TREASURE

D1.2: TREASURE tool & platform requirements and specifications

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Technical References

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EXECUTIVE SUMMARY

As part of the WP1 "Reference Framework definition" activities, Deliverable 1.2 "TREASURE tool & platform requirements and specifications" aims at providing an early overall picture of the final TREASURE Platform, investigating high-level components of the TREASURE assessment and advisory model and the related software platform structure, built upon stakeholders' requirements and pilot scenarios.

Starting from the consideration that the shift toward circularity is a collaborative effort of the whole automotive value chain and is not possible to be achieved by any one actor, company, or industry alone, the TREASURE Platform is conceived as a knowledge sharing and decision support system able to foster data sharing, facilitate the collaboration among the involved actors exchanging valuable information and KPIs towards a more Circular Economy practices implementation.

The platform addresses both Beginning- and End of Life actors, as well as final consumers supported by proper software modules, which will be developed within the TREASURE project, namely the Disassemblability, Recyclability and Eco-design modules, providing useful, industry and physics-based instructions on the procedures of disassembly, recycling, and Eco-design and KPIs which will support and guide decision making towards a Circular Economy. On top of the modules, a Circular AI-based advisory tool will be developed to provide intelligence to the system.

TREASURE aims at filling the information gap existing between Beginning-of-Life (BoL) and End-of-Life (EoL) actors through the development of an AI-based assessment tool able to connect and facilitate the interaction among the key involved stakeholders dedicated to car electronics: car parts suppliers, car makers, dismantlers, and shredders. At the same time, TREASURE aims at assisting both BoL and EoL actors in performing their operations (e.g., car parts design, disassembly, dismantling operations, recycling flowsheet architecture), taking the most suitable decision according to up-to-date information, optimal CE performance as well as in assessing the impact and the effect of their decision on the final customers.

This document summarized the preliminary system requirements emerged from the discussions with the use cases and drafted a high-level software architecture, therefore laying the foundation for the development of the TREASURE Platform.

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1. Introduction

Leveraging on the findings reported into D1.1 "TREASURE reference framework" submitted by SUPSI at M4, D1.2 aims to provide an early overall picture of the TREASURE Platform. In particular, starting from the needs and the requirements collected from the 3 use cases and 4 pilot cases, in accordance with D1.3, this document exploits the value chain digitalization reference framework that allows highlighting the data flows in the various phases of the project and the interactions with the platform.

1.1. Project Overview

TREASURE – "*leading the TRansition of the European Automotive SUpply chain towards a circulaR futurE"* wants to support the transition of the automotive sector towards Circular Economy (CE), by providing a concrete demonstration of how the industry can benefit from the adoption of Circular Economy practices and principles, both from a business and a technological perspective. One of the main encountered issues highlighted by the automotive actors, refers to the huge information gap existing between Beginning-of-Life (BoL) and End-of-Life (EoL) actors along the whole automotive value chain up to the final consumers.

TREASURE aims at filling this gap through the development of an AI-based assessment tool able to connect and facilitate the interaction among the key involved stakeholders dedicated to car electronics: car parts suppliers, car makers, dismantlers, and shredders. At the same time, TREASURE aims at assisting both BoL and EoL actors in performing their operations (e.g., car parts design, disassembly, dismantling operations, recycling flowsheet architecture), taking the most suitable decision according to up-to-date information, optimal CE performance as well as in assessing the impact and the effect of their decision on the final customers.

To this aim, a web-based platform will be developed as a novel information sharing tool among all stakeholders, both in forward and backward directions, ensuring secure access and confidentiality. The platform will be developed in order to enhance the connection among the actors, making information available through specific modules (namely the Disassemblability, Recyclability and Eco-design modules) that will be built and tailored according to their needs.

The platform will be tested with a set of dedicated demonstration actions within the project boundaries. However, it will be designed assuring that its potential can go beyond the project and its sustainability will be properly defined and agreed within the TREASURE consortium, guaranteeing the possibility for its scale-up and adoption by a wider group of stakeholders and applications.

1.2. Scope of the deliverable

D1.2 "TREASURE tool & platform requirements and specifications" is the deliverable associated to Task 1.2 focused on the investigation of the high-level components of the TREASURE assessment and advisory model and the related software platform structure. Starting from the findings provided by Task T1.1 and building upon the stakeholders' requirements and pilot scenarios gathered and formalized in compliance to Task T1.3, D1.2 provides an overview of the TREASURE Platform goal as well as a preliminary high-level software architecture.

Working together with Task 1.3, the use case scenarios have been analysed, deeply investigating how the platform modules could support their transition from the AS-IS to the TO-BE scenarios. Indeed, this deliverable identifies the different scenarios to be implemented considering the targeted stakeholders and include the business requirements to give an overview of the current needs that the stakeholders have and to which the TREASURE Platform should provide a solution.

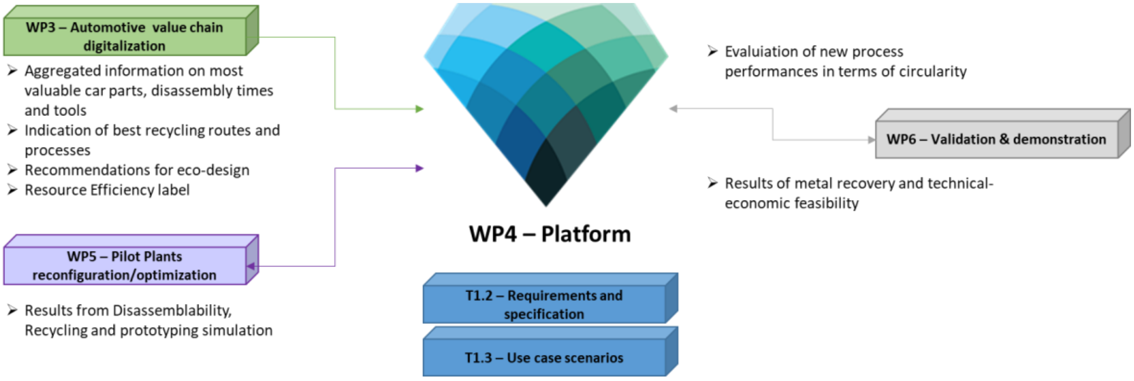

Figure 1 - TREASURE Platform positioning

The overall platform design, development and integration will be performed in the frame of WP4, starting from the outcomes of Task 1.2 and 1.3, that are the use case scenarios and the platform preliminary requirements and specifications, reported respectively in D1.2 and D1.3.

WP3 will mainly fuel WP4 providing the main contents of the platform modules, namely aggregated information on car/parts/elements, indication of disassembly procedures and development of recycling modules (simulation models) to assess recyclability and determine best recycling routes, recommendation for eco-design, and will provide KPI's to support this. Following up on the developments in WP3, WP4 will be focussed on the technical development of the integration and linking of the modules themselves.

