
- If evidence is not available, or sufficient, consider what CapMat level you wish to achieve and define the actions and timeframes. This could include policies to be defined, procedures to be documented, or internal documentation to be prepared for public access.
    - Once actions are complete, repeat the CapMat assessment for the Requirement and evaluate your progress.
- As CapMat levels reach the agreed target, begin to prepare self-assessment statements and evidence links for the CoreTrustSeal application.

Not all repositories will meet the required thresholds for compliance the first time they self-assess and self-assessment should be repeated after taking corrective action.

There is not yet a formal certification to confirm a TDR as FAIR enabling. By applying the *CoreTrustSeal+FAIRenabling CapMat* approach a repository can evaluate its current status, plan for improvement and monitor progress towards a CoreTrustSeal application and the enabling of the FAIR data principles in a single process. This has direct benefits for service delivery and therefore to data depositors, users and funders, whether or not a repository chooses to progress to certification as a TDR.

[41] To identify relevant stakeholders, you can use the FAIRsFAIR material (incl. Stakeholder mind map) created to help planning for CoreTrustSeal certification: Herterich, Patricia. (2020). FAIRsFAIR support towards achieving CoreTrustSeal certification - roadmapping exercise. Zenodo. https://doi.org/10.5281/zenodo.3741693

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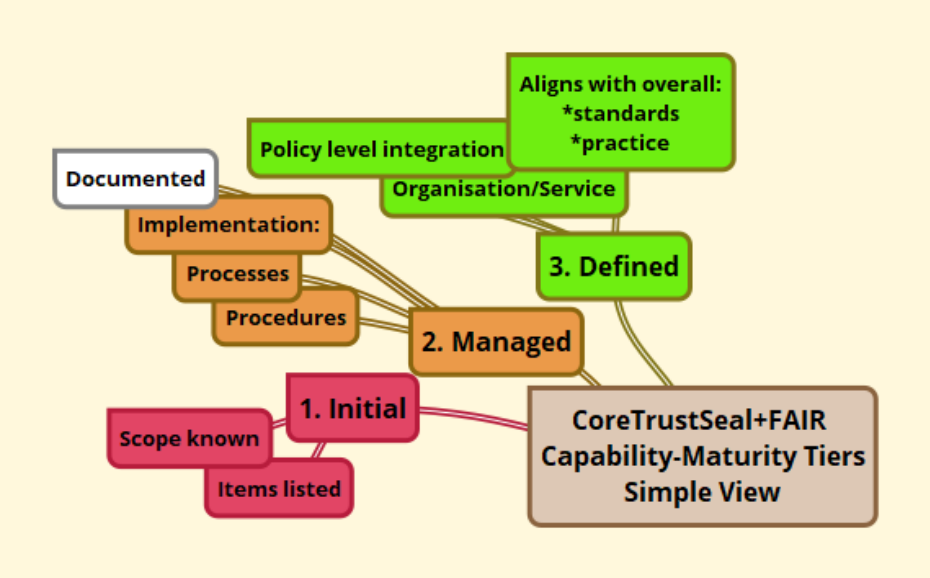

Diagram 5: *CoreTrustSeal+FAIRenabling CapMat*: 3 Level Simple View

Subject to approval by the CoreTrustSeal board, the authors recommend that a capability level of **2. Managed** across all Requirements and Principles should be sufficient to demonstrate CoreTrustSeal compliance and FAIR enabling. Levels of 3 and above are highly desirable, but not all repository data services are in a position to influence integration of practice at the policy level. See diagram 6 below and Appendix 2 for levels 4-5.

Once compliance with Requirements/Principles reach capability levels of **3. Defined** it becomes more meaningful to talk about the overall maturity of an organisation or service. Some repositories will seek to continuously improve beyond the targets set by the CoreTrustSeal Requirements and FAIR Principles. Further progress can be made by achieving level **4. Quantitatively managed** or **5. Optimising**.

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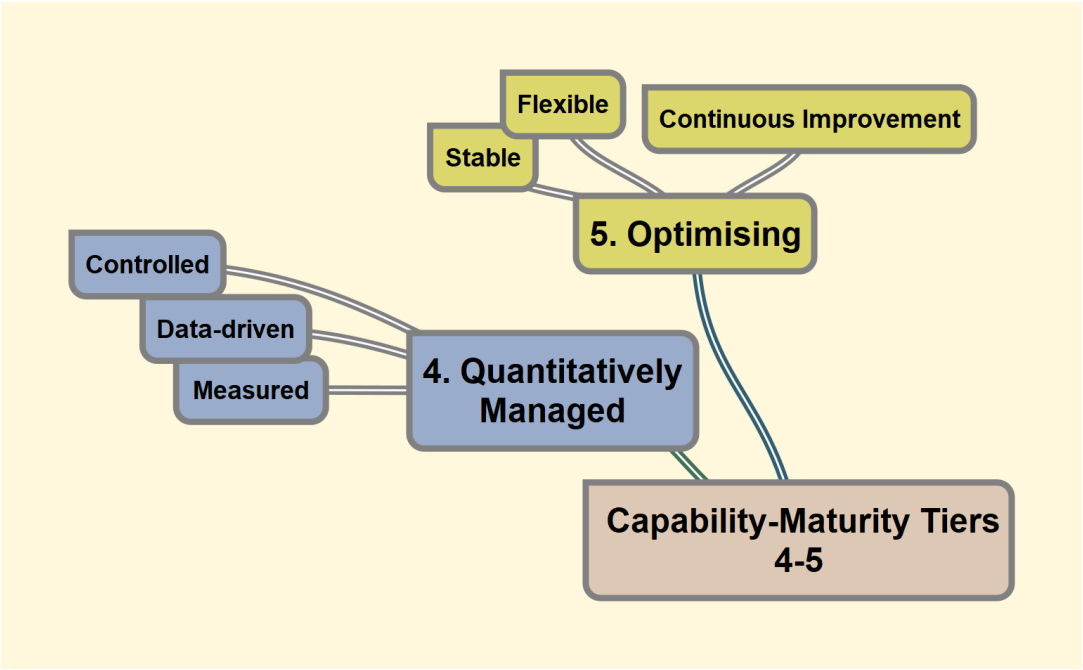

Diagram 6: *CoreTrustSeal+FAIRenabling*. Levels 4 and 5

CoreTrustSeal Requirement R6. on Expert Guidance incorporates factors related to community engagement[42], so an additional three level self-assessment is also proposed for this dimension of repository practice.

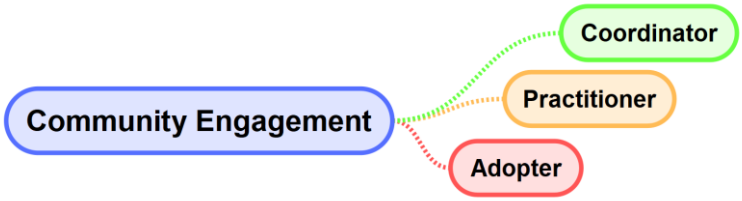

Diagram 7: Levels of Community Engagement (simple)

Further details are presented under R6, with formal definitions included in Appendix 2.

