Product Passport through Twinning of Circular Value Chains

Deliverable 3.3

CRIS integrated platform v1

WP3: CRIS integration and deployment

Editor: Elias Kriticoglou

Lead beneficiary: BIT

Version: 1.0

Status: Final

Delivery date: 30/06/2024

Dissemination level: PU (Public)

This project has received funding from the European Union's Horizon Europe research and innovation programme under Grant Agreement No 101092008

Document Factsheet

Grant Agreement No.	101092008
Project Acronym	Plooto
Project Title	Product Passport through Twinning of Circular Value Chains
Start date	01/01/2023
Duration	36 months

Deliverable Name	D3.3 CRIS Integrated Platform V1
Related WP	WP3 CRIS Integration and deployment
Due Date	30/06/2024

Author	Elias Kriticoglou (BIT)
Contributor(s)	Loukas Antoniou (BIT), Margherita Forcolin, Eleni Gkinou (MAG)
Reviewer(s)	Yiannis Mourtos (AUEB), Maria Zoidi (AEGIS)
Approved by	All partners

Document History

Version	Date	Author(s)	Organisation	Description
0.1	5/05/2024	Elias Kriticoglou	BIT	ToC
0.2	18/05/2024	Elias Kriticoglou, Loukas Antoniou	BIT	Requirements table. Platform description.
0.3	10/06/2026	Margherita Forcolin, Eleni Gkinou	MAG	Internal process modelling, integration approach and patterns
0.4	21/06/2024	Elias Kriticoglou	BIT	Internal component description, Full document for Peer review
0.5	24/06/2024	Yiannis Mourtos	AUEB	Peer review
0.6	24/06/2024	Maria Zoidi	AEGIS	Peer review
0.7	28/06/2024	Elias Kriticoglou	BIT	Integration of comments from internal review
0.8	29/06/2024	Armend Duzha	MAG	Quality check
1.0	30/06/2024	Elias Kriticoglou	BIT	Final version ready for submission

Executive Summary

Following an in-depth analysis of the pilot, user needs have been identified and translated into functional and non-functional requirements have been derived and documented in D1.5 - CRIS Requirements and Specifications. Based on these findings, the system architecture has been designed and implemented. This approach ensures that the platform is user-centric and user friendly, and it meets the requirements defined. Additionally, the identified tools and technologies to be provided through the platform have been analysed to define, for each type of technology, how the integration could be implemented. The CRIS integrated platform (aka Plooto platform) proposed in this document sets the foundations for the technical implementation and integration of the different components and services to be experimented in the different pilots.

The main goals of the Plooto platform are to provide the modelling features that allow users to define the system they want to monitor and operate on, and to provide the operational environment where they can execute the foreseen operations – orchestrating the different services, collecting data and monitoring their system.

To achieve these goals, the critical points for the implementation of a successful platform, consist of:

The **main user interface (UI)** that features modelling and customisation functionalities such as: the Dashboard that gives access to the user's operational environment; the Inventory that contains modelling features to design the Internal processes, and the Value Network; the System, that allows to connect with external systems, and the Configuration that contains administrative functionalities.

The **internal processes** needed to define the Digital Assets and their properties, associate telemetries with data sources, and aggregate the assets in networks

The **integration approach** of different data, and third-party services and tools to enrich the system's capabilities and the user experience. The types of items that could be integrated can be very diverse, spanning from data streams to complex applications. Therefore, four different integration patters have been formalized and implemented.

The evaluation of the platform – part of the evaluation process in WP4 - serves as a basis to validate the capabilities of the system, but will also identify the weaknesses and improvements that must be analysed, implemented, and included in the next version of PLOOTO platform, to ensure that the final product provides functions that meet the users' expectations and requirements, and enhance the efficacy of the system.

Table of Contents

List of Figures

List of Tables

Acronyms and Abbreviations

Acronym	Description
API	Application Programming Interface
DA	Digital Asset
DB	Database
DPP	Digital Product Passport
DT	Digital Twin
FR	Functional Requirement
IAM	Identity Access Management
IP	Integration Pattern
KG	Knowledge Graph
LCA	Life Cycle Assessment
NF	Non-Functional requirement
PMS	Process Modelling and Simulation
RM	Raw Material
SBSC	Sustainability Balanced Scorecard
SC	Supply Chain
UI	User Interface
WS	Web Service
VN	Value Network

1 Introduction

1.1 Purpose and Scope

This deliverable presents an overview of the work carried out in Task 3.2 Solution integration and deployment to release the first version of the Plooto platform.

The innovative aspects of the Plooto platform can be summarised as:

- **Modular**: A main deployment module with core features such as Value Network (VN) and Digital Twin (DT) process modelling features, customisable dashboards, different rendering option through widgets.
- **Extendable**: can be complemented with embedded added value tools or services such as Sustainability Balanced Scorecard (SBSC), and Digital Product Passport (DPP).
- **Open**: can integrate different types of software and data via implemented Integration Pattern (IP) or data via the IDS-compliant connector.
- **Customizable**: can be further customised integrating Value Network-specific (i.e., Optimization, Simulation, and Analytics).

The scope of this document is therefore to describe how the Plooto system has been implemented, the main features provided by the platform as modelling environment, and the generated integration approaches.

Key services to be integrated (i.e., Value Network modelling, optimisation, simulation and analytics) are described in D2.3, the Sustainability Balanced Scorecard (SBSC) is described in D3.5, and the Digital Product Passport (DPP) is described in D3.1.

The following table summarises the current status of the different logical building blocks:

Logical component	Task and implementation status
Digital Twin modelling and orchestration	Task 2.1 Supply-chain digital twin modelling and orchestration services - designed the 1st version of internal DT processes (for all partners in the three pilots) to be monitored in the platform. Next steps: - Fine tune existing models after 1st run of pilot operations. - Production of new models if required by the pilots. Task 1.3 Information modelling framework - produced the first version of the knowledge graph and IMF models for the Spanish pilot. Next steps: - Produce the IMF models for the Italian and the Greek pilot. - Formalise the ontology - Synchronization with DT models

Logical component	Task and implementation status
	Task 2.4 Predictive analytics and AI services – implemented different analytics prototypes for the three pilots (refer to D2.3). Next steps: - Verify the services in the 1st run of pilot operation - Refine and extend the service based of feedback from users - Complete all foreseen analytics Task 2.5 Prescriptive analytics and Optimisation services - categorised and parametrised the variables to be used for Italian and Spanish pilot, implemented the first version of the optimization service for the corresponding Value Networks and integrated them into the Plooto platform. Next steps: - Verify the services in the 1st run of pilot operation - Refine and extend the service based of feedback from users. Task 2.6 Process modelling and simulation services - produced the process models for the three pilots. Next steps: - Fine tune existing models after 1st run of pilot operations.
Data collection and preprocessing	Through a collaborative effort of all WP2 tasks, data relevant for all logical components has been collected. Data has been harmonised. Historical time series have been collected for the Italian and Greek pilot and used to assess or specify technical components (e.g., Plooto platform, Analytics service). Next steps: - Verify the completeness of data eventually including additional data. - Receive data series for all relevant processes for training and testing purposes. - Harmonise data in Data Lakes.
RM recovery and dataspaces	Task 2.2: Waste supply chain data space - specified the data models and aligned them with Plooto systemic entities; defined the collaboration models and related RM-recovery dataspace architecture design; implemented Authentication, Authorisation, Negotiation, and data exchange functionalities between Plooto users; defined discoverability, negotiation, and data exchange processes for all collaboration models based on IDS-compliant connectors. Next steps: - Enhancement of discoverability and negotiation process between Plooto users. - Implementation of collaboration models with organisations outside the Plooto ecosystem via IDS-connectors.
User tools, visualisations	Task 3.1: Product passport and certification tools - formalised the first prototype of DPP services (documented in D3.1). Next steps: - Verify and validate the services during the 1st run of pilot operations - Consolidate the data to be included in the DPP based on feedback received during the 1st run oof pilot operations. - Complete the services accordingly.