Then, the early outcomes of the platform will be tested within WP5 activities on different cases/pilots, which will provide feedbacks from the results of disassembly, recycling, and prototyping simulation activities. The TREASURE Platform validation and demonstration process will then be performed within WP6, evaluating the new process performances in terms of circularity and economic feasibility.

Accordingly, Task 1.2 outcomes have to be considered as preliminary inputs for WP4, which will be then finalized and arranged according to the project evolution. In order to better clarify what to expect between Task 1.2 and the activities under WP4, the following table summarizes the main findings:

Table 1 - Activities summary

WP1 (Task 1.2)	WP4
D1.2 (Report) Platform objectives and early logical picture. Use case data level and flows analysis. Early platform functionalities. Early list of system requirements. High-level software architecture.	**D4.1 (Report)** Sequence diagrams. Full list of technical requirements. Detailed technical software architecture. Overview of the platform modules. Preliminary MVP. **D4.3 (Other)** Data lake development. **D4.7 (Other)** Platform eco-design, dismantling and recycling modules.

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	D4.9 (Other) Platform Circular AI-based advisory tool.

1.3. Contribution to other WPs

This deliverable belongs to WP1 "Reference framework definition" and it identifies the different scenarios to be implemented considering the targeted stakeholders and includes the business requirements to give an overview of the current needs that the stakeholders have and to which the TREASURE Platform should provide a solution. Moreover, the document provides an overview of the high-level software components architecture.

Therefore, it is evident to highlight that this deliverable is directly related to the technical work packages:

- WP3 "Automotive value chain digitalization": D1.2 provides an early logical picture of the platform and an overview of the main platform modules that have been defined collaboratively with WP3 leaders.
- WP4 "TREASURE Platform design, development and integration": D1.2 mainly provides input, requirements and the guiding principles for the concrete platform development and implementation.
- WP5 "Pilot plants reconfiguration/optimization": D1.2 collects the user-requirements and provides an overall picture of the pilots and their testing environment.

2. TREASURE Platform overview

Collaboration and information exchange across stakeholders involved in the automotive industry is still a big challenge that needs to be overcome in the automotive industry. Indeed, poor collaboration and partnerships exist, and few data are shared among the whole value chain. Organizations mainly focus on increasing their own business rather than thinking on the success of the entire industry.

However, the shift toward circularity is a collaborative effort and cannot be achieved by any actor, company, or industry alone. In the automotive industry too, all stakeholders including car and parts suppliers, consumers as well as dismantlers and recyclers must be engaged in looking towards a common objective.

Moreover, data sharing for manufacturing is an important enabler of collaboration among stakeholders and it is therefore fundamental in order to enhance a proper implementation of CE practices. More in detail, as reported in the World Manufacturing Forum Report 2021[2], data sharing has been listed as one of the three main CE Enablers at a Value Chain level, together with Infrastructure Networks and Standardization of requirements. Unfortunately, data sharing is complex and several challenges, such as the need to comply with privacy laws, cybersecurity threats, data quality, and the lack of standardisation in data collection practices have to be overcome. A secure data sharing among all stakeholders across the supply network has to be guaranteed to foster the collaboration among the partners, ensuring safeguarding company confidential information.

[2] https://worldmanufacturing.org/wp-content/uploads/WMF2021_E-Book_b.pdf

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2.1. Platform objectives

The TREASURE Platform is mainly conceived as a knowledge sharing and decision support system, which securely collects data from multiple sources and actors in the automotive supply chain, processes them through proprietary assessment and advisory engines (tools such as the disassembly, recycling, and Eco-design modules) and gives back value-added knowledge through properly designed software modules to support a complete transition of the automotive industry towards CE.

The TREASURE platform is expected to act as a unifying and standardizing entity whose competitive value proposition leverages on a set of precise selling points:

- **Supply chain-wise data acquisition** allows to constantly expand the knowledge basis for CE assessment and advisory in compliance with LCA principles. This lays the foundation for value-adding CE enhancing initiatives involving the entire supply chain instead of single-actor bottom-up projects with limited visibility and disputable results.
- **Centralized data repository**. This holistic approach of linking product/process/resources dataflow in a common reference architecture is becoming increasingly important for the manufacturing of high-volume components, in which various types of data of different formats must be aggregated. Therefore, TREASURE promotes an efficient and secured data collection from product/process/manufacturing providing a seamless integration, flexible enough to trigger value-adding decision making. Avoiding data silos between the different actors in the supply chain, TREASURE developments foresee a global responsive system based on the adoption of standards and decision-making integration throughout the several phases of product and process development, usage, and end of life activities.
- **Modular user-centred interfaces**. Specific software solutions and modules are developed for the identified specific user groups, thus conveying dedicated information, and promoting group-relevant decision making.
- **TREASURE Assessment and Advisory Engine** is meant to generate a more informed decision-making process through optimization and decision support algorithms able to automatically or semi-automatically suggest improvement of the sustainability and circularity performances of products along their whole life cycles. The goal of the decision method is to provide metrics that allow decision makers to justify their choices.

2.2. Early logical picture

According to the above-mentioned consideration, TREASURE Project aims to develop a platform able to face data sharing issue and foster digitalization and, more specifically, the collaboration of the Automotive Value Chain, with the goal of enhancing a proper implementation of Circular Economy practices along the automotive industry.

More in detail, the TREASURE Platform aims to:

- foster the communication and connection among TREASURE Partners Value Chain.
- facilitate the collaboration between Beginning- and End-of-Life actors.
- exchange valuable information, knowledge and KPIs on circularity.
- enhance the digitalization of the Automotive industry stakeholders.

As represented in Figure 2, the platform aims to guarantee a proper and secure data flow among all the identified actors, which have been classified for the scope of the project in:

- **Beginning-of-Life (BoL) actors**: car parts suppliers, organizations, including electronic part/component suppliers, that design and supply car parts and components to car manufacturers, and car makers, namely companies manufacturing cars assembling all the required parts;
- **End-of-Life actors (EoL)**: dismantlers, shredders and recyclers, therefore those organizations that disassemble car parts and their components and try to recover materials/elements (ranging from shredding and physical sorting up to and including final treatment processes such as e.g. metallurgical processing) that can be recycled into new resources/metals/materials which can be applied in car or other parts;
- **Consumers**: final car users.

