Circular TwAIn

AI Platform for Integrated Sustainable and Circular Manufacturing

Deliverable

D3.3 Data Space and AI Toolkit Reference Implementations - 1st version

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D3.3 Data Space and AI Toolkit Reference Implementations - 1st version

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Definitions and acronyms

AIoD	*AI-on-Demand Platform*
CA	*Consortium Agreement*
CT	*Circular TwAIn*
DoA	*Description of Action*
EC	*European Commission*
EFFRA	*European Factories of the Future Research Association*
EU	*European Union*
GA	*Grant Agreement*
PPE	*Personal Protection Equipment*
PC	*Project Coordinator*
RA	*Reference Architecture*
TC	*Technical Coordinator*
WP	*Work Package*

Disclaimer

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Executive Summary

The present document, entitled D3.3 "Data Space and AI Toolkit Reference Implementations - 1st version" reports on the initial outputs of T3.5 "AI for Manufacturing Reference Implementations" activities. In this direction, the main scope of this deliverable is to report on the early outcomes of T3.5 activities by M12 of the Project's implementation.

As the actual deliverable is of type OTHER, this document represents an auxiliary document that comes as an accompanying report describing the methodology followed for the collection of all the information presented in the dedicated wiki page which documents the initial version of Circular TwAIn Project's portfolio of reference AI implementations. In its first release, the created wiki page documents all the aggregated information collected by M12, regarding existing technologies and reference AI implementations in manufacturing business cases, with a focus (where applicable) on circularity and sustainability aspects, while also presenting their implementation status.

The Circular TwAIn Project's portfolio of reference implementations wiki is available through the following link:

<p align="center">http://wiki-circular-twain.s5labs.eu/</p>

The wiki is intended to be used from a diverse audience, including developers, researchers, and pilot partners, who will leverage its content during the WP4 and WP5 activities of the Project. Thus, it is foreseen that the wiki will be updated and further enriched throughout the course Project; improving the already recorded information and collecting new implementations that may emerge; along with solutions for circularity Data Space implementations, and the Project's user journeys. All this new information will be recorded in the 2nd version of the wiki due in M33.

Moreover, to promote sustainability of results, the Wiki will be kept online (in its current URL or in a URL chosen by the Consortium) for at least 2 years following the conclusion of the Project.

1   Introduction

This deliverable, namely D3.3 - Data Space and AI Toolkit Reference Implementations - 1st version provides the initial outputs of T3.5 activities by M9 of the Project's implementation. In alignment with the DoA, the objective of T3.5 is to compile and collect a diverse range of cutting-edge technologies and reference implementations of artificial intelligence (AI) such as frameworks/libraries, platforms, trained models, preconfigured pipelines, notebooks, etc.; within the context of manufacturing business cases, while focusing on Circular Economy and sustainability aspects.

In this direction, D3.3 reports the methodology adopted for the selection of reference implementations, also presenting the early result which consist of the creation of Project's portfolio of reference implementations that will be leveraged in WP4 and WP5 activities, contributing to the development and implementation of advanced AI solutions for manufacturing. The findings and insights derived from this deliverable will serve as a foundation for further research and development, empowering the Project's stakeholders to adopt and implement AI solutions that align with the principles of the Circular Economy and drive positive change within the manufacturing industry, as they will be able to easily identify and select the most appropriate tools and techniques for their specific manufacturing needs.

1.1   Deliverable scope

As the actual deliverable is of type OTHER, D3.3, represents an auxiliary document that comes as an accompanying report; describing the methodology followed for the collection of all the information presented in the dedicated wiki page. As such, this report is documenting the 1st version of Circular TwAIn Project's portfolio of reference implementations. In its first release, the created wiki page documents all the aggregated information collected by M12, regarding existing technologies and reference AI implementations in manufacturing business cases, with a focus (where applicable) on circularity and sustainability aspects, while also presenting their implementation status.

The information collected derived from review of open-source initiatives and the Consortium partners' background, utilising a common reporting template for gathering all appropriate information from both the technical and pilot partners, towards describing these reference implementations. It shall be noted that, the Consortium's intention was to identify and document available AI reference implementations of a broader information scope that are however relevant to the notion of circularity.