Logical component	Task and implementation status
	Task 3.3: Balanced scorecard and sustainability assessment services - defined the first prototype of the SBSC services and the visualization tool (documented in D3.5). Next steps - Verify and validate the services and the visualised KPIs during the 1st run of pilot operations. - Integrate the tool into the platform via the iFrame integration pattern. - Evaluate the possibility to dynamically valorise the KPIs from information made available through the platform.
Multi supply chain DT view	In Task 2.1: Supply-chain digital twin modelling and orchestration services – designed, implemented and integrated the Supply Chain modelling features into the Plooto platform (documented in D2.3). These features have been used by the pilot partners to draft the pilot-specific collaboration in terms of shared assets and shared telemetries. Next steps: - Integrate security and governance services (Task 2.3) - Integrate optimization services - Integrate analytics - Automate workflow management
Workflow management and orchestration	Initial draft of workflows orchestrating different services (e.g., simulation, analytics, and optimisation) have been designed and presented in this document (see Section 3.6). Next steps: - Additional investigations are needed to decide, for each workflow, the actual implementation approach (Service to Service vs Service to Platform to Service), which might depend on the pilot's characteristics. - Once the services have reached an adequate maturity, Implement the workflows accordingly

Table 1: Overview of the Plooto logical building blocks and their status

1.2 Relation with other deliverables

The CRIS integrated platform proposed in this document sets the foundations for the technical implementation and integration of the different components and services.

It takes as input information concerning the pilots' needs and goals defined in D1.5 CRIS Requirements and Specification V1. In addition, this document directly relates to D2.3 Plooto Complete Suite of Services V1 that describes the services that will be executed through the platform.

In addition, it relates to WP4 activities providing the physical environment where pilot activities will be executed and evaluated.

1.3 Structure of the document

The document is structured as follows:

- **Section 2** summarized the requirements that have been elicited in D1.5 and explains how they have been addressed in the implementation of the platform.
- **Section 3** details the CRIS architecture and its components.
- **Section 4** describes the Plooto platform.
- **Section 5** introduces the integration approach.

2 Requirements for CRIS implementation

This section reports the requirements that have been derived in D1.5. The requirements table has been enriched with a brief description on how the requirement has been implemented.

Id	Requirement description / Priority	How it has been implemented
FR-01	The user should be able to establish and manage collaborations with other partners within the supply chain. (High)	The collaboration along the supply chain is Implemented and managed through the Supply Chain services described in D2.3.
FR-02	Data exchanged among partners should be maintained in a secure way. Users should have access only to the information and features that are relevant for their case. (High)	Authorization/Authentication mechanism ensures that each user has access only to the information he/she is entitled to access, either based on his/her identity or his/her role in the organization. All data related to the pilot ecosystem (assets, telemetries and networks) is securely stored in Plooto internal DBs. Data related to the collaboration along the Supply Chain is stored in Blockchain.
FR-03	The user should be able to use/combine tools/ technologies locally available. (High)	Different integration patterns have been implemented (see Section 5.1) allowing users to use them within their processes.
FR-04	The user should be able to define processes eventually combining services and tools from different providers. (High)	Processes can be defined as networks of interconnected DAs through native features of Plooto platform. Different technologies can be integrated (see FR-03)
FR-05	The user should be able to monitor internal processes having real time information (High)	Once the process is modelled, the telemetries associated with DAs feed data into the system. Users can customise their Dashboard to define what to monitor. This is provided by native features of Plooto platform (see section 4.1)
FR-06	The user should able to use and integrate different types of assets. (High)	In Plooto platform anything can be modelled as a digital asset (DA) where it is a machine, a process, a service, or material. (see section 4.1)
FR-07	The user should be able to simulate the production process based on user defined parameters. (High)	The PMS tool is integrated into the platform using the iFrame mechanism. In this way it is always available for users that want to run some simulations in the PMS tool.
FR-08	The user should be able to simulate parts of the production process. (Medium)	PMS tool allows to run simulations both for the entire process and for parts of the production process.

Id	Requirement description / Priority	How it has been implemented
FR-09	The user should be able to execute process optimization scenarios based on user defined parameters. (High)	Optimization services are integrated in the platform.
FR-10	The user should be able to optimize the supply chain. (High)	Optimization service will essentially optimise the value network with respect to specific variables of relevance for the value network. Each pilot has defined the focus of optimization, which is described in D2.3
FR-11	The user should be able to use analytics services to gain insight about the processes and possible improvements. (High)	Analytics services implemented for the three pilots are integrated into the platform and made available following two integration patterns: iFrame Integration pattern (see Section 5.1.3) if users want to use the service's UI (if available), otherwise the APIs integration pattern (see Section 5.1.2)
FR-12	The user should be able to assess the production process and detect environmental hotspots and/or potential areas for improvement through LCA. (High)	An LCA analysis has been carried out for the Greek pilot, to formalise the input/output parameters, the metrics and the corresponding algorithms, and the relevant KPIs. This analysis is being transformed in a software component that can be integrated via the APIs integration pattern.
FR-13	It should be possible to compose the Digital Product Passport aggregating data from different processes. (High)	Specific DPP services have been defined (see D3.1). These services collect DPP data from the intra-Value-Network communication exchange and incrementally compose the information to be made publicly available in the passport.
FR-14	The Digital Product Passport should be maintained in a secure way and it should be publicly available. (High)	All information about the passport is safely stored in blockchain. They are made available via commonly used mechanisms such as URL or QR code. The DPP services and the related use of block chain are described in *D3.1 Product Passport and certification tool V1.*
FR-15	The agreements among the parties in the supply chain should be managed within the platform (High)	Specific SC services have been implemented in the platform (see Section 4.3).
NF-01	The platform should be able to connect with external systems (mobile apps, legacy systems, open data sources etc.) (Low)	The integration patterns (see Section 5.1) have been developed to allow the platform to connect with external systems. Additionally, Plooto will leverage Data Lakes technologies to extract and transforms the data and stores it in a data lake. From the data lake data can be used by the platform by defining the corresponding data store.

Id	Requirement description / Priority	How it has been implemented
NF-02	The platform should have UI customization features and offer customization display capabilities. (High)	UI customisation features are provided by native features of the platform.
NF-03	The platform must be able to generate and send notifications and alerts. (High)	This has been implemented by a specific component (see Section 3.5)
NF-04	The platform must grant user-based and role-based access through secure protocols. (High)	A user-based and role-based IAM has been implemented with Keycloak
NF-05	The platform should be compliant with Data Spaces. (High)	Plooto is compliant with Data Spaces by design.
NF-06	The platform should be able to connect with external party's trough IDS-Connectors. (Medium)	Plooto-IDS connector will be implemented to allow organizations that do not have Plooto, to take part in collaborative supply chains (see D2.1)
NF-07	The agreements among the parties in a supply chain should be securely stored. (High)	All step of the negotiation process and the final agreement are securely stored in Blockchain.
NF-08	It must be impossible to tamper the agreements among the parties in a supply chain. (High)	The use of Block chain to store the information related to the agreements ensure that it is impossible to tamper data. The negotiation process, as well as the secure storage of the agreement, is supported by blockchain technology, with acceptance verified through hash matching.
NF-09	The platform should provide access to the different modelling tools. (High)	Tools will be integrated using the iFrame mechanism. (see Section 5.1.3)

Table 2: Requirements for CRIS implementation

3 CRIS Architecture

3.1 High Level Architecture

CRIS is implemented as a layered architecture that has been described in D1.5 and is depicted in Figure 1. The four layers are:

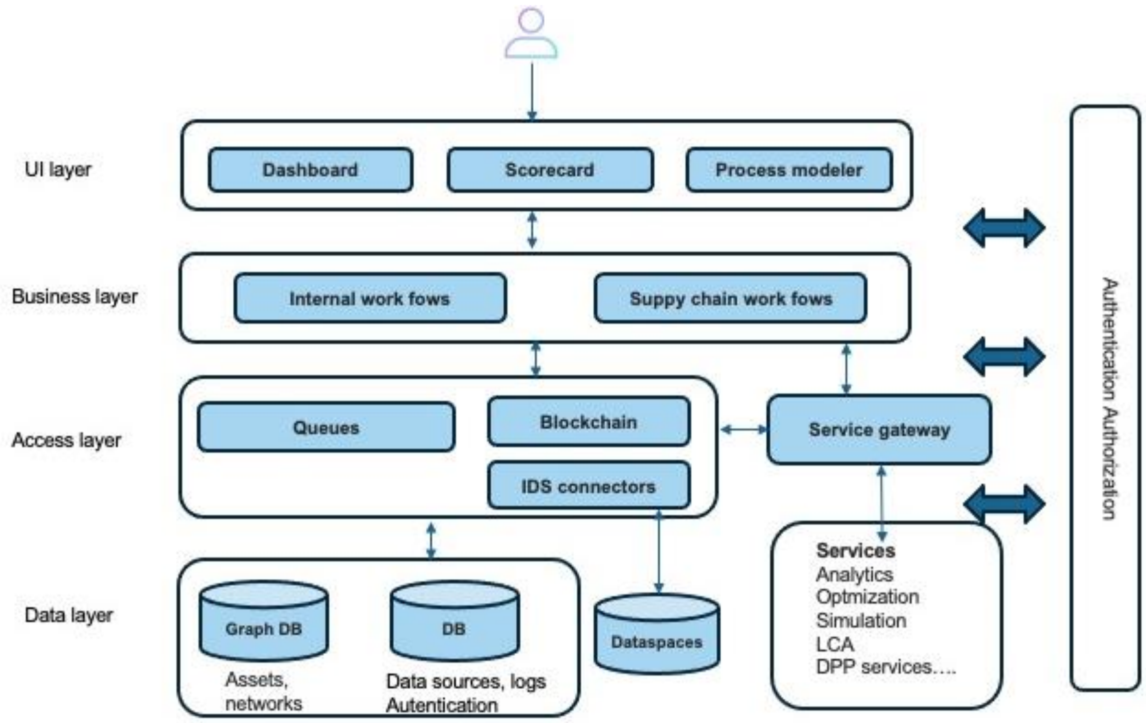

Figure 1: CRIS Layered architecture (source D1.5)

UI Layer represents the main interface. It includes 1) the dashboard, which is the operational environment where users can monitor their assets, 2) DT modelling tools, which allow the modelling of Digital Twins (DT) processes and Value Networks (VN), 3) Integrates visual tools like the Process Modelling and Simulation (PMS) tool or Sustainability Balanced Scorecard (SBSC) that allows the impact assessment of the pilot.

Business layer holds the business information of the pilot, in Plooto case this business dimension contains the internal DT processes the user is interested in monitoring or operating on, and – when applicable - the Value Network that represents the whole pilot and gives users visibility over data and assets shared along the Value Network.

Access layer manages all aspects related to accessing data. More specifically, in Plooto this includes dedicated queues to access data bases, IDS connectors to interact with external organisations, and Blockchain to manage sensitive data such as data related to the digital product passport (DPP) or the negotiations and agreements between partners in the value chain.

Data Layer is responsible to manage different data bases, for instance graph DB to store information related to the assets networks, databases dedicated to store data related to authentication, log or telemetries. Formally, RM-recovery Waste dataspace belongs to this layer, but it physically resides outside the platform.

The specifications and requirements in D1.5 provided the ground to implement the Plooto platform that is described in detail in the following sections.

3.2 Component description

This section describes the main components of CRIS architecture that have been implemented so far. Figure 2 provides the Component View of CRIS architecture, which was reported in D1.5, and serves as a guideline for the subsequent sections.

In the figure it is possible to identify the following amin blocks:

CRIS main interface – represents the platform main User Interface (UI), and contains all the visual tools that are integrated into the platform and made available to the user.

The main UI is described in Section 4.1.1.

Tools are integrated via the iFrame Integration Pattern (IP) (see Section 5.1.3). The description of the individual tools is not in the scope of this deliverable, as a reference the PMS tool has been described in *D1.5 CRIS requirements and specifications*, while the Balanced Scorecard tool is described in *D3.5 Plooto Balanced Scorecard v1.*

CRIS Core engine – aggregates the internal components that guarantee the functioning of the platform. This block is described in detail in the following paragraphs.

External services - it is used to send alerts and notifications via email to involved stakeholders. During the implementation phase this service has been renamed Email service.

Services – this block aggregates all external services that have been implemented in Plooto and can be executed in the value chains to fulfil advanced needs of the user. The individual services are fully and extensively described in *D2.3 Plooto complete suite of services v1*, while for the integration into the platform the most appropriate Integration Pattern (IP) will be selected depending on the characteristics of the individual service. Section 3.6 provides a summary of the key services implemented in Plooto and how those are orchestrated.

Additionally, the figure includes artefacts (yellow boxes) that are described in other deliverables. In particular, the Digital Product Passport (DPP) concept and its services are described in *D3.1 Product Passport and Certification Tool*, while the DT modelling, the simulation models (aka PMS models), and the DT value chains (now DT Value Networks), these are described in D2.3.

Moreover, Plooto plans to use Blockchain to store information related to the DPP and those related to the agreements between the parties in the Value Network (VN). This is described in D2.3.

Finally, Plooto implements its own IDS connector, which is described in *D2.1 RM recovery and waste data space.*

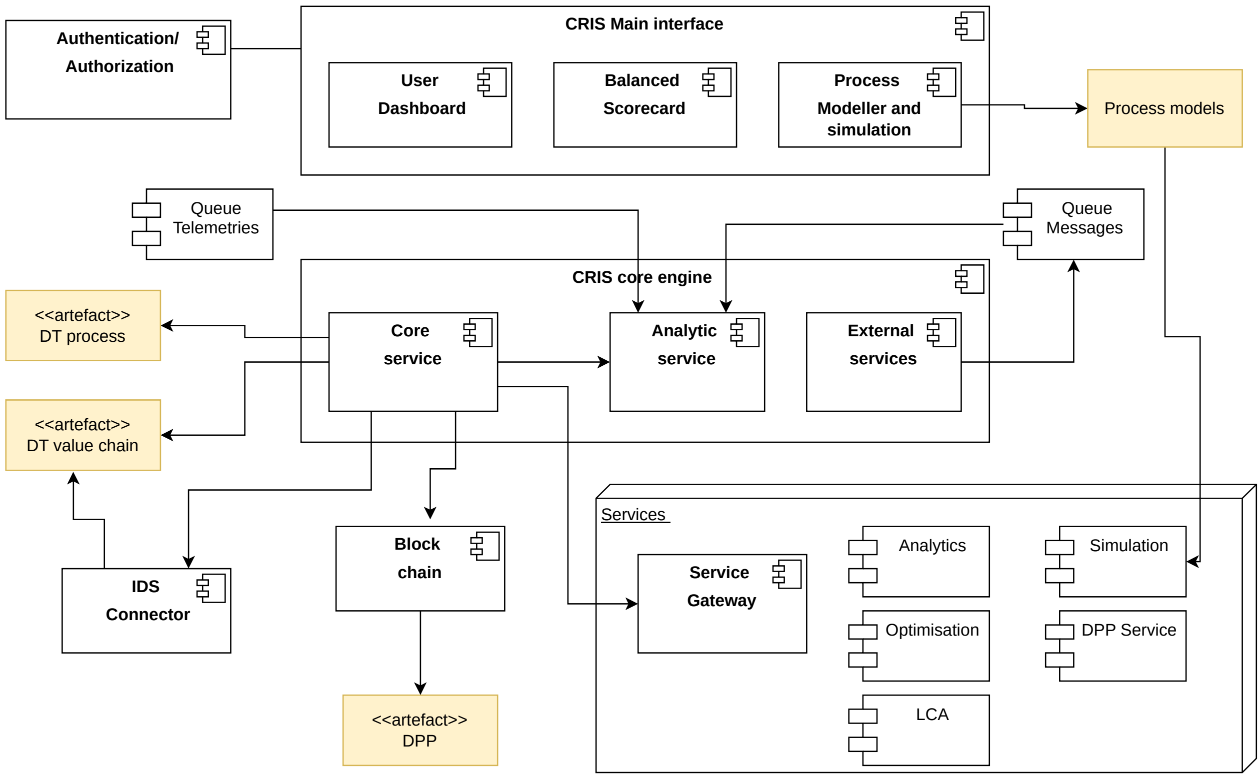

Figure 2: CRIS Architecture Component Diagram

3.3 Core service

Is the core component of the platform that manages all the requests coming from the users, propagates them to other services, and return a response that can be rendered in the dashboard.