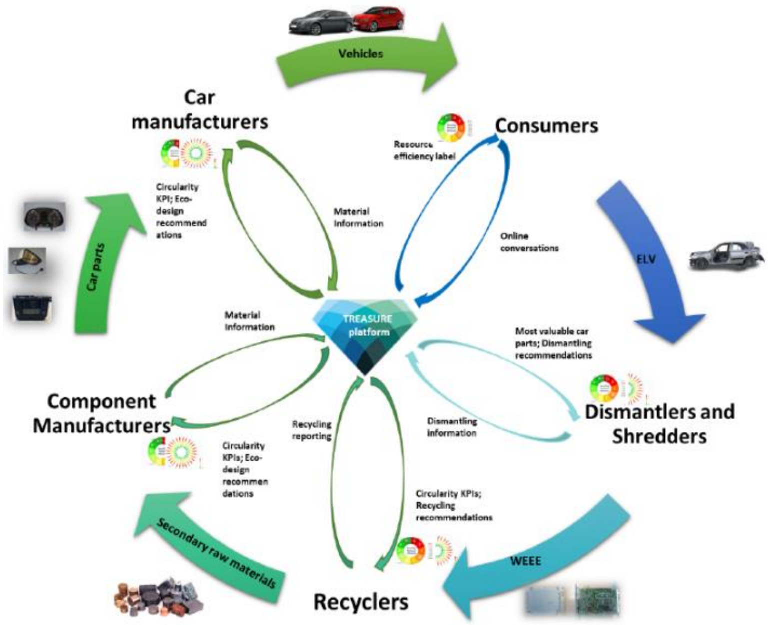

Figure 2 - TREASURE Platform concept

The initial knowledge will be generated by acquiring and managing data coming from available public and private databases (e.g., RMIS, IMDS, MISS) as well as from the stakeholders themselves who will further populate the platform with useful data on car parts, components and elements, assembly and dismantling procedures, recycling routes. Moreover, new data and information for improving current operations will flow into the platform from the disassembly and recyclability assessments results as well as in the form of feedbacks from disassembly and recycling workers.

The outcome of the platform will mainly be a set of advisory services in the form of KPIs (technological and CE indicators mainly) and recommendations. Figure 3 reports an early logical picture of the platform, which is meant to connect and exchange valuable information among the actors.

The platform exchanges KPIs on recycling rate, disassembly and recycling instructions, information for identification of materials/elements/compounds with a low recycling/recovery rate or losses/emission as technology/physicis based input to Eco-design recommendations.

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In particular, **3 main modules** are foreseen to support the 3 use cases described in the form of user journeys in Section 2:

- A **Disassemblability module** providing information on critical and valuable car parts to be disassembled and useful disassembly instructions.
- A **Recyclability module** providing information on the recycling/recovery rates of car raw materials/elements/compounds (including losses and emissions) and containing indications of best recycling routes and processes for optimum recovery by development and application of recycling process and flowsheet simulation models.
- An **Eco-design module** providing information on hardware car parts, valuable recommendations for the design phase based on KPI's as derived from the disassembly and recycling module.

Most of the insights on the content and outputs of the 3 modules will be mainly defined within T3.4 "Eco-design, disassemblability reusability and recyclability guidelines and integration with CE indicators", in D3.4 "Report on KPIs to be embedded in the TREASURE Platform" which is led by UNIZAR and is due to M18.

On top of the modules, a **Circular AI-based advisory tool** will be developed to provide intelligence to the system.

The platform will be also complemented with a Semantic Social Network Analysis Module, connecting the EDGERYDERS Platform, to check the social impact of adopted CE practices and offer to customers a graphical index assessing the circularity level of cars.

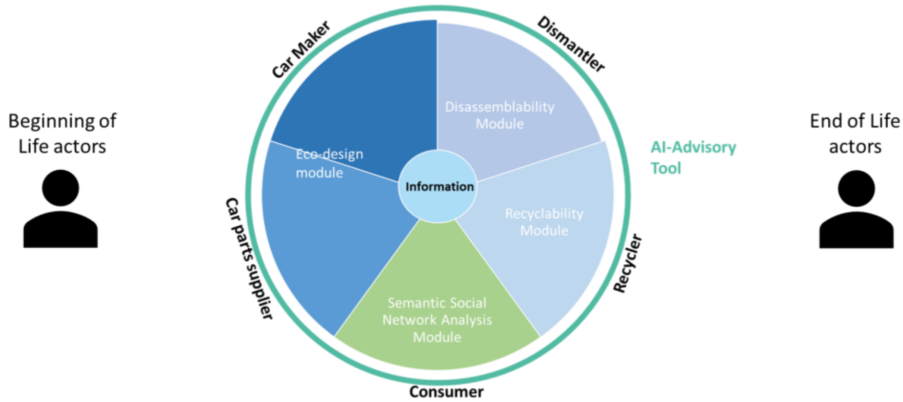

Figure 3 – Early logical picture of the platform

Before defining the platform modules in detail, it has been necessary to investigate how the platform is meant to support the different use-cases and to clearly understand the main information flows to be expected. The following section reports a detailed Use Case Analysis, performed in accordance with T1.3.

3. Use case Analysis

As anticipated in D1.1, this document intends to cover the value chain digitalization framework, highlighting the data flows and the interactions among the different stakeholders and the TREASURE Platform.

In order to properly define the different data flows, it was necessary to deeply investigate the needs and the expected scenarios of the 4 pilot cases. Accordingly, together and in accordance with T1.3, after a general discussion held during a workshop performed in the context of the framework definition, specific bilateral calls focused on the different pilots were organized. All and only the organizations involved in the pilot were required to attend the dedicated call, in order to properly focus the discussion on the target use-case.

Overall, 6 calls were organized and addressed to:

- Disassemblability use case 1, pilot case 1, mainly involving POLLINI and EUROLCDs (the call was organized on the 8th of November 2021).
- Disassemblability use case 1, pilot case 2, mainly involving ILSSA and SEAT (the call was organized on the 15th of November 2021).
- Recycling use case 2, mainly involving UNIVAQ, UNIZAR and EUROLCDS (the call was organized on the 9th of November 2021).
- Recycling use case 2 with MARAS (the call was organized on the 15th of December 2021).
- Eco-design use case 3, mainly involving WALTER PACK and EUROLCDS (the call was organized on the 9th of November 2021).

In addition, a dedicated call with EDGERYDERS and POLIMI was organized on the 10th of November 2021, to properly discuss the connection between the TREASURE Platform and the Semantic Social Network Analysis tool.

During the calls, after a broad presentation of main platform concept, the stakeholders were asked to illustrate the AS-IS and the TO-BE scenario, highlighting the main expected and desired functionalities of the platform that would support them achieving the future scenario.

Details about the use-cases current AS-IS scenarios, the TO-BE situation after the introduction of TREASURE tools, the list of industrial requirements and the use-case specifics are reported in D1.3. The following sections depict the specific data flows for the use-cases expected scenarios.