[42] See Appendix: Capability-Maturity and Community Engagement Descriptions, for formal definitions.

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The subsections below are presented in the sequence of the CoreTrustSeal Requirements (see diagram 1 above) and structured as follows:

Rnn CoreTrustSeal Requirement ID and Short Name

Rnn. CoreTrustSeal Requirement Identifier and full text.

1. Initial	Guidance on reaching an *Initial* level of capability.
2. Managed	Guidance on reaching a *Managed* level of capability.
3. Defined	Guidance in reaching a *Defined* level of capability.

Principle: 'Number and text of the FAIR Principle' if there is a CoreTrustSeal to FAIR mapping.

+FAIRenabling: Comments and suggestions on how a repository may seek to extend its CoreTrustSeal-compliant practice to be explicitly FAIR enabling.

Figure 2: Example of Requirement and Capability Maturity Level Layout in the Proceeding Sections

Organisational Infrastructure

Diagram 8: CoreTrustSeal Organisational Infrastructure to FAIR Principle Mapping

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R01. Mission/Scope

R01. The repository has an explicit mission to provide access to and preserve data in its domain.

The key concepts for a data service mission statement might include: *designated community*, *deposit*, *store*, *curate*, *preserve*, *access* and *reuse*.

1. Initial	Self-assessment statements and evidence reference the key concepts and demonstrate that they are important to the applicant.
2. Managed	A mission statement is in place incorporating locally relevant key concepts.
3. Defined	A formal mission statement exists as part of a policy framework that ensures it is aligned across repository practice. It is clear who approves the mission statement and how it is reviewed and revised over time.

R02. Licenses

R02. The repository maintains all applicable licenses covering data access and use and monitors compliance.

1. Initial	Every digital object being curated is known and recorded. The repository is aware that a rights statement is required for each, potentially with different rights applying to different parts of the data and metadata.
2. Managed	Every digital object, and relevant part of a digital object, has clear rights associated with it; defining permissions, prohibitions and duties of depositors, repository and end users. These rights permit the repository to store, curate, preserve and provide access to the digital objects for the defined period of responsibility (including 'indefinite') whether or not the original depositor or other rights holders remain available.
3. Defined	Rights management is integrated with the wider policy and practice framework and is managed in line with internal and external changes that impact rights.

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Principle: 'R1.1. (meta)data are released with a clear and accessible data usage license'.

+FAIRenabling: digital object metadata includes license information covering (meta)data reuse.

R03. Continuity of Access

R03. The repository has a continuity plan to ensure ongoing access to and preservation of its holdings.

1. Initial	Every digital object being curated, and every function that delivers the service around those objects is understood. The level of curation and level of service required to maintain these over time is known.
2. Managed	Policies and procedures are in place for each function. These go beyond the day to day process definitions (R12). For R03 they consider how the impact of a disaster can be mitigated, minimised and recovered from. This level would permit a succession plan to be *developed* for handover of digital objects and related functions in the event that the repository ceased to function.
3. Defined	Business continuity and disaster recovery measures are integrated across the whole organisation. This level of capability is necessary for the successful *implementation* of a succession plan.

Succession Plans: Depending on local circumstances (host organisations, rights and other issues) developing a succession plan covering all repository functions that is formally agreed with a successor organisation[43] may not be possible. Repositories that reach a level of **3. Defined** are in the best position to address the issue of succession if it becomes necessary (e.g. cessation of funding).

R04. Confidentiality/Ethics

R04. The repository ensures, to the extent possible, that data are created, curated, accessed, and used in compliance with disciplinary and ethical norms.

[43]Necessary to reach the CoreTrustSeal Compliance Level 4. 'fully implemented'

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1. Initial	Repositories know all the relevant legislation and ethical policies and practises that apply to the functions they offer and their digital objects.
2. Managed	The characteristics of each digital object (e.g. contains sensitive data, access restricted to a geographic area) are associated with relevant legal and ethical standards. Functions applied to those objects meet those legal and ethical standards.
3. Defined	Legal and ethical practice is integrated into a whole-organisation policy and procedural framework.

R05. Organisational Infrastructure

R05. The repository has adequate funding and sufficient numbers of qualified staff managed through a clear system of governance to effectively carry out the mission.

1. Initial	The applicant is clear on what *they* are responsible for, when responsibility is with a host organisation (if present) and when responsibility is shared with a third party (NB: this is the minimum necessary for a clear 'insource/outsource' statement in R0. Context). Staff names, job titles and role descriptions are in place. Departmental names and function descriptions are in place. Projects and groups are listed and their purposes and intended outcomes are known. Individual, departmental, project and group costs and budgets are known.
2. Managed	Any hierarchies and decision making workflows are documented. Organisational structure descriptions or diagrams exist. Human and financial resources are managed in line with relevant workloads and funding availability. Funding is sustainable and sufficient.
3. Defined	Governance and resources are managed across organisational policy and practice. Cross-sectional alignment is in place across repository data curation and preservation, governance, technology and security.

R06. Expert Guidance

R06. The repository adopts mechanism(s) to secure ongoing expert guidance and feedback (either in-house, or external, including scientific guidance, if relevant).

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This Requirement contains two areas for evaluation:

- That the expertise needed is understood and is sought externally (Capability Level)
- That the repository engages with the wider community in relevant areas of practice (Community Engagement tiers: adopter, practitioner, coordinator)

Levels of Internal and External Expertise

1. Initial	The repository has listed the knowledge, skills and expertise related to their (meta)data and functions. This includes technical infrastructure to the degree implied by the scope of R15.
2. Managed	The organisation monitors and maintains processes and procedures, ensuring the appropriate internal knowledge skills and expertise remain available to deliver them. Defined relationships with external service or information providers are in place to provide relevant guidance and expertise.
3. Defined	Alignment of objects and functions with internal and external expertise is integrated into the wider organisational policy and practice. These include managed feedback from the designated community that is explicitly met with responses that address their evolving needs.

Levels of Community Engagement

Adopter	For each area of expertise, define how the repository **monitors** community **practice** and **integrates** it into local practice.
Practitioner	In addition to adoption, the repository also engages with the **design**, **development**, and **review** of community practice. Consults and collaborates widely.
Coordinator	The repository is an adopter and practitioner that also takes a **community** coordination and **leadership** role. Driving **maintenance** and updates of existing practice and identifying **next steps** for the development of policy and implementation standards. Actively **communicating** and **promoting** existing and emerging approaches to the immediately impacted communities and the wider data infrastructure landscape.