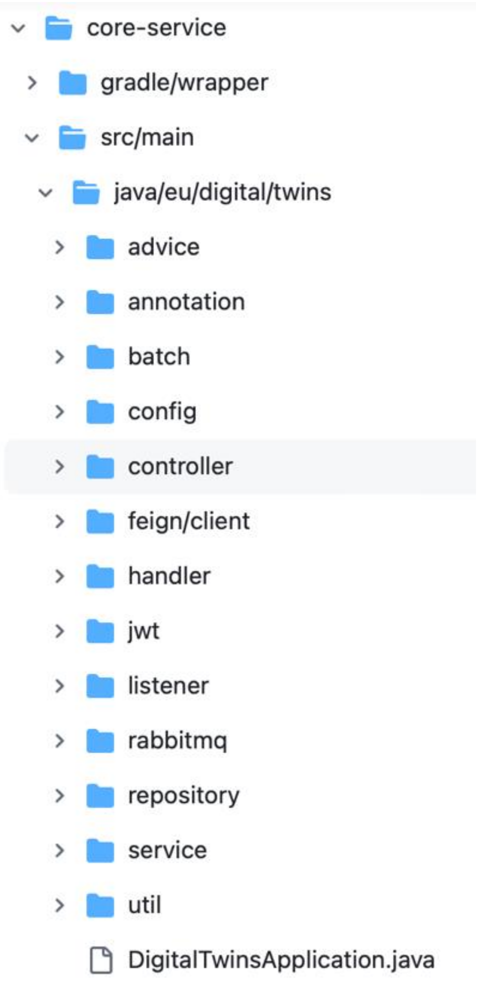

Figure 3: Libraries of Core Service

The Core service manages the user business logic of the application concerning Networks, Assets, their relationships, and the processes the assets are involved into.

The component comprises several libraries (Figure 3). The goal of the key classes is briefly described hereafter.

Listener - manages and verifies the account for instance during the collaboration set-up.

Controller – manages the visual elements of the platform, such as assets, organisation, network, dashboard, etc.

Repository – manages the different databases with dedicated classes.

Service – orchestrate the different external services

FeignClient is the main interface for the user to upload telemetries. Its internal class AnalyticsClient.java has the following methods:

- createTelemetryToken
- findLatestTelemetryValues
- findLatestTelemetryValue
- findAmountOfLatestValuesForTelemetry

3.4 Analytic service

This service is responsible for batch-consuming messages from the telemetry-logs queue (**Queue telemetries** in Figure 2) and storing the data in a database. This feature is propaedeutic for generating analytics. Users can post data regarding a given Data source to that queue. It can be used to send data streams related to a given telemetry or group of telemetries.

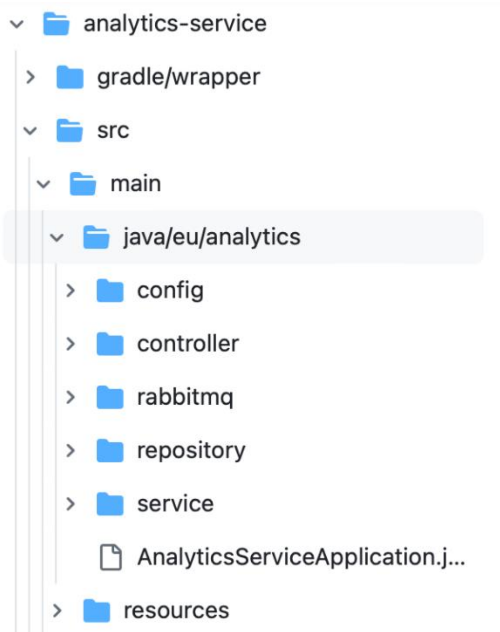

Figure 4: Libraries of Analytics service

The component comprises several libraries (Figure 4), the goal of the key classes is briefly described hereafter.

RabbitMQ processes a list of telemetry log event requests, converting them into telemetry log entries.

Repository listens to a RabbitMQ queue for incoming telemetry log event requests and processes them.

Service retrieves and manipulates telemetry log data.

3.5 External service

This component, which has been renamed as email service, consumes messages sent by the Core service to Queue messages. It is used to send alerts and notifications via email to involved stakeholders.

The libraries breakdown is represented in Figure 5.

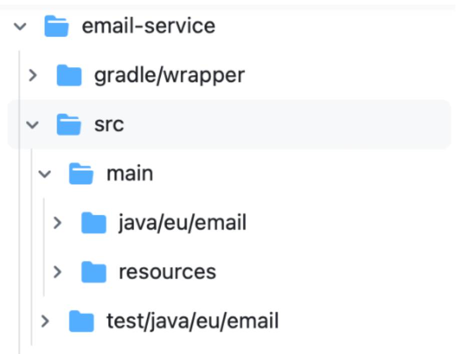

Figure 5: Libraries of external service

Queue messages consumed by the External service

3.6 Services

As anticipated, the Services block in Figure 2 aggregates all external services that could be integrated in the platform. This choice comes from the fact that Plooto is designed to be a modular platform where user-specific services are integrated on the basis on the Value Network's needs.

The types of services considered in the DoA (i.e., Analytics, Simulation, and Optimization) are services that are intended to complement the Value Network but, at the same time, they depend heavily on the characteristics of the Value Network itself and its business goals.

Therefore, the services have been designed and then specialised for the individual pilot. More specifically, **Optimisation service**, which tackles the Optimisation of the supply chain, has been specialised for the Italian and the Spanish pilot, that implement a Value Network, while for the Greek pilot, that is not involved in a Value Network, the optimisation service is not applicable.

Simulation services have been specialised for all three pilots, with the possibility to run simulations on the whole supply chain as well as on selected parts of the supply chain.

Similarly, **Analytics services** have been specialised for the three pilots, addressing specific needs in each pilot. For instance, in the Greek pilot analytics focuses on anomaly detection, forecasting, and environmental impact including LCA assessment. In the Italian pilot the focus is, on one hand, on the usability of prepreg materials after varying storage conditions, on the other hand on the prediction of prepreg quality. In the Spanish pilot the focus is on the prediction of magnetic properties/recommender of process parameters for pellets manufacturing.

Concerning the orchestration of the different services in each pilot, depends on the objectives and characteristics of the pilot itself, in any case two approaches are possible:

1) The services communicate between themselves → Service2Service
2) The services communicate via the platform → Service2Platform2Service

The first option is simpler as the relationships between the services need to be clearly defined, at the same time it leads to a more rigid solution since any variation could lead to heavy changes in the software components.

Figure 6 provides an example describing a flow in which:

1. The analytics services detect an event (e.g., anomaly) that is channelled to the platform.
2. The platform alerts the user via the external service (Section 3.5).
3. The user can decide to run a different analytics service (Prediction) or a simulation (What-if scenario).
4. The results of the prediction or simulation enrich the corresponding DT process.
5. The user can assess the sustainability of the process using the Balanced Scorecard.
6. The results of the assessment are once again stored in the corresponding DT process in the platform.