3.1. Car electronics disassembly processes (DIS use case)

The first use case (named DIS) refers to car electronics disassembly processes.

DIS will consider at least the five electronic car parts selected by SEAT (see D3.1 for details) and manually disassembled from ELVs by ILSSA (see D3.2 for details). Within the DIS use case, the disassembly of car electronics will go ahead, by desoldering valuable electronic components (e.g., microchips, capacitors, diodes, etc.) from PCBs. This activity will be executed by POLLINI (supported by POLIMI and TXT).

Considering the technologies adopted for managing ELVs and their car parts during disassembly, it’s mandatory to improve both sustainability performance, output quality level and technological development of these processes through I4.0 technologies, in order to support a real adoption of CE practices.

Dismantlers organizations will rely on the platform to:

- Enhance the information sharing on electronic car parts.
- Increase the effectiveness of dismantling operations.
- Improve knowledge about car parts to be disassembled.
- Improve balance between disassembly depth/intensity (and costs) and optimal recycling performance.

Moreover, POLLINI aims to combine fully manual disassembly operations with semi-automated procedures to manage the Printed Circuit Boards desoldering stage.

See D1.3 for a proper description of the use case AS-IS and TO-BE scenario and a detailed list of Business requirements.

The main data flows expected in order to achieve use case 1 TO-BE scenario are depicted in Figure 4.

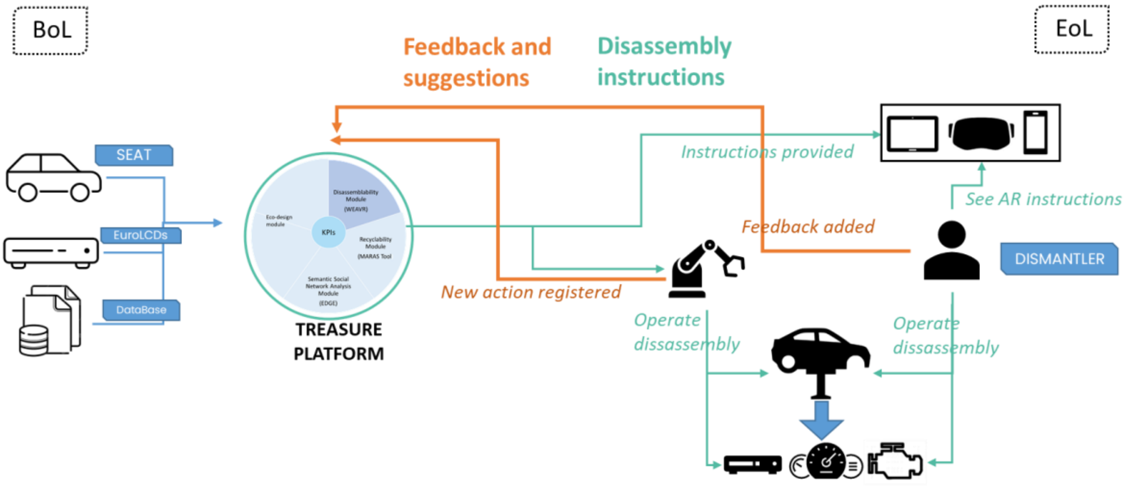

Figure 4 - Use case 1 data flows

First of all, core information about the car, car parts (Printed Circuit Boards) and elements, containing detailed compositional data on product material usage in terms of materials/compounds/elements, flow into the platform from different sources and actors. In particular:

- The car maker (SEAT) provides information about the car (3D CAD) and the disassembly instructions (text procedures, photo, video and/or 3D images).
- The car parts supplier (EUROLCDS) will provide information about the PCBs (3D CAD) and their disassembly instructions (text procedures, photo, video and/or 3D images).
- Additional information on car parts elements will be acquired by external databases.

Disassembly instructions

The collected data will be ingested by the TREASURE platform, through a specific disassembly module, that will combine all the received information to generate effective and efficient disassembly instructions for the car/car parts under operation.

The latter will be communicated to the worker by installing them into the most suitable device that can be a tablet, a smartphone, smart glasses or even headsets depending on the company willingness. Therefore, the worker will be able to see the instruction in Virtual/Augmented Reality in real time and for each of the specific operations.

The instructions elaborated by the dedicated disassembly module, in the form of text and visual images or videos, will guide operators step by step in the dismantling process, suggesting operations and letting the worker choose the most suitable one in terms of time and costs. Instructions will also support operators in identifying the location of each electronic car part

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within the car, by giving additional information about their market value, materials content through a set of KPIs and the best disassembly procedures to be followed for an efficient and effective dismantling.

In addition, in the POLLINI use case, where a collaborative robot will be available into the semi-automated line, the disassembly procedures will be communicated to the cobot too, that can support the worker in performing specific operations. In particular, the platform will be able to communicate the cobot when to execute specific operations in collaboration or on behalf of the human worker. In this way, the worker will not only be guided in performing procedures showed in Virtual/Augmented Reality, but the cobot will support him/her in a collaborative way.

Feedback and suggestions

The platform also gives the possibility to record feedback based on the dismantling assessment (defined in T3.2) and suggestions from the workers on the performed operations in both a qualitative and quantitative way. Indeed, the workers can add useful information (e.g., time spent for each single operation) that will be made available to car makers and designer.

For example, in case of a new car model or a new electronic car part, predefined disassembly instructions might not be available. In this case, the operator will perform the work and eventually train the cobot. More in detail, the platform will replicate the Digital Twin of the car/part and of the robot, and the worker will execute the operations in Virtual Reality, training the robot in a virtual environment. The resulting operations will then flow into the platform in order to keep them for future dismantling. In the same way, if feedback for improving current dismantling operations arise, the worker will have the possibility to communicate them to the platform, in order to have a continuous improvement process in place.

This feedback will be available to car makers and car parts suppliers through the platform, in a proper collaborative space.

TREASURE Platform integration boundaries

TREASURE Platform integration boundaries refer to a list of boundaries identified by the consortium to be considered during the development of the TREASURE Platform. These boundaries can be represented by either information gaps, information sharing permissions, database access restrictions, etc.

Hitherto, the main integration boundaries that have been identified by the involved partners are linked to information sharing permission, platform access restrictions and platform update. In particular:

- It was highlighted that some information on the car and parts composition are confidential (e.g., CAD Diagrams) and therefore, SEAT and EUROLCDS will carefully assess the core information that will be shared and provided to the platform.
- In addition, dismantling instruction will be shared with only authorized users belonging to dismantlers organization, in order to avoid undesired information sharing. Proper users access permission and access policy will be implemented.
- Moreover, it is important for the platform to be up to date, otherwise it would not be suitable for all vehicle models, resulting in a difficult match between the platform DB and the car fleet consisting of dated vehicles.

