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List of Abbreviations

2D, 3D	Two or three Dimensional
ADP	Aeroports De Paris
AGEC (French)	Anti-waste for a circular economy law
AOCCS	Airport Operation Control Centre system,
AutoCAD	Design Software using DWG as a file format
BIM	Building Information Modeling
BOM	Bill of materials
CAD	Computer Aided Design
CCF	Company Consultation File or Tender Documents
CDG	Paris-Charles de Gaulle airport
CE	Circular Economy
CED	Construction and equipment department
CMMS	Computerized Maintenance Management System
CO	Control Office or Control Body
CSTB	Centre Scientifique et Technique du Bâtiment / Scientific and Technical Centre for Building. French agency dedicated to the construction sector in Research and expertise; evaluation; certification; and knowledge dissemination.
DE	Demand of technical studies
DO	Demand of Opportunity
DPMT	Design and Project Management Team
EAQM	Emissions and Air Quality Monitoring
EPR	Extended Producer Responsibility
EXE	Execution
FME	Feature Manipulation Engine is a proprietary graphical tool created by Safe Software (Canada). It is classified in the ETL (Extract Transform Load) family software.
GIS	Geographic Information System
HVAC	Heating, Ventilation, and air conditioning
IFC	Industry Foundation Classes
INHW	Inert non-hazardous waste
IT	Information Technologies
IWMS	Integrated Workplace Management System
LHW	Landfill for Hazardous Waste
LISA	Shuttle connecting gate K,L and M
LIW	Landfill for Inert Waste
LNHW	Landfill for Non-Hazardous Waste
LTECV (French)	Energy transition law for green growth

NHINW	Non Hazardous Non Inert Waste
NHW	Non-hazardous waste
O&M	Operation and Maintenance
OIP	Operations implementation program
OPPF	Overall Project Performance File
PD	Preliminary design
PDF	Portable Document Format
PEE	Personal Protective Equipment
PEMD	Produits, équipements, matériaux et déchets (see RMW)
PIF	Poste d'Inspection Filtrage (Security
PMBS	Products and materials from the building sector
PO	Project Owner
POA / POA CE	Project Owner Assistant / Project Owner Assistant Circular Economy
PPE	Personal Protective Equipment
RIM	Resource Information Modeling
RM	Ressource and Materials
RMW	Ressource, Material, Waste (PEMD in French)
SSE	Social ans solidarity Enterprise
SIS	Screening Inspection Station
STS	Special Technical Specification
WM	Waste Management
WEEE	Waste from Electrical and Electronic Equipment

Glossary

The text below explains the meaning of the various technical terms used throughout the document.

Careful removal: Removal and packaging to guarantee the quality of the materials with a view to recovery in compliance with the recycling sites' CDCs.

Dredging: Any work to remove building components other than the load-bearing structure (finishings and finishing products) that does not prejudice their disposal under appropriate regulatory conditions.

Energy recovery

Designed for waste that cannot be recycled or recovered in material form, energy recovery consists of leverage the energy produced during waste treatment by combustion or methanisation. The energy produced is used in the form of heat or electricity.

Energy recovery can be direct: the waste is burnt in a dedicated facility, built, and operated according to defined criteria to minimize environmental and health impacts. It can also be deferred, either by the production of a solid recovered fuel, or by the production of a gas or coke in gasification or pyrolysis processes.

A non-hazardous waste incinerator carries out an energy recovery operation if this operation complies with the conditions defined in article 33-2 of the amended decree of 20 September 2002, relating to incineration and co-incineration facilities and to facilities incinerating waste from care activities with infectious risks.

EPR - Extended Producer Responsibility Extended Producer Responsibility (EPR) schemes are special systems for organizing waste prevention and management for certain types of products.

Hazardous waste (HW): Any waste that has one or more of the hazardous properties (flammable, toxic, corrosive, dangerous for the environment) listed in Annex III of Directive 2008/98/EC of the European Parliament and of the Council of 19 November 2008 on waste. They are indicated by an asterisk in the list of waste mentioned in article R. 541-7 of the French Environment Code.

E.g. asbestos, lead, WEEE, light bulbs, neon lights, paint containing organic solvents, etc.

Inert non-hazardous waste (INHW): Any waste that does not undergo any significant physical, chemical or biological change, does not decompose, does not burn, does not produce any physical or chemical reaction, is not biodegradable and does not deteriorate the materials with which it comes into contact in a way likely to harm the environment or human health.

Ex: Concrete, stone, tiles, bricks, ceramics, earthenware, pebbles, etc.