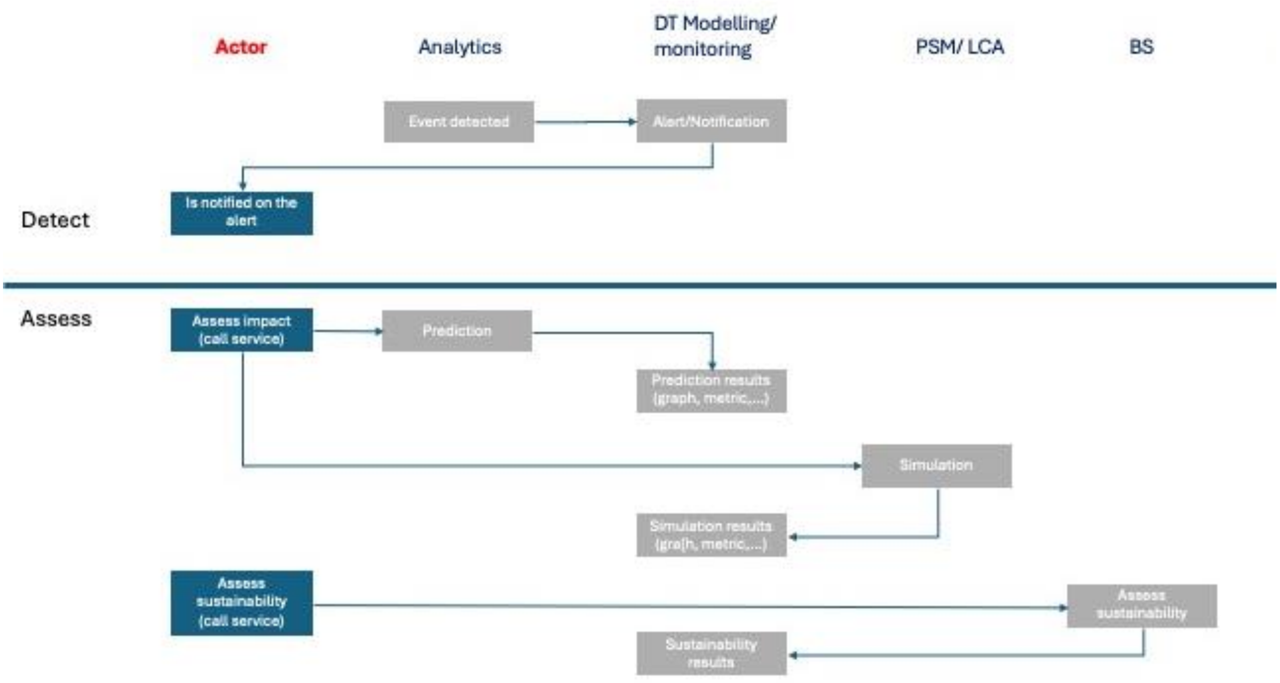

Figure 6: Example of service flow: Event detection/Impact assessment

Figure 7 provides an example describing a flow in which:

1. Analytics can be used to validate a predefined Process model.
2. The validated model can be consumed by the Optimization service if the user provides the appropriate parameters for optimization.
3. The results of the optimization return to the Process modeller that can validate the optimization scenario.
4. If the scenario. Is not validated, step 2 and 3 can be repeated until the optimal (final) solution is reached.
7. At that point the outcome is stored in the corresponding DT process in the platform.

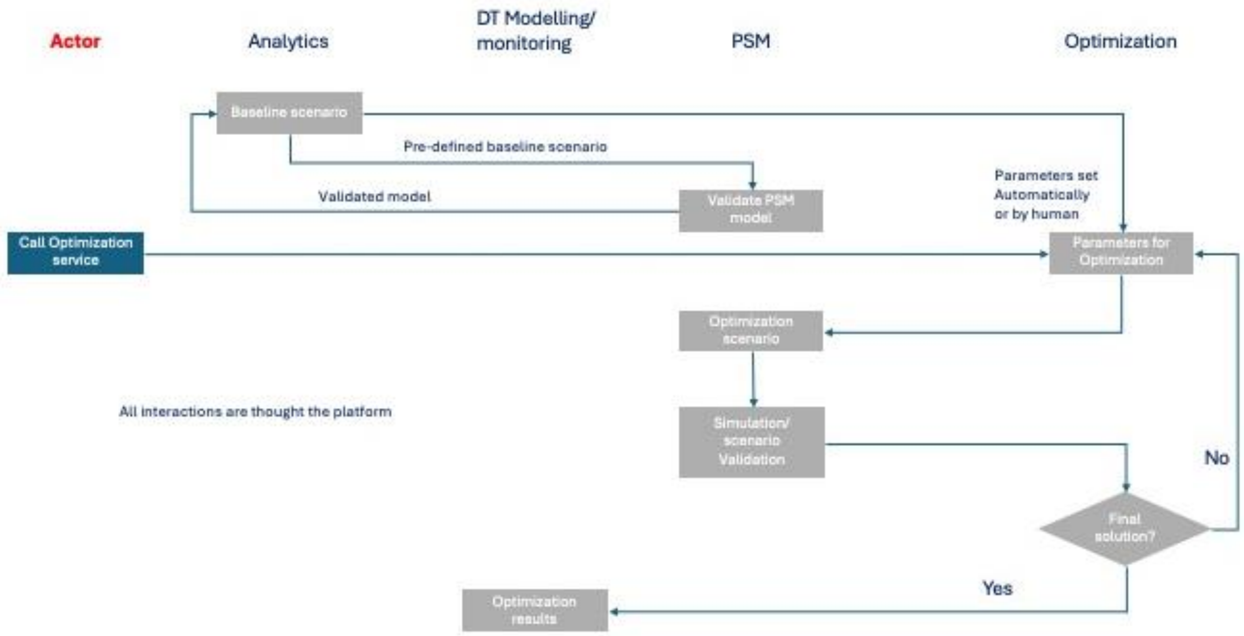

Figure 7: Example of service flow: Analytics, Simulation and Optimization

In terms of readiness, the core components described above are final, therefore, the enhancements foreseen for the final version concern essentially the integration of the different tools and services, and the orchestration of the different services based on the pilots' scenarios.

It must be noted that, the integration process of such items into the platform will proceed incrementally, depending on the maturity of each pilot and its process, the availability of data, and the clarity of how the different services should be orchestrated.

However, as noted above, the pilot's flows and related orchestration aspects will be addressed, detailed and formalised during the first run of the pilot operations starting at M19.

4 Plooto Platform

Plooto platform has two main goals: 1) to provide the core modelling features allowing users to *define the system they want to monitor and operate on;* 2) to *provide the operational environment* where users can execute the foreseen operations – orchestrating the different services, collect data and monitor their system.

Plooto platform is built on top of MIRA, the Digital Twin enabler platform developed by MAG in previous EU funded project (e.g., FACTLOG, TREEADS, AquaSPICE), which allows to model a system in terms of *interconnected Digital Twins* (DTs).

Plooto adopts the DT definition from the Digital Twin consortium) [1] that states:

"A digital twin is a virtual representation of real-world entities and processes, synchronized at a specified frequency and fidelity"

This concept establishes a biunivocal relationship between the digital twin and its physical counterpart. This synchronized bi-univocal relationship allows to manipulate the structure and behaviour of the virtual object as if it is the real object, thus to simulate and predict the behaviours of the physical world.

The state of the physical system is reflected in the digital system and vice versa.

Digital Twins play five key roles:

1) **Explain** what happened in the past, for instance in the case of sensor-based DTs it is possible to look for patterns and anomalies in sensor readings.
2) **Predict** future behaviours, for example, given the historical behaviour of a specific sensor one can predict future values.
3) **Explore** alternatives in the digital world and evaluate these alternatives against the desired criteria (simulation).
4) **Change** the physical world based on the explorations in the digital world.
5) **Generate** synthetic data for testing, which provides a powerful tool to operate with when data is incomplete and uncertain [2].

Although Digital Twins were initially associated to sensors and machineries, their applicability has expanded to include potentially everything, from organizational entities, to services, processes, and people. This more general concept that can be referred as Digital Asset (DA), is the one used in Plooto.

A Digital Asset is a digital object that has properties and telemetries, where:

Property is an attribute characterizing the asset.

Telemetry represents data that is (automatically) collected, transmitted and measured from other (remote) sources. Therefore, telemetry enriches the digital assets providing the data to be analysed to monitor and control the physical system.

Additionally, DAs can be in a Relationship with one another or be part of Networks. Networks are networks of digital assets that can represent different things, such as processes, hierarchies, or any permanent aggregation of digital assets.

4.1 Modelling environment

The Plooto platform is complemented with a modelling environment that can be used to model both the Internal Process of the organization and the Value Networks it is involved into.

The User Interface (UI) is simple and intuitive as it can be seen in Figure 8, that represents the UI main menu.