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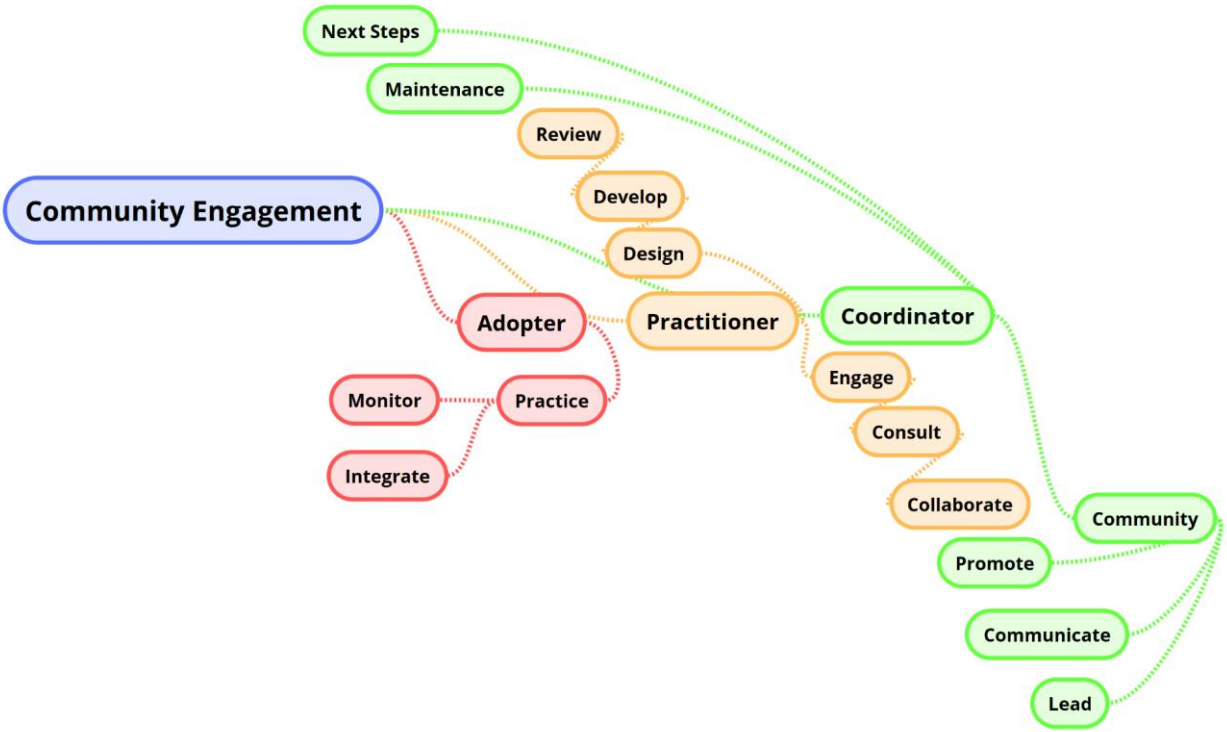

Diagram 9: Community Engagement Tiers

Repositories should seek to progress through adopter, practitioner and coordinator status in areas they prioritise and where they have appropriate expertise. 'Adopter' should be the minimum target for a CoreTrustSeal applicant. Increased community engagement increases confidence in the repository's overall CoreTrustSeal and FAIR enabling practice. These levels have been developed from the basis of the three community engagement levels provided in *Appendix: Capability-Maturity and Community Engagement Descriptions*. Key words in the diagram are from the Levels of Community Engagement above.

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Digital Object Management

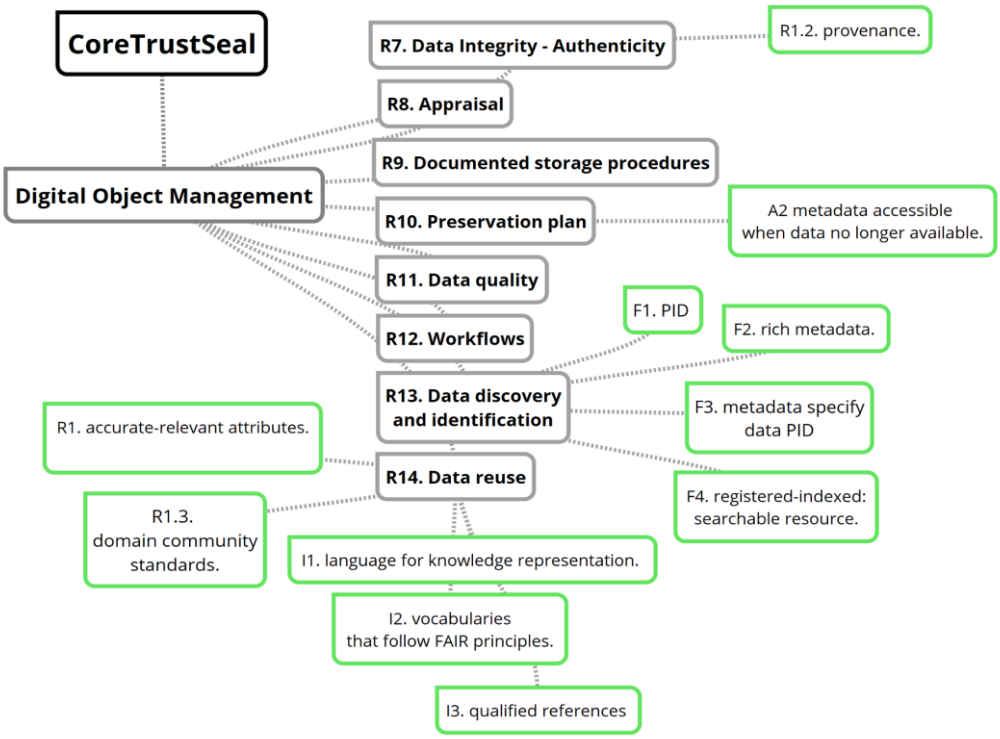

Diagram 10: Digital Object Management Requirements to FAIR Principles

R07. Integrity and Authenticity

R07. The repository guarantees the integrity and authenticity of the data.

Though presented together in *CoreTrustSeal v2.0* the concepts of integrity and authenticity are sufficiently distinct to require separate capability-maturity levels.

Integrity

1. Initial	Objects are subject to integrity checks at the point of deposit, transfer to archival storage and transfer to access. Stored objects are subject to periodic integrity checks.
2. Managed	Integrity measures are aligned with processes and procedures. Any functions where change is not specifically permitted are supported by assurance that unintended change is avoided.

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3. Defined	Integrity measures are part of an overall policy and procedural framework that defines which actors and agents are responsible for ensuring integrity and this is assured through governance and technical measures.

Authenticity

1. Initial	The minimum level of pre-repository digital object provenance that is required by the designated community is available (cf: R08 Appraisal). Permitted and required changes to the object made during repository custody are listed.
2. Managed	Changes made to objects, whether originals or copies, follow documented processes, and changes are recorded. A documented version system is in place. Relevant information is made available to end users. This depends on a rights framework being in place (R2) and actors and their roles being known (R05).
3. Defined	All changes are part of an overall policy and procedural framework that is enforced through governance and technical measures. Actions and outcomes are recorded at a clearly defined level of granularity.

Principle: 'R1.2. (meta)data are associated with detailed provenance'

+FAIRenabling: Applicant confirms that metadata includes provenance information about data creation and curation in line with the needs of the designated community. The FAIR Principles do not make specific reference to integrity, but requiring valid provenance implies that unintended changes should be avoided.

R08. Appraisal

R08. The repository accepts data and metadata based on defined criteria to ensure relevance and understandability for data users.

1. Initial	The minimal, acceptable and ideal characteristics of digital objects to be accepted into the repository are known.