TREASURE Platform integration goals

TREASURE Platform integration goals refer to a list of goals identified by the consortium to be reached at the end of the project through the TREASURE Platform. These goals are directly related to either KPIs & methodologies identified in WP2, and value chain digitalization modules identified in WP3.

The following integration goals were highlighted by the involved partners:

- The platform software must communicate which parts are to be disassembled, where they are located inside the vehicle and how to recognize them.
- The platform must collect information for improving the disassemblability of the car/car parts at the BoL stage.
- Bring together producers of cars, car parts and electronics and EoL.

3.2. Car electronics recycling processes (REC use case)

The second use case, namely REC use case, refers to car electronics recycling processes and it is led by UNIVAQ. More in detail, the 5 electronic car parts disassembled by the DIS use case (where the disassembly is done by SEAT, UNIZAR and ILSSA) will be recycled by (bio-) hydrometallurgical processes and in-Mold/Structural Electronics (IMSE) samples (supplied by TNO) and LCDs samples (supplied by EUROLCDs) will be recycled in order to check for the reuse of materials in automotive applications.

Together with the hydrometallurgical recovery of materials, MARAS's recycling simulation models will execute a recyclability assessment. In particular, assessment and optimisation of recycling of critical/minor elements (as well as all other carrier metals/materials included) of flexible electronics will be done based on processing these car parts in the UNIVAQ hydro metallurgical pilot plant and by assessing the recycling performance based on existing recycling infrastructures by application of the recycling models/modules. Comparison of new flexible designs with conventional designs will be carried out, as well as the performance of the UNIVAQ process compared to existing metallurgical processes

See D1.3 for a proper description of the use case AS-IS and TO-BE scenario and a detailed list of Business requirements.

Accordingly, the platform will mainly support recycling actors in:

- Increasing the information sharing on electronic car parts and digitalisation.
- Providing 'standards' on data detail required for proper and reliable recycling assessment and feedback.
- Improving knowledge about car parts to be recycled.
- Calculation of recycling/recovery rates of all materials/elements/compounds present in the product/part.
- Balancing between disassembly depth/intensity (and costs) and optimal recycling performance.
- Suggesting best recycling routes.

The main data flows expected in order to achieve use case 2 TO-BE scenario are depicted in Figure 5.

The first step is the same as for use case 1. Indeed, the platform receives core information about the car, car parts (PCBs) and elements, containing detailed compositional data on product material usage in terms of materials/compounds/elements, from different sources and actors.

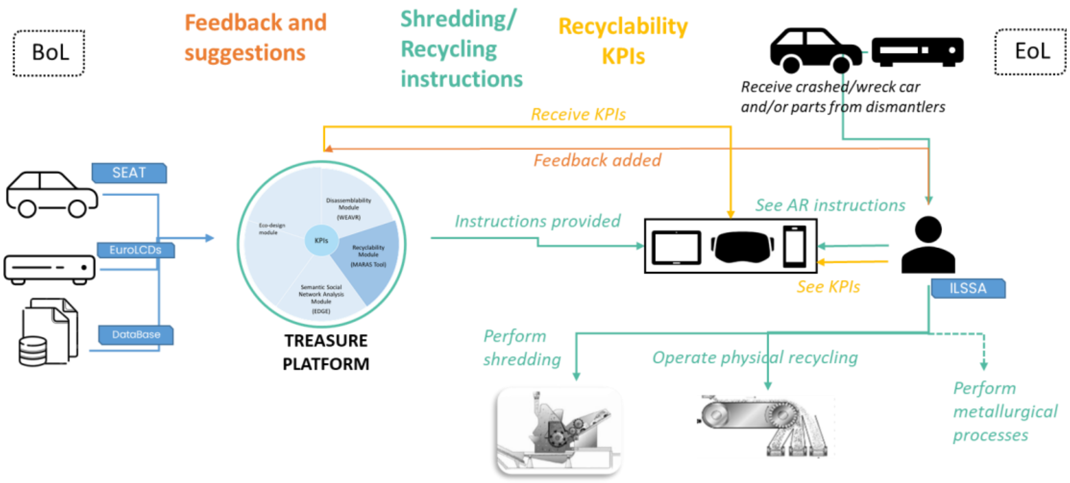

Figure 5 - Use case 2 Data flows

Then, the collected data will be ingested by the TREASURE Platform, through a specific recyclability module that will combine all the received information and the outputs of recycling systems simulation tools for recyclability analysis (developed under T3.3) to generate KPIs and shredding/recycling instructions.

Recyclability KPIs

The platform provides the car designer/producer, the shredding/physical recycling operator and recycler with KPIs on recycling/recovery for whole parts/product as well as for individual elements/materials of car/car parts under consideration (based on full mass & energy/exergy balance for all materials/metals/elements/compounds of disassembled parts).

Shredding/Recycling instructions

Moreover, the shredding/physical recycling operator and recycler will receive shredding/recycling instructions for the car/car parts under operation in order to optimize the shredding and recycling processes and at the same time increase operators' performances (e.g., best recycling flowsheet architecture implying the best recycling flowsheet configuration in relation to disassembly activities and most suitable subsequent processing). Eventually, the platform will support operators in performing metallurgical processes. Indeed, one of the goals within use case 2 is to extend current processes of ILSSA by combining a plant for metallurgical activities (e.g., UNIVAQ plant).

In addition, the platform will provide indications for identifying critical car parts, embedding valuable materials/elements worth to be recycled. As an example, the worker will be able to see through the specific device (e.g., smartphone, tablet, headset) if the car parts under operation embed precious/critical materials/elements and will be guided in how to handle them.

As for disassembly operations, both KPIs and instructions will be communicated to the worker by installing them into the most suitable device that can be a tablet, a smartphone, smart glasses or even headsets depending on the company willingness. The worker will then be able to

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evaluate which is the suitable operation to be performed step by step, according to its objectives (for example increase recyclability, reduce time and/cost). Instructions and KPIs refer to the shredding and physical recycling and metallurgical and other final treatment processes subsequent to disassembly operation.

Feedback and suggestions

The Recycling module will enhance a proper link between the Design phase and the Recycling phase, by providing specific feedback and recommendations on "Design for Recycling" based on the recycling assessment (defined in T3.3) in which losses and issues of critical importance to increase recycling are pinpointed.

Moreover, the platform through WEAVR also gives the possibility to the single worker to add specific feedback on the operations, referring for instance to the level complexity, the achieved rate of recycling, times or money spent for the specific operation.

This feedback will be recorded by the platform and made available to car makers/designer through the platform, in a proper collaborative space.