In this direction, partners were encouraged to contribute with AI reference implementations, regardless of whether they directly aligned with the Project's specific scope and objectives. The intention behind this broader information scope was to create a rich and diverse collection of AI reference implementations, both directly aligned with the Project's scope but also going beyond the immediate boundaries of the Project by incorporating valuable insights and innovations from the Consortium partners. By considering a broader range of AI reference implementations, we can showcase the full spectrum of possibilities and inspire future advancements in the field of AI-driven manufacturing, ultimately contributing to the overall progress and impact of the circular and sustainable initiatives.

1.2   Structure of the deliverable

To fulfil all the objectives of D3.3, the remaining of this deliverable is structured as follows:

- Section 2 presents the methodology followed for the creation of the Circular TwAIn Project's reference implementation wiki,
- Section 3 describes the Circular TwAIn Project's reference implementation wiki and its structure,
- Section 4 finally provides the conclusions of this deliverable and the next steps of work.

2   Methodology

The overall methodology followed for the identification and collection of "reference implementations" aimed at identifying available implementations both from open-source initiatives and using partners background knowledge, especially when it comes to proprietary solutions and reporting both complete solutions and fragments that might become relevant during the Project. As reference implementation we consider specific implementation of a software or technology that can serve as an example or best-practise for others to follow. It is a concrete implementation that demonstrates the intended functionality, design, and best practices of a particular specification, protocol, or framework. The reader shall note that the main purpose of this work was not to create a repository of any kind of AI for Manufacturing assets, as similar repositories are already available (such as the AI4EU marketplace platform[1]). The main aims was to provide the Consortium with a clear and authoritative guide that can be used in helping them understand how to correctly implement and use a given technology under the prism of circularity scenarios; also serving as a reference point to compare their own implementations, ensuring compatibility and adherence to specified standards (where applicable) and make the necessary modifications or optimizations as required. Moreover, this repository is expected to be populated also with the outputs coming from the Project itself, acting as a key reference source for circularity-relevant AI implementations.

In this direction the work commenced by identifying open-source projects, online platforms (e.g., AI4EU, EFFRA (European Factories of the Future Research Association) Structured Wiki[2]) and communities that focus on circularity, sustainable development, and related topics. Online code repositories like GitHub have also been reviewed for finding open-source initiatives; using relevant keywords, such as the "AI algorithm" or "AI framework" combined with terms like "industry", "manufacturing", "circularity", "implementation," "code," or "repository.". Within the identified open-source initiatives, projects and code repositories related to circularity, attention has been given to keywords such as "Circular Economy," "sustainability," "recycling," "remanufacturing," among others. Diving into the projects' documentation, work included reading through the README files, project descriptions, and any available technical specifications; while looking for information on circularity methodologies, algorithms, models, or datasets used by the Project.

In addition, investigation was also carried into proprietary AI implementations, by exploring academic research papers, industry reports, and case studies to identify reference AI implementations related to circularity. In contrast to open-source solution which typically provide a wealth of resources and benefits, the search for AI implementations considered also proprietary solutions as these often:

a) provide comprehensive and feature-rich functionality that may not be available in open-source alternatives,

b) usually come with professional support and maintenance services provided by the vendor; crucial for enterprise-level applications where timely assistance, bug fixes, and updates are essential,

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[1] *https://www.ai4europe.eu/*

[2] *https://portal.effra.eu/wiki*

c) provide seamless integration with existing systems which can simplify deployment, interoperability, and data management; particularly advantageous when leveraging AI within a specific industry or domain that relies heavily on proprietary technologies,

d) provide access to advanced algorithms, models, or techniques that are not available in open-source implementations, offering a competitive advantage by enabling unique or differentiated functionality,

e) undergo rigorous security testing and adhere to industry-specific regulations prioritising security and compliance, offering features like data encryption, access controls, and audit trails.

Upon completion of the research collection phase, an analysis and synthesis of the collected information was undertaken, organising the gathered information into categories, such as applicable domain/industries, AI techniques, data sources, modelling approaches; towards identifying common patterns, notable findings, and successful case studies.

The last steps of the work (for this first version) included the documentation of the findings, by compiling all research findings into a dedicate wiki including summaries of open-source initiatives, private implementations, relevant methodologies, and examples of AI applications in circularity.