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2. Managed	A selection and appraisal process is in place that checks each digital object that is considered for deposit. Preferred and acceptable file format lists and metadata standards/schemas exist. Minimum metadata and documentation at the point of deposit are defined. Any objects that fail to meet the acceptance criteria are rejected, or the reasons for exceptions are documented.
3. Defined	Appraisal and selection processes at the point of deposit are integrated into wider organisational policy and practice. Data management plans (DMP) are integrated at the point of deposit and appraisal outcomes feed into curation and preservation plans.

R09. Storage

R09. The repository applies documented processes and procedures in managing archival storage of the data.

1. Initial	Storage locations and media for all digital objects are known through deposit, curation, archival storage, discovery and access (and re-use if mediated by the repository). All storage locations form part of a backup system with at least two copies in separate locations. Backup frequency is known for each location.
2. Managed	All storage media management follows processes, procedures and other implementation measures including management as part of overall information technology infrastructure and technical watch (R15). Storage media are monitored for capacity and failure and are subject to a periodic media refreshment plan. Storage media types are assessed for obsolescence.
3. Defined	Storage is integrated into an overall technical infrastructure management plan which is in turn integrated into the wider organisational policy and practice. Storage locations are assessed for disaster threats. Storage media types, location risks, numbers of copies and backup periodicity all meet a documented minimum threshold (e.g. NDSA levels of Preservation[44] for Storage).

[44] https://ndsa.org/publications/levels-of-digital-preservation/

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R10. Preservation Plan

R10. The repository assumes responsibility for long-term preservation and manages this function in a planned and documented way.

1. Initial	Preferred and accepted deposit (R08), access (R14) and preservation file formats and metadata standards/schema are listed. Every (meta)data object in the repository is listed and their file format and metadata standards/schemas are known. Any minimum periods of retention (bit level assurance) are documented.
2. Managed	The curation and preservation levels of all digital objects are documented. The needs of the designated community and the wider technical dependencies (risks) for (meta)data are monitored and used to define and implement curation and preservation actions. Actions, including normalisation, migration, emulation and updates to metadata and documentation ensure (meta)data remain findable, accessible, interoperable and reusable in line with the needs of the designated community. Preservation actions are taken as soon as is practical, in response to or in advance of identified changes to circumstances. Any minimum periods of preservation are documented.
3. Defined	Preservation planning is integrated into the wider organisational policy and practice including governance, resourcing, expert guidance (with community engagement) and technical infrastructure.

Principle: A2. 'Metadata are accessible, even when the data are no longer available'

+FAIRenabling: The repository preservation policy ensures that metadata is preserved even when an object is removed from the repository. Any exceptions are defined and documented.

CoreTrustSeal+FAIR and CapMat note: Principle A2 is an explicit requirement that metadata is *preserved* after data is unavailable so it is mapped to R10, but this is also associated with standard practice for persistent identifier management (R13 Data Discovery and Identification). The 'tombstoning' of metadata records is included in the CapMat levels for R13.

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R11. Quality

R11. The repository has appropriate expertise to address technical data and metadata quality and ensures that sufficient information is available for end users to make quality-related evaluations.

1. Initial	The repository is aware of the expectations at the point of reuse (R14). Curation activities ensure that any quality levels not met at the point of deposit are addressed to meet reuse and preservation needs. The repository is aware of relevant standards and works to meet them.
2. Managed	The quality expectations of digital objects not met at the point of deposit are integrated into a curation plan. Curation actions take place against the defined standards. Quality assurance of standards compliance takes place and any exceptions are documented. The digital objects at the point of access either reach defined quality thresholds or reasons for not meeting quality standards are documented.
3. Defined	Standards selection and quality assurance measures are integrated into the wider organisational policy and practice.

R12. Workflows

R12. Archiving takes place according to defined workflows from ingest to dissemination.

1. Initial	The repository is aware of the processes in place for deposit, curation, preservation, archival storage, discovery and access.
2. Managed	Documented workflows exist for deposit, curation, preservation, archival storage, discovery and access. Curation actions take place in line with defined standards and a curation plan developed at the point of deposit.
3. Defined	Workflow design, management and change management are integrated into the wider organisational policy and practice.

R13. Discovery & Identification

R13. The repository enables users to discover the data and refer to them in a persistent way through proper citation.

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Note: Though presented together in *CoreTrustSeal v2.0* the concepts of discovery and identification are sufficiently distinct to require separate capability-maturity levels and separate alignment with the FAIR Principles.

Discovery

1. Initial	The digital objects' data, metadata and documentation are structured and presented in a way that passively permits indexing and harvesting by resource discovery systems.
2. Managed	Standards compliance processes are in place to ensure that (meta)data can be included in resource discovery systems suitable for the designated community. These may include local systems, 'pushing' metadata to third party systems and data catalogues or providing standardised metadata that can be pulled or harvested by other systems (e.g. OAI-PMH). Processes, procedures and other implementation measures are in place for all items on the lists.
3. Defined	Managed areas of focus are further integrated into the wider organisational policy and practice.

Principle: 'F2. data are described with rich metadata (defined by R1 below)'

+FAIRenabling: The repository provides evidence that resource discovery metadata is sufficient for their designated community of users.

Principle: 'F4. (meta)data are registered or indexed in a searchable resource'

+FAIRenabling: A disciplinary repository may be expected to provide information for both general purpose resource discovery systems (exposure for indexing by search engines, high level metadata such as Dublin Core or DataCite), and metadata to support their more specialist designated community of users.

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Identification

1. Initial	Every (meta)data object in the repository is known and has its own identifier in place.
2. Managed	Every object identifier is locally unique and persists over time. Processes are in place to ensure that the identifier continues to resolve correctly over time and that a metadata record persists even if, for some reason, the digital object is no longer accessible.
3. Defined	Local practice aligns with community agreed minimal standards for designing and managing globally unique identifiers and resolution systems including minimal practice for ensuring persistence and handling 'tombstone' metadata records for objects that are no longer accessible.

Principle: "F1. (meta)data are assigned a globally unique and persistent identifier"

+FAIRenabling: All objects in the repository are persistently identified. Any exceptions are documented and explained, including a timetable for complete coverage of persistent identifiers.

Principle: 'F3. metadata clearly and explicitly include the identifier of the data it describes'

+FAIRenabling: The repository provides evidence that digital object metadata includes its persistent identifier.

R14. ReUse

R14. The repository enables reuse of the data over time, ensuring that appropriate metadata are available to support the understanding and use of the data.

The ReUse Requirement of CoreTrustSeal assesses two broad areas:

1. The means by which the repository identifies and addresses the needs of the designated community.

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2. The characteristics of the data and metadata in the digital objects that meet these needs.

1. Initial	The repository has a definition of its designated community and documents assumptions about that community's specific needs. The repository documents the formats, metadata standards and other requirements for representing (viewing, editing etc.) the (meta) data and is aware that these may need to be updated over time.
2. Managed	The repository actively engages with their designated community to identify their needs in terms of (meta)data usability. This 'community watch' activity is applied alongside a 'technology watch' function that monitors potential risks to the current (meta)data approaches used for digital objects including obsolescence and seeks equivalent or improved alternatives.
3. Defined	Monitoring and change related to continued reusability of digital objects is integrated into the wider organisational policy and practice.