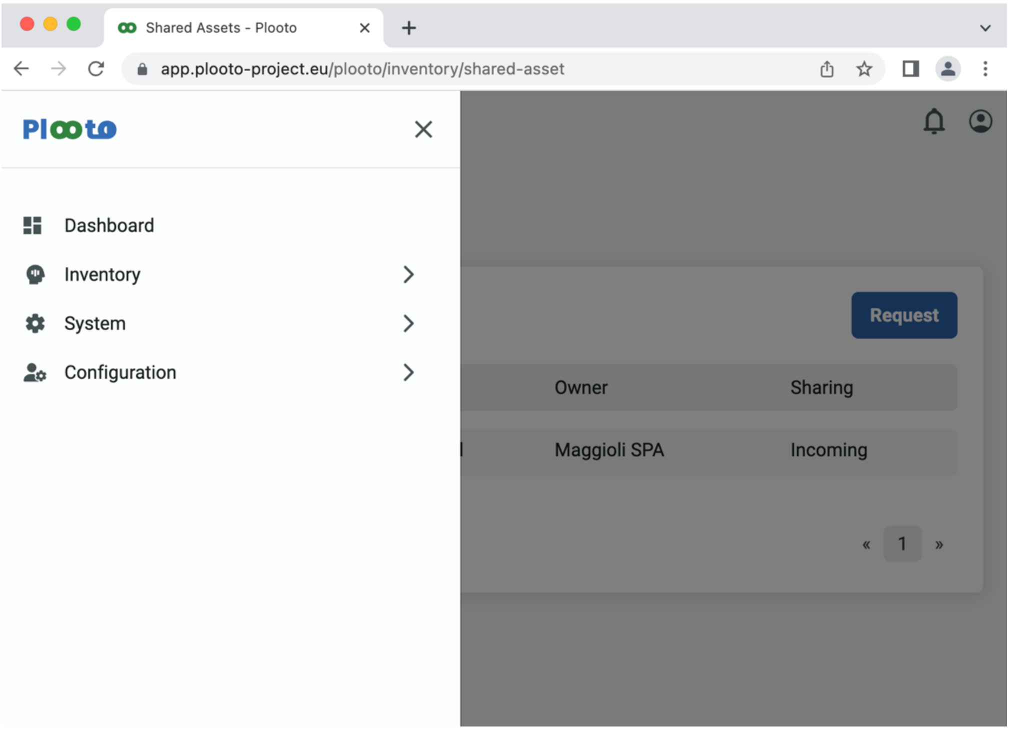

Figure 8: User Interface main menu

4.1.1 Dashboard

The dashboard gives access to the users' operational environment. The dashboard has customisation features allowing the user to autonomously design the appearance of the UI by adding widgets to the dashboard.

There are five types of possible widgets, corresponding to different rendering of the data:

- **Metric** provides the latest value of an asset (or network) telemetry.
- **Chart** provides the evolution of a telemetry over time.

- **Network Summary** provides an overview of a network and its latest telemetries
- **Asset Summary** provides an overview of an asset and its latest telemetries
- **iFrame** allows to embed external tools into Plooto.

Widgets allow the user to focus on the assets or telemetries that he/she wants to control.

An example of user dashboard is presented in Figure 9.

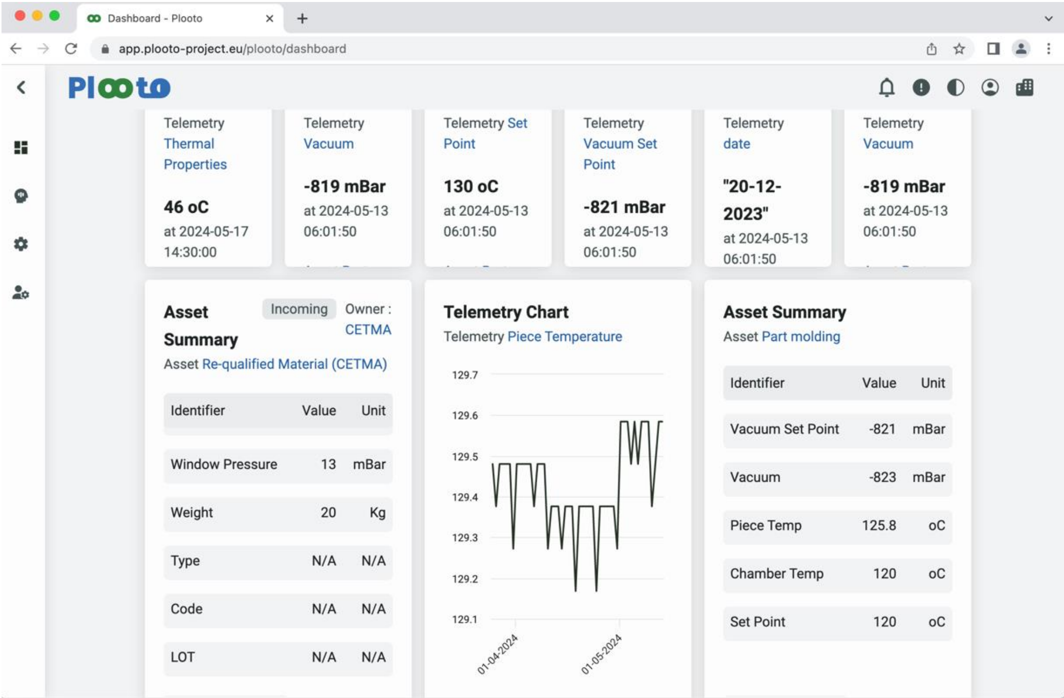

Figure 9: example of a user dashboard

4.1.2 Inventory

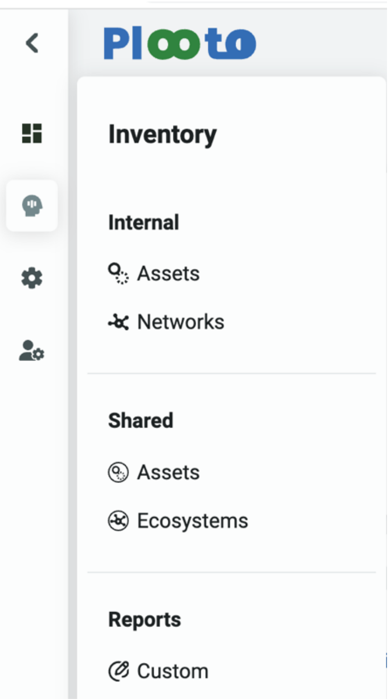

Figure 10: Inventory sub menu

The menu Inventory contains the modelling features to design the Internal processes (submenu *Internal*) and the Value Network (submenu *Shared*).

Internal submenu

The option *Assets* redirects the user to the Asset management page where it is possible to describe the asset in terms of its telemetries, the networks it is involved into and associate the data sources that feed data into the telemetries.

The option *Networks* redirects the user to the Network management page where it is possible to select the assets participating in the network, define relationships among the assets and associate the data sources that feed data into the telemetries.

Shared submenu

This submenu aggregates the features used to establish collaboration among partners and define the value network.

In this case, the option *Assets* is used to establish the collaboration between two partners by sharing assets and telemetries as described in D2.3.

The option *Ecosystem*, provides the possibility to view and operate the value network.

Report submenu

This submenu is used to obtain custom reports of an asset or network the telemetries. The user chooses the type (asset/network), based on the type the system allows to choose among the defined assets or networks, and based on the selected asset or network, the system allows to choose a telemetry. By default, the report fetches data corresponding to the current date/time, but is is also possible to define a period and obtain the varying of the telemetry over time, as shown in the example reported in Figure 11.