TREASURE Platform integration boundaries

As for the dismantling use case 1, the main integration boundaries that have been identified by the involved partners are linked to information sharing permission, platform access restrictions and platform update, data/information exchange formats.

TREASURE Platform integration goals

The following integration goals were highlighted by the involved partners:

- Connecting producers of cars, car parts, electronics, components (or other products) and EoL.
- Define standards for data format and detail.
- Advising operators on how to increase their performances (e.g., having information about the type of car wrecks) entering the shredding or recovery process (as a novel concept of modular/disassembly driven recycling could imply that no shredding will occur on the dismantled car parts but sent them to the most suitable/efficient subsequent final treatment processing).
- Assessing how to manage scrapped PCBs present in steel (and other materials) are best to be processed in most suitable final treatment processing; this will imply that for these parts, it will be most likely that the shredding concept will not be applied, but a modular approach to recycling. If the recycling routes are reconsidered by selection the most efficient way of processing the disassembled parts (including PCBs) by sending them to the most dedicated material recovery plant) this action could positively influence the whole ELV management process in terms of circularity performance.
- Improve operators' knowledge on materials.
- The platform must collect information for improving the recyclability of cars and car electronics at the BoL stage.

3.3. In-mold/structural electronics prototyping processes (ECO use case)

The third use case refers to In-Mold/Structural Electronics (IMSE) prototyping processes, aimed at reusing specific materials recovered from both car electronics (e.g., copper and silver) and

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selected plastic car parts (e.g., climate module and mid-console) in order to produce new in-mould/structural electronics.

This use case is led by WALTER PACK, IMSE producer, that will assess TNO prototyping process and discuss about IMSE adoption in new production processes. UNIZAR is mainly involved for studying the thermodynamic rarity of materials embedded in car electronics.

See D1.3 for a proper description of the use case AS-IS and TO-BE scenario and a detailed list of Business requirements.

The TREASURE Platform is supposed to facilitate the “design for dismantling” approach that can be an effective solution to the existing difficulties in dismantling ELVs. Indeed, it has been highlighted that certain parts of the ELVs are difficult to disassemble and use in practice because of their design and the way they have been assembled. Moreover, current means of manufacturing in-mould electronics does not facilitate its dismantling in a way that enhance a proper recycling of valuable components and materials.

Therefore, the extended producer responsibility policy requires carmakers to contribute in processing scrap cars either for their own developmental needs or for social responsibility. The “design for dismantling” approach can also provide guidelines in the design of automotive products.

The main data flows expected in order to achieve use case 3 TO-BE scenario are depicted in Figure 6.

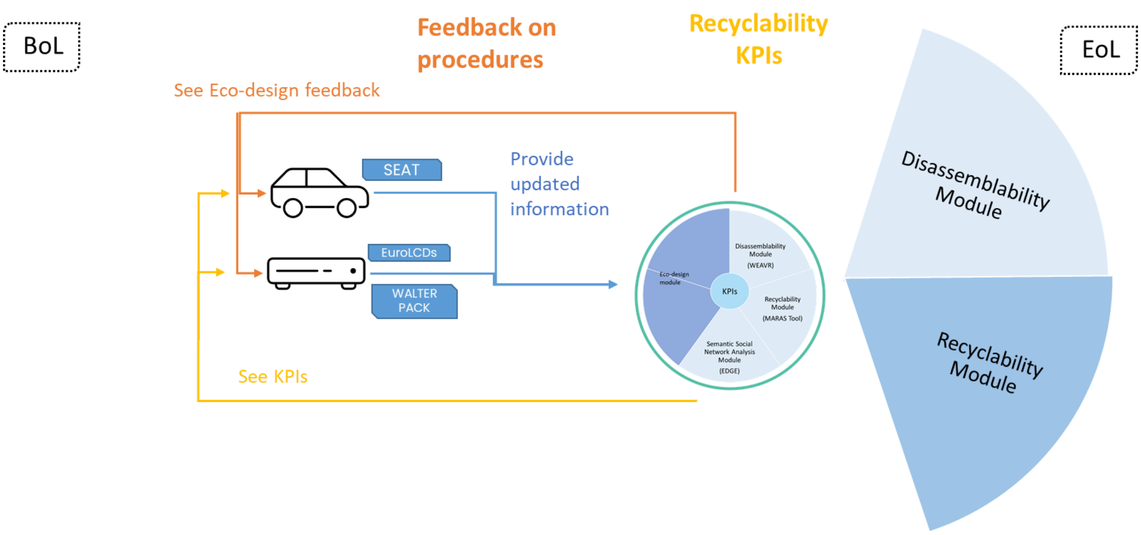

Figure 6 - Eco-design use-case data flow

In case of the eco-design use case, the platform will mainly act as a recommendation system providing feedbacks collected from the disassembly and recyclability modules.

Feedback on procedures

In particular, the feedbacks collected will be managed by the platform (recorded and made available in a proper collaborative space) in order to provide car makers and car parts suppliers with specific feedback and recommendations on “Design for Recycling” based on the recycling assessment in which losses and issues of critical importance to increase recycling are identified.

When a new car and a new electronic part must be designed, the platform will collect car parts' useful data in order to elaborate a set of CE indicators quantifying positive and negative implications of CE on the whole automotive value chain. BoL actors, namely car parts suppliers and carmakers, will be then assisted in the car part design and selection phase.

Recyclability KPIs

Moreover, the platform will show useful KPIs on the Recyclability rates of their car/car parts, timing, cost faced by EoL stakeholders. In particular, the platform will allow BoL actors to identify critical/bottlenecks processes in order to let them think how to improve new product releases.

TREASURE Platform integration boundaries

No specific integration boundaries have been identified by the partners involved in this use case.

TREASURE Platform integration goals

The following integration goals were highlighted by the involved partners:

- Connecting producers of vehicles, car parts and electronics with dismantlers and recyclers.
- Providing suggestions to BoL actors, in order to enhance the "Design for recycling".

3.4. Semantic Social Network Analysis (SSNA)

A successful transition to the circular economy depends largely on consumers, as they are the ones to demand sustainable change, and in turn create business opportunity.

The platform will therefore address and involve the final consumers to gain important information for the automotive players on the impact of CE strategies in the market from the final customers' behaviours.

For this scope, the platform will leverage on a Semantic Social Network Analysis (SSNA) both to check the social impact of adopted CE practices from a customer perspective and offer to customers a graphical index assessing the circularity level of cars. The specific platform module will be mainly devoted to connect EDGERYDERS Toolset and the TREASURE Platform.

SSNA is a methodology and a toolset developed by EDGERYDERS that combines ethnography and data science from thousands of interactive citizens and stakeholders' contributions on a public forum.