Internal re-use - the re-use of components on other projects for the Owner. The elements are offered to the client, either for direct re-use on another site in progress, or for storage to meet future needs.

Landfill: reserved for final waste (that from which the recoverable part has already been extracted and that which cannot be recovered under acceptable technical and economic conditions), landfill consists of storing waste in highly controlled conditions in order to control its impact on the environment, i.e. Landfill for Non-Hazardous Waste (LNHW), Landfill for Hazardous Waste (LHW) and Landfill for Inert Waste (LIW).

Methodical removal: Removal of products to preserve their integrity and aesthetic or intrinsic quality with a view to re-use. Specific packaging may be required for products intended for sale.

Non-hazardous waste (NHW): Any waste that does not exhibit any of the 15 hazardous properties listed in Annex III of Directive 2008/98/EC of the European Parliament and of the Council of 19 November 2008 on waste. This type of waste is subject to more flexible regulations than hazardous waste.

E.g. plaster, wood, paper, cardboard, plastics, carpets, metals, etc.

On-site re-use/reutilization - the re-use of components removed from the existing structure for use during the construction phase.

Off-site re-use - for elements that cannot be re-used on site, an off-site outlet is sought. This outlet may be a local re-use channel (platform or transformation players) or a project in the area or use by social and solidarity enterprise players or local companies.

Overall recovery rate: LTECV law target of at least 70% of materials and waste produced on construction sites. The overall recovery rate to be achieved includes the re-use, recycling and material recovery of all inert waste, non-hazardous non-inert waste and non-hazardous WEEE.

PMBS - Products and materials from the building sector - an EPR channel for managing waste from the building sector, introduced by the law of 10 February 2020 on the fight against waste and the circular economy (AGEC)

Re-use: Any operation by which substances, materials or products that are not waste are used again for a purpose identical to that for which they were conceived.

Recovery: Any operation the principal result of which is that waste is used for a useful purpose in substitution for other substances, materials or products which would have been used for a particular purpose, or that waste is prepared for use for that purpose, including by the waste producer.

Recovery rate for non-hazardous non-inert waste: LTECV law target of at least 55% of materials and waste produced on construction sites. It includes recycling, re-use of materials and material recovery of all non-hazardous non-inert waste.

Recycling: Any recovery operation by which waste, including organic waste, is reprocessed into substances, materials, or products for its original function or for other purposes. Waste-to-energy operations, waste-to-fuel operations and landfill operations do not qualify as recycling operations.

Re-use rate: Unless otherwise specified, the re-use rates to be achieved include re-use, reutilization of products and equipment and upcycling.

Sorting: operation consisting of separating different types of waste according to their nature (concrete, untreated wood, glass, plastics, etc.) from a mixture of waste with a view to its final processing or outlet. Sorting can be manual and/or mechanized.

Upcycling: Upcycling is the act of recovering materials or products that are no longer in use to transform them into materials or products of superior quality or utility. It is therefore a form of "top-down" recycling.

1 Part 1 "Methodology" of the Report including a methodology proposal for increasing the circular economy in refurbishing airport terminals projects.

2 Executive summary

2.1 Introduction

ADP's Terminal Buildings are old and complex industrial buildings, they are regularly updated by construction projects to keep them on the best standard (as per their technicality or their quality of the services proposed to the passengers). Construction projects and mostly refurbishment projects are responsible for major waste production although materials and equipment may be favourably reused or recycled. ADP and BATIRIM have decided to experiment jointly the feasibility of implementing an innovative approach based on a 2D and 3D digital interface.

The report is in three parts. Part 1 describes the defined methodology, including software parameterisation and the development of specific analysis tools. Part 2 focuses on the analysis of the collected data to identify the most valuable elements for reuse. The third part summarises the results and the conclusions drawn by the project team.

2.2 Brief description of the work performed, and results achieved

The work was organised in two steps. The first step defined the methodology adapted to an airport terminal. This first phase focused on the data exchange needs between the digital deconstruction solution and the BIM design solution. The IT connectivity requirements and the information data model were defined in this phase. The second phase implemented this forward-looking approach and its digital modelling techniques on an airport deconstruction/construction project by BATIRIM. The information collected during this inventory was used to analyse "in vivo" the reuse potential of some typical functions of an airport. One of the objectives of this sub-task is to define simple metrics to evaluate, during the preliminary design phase, the potential for reusing a building zone, without having to immediately carry out a field survey for PEMD diagnostic.