Principle: 11. (meta)data use a formal, accessible, shared, and broadly applicable language for knowledge representation.'.

+FAIRenabling: The repository describes the knowledge representation approaches (schemas, ontologies etc.) they use to ensure machine-actionable interoperability.

Principle: 'I2. (meta)data use vocabularies that follow FAIR principles'

+FAIRenabling: The repository describes how digital objects are linked to other data and metadata to meet the needs of the designated community.

Principle: 'I3. (meta)data include qualified references to other (meta)data'.

+FAIRenabling: The repository provides evidence that links to other datasets and metadata records are provided according to the standards of their designated community.

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Principle: 'R1. meta(data) are richly described with a plurality of accurate and relevant attributes.'

+FAIRenabling: The repository describes how the metadata provided for digital objects meets the needs of their designated community.

Principle: 'R1.3. (meta)data meet domain-relevant community standards.'

+FAIRenabling: (as for I1) the repository describes the knowledge representation approaches (schemas, ontologies etc.) they use to ensure machine-actionable interoperability and how those meet the needs of their designated community.

Technology

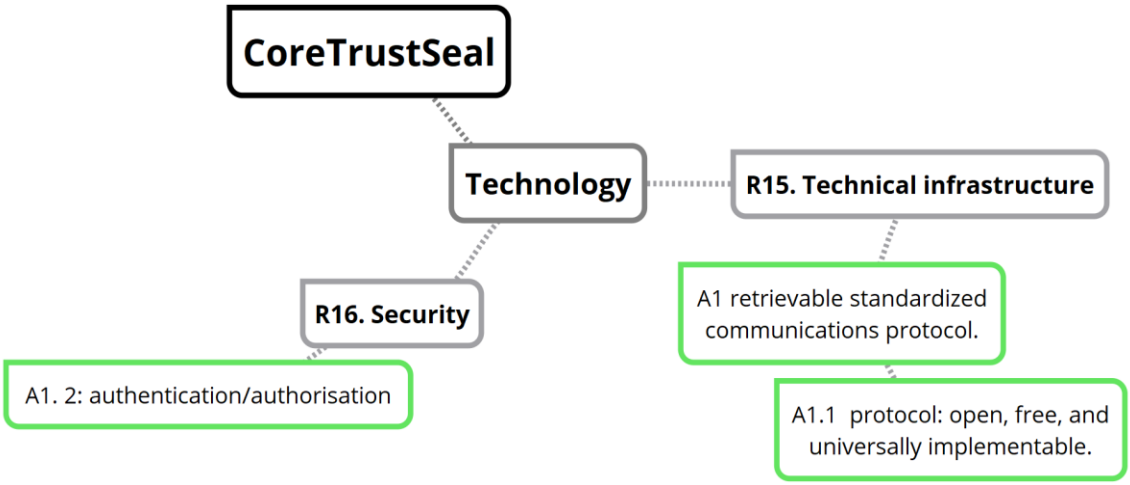

Diagram 11: Technology Requirements to FAIR Principles

R15. Technical Infrastructure

R15. The repository functions on well-supported operating systems and other core infrastructural software and is using hardware and software technologies appropriate to the services it provides to its Designated Community.

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1. Initial	Parts of technical systems are listed, issues with technical systems and responses to issues are listed.
2. Managed	Lists of components and services, lists of issues (bug fixes, change requests) and research and development projects are managed through processes, procedures and other implementation measures.
3. Defined	IT service management is integrated with overall repository, governance and resource management.

Principle: 'A1. (meta)data are retrievable by their identifier using a standardized communications protocol'.

+FAIRenabling: The repository describes the method by which objects can be accessed.

Principle: 'A1.1 the protocol is open, free, and universally implementable'.

+FAIRenabling: (as for A1) the repository describes the method by which objects can be accessed.

R16. Security

R16. The technical infrastructure of the repository provides for protection of the facility and its data, products, services, and users.

Security is a similarly broad area to technical infrastructure, and as noted above expectations would increase for repositories curating sensitive data. In a similar approach to R15, the reverse engineering of minimal and ideal practice from more advanced security standards (e.g. ISO27001) may be the best approach to defining the 'core' and from there a set of capability-maturity levels.

1. Initial	The scope of security is defined, and any security issues and responses to issues are listed.

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2. Managed	Potential threats to the repository and its data, products, services, and users are analysed and risks assessed. Processes are in place to periodically review risk, to mitigate risks where possible and to minimise and respond to threats (whether malicious or through human error) to the IT infrastructure.
3. Defined	Information security management is integrated with overall repository, governance and resource management.

Principle: 'A1.2 the protocol allows for an authentication and authorization procedure, where necessary.'

+FAIRenabling: The repository defines their terms for applying authentication and authorisation and the protocol in place to apply access control.

Conclusion & Next Steps

Repositories offering long-term preservation data services are already familiar with the concepts behind the FAIR Data Principles and undertake many activities that enable them. The CoreTrustSeal Trustworthy Digital Repository Requirements (v2.0) have been mapped and aligned with the FAIR Data Principles to support repository self-assessment of FAIR enabling capability. Mapping decisions were guided by reference to a number of additional sources including the RDA Indicators and the FAIRsFAIR metrics[45] as applied by the F-UJI tool[46].

The mappings align the repository characteristics necessary to achieve Trustworthy Digital Repository (TDR) status with those that demonstrate a TDR is enabling FAIR (meta)data. The capability maturity (CapMat) approach is designed to support a self-assessment of repository capability against each requirement/principle 'area of focus'. The model focuses on the provision of supporting evidence (required by the CoreTrustSeal to support self-assessment statements) and can be used to identify current readiness levels and set targets for progress. Achieving sufficient capability can provide an indicator of overall repository maturity. Though the subtleties of trustworthy repository requirements and FAIR indicators will continue to

[45] D4.5 Report on FAIR Data Assessment Toolset and Badging Scheme https://doi.org/10.5281/zenodo.5336159
[46] https://www.f-uji.net/

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evolve, there is an immediate benefit to repositories applying this approach. The CapMat levels lead up to and beyond those sufficient to achieve CoreTrustSeal TDR status and to demonstrate FAIR enabling practice. Repositories using *CoreTrustSeal+FAIRenabling CapMat* should do so in conjunction with the CoreTrustSeal Extended Guidance. Self-assessment and evidence should always demonstrate that the needs of a defined designated community of (meta)data users are being met.

Repositories are acknowledged to be key nodes in the network of research infrastructure. Improvements in the provision of FAIR enabling trustworthy repository data services have immediate benefits for the full lifecycle of research. The use of these approaches provides further validation and testing of the alignment between FAIR research (meta)data objects and FAIR enabling trustworthy repositories. It also provides a stable baseline and a clear exemplar for the expansion of requirements and assessments (possibly including certification) to a wider range of data services (including e.g. metadata registries) and FAIR digital objects (such as semantic artefacts). This reflects the acknowledgement that the evaluation of digital objects is partially dependent on the evaluation of the repositories and other data services that care for them. The wider challenges for standardisation and evaluation of an interoperable EOSC have been previously covered by the authors[47].