The information gathered on consumers' behaviours in terms of recyclability are encoded and then visualized with graphs. This information will be then ingested by the platform and conveyed to car makers mainly for assessing the impact of their CE practices in the market.

Moreover, with the goal of increasing consumers' awareness about CE strategies adopted by automotive actors, it is expected that the platform is going to provide them with information in the form of CE indicators and graphical indexes reporting the circularity level of their cars.

3.5. AI-based Advisory Tool

The Circular AI-based advisory is meant to provide Intelligence to the system. In particular, Artificial Intelligence will be exploited to:

- Enhance the cobot smart learning based on the executed operations of the different car/parts under work.

- Provide operators (both dismantler and shredder/recycler) with recommended/most optimal processing flowsheet architecture as defined in the recycling simulation models as a function of disassembly to optimize recycling performance.
- Based on the peculiarities of EoL actors and on future technological trends, the platform might also provide BoL with forecasts and recommendations in terms of which elements/material combinations to use or avoid in assembly and provide corresponding recycling/recovery rates by application of AI based recycling assessment

4. Requirements and users' functionalities

Building upon stakeholders' requirements and pilot scenarios gathered and formalized in compliance to Task T1.3, a preliminary list of specific system functional and non-functional requirements and functionalities per target users have been identified to drive the development of the TREASURE Platform.

4.1. System requirements

This section provides a list of the technical requirements that have emerged during the brainstorming calls held with the TREASURE partners, and then gathered and formalized together with the Use Case scenario analysis in Task 1.3.

A requirement is a service, function, or feature that a user needs in the software. Requirements can be functions, constraints, business rules or other elements that must be present to meet the need of the intended users. Requirement gathering techniques in agile software development come in many shapes and forms, but the most common form is a User Story. A User Story is a requirement expressed from the perspective of an end-user goal. User stories represent the needs of the customer in a simply written narrative that can be easily understood.

The main difference between user stories and use cases is their objectives. The user story focuses on the experience and what the person using the product wants to be able to do, while a use case focuses on functionality and what the product should do. Use cases analysis has been provided in section 2 "Use case data flows", here a more detailed list of technical requirements is provided.

One of the principles behind User Stories is that the product could be fully represented through the needs of its users. Because the User stories are short and simple descriptions of a feature told from the perspective of the person who desires the new capability, usually a user or customer of the system. The focus is on why and how the user interacts with the software. A user story is essentially a high-level definition of what the software should be capable of doing.

The main stakeholders that the TREASURE Platform addresses have been deeply analysed in the previous Section 2. The TREASURE Platform has to meet the requirements of the different stakeholders, that have been listed in the form of user stories in the previous section. Then, the main TREASURE Platform system requirements, both functional and non functional, have been elicited, and they are listed in the following table.

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Table 2 - Early system requirements

ID	System Requirement	Description	Functional (F)/Non functional (NF)
R_1	SEE KPIS	The platform must enable to show KPIs in form of numbers, colour-based, graph-based diagrams related to specific car/parts /elements.	F
R_2	COMPARE KPIS	The platform must enhance the comparison of different KPIs on car/parts /elements procedures.	F
R_3	UPLOAD/UPDATE DATA	The platform must enable to upload and update data on specific car/parts/element into a proper shared space.	F
R_4	MANAGE USERS ACCESS	The platform must manage user accesses based on different access policies.	F
R_5	PROVIDE "WYSIWYG" EDITOR FOR PROCEDURES	The platform must provide "What you see is what you get" editor for procedures development.	F
R_6	DOWNLOAD PROCEDURE	The platform must allow to download procedures to make them available to users.	F
R_7	SIMPLE USER INTERFACES	The platform must allow to view requested data/information (e.g., KPIs, graphs, instructions) through specific devices and simple interfaces.	NF
R_8	SECURITY	The platform must guarantee security of data access and management.	NF
R_9	INTEROPERABILITY	The platform should follow the interoperability guidelines (tools, technologies, and procedures) to facilitate the interchange of information in different systems environments.	NF
R_10	OPEN INTERFACES	The platform should possibly be implemented using open interfaces to be able to communicate with other systems.	NF
R_11	LOG RECORDING	The platform must enable to save log of any operation.	F
R_12	FEEDBACK RECORDING	The platform must enable to save feedback.	F

A full list of the system technical requirements will be defined in the scope of Task 4.1 "Technical requirements and solution design", led by TXT. In particular a first list will be provided in D4.1" TREASURE technical architecture (1st version)", which is led by TXT and due to M9, and then finalized in D4.2 "TREASURE technical architecture (final version)", led by TXT and due to M28.

4.2. Users' functionalities

In this section, users' functionalities have been listed per each of involved actor that will access the TREASURE Platform in order to effectively depict the possible roles and actions.

The disassembler:

- Log-in using a specific device with the TREASURE application installed.
- Look for certain car/electronics and identifies parts with critical raw materials.
- The system suggests the specific parts to be disassembled and the procedures to follow.
- Select a specific car part to be disassembled.
- View the proper instructions and KPIs with the device in VR/AR.
- Follow the instructions and confirm/deny the operation using the device.
- Provide feedbacks/considerations on a specific operation using the device.
- If needed, activate the cobot to perform some operations collaboratively.
- If predefined operations for the cobot are not known, the worker teach the cobot and operations are recorded.

The shredder/physical recycling operator and recycler:

- Log-in using a specific device with the TREASURE application installed.
- Look for a specific element/material present in a specific car/part, as applied in the particular design.
- View the proper instructions and KPIs with the device (e.g., tablet, smartphone, headset) through which the operator will see KPIs, Instructions, etc.
- Follow the instructions and confirm/deny the operation using the device.
- Provide feedbacks/considerations on a specific operation using the device.

The car parts designer/car maker:

- Log-in into the TREASURE Platform web app.

(Teach the system)

- Add information on the car and parts composition.

(Use the TREASURE support-system)

- Search for a certain car/part.
- View the proper information and KPIs (e.g., critical raw materials contents, recyclability rates, time and cost associated to dismantling/shredding operations) on the specific car/part.
- View graphs assessing the impact of their Circular Economy practices in the market.
- View eco-design suggestions on the specific car/part.
- Update information on the car and parts composition.

The consumer:

- View a subset of CE indicators and graphical indexes reporting the circularity level of their cars.

5. TREASURE Platform high level software architecture

The TREASURE Platform will be a web-based and data-driven platform able to foster the communication and connect TREASURE Partners, exchange valuable information and knowledge for a proper implementation of CE practices along the automotive value chain.

As already described in Section 2, the platform will be composed of 3 main modules: Disassemblability, Recyclability and Eco-design modules. On top of the modules, a Circular AI-

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based advisory tool will be developed to provide intelligence to the system and a Semantic Social Network Analysis Module will be included as well.