Early findings revealed that the domain is new and does not hold many well-defined/used implementations to re-use. Nevertheless, an attempt was made to provide as much as possible information, by also identifying reference implementations that might not be directly related to Circular TwAIn Project's circularity and sustainability objectives. As stated above, the intention behind this, was to publish and make available a wiki that at the end of the Project will hold valuable information that can serve the wider community (AI developers, researchers, organisations) that are working on the topics of circularity in manufacturing, allowing them not only to retrieve information, but also contribute to it (using a moderated editing mechanism). The final result could be also included in, or referenced by other open-source platforms, such as the AI-on-Demand Platform (AIoD), acting as a lighthouse information repository that covers various aspects that have to do with AI implementations and examples to satisfy different circularity scenarios in manufacturing settings.

The reader shall also note that while the Consortium's intention is to re-use as many as possible of the identified reference implementations within the Project's use cases. However, what exactly will be finally re-used depends on a lot of aspects such as:

- their relevance for the Project's pilot scenarios (Manufacturing, WEEE, Battery, Petrochemical) and their applicability in the respective use cases,
- adoption barriers, that may be encountered when implementing AI solutions, such as:
  - the requirement for access to high-quality, relevant, and comprehensive data;
  - lack of openly available pre-trained models;
  - requirement for technical expertise and resources to develop, deploy, and maintain them due to the complex technologies, algorithms and data processing pipelines involved;
  - scalability issues;
  - interoperability issues.
- the license of the reference implementations

- their compatibility with the Reference Architecture (RA) developed in T3.3, and mostly with the AI toolkit delivered in T5.2, as ease of integration is of key importance for their efficient utilisation.

In the second iteration of this work (due in M33), the wiki will be extended with a section reporting available solutions for circularity Data Space implementation (following the same searching and reporting methodology as undertaken in the AI reference implementations case), as well as a dedicated section where the user journeys will be defined (based on the pilots use cases) identifying where these listed reference implementations can support them and how these can fit to their end-to end flow towards resolving circularity issues.

In regard to the wiki's content, efforts have been made to meticulously collect the online information for the various presented AI reference implementations, nevertheless it is important to note that the accuracy and completeness of the information presented in the wiki rely on the available information provided by the implementation owners and publicly accessible resources. While every effort has been made to ensure the reliability of the content, please be aware that the nature of this wiki page means that the information may be subject to change, updates, or modifications by the implementation owners.

Thus, the wiki provides the associated URLs and users are advised to consult the official documentation and sources linked within each reference implementation for the most up-to-date and accurate details.

3   Circular TwAIn Project's Reference Implementation Wiki

As the context of the Circular TwAIn Project's portfolio of reference implementations is anticipated to evolve throughout the Project' implementation, it has been commonly agreed among the partners to utilise a dedicated wiki page to record all relevant reference implementations.

The wiki, which is based on the MediaWiki[3] open-source package, is available through the link below:

<p align="center">http://wiki-circular-twain.s5labs.eu/</p>

3.1 Wiki Main Contents

This wiki records and describes all ongoing work, acting as the live documentation for the portfolio of reference implementations of the Circular TwAIn Project.

Below, a screenshot of the wiki's main page is shown, where the users can navigate into four links:

1. **Portfolio of circularity reference AI implementations,** a subsection presenting all identified circularity reference AI implementations (up to M12)

2. **Solution for circularity Data Space implementations**, a subsection that will be generated and presented in the 2nd version (due in M33) documenting available solutions for circularity Data Space implementations, providing solutions that enable organisations to manage and leverage circular data effectively in the context of Data Spaces. These solutions can be utilized by businesses, governments, research institutions, and other stakeholders involved in the Circular Economy towards serving various purposes facilitating data exchange and interoperability, enabling transparency and traceability in supply chains, supporting circular product design and assessment, measuring circularity performance, and fostering collaboration for circular business model innovation.

3. **Circular TwAIn Project's User Journeys**, a subsection that will be generated and presented in the 2nd version (due in M33) documenting the various CT user journeys, where the reference implementation can be used. In essence the user journeys will provide a holistic understanding of how these reference implementations can be utilised from the different actors, mapping the various steps and touchpoints that users have to go through to achieve their goals. These user journeys will be developed once there is a substantial amount of recorded reference implementations, coming also from the Project's outputs, to be in a position to demonstrate in this manner meaningful pathways that can be used to tackle specific, as well as some generic problems that are requiring data management and AI execution.

4. **Circular TwAIn Project's official website**, offering a direct link to the Project's website.