3 Proposed design methodology

3.1 Actors and interactions in a circular economy project

Including circular economy in a construction project is a new process. Roles and responsibilities within the project management need to be defined accordingly. Figure 1 proposes a possible organization based on BATIRIM's expertise. Unfortunately, this organization was not implemented in the present test because only the diagnostic phase was performed (Upstream Phase). The scheme below defines the actors and their tasks during the design and construction stages.

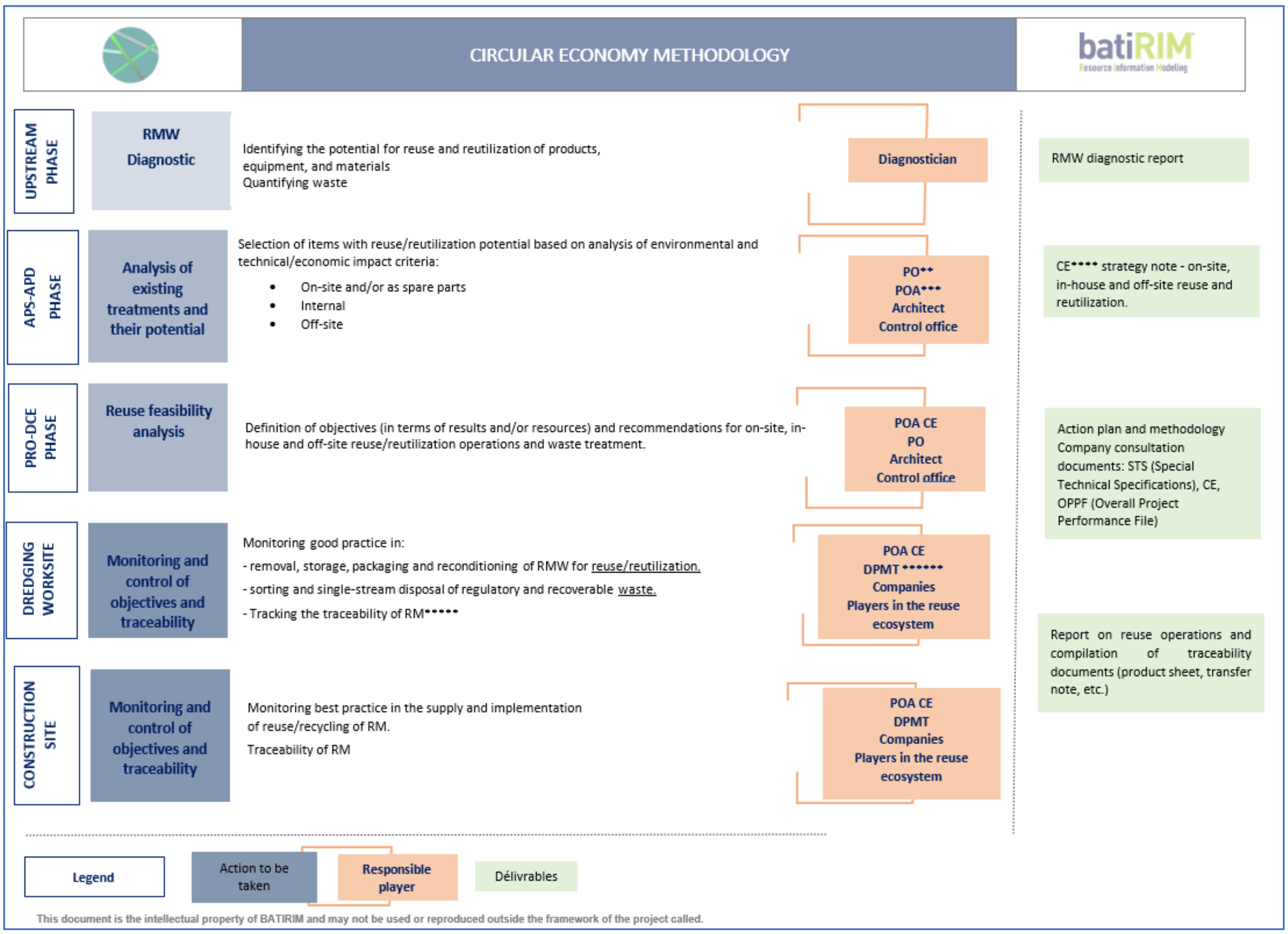


Figure 1: Overview of actors, responsibilities and deliveries (Batirim©).