Though this work (T4.1) has achieved its goals there is, as yet, no single standard and process for assessing and certifying trustworthy digital repositories (TDR) that enable FAIR research (meta)data objects for the long term. One scenario for ensuring uptake of the ongoing alignment of CoreTrustSeal Requirements and the FAIR Data Principles is to add lightweight components to the CoreTrustSeal that integrate FAIR concepts and allow for an applicant to request, and be awarded, a *CoreTrustSeal+FAIR enabling* designation that reflects the evidence provided. Any changes to the CoreTrustSeal are based on a community-driven revision of the Requirements.

There are a number of barriers to proposing a +FAIR certification to the CoreTrustSeal in its next scheduled revision (2022), but sufficient progress on defining FAIR assessment and practice at the general and disciplinary level would enable integration into their certification process at the following review (2025). This could be based on submission of a repository self-assessment that demonstrated a CapMat of **2. Managed** for each Requirement with one or more aligned FAIR Principles. Repositories have a long history of TDR standards development

[47] FAIR Ecosystem Components: Vision, https://doi.org/10.5281/zenodo.3734273

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[48, 49, 50, 51], and a track record of defining best practice standards[52] and supporting organisation [53, 54, 55]. The equivalent standards and associated governance bodies are only beginning to emerge for FAIR[56]. FAIR object indicators, metrics and tests have not yet been extended to address the more specialist needs for FAIR enabling, such as that delivered by the disciplinary repositories, which are a significant proportion of CoreTrustSeal applicants. There has also been limited work to date on FAIR object evaluation across a whole repository collection. It is expected that in future the evaluation of objects in a collection would form part of an assessment of repository practice.

The authors of the FAIR Principles see machine actionability as a key goal, and this will doubtless be critical to the successful delivery of a federated and interoperable EOSC. Machine-actionable testing of objects or of repositories (e.g. via interrogation of repository-declared metadata[57]) depends on community agreement and defined practice so that assessments can be designed and implemented at scale. One simple example raised in public feedback was that many persistent identifiers resolve to a non-standard 'landing page' of digital object metadata, presenting a significant challenge to automating FAIR object evaluation.

Repositories may have extremely heterogeneous collections, with some objects falling short of desired criteria for some valid reason e.g. an older but high-value, high-demand dataset that is complex or costly to bring up to standard. At present a human-mediated assessment such as that offered by CoreTrustSeal is capable of more subtle judgments compared to an entirely

[48] Core Trustworthy Data Repositories Requirements 2020–2022 Extended Guidance, Version 2.0: September 2019, https://doi.org/10.5281/zenodo.3638211
[49] DIN 31644, 2012 Edition - Information and documentation - Criteria for trustworthy digital archiveshttps://global.ihs.com/doc_detail.cfm?document_name=DIN%2031644&item_s_key=00585595
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machine-automated process. Repositories increasingly function through a series of complex relationships between partners, with the 'quality' of the data they receive depending on other data service providers and research lifecycle phases. The wider adoption of more standardised and 'living' data management plans (DMP) will enable the flow of information between stakeholders and mitigate some of these issues.

The immediate implementation of the *CoreTrustSeal+FAIRenabling CapMat* by repositories will support the expansion of trustworthy digital repositories, while ensuring the FAIR Data Principles are addressed. Though adding a formal +FAIRenabling certification option to CoreTrustSeal may depend on other advances in FAIR, the Board can and should update the CoreTrustSeal Requirements to reflect the language and concepts defined by the FAIR Data Principles.

The maintenance of the *CoreTrustSeal+FAIRenabling CapMat* will be defined by the FAIRsFAIR sustainability plan. A governance body, e.g. through the Research Data Alliance (RDA) working group and maintenance model, could ensure updates to maintain alignment with the next version of CoreTrustSeal (v3.0) in 2022. This would align with RDA adoption of new editions of the CoreTrustSeal Requirements and could be undertaken by the CoreTrustSeal Board. Each iteration of the CoreTrustSeal to FAIR enabling alignments, and their associated capability-maturity levels must be iterated and re-tested. Repositories using the *CoreTrustSeal+FAIRenabling CapMat* model should seek to contribute to the wider community discussion, particularly on what it means for a trustworthy repository data service to be **4. Quantitatively Managed** and **5. Optimising** through continuous improvement.

The ongoing maintenance of FAIR data maturity indicators must be aligned with the development and community adoption of metrics, tests and tools for the automated assessment of FAIR digital objects. In addition to informing the expectations of FAIR enabling practice, the resulting FAIR object assessments could provide the basis for profiling a repository data collection and integrating the outcomes into repository evaluation.

The development of clear community standards is a dependency for delivering machine-actionable assessments of both the digital objects, and the repositories storing them. These will require widespread changes that may require targeted investment in repositories as part of a wider research infrastructure uplift.

The experiences of repositories during their ongoing trust and FAIR journey can provide useful insights for the wider network of data services that must ensure FAIR digital objects whilst simultaneously (inter)operating in a trustworthy manner. A number of key recommendations

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for long term digital preservation and the wider EOSC infrastructure are provided in the Recommendations for a FAIR EOSC White Paper[58] and the FAIR Forever? Final report[59].

[58] D5.7 Recommendations for a FAIR EOSC - White Paper FAIRsFAIR Synchronisation Force 2021 https://doi.org/10.5281/zenodo.5793105

[59] FAIR Forever? Long Term Data Preservation Roles and Responsibilities, Final Report https://doi.org/10.5281/zenodo.4574234

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Appendix 1: Change Log - CoreTrustSeal to FAIR & CapMat

This appendix provides a brief consolidated change log of the steps taken towards this v01.00 release of *CoreTrustSeal+FAIR enabling CapMat*. As a result of public feedback no changes have been made to the CoreTrustSeal to FAIR alignments between version 00.04 and version 01.00

Change Log Note for *CoreTrustSeal+FAIRenabling, Capability and Maturity* (M4.3)[60]

This document covers the fourth iteration (v00.04) of CoreTrustSeal to FAIR mapping. Previous versions were released as CoreTrustSeal plus FAIR Overview[61]. The most recent changes are described below. Feedback to this document will result in a v01.00 release with additional versions released as necessary during the project timescale.

This iteration of the CoreTrustSeal to FAIR alignment has benefited from engaged feedback from members of the CoreTrustSeal Board. Though many of the CoreTrustSeal Requirements contribute to enabling FAIR data, so there are multiple possible alignments, a single mapping (One FAIR Principle to One CoreTrustSeal Requirement) has been identified to simplify integrating statements and evidence about FAIR enabling into the CoreTrustSeal self-assessment process.