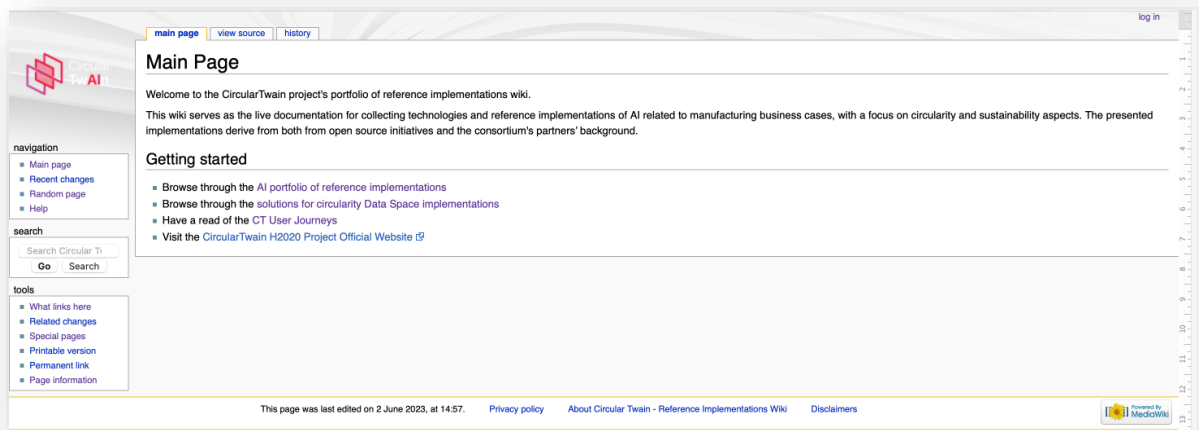[3] https://www.mediawiki.org/wiki/MediaWiki

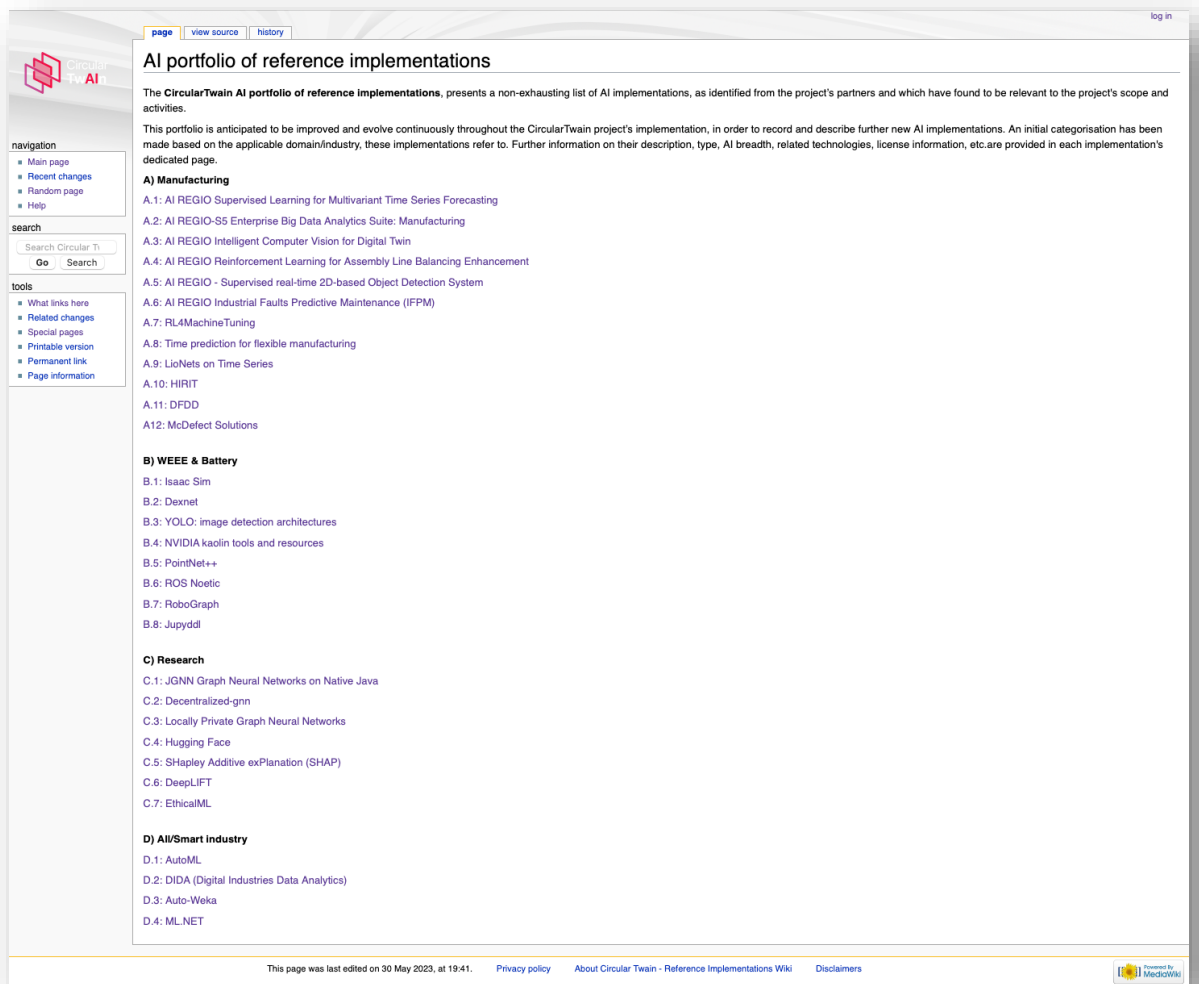Figure 1: Main page of Circular TwAIn's reference AI implementations wiki