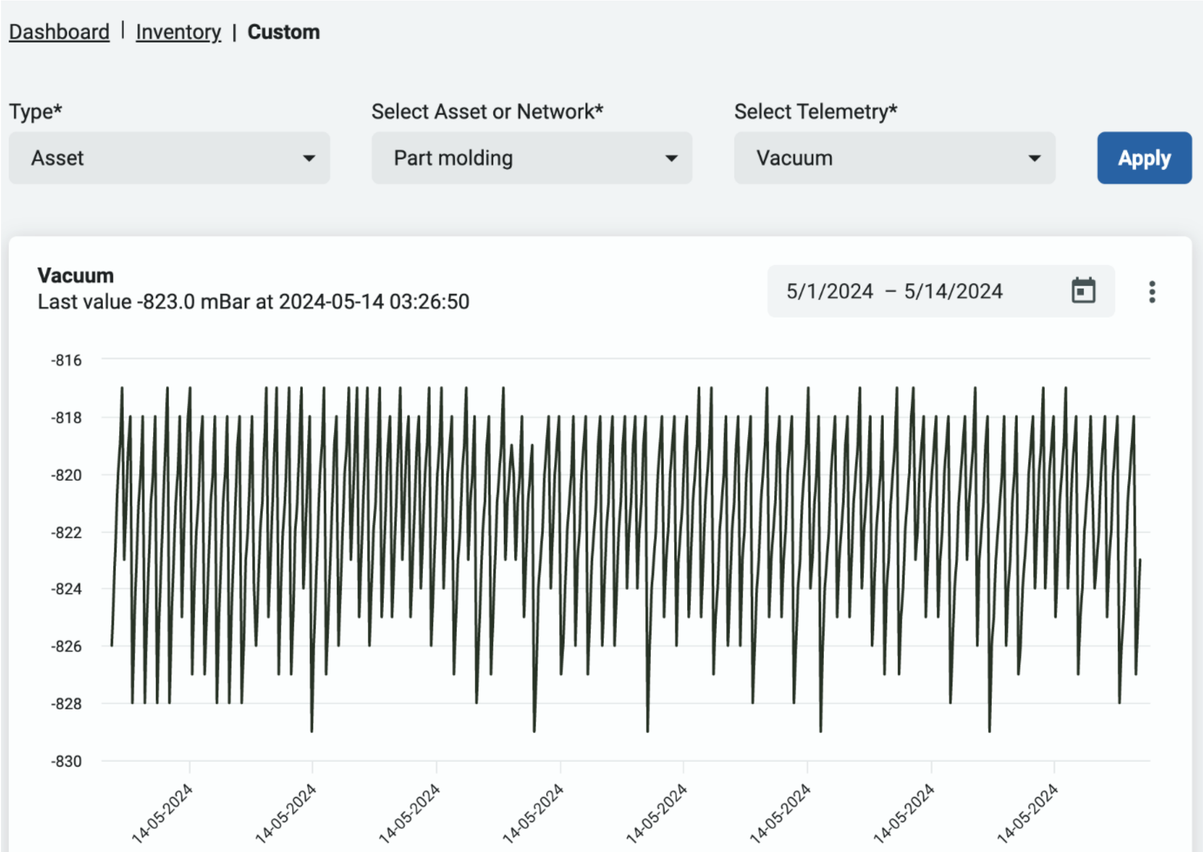

Figure 11: Example of custom report

4.1.3 System

The menu System allows to connect with external systems.

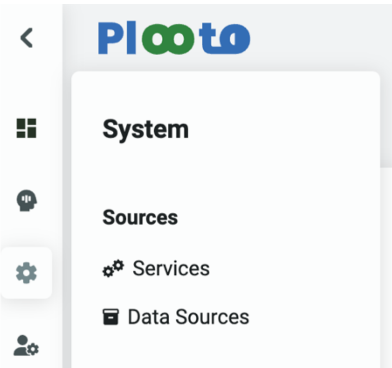

Figure 12: System submenu

With the option *Services* users can declare and configure the services they want to use in their ecosystem (e.g. optimization).

With the option *Data sources*, users can describe the data structure of the DataStream that will be feeding the telemetries, and populate the data source importing data.

4.1.4 Configuration

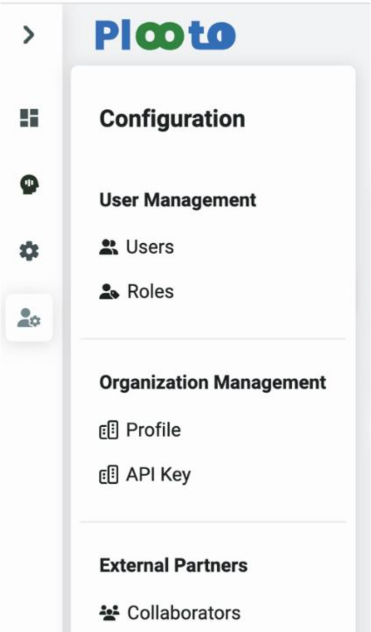

Figure 13: Configuration sub menu

The menu Configuration contains administrative functionalities concerning user and organization management. More specifically, the options *Users* allows to invite new users, while the option *Roles* concerns the management of roles (currently this features is restricted to the administrator).

The option Profile in the Organization Management sub menu, provides an overview of the organization profile. While the API key allow to get a token to be used by external APIs.

Finally, the External Partners gives an overview of external collaborators and that are connected to the user.

4.2 Internal process modelling

To model the system and the internal processes the user needs to:

- **Define** the Digital Assets that represent the objects the user wants to monitor and operate on.
- **Define** the DA's characterizing properties and the telemetries that will provide the data supporting the monitoring phase.
- **Associate** telemetries with data sources in order to automate data acquisition
- **Aggregate** the assets in networks that are related to a specific goal, eventually establishing relationships among assets.

Once the system is modelled, the user can customize the dashboard to have a complete overview of the assets, their status, and any critical issue. Additionally, the dashboard allows to execute the services integrated into the platform, according to the specific goals of the user.

A more detailed description of the modelling features provided through the platform can be found in Plooto guidelines that are available at the following link: Plooto - User and Integration Guide - 20 June 2024-v1.pdf

Figure 14 provides as an example the DT model of the requalification of expired prepreg (CETMA) for the Italian pilot.

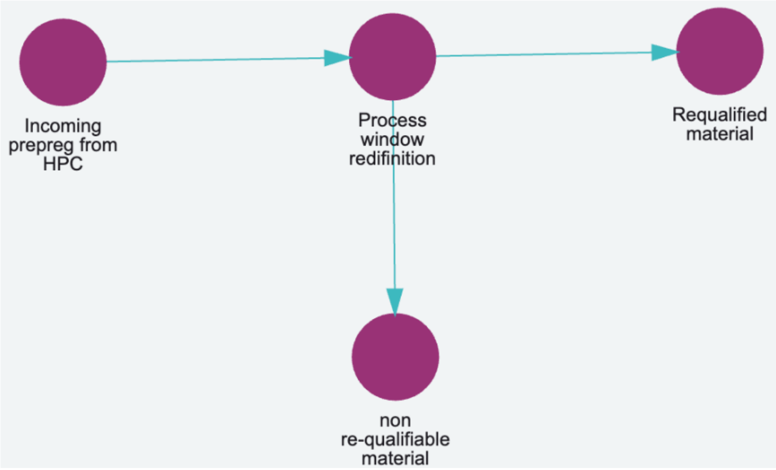

Figure 14: Example of internal process DT model

4.3 Collaborative Value Network modelling

To model the Value Network (VC) the user needs to access the specific features that have been implemented in Plooto allowing to establish a collaboration between two partners.

Effective collaboration involves a delicate balance between sharing knowledge and information among multiple parties while also safeguarding the integrity and confidentiality of that data involved. This balance is crucial not only for fostering trust, cooperation, and successful outcomes in collaborative endeavours, but also to prevent any infringement or misuse of shared information.

The requisites for effective collaboration are:

- **Sharing Knowledge and Information**: which is based on an open communication where parties can freely exchange information among themselves.
- **Ensuring Data Integrity**: ensure that the data being shared are accurate, reliable, and consistent. Furthermore, the quality and reliability of information should be maintained throughout its lifecycle.
- **Protecting Data Confidentiality**: requires implementing security measures such as access controls, encryption, and data anonymization to prevent unauthorized parties from accessing or exploiting sensitive information.
- **Preventing Data Infringement**: Data infringement refers to any unauthorized use, access, or exploitation of data that violates the rights or interests of the data owner. In a collaborative setting, it's crucial to establish clear guidelines and agreements regarding the use and handling of shared data to prevent any unintentional or malicious infringement.

Plooto approach: Based on the above requisites, the VN modelling introduces the concept of Shared Assert (SA). A SA represents the connection point between an organization and its external collaborators. Together with the asset, the parties need to agree also on the asset's data to be shared.

Therefore, once the partners have defined their internal process they need to:

- Establish the collaboration: one of the partners invite another partner to collaborate forwarding the request through appropriate features of the platform (Inventory\shared\assets) (see section 4.1.2). In this phase the inviting partner can complement his/her request for collaboration with documents such as specification, contractual agreements, DPP information etc.
- Agree on and connect the resources and data to be shared: once the collaboration is established the inviting partners selects the asset and telemetries to share and forward the request to the invited partner.

Figure 15 depict the VN of the Italian pilot, that shows the matching between the shared assets of different partners.