An early picture of how the platform will be technically implemented is drafted in the following sections, which provide a preliminary logical architecture, while more details about the module and tools as well as the technologies that will be used to develop the platform will be found in D4.1.

5.1. High-level software Architecture

This section provides an early logical architecture of the TREASURE Platform, with principles of software architecture design. The detailed 1st version of TREASURE Platform architecture can be found in D4.1" TREASURE technical architecture (1st version)", which is led by TXT and due to M9, while the final version of the architecture will be provided in D4.2 "TREASURE technical architecture (final version)", led by TXT and due to M28.

Several relevant Reference Architectures in relation to data-driven manufacturing will be considered as a baseline for designing the TREASURE Platform Reference Architecture. Some of them are the Reference Architectural Model Industry 4.0, the Industrial Internet Reference Architecture, the International Data Spaces Reference Architecture Model, FIWARE Smart Industry Reference Architecture, etc.

The TREASURE Platform will deal with several different industrial scenarios, where Artificial Intelligence will have effects on the existing processes by enhancing the implementation of Circular Economy practices along the whole automotive value chain that will be interconnected.

Accordingly, a proper Reference Architecture following a data-driven approach and capable of driving the automotive sector transformation into a networked, data driven environment, empowered at the same time with the concepts of AI has to be developed.

Figure 7 provides an early logical architecture conceived for the development of the TREASURE Platform.

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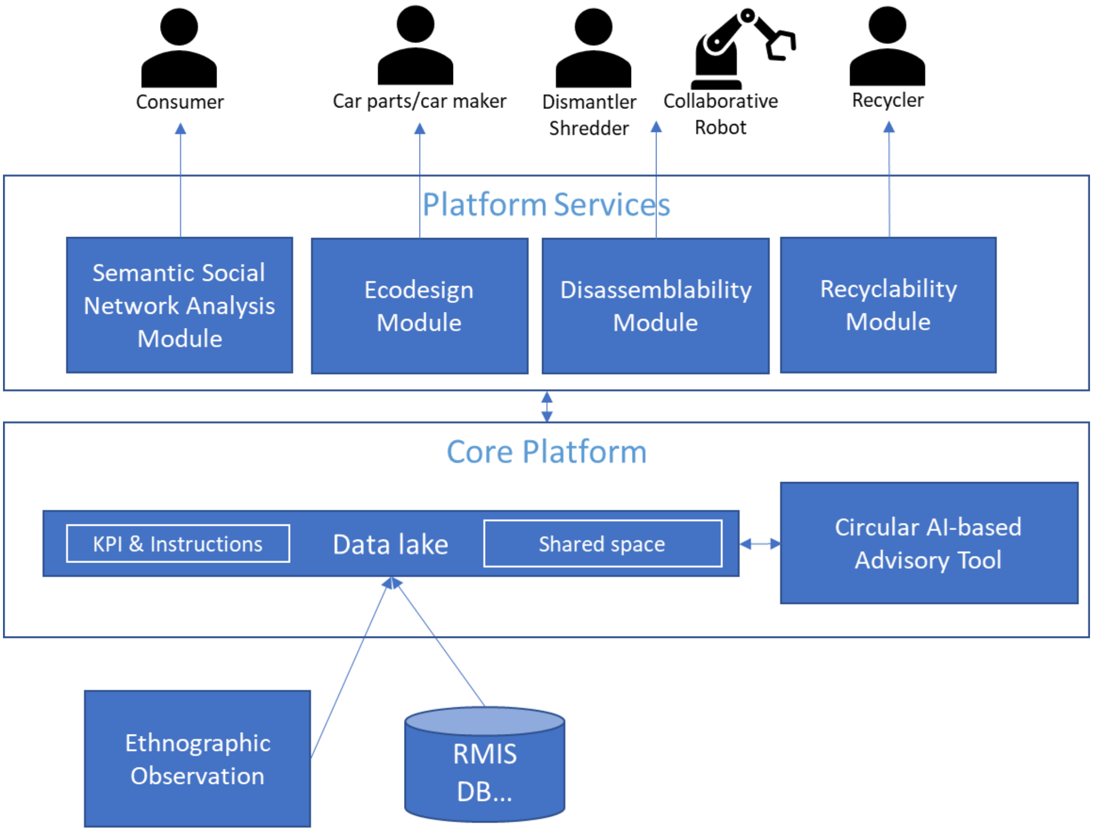

Figure 7 - TREASURE Platform architecture

First of all, the platform will gain the initial knowledge ingesting raw data from available public and private databases (e.g., RMIS, IMDS, MISS) as well as from the stakeholders themselves who will further populate the platform with useful data on car parts, components and elements, assembly, and dismantling procedures, etc. Data from the Semantic Social Network Analysis as well will flow into the core platform.

More in detail, raw data in their different original forms will flow into the platform data lake environment, a system repository to securely store data. A proper data lake will be developed for the TREASURE Platform both in terms of hardware and virtualization software and it will be stored online, using the cloud services from one of the most recognized private or public commercial vendors in the market. A proper shared space, in the form of folders, will be created to store data from the different sources.

Data scientists will develop several algorithms, which will be trained and run on top of the data lake, to provide smart KPIs and instructions to the modules. These algorithms will compose the Circular AI-based advisory tool, supporting both BoL and EoL stakeholders. Information included in the system will initially stem from physical and virtual assessments, but furtherly completed with feedbacks from each use case once the platform will be operative. This tool will complement the three main modules, providing intelligence to the system.

On top of the core platform system, the modules will be developed and reveal the main outcome of the platform, namely a set of advisory services in the form of KPIs (technological and CE indicators) and recommendations addressed to the identified target users. As already stated, more details about the module and tools as well as the technologies that will be used to develop the platform will be found in D4.1 "TREASURE technical architecture (1st version)", in charge of

TXT and due to M9, while the design of the three main modules will be performed within Task 4.4.

6. Conclusions and Next Steps

The present deliverable (D1.2) documents the early results from the discussion with the use cases that are going to adopt the TREASURE Platform in their operations. The documents have been developed to define an early logical picture of the platform, identifying the preliminary system requirements and architecture to be used as input by WP4 activities.

To drive these outcomes, a comprehensive use case analysis has been performed, together with Task 1.3, defining the use-case scenarios (that are documented in D1.3) and the platform functionalities that are supposed to enhance the transition towards the TO-BE status.

The next steps will mainly flow into WP4, that addresses the technical design, implementation and integration of the platform. The activities will be carried out strongly collaborating with the other Work Packages, mainly WP3 aimed at providing the main contents of the modules, WP5 for testing activities, and WP6 for the final validation of the TREASURE Platform and its technical implementation.