Figure 2: Screenshot of portfolio of circularity reference AI implementations

In the next section, we describe the content of the first section (i.e., *Reference AI implementations*), which is the only one currently available in the wiki. The structure of the

other sections, namely *Solutions for circularity Data Space implementations* and *Circular TwAIn project's User Journeys* will be discussed in the next version of this deliverable.

3.2 Contents structure of Reference AI implementations section

The Circular TwAIn portfolio of Reference AI implementations, presents a list of AI implementations that are relevant to the notion of circularity, as identified from all the Project's partners and which have been considered relevant to the Project's scope and activities. As discussed above, this list will be also populated with the outputs of the Project during its implementation.

This current portfolio, containing a total of 31 AI implementations. is anticipated to be improved and evolve throughout the Circular TwAIn Project's implementation, by recording and describing any new AI implementations that might emerge.

In this direction, an initial categorisation of the recorded AI reference implementations has been made based on the applicable domain/industry, where these implementations refer to and which are namely:

A) Manufacturing
B) WEEE
C) Battery
D) Research
E) All/Smart industry

To capture all necessary information in a consistent manner, a common structure has been used in each implementation's dedicated page to fully describe each of the listed AI reference implementations, based on the publicly available information.
 A brief description of the content covered is described as follows:

- **Short Description**: *Brief description of the implementation and why it is relevant to Circular TwAIn.*
- **Reference, URL**: *URL of where detailed information can be found.*
- **Relevant Domain/Industry**: The relevant domain or industry that the AI implementation refers to.
- **Application in relevant Projects/Initiatives**: *Yes/No (if Yes specify Projects/Initiatives).*
- **Type**: *e.g., Platform, Preconfigured Pipeline, Trained Model, Experimentation Concept, Notebook, Frameworks/libraries.*
- **AI Breadth**: *e.g.: ML, DL, Computer Vision, etc.*
- **Learning Ability**: *e.g., Supervised Learning, Unsupervised Learning, Reinforcement Learning.*
- **Related technologies**: e.*g., scikit-learn, TensorFlow, Spark MLlib, etc.*
- **License Information**: *The applicable license as defined by its owner (e.g.: Proprietary, Restricted, Open source).*
- **Related to circularity and sustainability**: *Yes/No.*
- **Audience**: *Targeted stakeholder (e.g., End-User, Designer, Manufacturer, Developer, etc.).*

3.3 Tentative structure of section "*Solutions for circularity Data Space implementations*"

The section presenting "Solutions for circularity Data Space implementations" (due in the wiki's 2nd iteration, in M33 of the Project) is anticipated to document all identified available solutions for circularity Data Space implementations, that can enable organisations to manage and leverage circular data effectively in the context of Data Spaces.