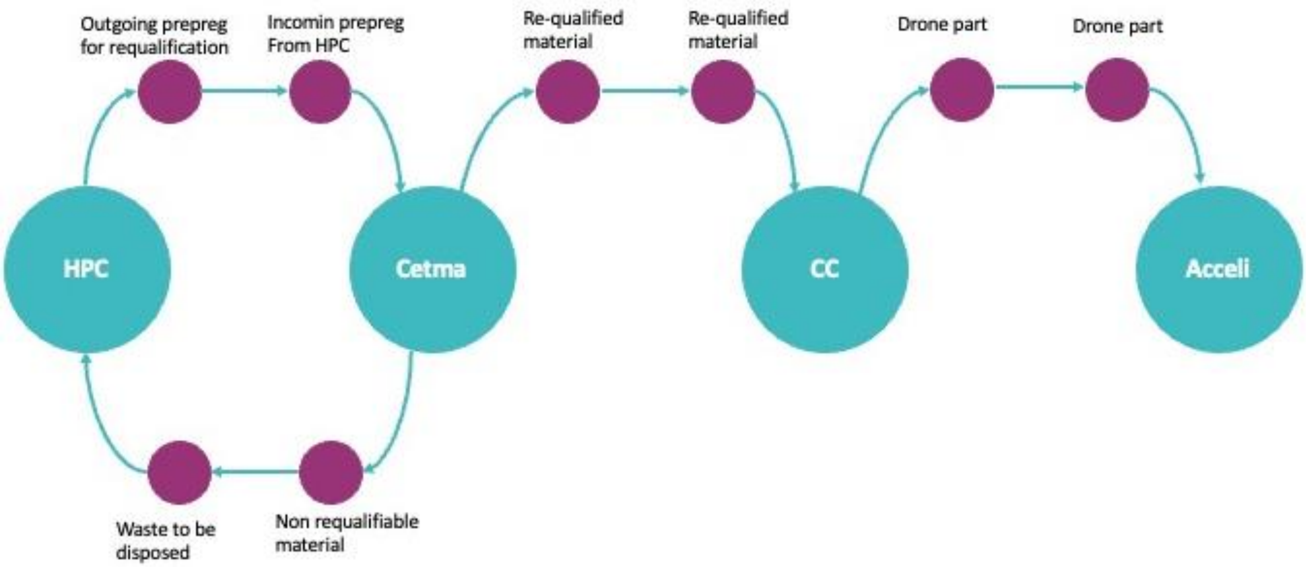

Figure 15: Value Network model of the Italian Pilot

Refer to D2.3 for a more detailed description of the Value Network services.

5 Integration and deployment

5.1 Integration approach and integration patterns

CRIS has the capacity to smoothly integrate different data, services, and tools. To ensure a high elasticity and scalability of the system as it allows to include third parties' services or tools to enrich the system's capabilities and the user experience.

Theoretically, the types of items that could be integrated can be very diverse, spanning from data streams to complex applications (e.g. legacy systems owned by the organization). For the integration perspective these technologies can be grouped in four main categories. For each category a specific integration pattern has been defined and implemented.

The four-integration pattern identified are:

- Data streams / Events
- APIs / Web Services
- Legacy systems / Applications
- Full custom

5.1.1 Integration pattern 1 - Data streams / Events

Event and Data streams can be fed directly into the ecosystem through a queueing mechanism.

The technology pushes the data stream/event (string) in the dedicated queue using the unique Telemetry token with the following format.

```
{
"timestamp": "2023-06-14 12:34:00",
"value": "amazing_value",
"token": "5404329f-7b75-44bb-af87-68bf3b38adaa"
}
```

The queue is then consumed by the platform. The fetched data will enrich the related digital asset with the telemetry.

5.1.2 Integration pattern 2 - APIs/Web Services

From the integration perspective, APIs and Web Services are treated in the same way. In both cases it is a component that communicate in a standard way through a message.

Ideally the API or web service writes directly in the dedicated queue. This option is applicable to new developments, where the technology provider is in charge to push the message to the dedicated queue.

When this is not possible, for instance in case of already deployed APIs or web services, it is necessary to implement an adapter that consumes data coming from APIs, converts it to the expected format and pushes it into the dedicated queue.

5.1.3 Integration pattern 3 - Legacy/Application integration

This integration pattern concerns the integration of Applications and tools that could have been developed in the projects, like for instance the Balanced Scorecard tool, or the Process Modelling and Simulation Tool (PMS), or legacy systems owned by the organization (e.g., ERP). Such applications and tools should be regarded as coherent systems that serve a specific goal and have their own user interface.

To make such applications available through the platform, the iFrame mechanism will be used. Users are authenticated and authorised by CRIS, which will pass a token to the iFrame to ensure the compliance with the roles and policies defined by the organization in charge and to synchronize the application contained in the iFrame with the user credentials and location.

This integration pattern will be used for instance to provide access to the Process Modelling and simulation (PMS) tool, to the Sustainability Balanced Scorecard (BSC) tool, and to the Information Modelling Framework (IMF) tool and related ontologies.

5.1.4 Integration pattern 4 - Full custom

For technologies that do not fall in the cases presented above it is still possible to integrate them in CRIS. Regardless on the purpose (data, visualizations, transactions with external systems, orchestration, etc.) this integration pattern requires a thorough discussion and agreement with the technology provider.

This pattern has been introduced for completeness, but from the information collected so far, there are no cases requiring this type of integration.

5.2 Implementation and integration status per pilot

Several technical activities have concerned all three pilot ecosystems since the beginning of the project. The first activity has been the modelling of the internal processes using the Process Modelling and Simulation (PMS) tool. Based on these models and the aspects each partner wants to control, the corresponding assets and relevant telemetries have been defined.

Then the Value Network has been designed for the Italian and Spanish pilots. The Greek pilot is not involved in a value network monitored in Plooto, therefore the DT Value Network model is not applicable for the Greek pilot.

At the same, the goals and data needed for Optimisation, Analytics and Simulation services have been finalised and harmonised and the first prototypes have been implemented.

Since the optimisation service allows the assessment of the pilot performance through the value network, it is not applicable to the Greek pilot.

The Greek pilot is interested in improving the environmental impact of the production process, specifically in terms of energy consumption and water use/reuse, for this reason the LCA service will be used.

All services are documented in *D2.3 Plooto complete suite of services v1.*

Table 3 summarises the implementation status of each pilot.

Pilot	Process models	DT process	DT Value Network	Optimization	Simulation	Analytics	LCA
Italian	√	√	√	√	√	√	na
Spanish	√	√	√	√	√	√	na
Greek	√	√	na	na	√	√	√

Table 3: Implementation and integration status per pilot

Each partner has been granted access to the platform (credentials) to be ready for the piloting activities starting from M19.

5.3 Delivery and usage

The software of Plooto platform is maintained in a GitHub repository at the following URL. For Internal policies, the URL is not public to safeguard the PR of the developed software.

https://github.com/Maggioli-Greece/digital-twins

Plooto guidelines are available at the following link

Plooto - User and Integration Guide - 20 June 2024-v1.pdf

The document can be access only to verified users. Credentials can be provided upon requests.

Conclusions

This document reports the work done to implement the first version of Plooto integrated platform. The implementation of the platform relies on 1) the definition and modelling of the Value Networks and internal processes in all pilot ecosystems, 2) the definition and harmonisation of the goals and data needs for Optimization, Analytics, and Simulation services, 3) on the availability of the first prototypes of the services to be integrated.

The Plooto platform is modular, extendable, open, and customizable, supporting various integration patterns and ensuring secure data exchange and role-based access control. The requirements outlined in D1.5 were addressed, enabling collaboration, secure data handling, use of local tools, process definition, real-time monitoring, asset integration, and production process simulation.

Overall, the Plooto platform provides a robust, modular, and flexible environment for managing and integrating tools, services, and data in different pilot ecosystems.

Each partner has access to the platform, preparing for pilot activities from M19.

In the next version of this deliverable, due by M30, the feedback from the 1st run of pilot operations will help finalising the platform with orchestration capability and with the integration of all services and tools implemented in the different tasks.

References

[1] Digital Twin Consortium (2023). Definition Of A Digital Twin, Retrieved on 13.01.23, Definition of a Digital Twin - Digital Twin Consortium

[2] ODCS (May 2022). Evolution of Digital Twins. Retrieved on 10.02.23 from https://odsc.com/blog/evolution-of-digital-twins/