[60] https://doi.org/10.5281/zenodo.5346822
[61] https://doi.org/10.5281/zenodo.3734896

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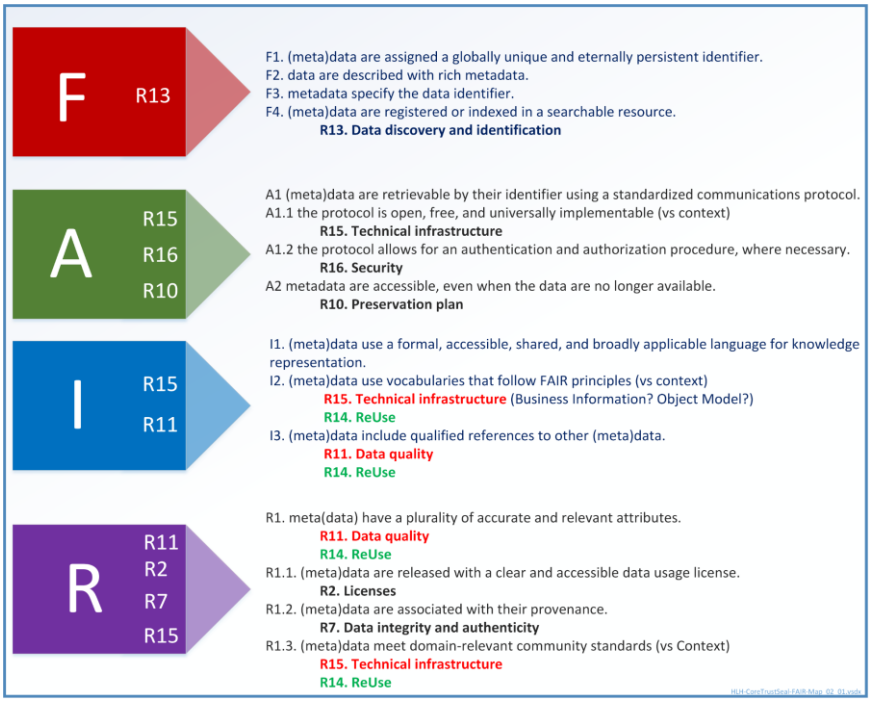

Diagram 10: ***FAIR to CoreTrustSeal.*** Prior mappings in red, new proposed mappings in green

The diagram above is based on the version used in the *Draft Maturity Model Based on Extensions and-or Additions to CoreTrustSeal Requirements*[62] (M4.2 2020-09) and *FAIRsFAIR-CoreTrustSeal-plus-FAIR Overview_03_00*[63] with updates to reflect the most recent revised mappings.

Amendments in this version provide a stronger focus on data reuse as a target outcome for long-term FAIR data enabling.

Principles I1 and I2 (previously R15 Technical Infrastructure) and Principle I3 (Previously R11. Data Quality) are moved to CoreTrustSeal R14: ReUse.

- Principle: I1. (meta)data use a formal, accessible, shared, and broadly applicable language for knowledge representation.
- Principle: I2. (meta)data use vocabularies that follow FAIR principles.
- Principle: I3. (meta)data include qualified references to other (meta)data.

[62] https://doi.org/10.5281/zenodo.4003598

[63] https://doi.org/10.5281/zenodo.4003630

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Principles R1 (Previously R11 Data Quality) and R1.3 (Previously R15 Technical Infrastructure) are moved to CoreTrustSeal R14: ReUse

Principle: 'R1. meta(data) have a plurality of accurate and relevant attributes.'

Principle: 'R1.3. (meta)data meet domain-relevant community standards.

There is some overlap between the 'Findability' focussed F2. data are described with rich metadata' and 'R1. meta(data) have a plurality of accurate and relevant attributes.' The previous mapping to 'Quality' was because this is where the curation work was undertaken. The decision has been taken to focus on digital object information, community information and associated standards (including disciplinary formats and metadata where relevant) under R14 as this provides the best alignment when looking for evidence of fitness of data for ReUse. These amendments also clarify the focus of R15 the 'IT Service Management' aspects of standards.

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Appendix 2: Capability-Maturity and Community Engagement Descriptions[64]

A separate text provides a design statement[65] for the FAIRsFAIR approach to levels of capability and maturity. This was developed to provide internal consistency in project work, in cooperation with discussions around the proposed Science Europe maturity matrices[66] and with a view to alignment with formal capability maturity models such as CMMI[67].

FAIRsFAIR *CoreTrustSeal+FAIR enabling Capability-Maturity* Definitions

Unless otherwise referenced quoted text is taken from the *FAIRsFAIR Capability/Maturity and Community Engagement Design Statement*[68].

"Compatible but simplified FAIRsFAIR approach (based on the CMMI levels below). Each tier description is applied to the organisation, repository or service entity being evaluated:

1. **Initial**. May be incomplete and fall short of the intent of the area of focus. Aware of and addressing performance issues.

2. **Managed**. Limited but complete coverage that delivers the full intent of the area of focus. Although lacking full alignment with overall organisational standards and practice, Identifies and monitors performance objectives. Includes and builds on level 1.

3. **Defined**. Complete coverage that delivers the full intent of the area of focus and aligns with overall organisational standards and practice. Identifies and monitors performance objectives that expand alignment to the whole organisation."

The following definitions are taken from CMMI 2.0[69].

> "**Level 4: Quantitatively Managed**. Measured and controlled. Organisation is data-driven with quantitative performance improvement objectives that are predictable and aligned to meet the needs of internal and external stakeholders.

[64] Originally released in M4.3 CoreTrustSeal+FAIRenabling, Capability and Maturity https://doi.org/10.5281/zenodo.5346822

[65] https://doi.org/10.5281/zenodo.4705235

[66] https://doi.org/10.5281/zenodo.4769702

[67] Capability Maturity Model Integration (CMMI)

[68] https://doi.org/10.5281/zenodo.4705235

[69] https://cmmiinstitute.com/learning/appraisals/levels

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Level 5: Optimising. Stable and flexible. Organisation is focused on continuous improvement and is built to pivot and respond to opportunity and change. The organisation's stability provides a platform for agility and innovation."