These solutions will be categorised in a similar fashion as described in section 3.2; where for each solution the following content will be covered:

- **Short Description**: *Brief description of the solution and why it is relevant to Circular TwAIn.*
- **Reference, URL**: *URL of where detailed information can be found.*
- **Applicable Building block:** e.g., technical, governance.
- **Relevant Domain/Industry**: The relevant domain or industry that the solution *refers to.*
- ***Application in relevant Projects/Initiatives***: *Yes/No (specify Projects/Initiatives).*
- **Type**: *e.g., Data Management Solutions, Analytics and Insights Solution, Collaboration and Networking Solutions, Traceability and Transparency Solutions, etc.*
- **Programming Language**: e*.g., Python, Java, etc.*
- **License Information**: *The applicable license as defined by its owner (e.g., Proprietary, Restricted, Open source).*
- **Audience**: *Targeted stakeholder such as end-users (i.e.,* businesses, governments), research institutions and other stakeholders involved in the Circular Economy*.*

3.4 Tentative structure of section "Project's User Journeys"

This section aims to give an understanding of how the AI reference implementations presented in the first section of the wiki, namely "Portfolio of circularity reference AI implementations" and the Data Spaces reference implementations to be recorded, can be effectively used by different Project's pilots (i.e., users of the wiki's findings).

The user journeys will outline the specific steps and interactions users need to go through in order to achieve their objectives. As a result, user journeys will enable the demonstration of meaningful pathways that can be utilized to address specific problems related to data management and AI execution, as well as some common challenges. It shall be noted that these user journeys will be created once a significant number of recorded reference implementations are available, including those generated by the Project itself.

The user journeys will be accompanied by relevant workflow or flow diagrams that align with the overall framework depicted in Figure 3. These diagrams will provide a detailed breakdown of the specific steps, processes, and interactions involved in each user journey, offering a deeper understanding of the workflow's intricacies.
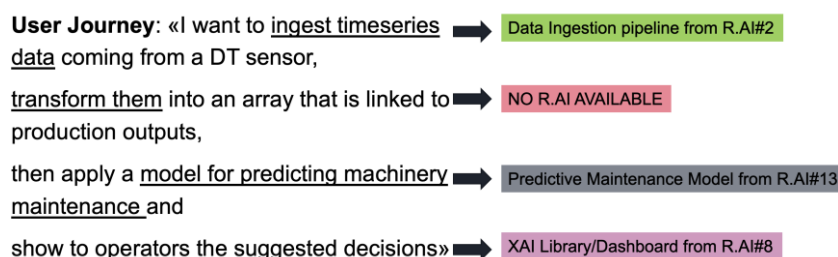

Figure 3: Tentative framework for presenting the various user journeys

4   Conclusions and next steps of work

D3.3 "Data Space and AI Toolkit Reference Implementations - 1st version" presents the initial outputs of T3.5 "AI for Manufacturing Reference Implementations" activities.

In this direction, as part of this first version, D3.3 presents the methodology followed for the identification and collection of existing open-source and proprietary reference AI implementations related to circularity, being the key scope of the Circular TwAIn Project; and their documentation in a dedicated wiki with the vision to be re-used within WP4 and WP5 activities towards solving real-life problems.

The first round of work, resulted in the identification of a total of 31 AI implementations which have been reported in a dedicated wiki page, categorised based on their applicable domain/industry.

As next steps of work, the work will continue to update and enrich the wiki list with new AI reference implementations that may emerge, while focus will be also given on identifying and recording available solutions for circularity Data Space implementations (such as circular analytics platforms, circular data management tools, collaborative circular platforms, etc.) which can be a valuable resource for sharing knowledge and facilitating collaboration among stakeholders.

The purpose of this wiki is to serve as a valuable reference point for knowledge collection, and collaboration within the field of circularity Data Space implementations. It is designed to be a manual editing platform that fosters community involvement and contributions. The wiki provides curated links to a wide range of available solutions, models, algorithms, and resources relevant to circularity AI and Data Space implementations; where data scientists and practitioners can explore these links to access existing solutions and gain insights into best practices, enabling them to leverage and re-use proven approaches in their own projects.

By explicitly stating that the wiki will not automatically interact with any other system, neither receiving nor transmitting information, it emphasizes the manual editing nature of the Platform, which ensures that the content is carefully reviewed and maintained also promoting accuracy and relevance. Furthermore, the sustainability strategy of the Project will be discussed and agreed upon by all stakeholders. This strategy will outline plans for the long-term maintenance and sustainability of the wiki, ensuring its availability and usefulness for a minimum of two years. Opening the wiki to the community after the Project's conclusion encourages ongoing collaboration and knowledge sharing among data scientists and practitioners in the field of circularity.

Moreover, the Project's user journeys will be drafted and reported within the wiki, towards transforming it into an information portal for "solving" real-life issues. All these new steps of work will be documented in the updated version of this deliverable, namely D3.6 – "Data Space and AI Toolkit Reference Implementations - 2nd version" due in M33.

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