3.1.1 Actor's description

Figure 2 proposes additional information to complete Figure 1. Roles and responsibilities depicted previously are detailed for each phase. As the full organization was not deployed, the following roles were left unattended. ADP-CDG would have played the role of the Project Owner and BATIRIM would have been the Project Owner Assistant on Circular Economy. The scheme below is a theorical description of the duties for each main function.

ROLE AND RESPONSIBILITIES

PO - Project Owner

Commits the project to a circular economy approach and defines the ambitions for reuse and recycling.

DPMT - Design and project management team

The design and project management team studies and prepares the deconstruction operations, considering the requirements and technical needs of the client. It proposes solutions for the complexities brought about by the possible presence of pollution (asbestos, lead, etc.). It defines the requirements for contractors, in relation to the removal, management, reduction and recovery of waste. The project manager oversees the proper execution of the works - the removal, sorting and disposal of products, equipment, materials and waste, and monitors the achievement of objectives.

POA CE - Project Owner Assistant Circular Economy

The POA CE project management team is responsible for carrying out a RMW (Resource, Material, Waste) diagnostic to identify the potential of the elements to be removed/deconstructed. It then assists the client in defining waste reduction and recovery objectives and proposes a methodology for achieving these objectives. It identifies the players involved in implementing the defined methodology and monitors the achievement of the objectives.

Dredging and construction company

Dredging and construction company responsible for carrying out the work to restore the structure. This includes general contractors holding one or more lots (for buildings), dredging contractors (for buildings), etc.
Undertake to ensure :

- The means for implementing a circular economy approach as requested in the CCF (Company Consultation File).
- The treatment of WEEE (Waste from Electrical and Electronic Equipment) complies with regulations and the hierarchy of waste treatment methods.
- Achieving the recovery targets set by PO.

CO – Control Office: validation of the suitability and technical, regulatory, and normative feasibility of the planned reuse operations.

Reuse and reutilization players: facilitators for the implementation of the reuse and reutilization approach for high-potential RWM. They master the process and methodology of removal, packaging, reconditioning and installation, while also mastering the techniques, regulations, and standards for reuse operations.

Figure 2 : Detailed responsibilities associated to main roles (BATIRIM©).

3.1.2 Interactions scheme

Once the roles and responsibilities are determined, it is generally necessary and more efficient to describe the interactions between each actor. Figure 3 below attempts to describe the working and communication processes between each partner.