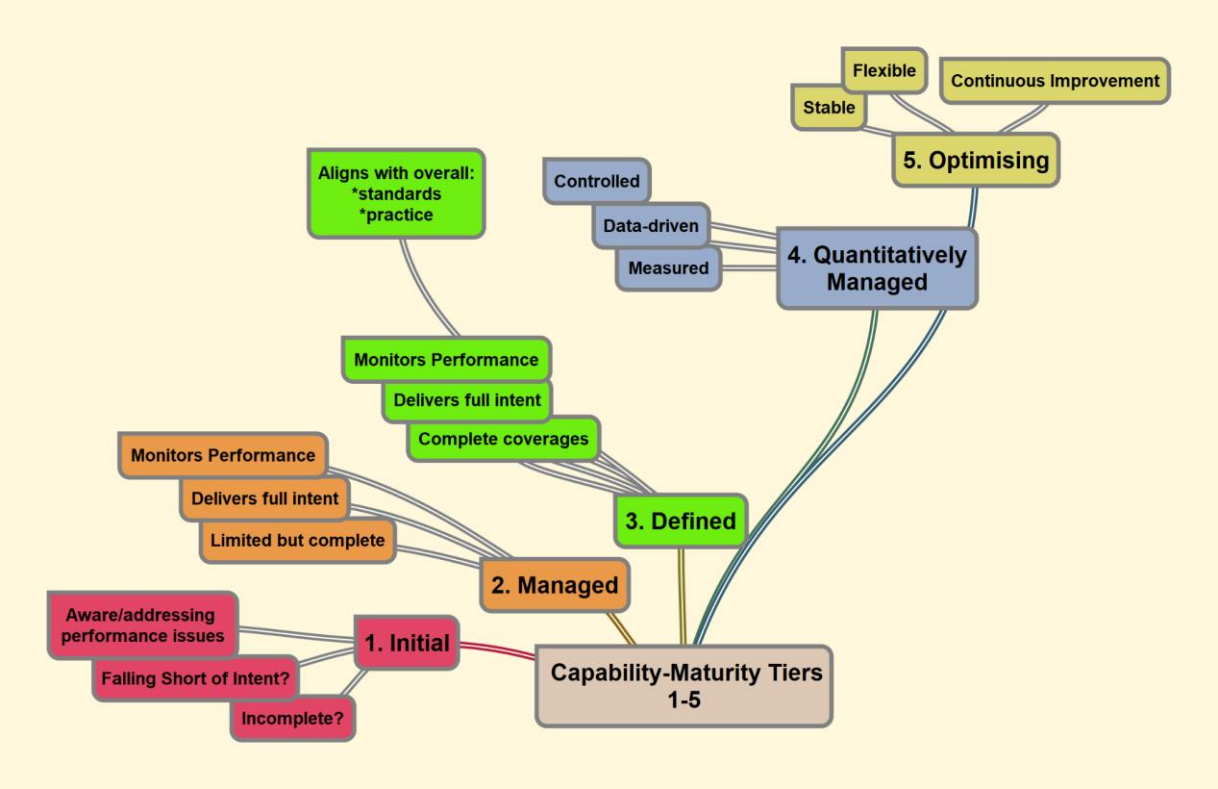

Diagram 11: levels 1-5

Community Engagement Definitions:

"Awareness: Monitors community practice and makes local practitioners aware of it.

Adoption: Also supports practitioners to embed community practice locally.

Collaboration: Also engages with the design, development and review of community practice. Consults and collaborates widely, potentially taking a community coordination and leadership role. Driving maintenance and updates of existing practice and identifying new areas for the development of policy and implementation standards. Actively communicating and promoting existing and emerging approaches to the immediately impacted communities and the wider data infrastructure landscape

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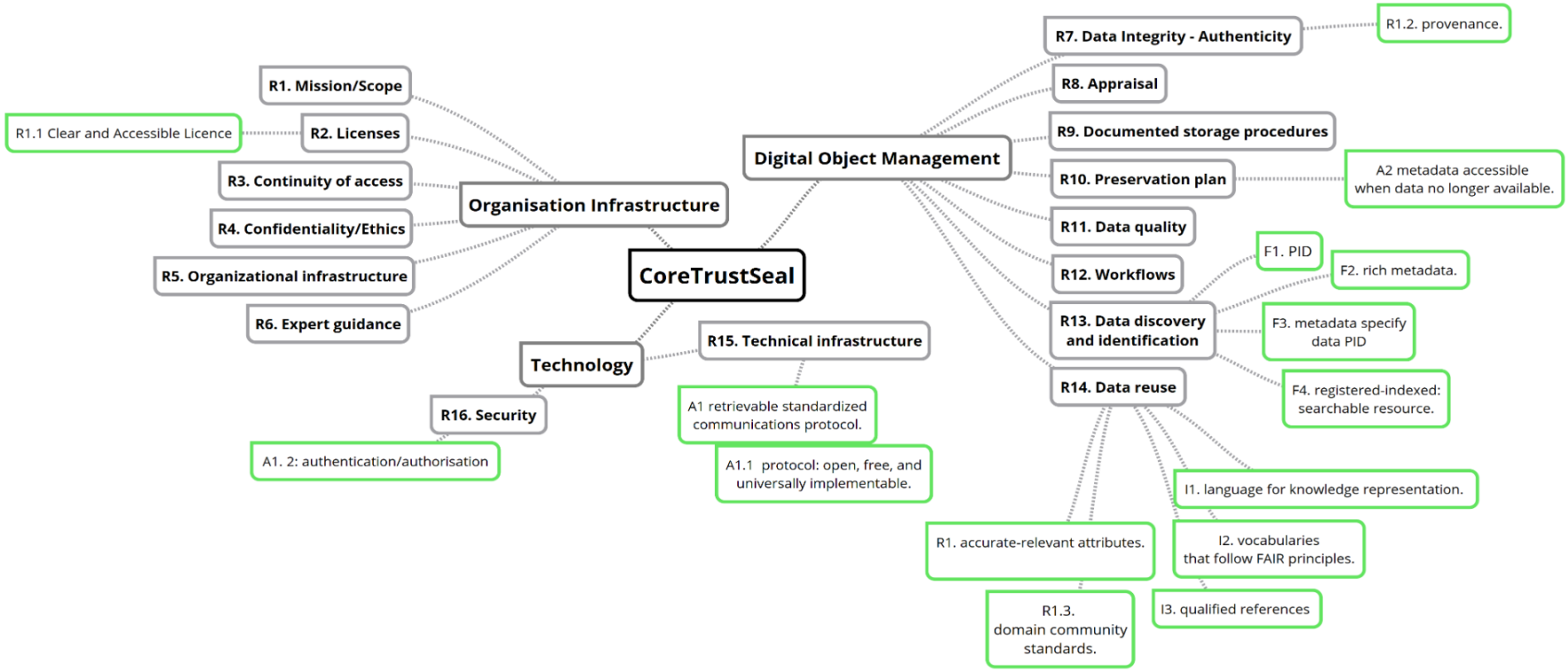
Appendix 3: CoreTrustSeal Requirements to FAIR Principles Alignment Diagram[70]



[70] Originally released in M4.3 *CoreTrustSeal+FAIRenabling, Capability and Maturity,* https://doi.org/10.5281/zenodo.5346822

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Authors: Hervé L'Hours; Ilona von Stein; Anusuriya Devaraju; Frans Huigen; Joy Davidson; Patricia Herterich; Jerry de Vries; Mustapha Mokrane
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D4.2 Repository Certification Mechanism: a Recommendation on the Extended Requirements and Procedures
Authors: Hervé L'Hours; Ilona von Stein; Frans Huigen; Anusuriya Devaraju; Mustapha Mokrane; Joy Davidson; Jerry de Vries; Patricia Herterich; Linas Cepinskas; Robert Huber
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M4.2 Draft Maturity Model Based on Extensions and-or Additions to CoreTrustSeal Requirements
Authors: Hervé L'Hours; Ilona von Stein; Frans Huigen; Anusuriya Devaraju; Mustapha Mokrane; Joy Davidson; Jerry de Vries; Patricia Herterich; Linas Cepinskas; Robert Huber;
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Authors: Maaike Verburg; Ilona von Stein; Linas Cepinskas; Hervé L'Hours; Patricia Herterich; Joy Davidson; Kevin Ashley; Olivier Rouchon; Andrea Greco; Serenella Muradore Gallas; Sara Pittonet Gaiarin
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Authors: Ilona von Stein; Hervé L'Hours; Linas Cepinskas; Benjamin Mathers; Ingrid Dillo; Maaike Verburg; Mustapha Mokrane; Patricia Herterich; Olivier Rouchon;
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