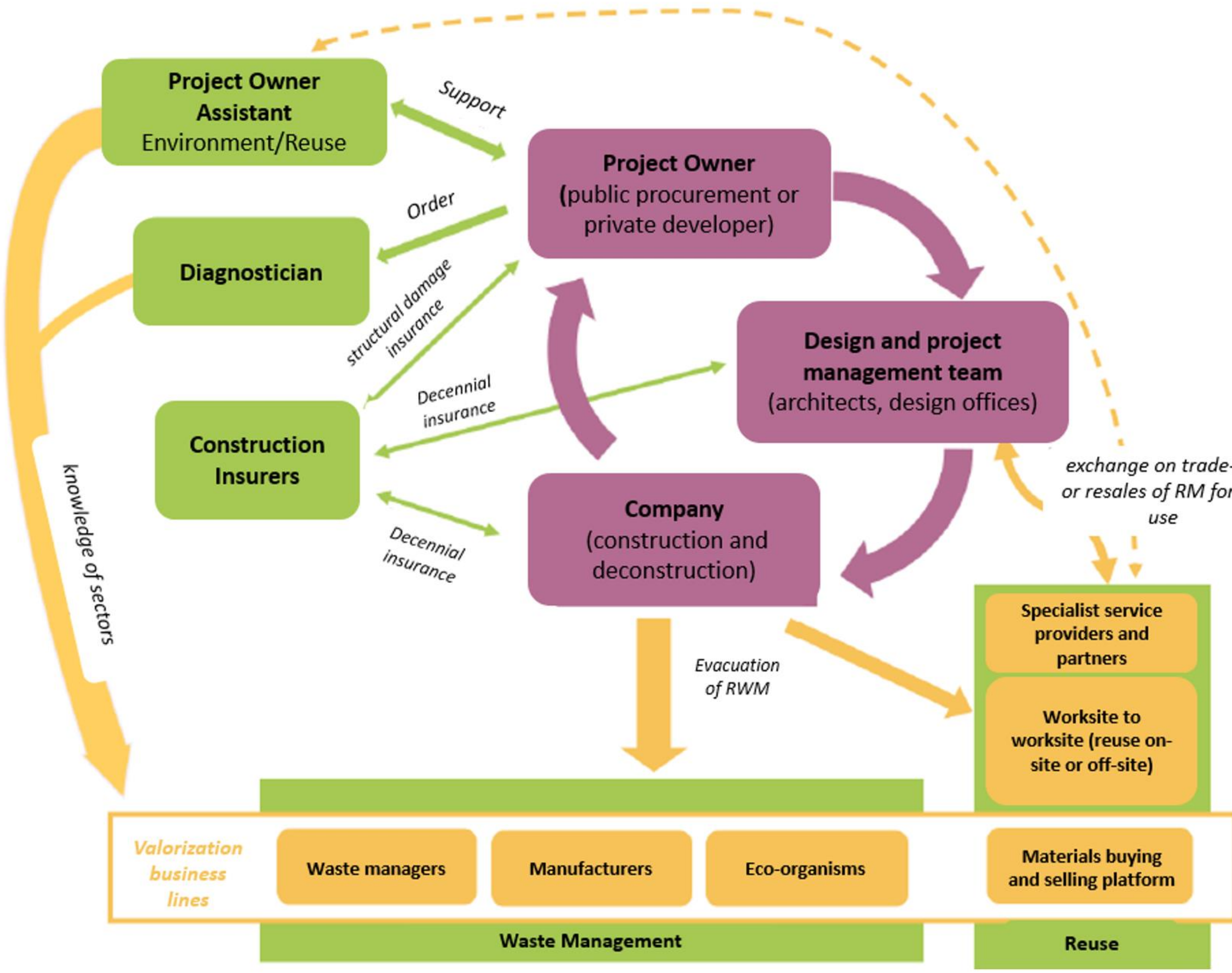


Figure 3: Diagram of the roles and interactions of the players involved in a selective dismantling operation. Source : CSTB and BATIRIM.

3.2 Data inventory

One of the objectives of this subtask was to define simple ratios that can be used to assess the potential for reuse of a building zone during the pre-design phase, without having to immediately carry out a field survey for RMW diagnostic (Resource, Material, Waste diagnostic also known as PEMD diagnostic in French). A ratio is the relative proportion of two quantities (usually expressed as a quotient), in the construction sector it is used to estimate the cost of construction from a functional measurement (e.g. the area of a room). In order to achieve this objective, it was necessary to establish a methodology to compare the result of the analysis and the elements of the diagnosed assets already identified in the Project Owner databases. Indeed, the airport's assets are identified through several major information systems. These systems were created at different moments, they do not share the same technology, but most of these systems are linked to each other and share the identification of the elements of the assets. The success of re-use is based on the ability to connect the elements diagnosed and their potential re-use or recycling flows.

For the ADP Group, the assets are followed with these main systems:

- CAD (Computer Aided Design), historically used to draw blueprints.
- BIM (Building Information Modeling), used to manage 3D design drawings.
- GIS (Geographic Information System), used to manage the spatial reference of the assets.
- CMMS (Computerized Maintenance Management System), used to manage maintenance operations.
- Airport Operation Control Centre system, use to manage the operation and resolve the issues that affect the (un)boarding pax process.
- Real estate management, used to manage lease contracts.
- IWMS (Integrated Workplace Management System), used to manage the facilities of the building.

3.2.1 Computer Aided Design as a main solution

CAD, or Computer Aided Design, was first introduced in the late 1950s. CAD allowed architects to create computerised versions of their designs, a major change from the hand-drawn pen-and-paper designs they were used to. As CAD continued to evolve over the next few decades, AutoCAD (DWG) was released in 1982. It was the first commercially available drafting software to produce 2D-based drawings of structures.

All of ADP's building plans were drawn using CAD technology and the DWG format is widely used throughout all stages of a construction project. The DWG format can be integrated into the BATIRIM software, but this software cannot natively use the drawing coordinate system to locate the result of the survey (product location). Therefore, in order to exchange data between BATIRIM and ADP systems, a development is needed to read and integrate the XY coordinates of the plan and to orient them correctly in order to model and locate the resource with XY.

DWG format can also be converted to PDF format, but the weakness of this conversion process is to lose the original coordinate system used to create the DWG. Therefore, this option was not considered any further.

CAD data focus only on the printing task, each object (a line, a circle,...) is defined with information to define its visual aspect (colour, type of line, thinness,.). The measurement of a functional object (such as the area of a room, the height of a door) is not directly calculated.

However, the industry is increasingly adopting BIM or Building Information Modelling instead of CAD, which offers entire processes to automate workflows and save time.

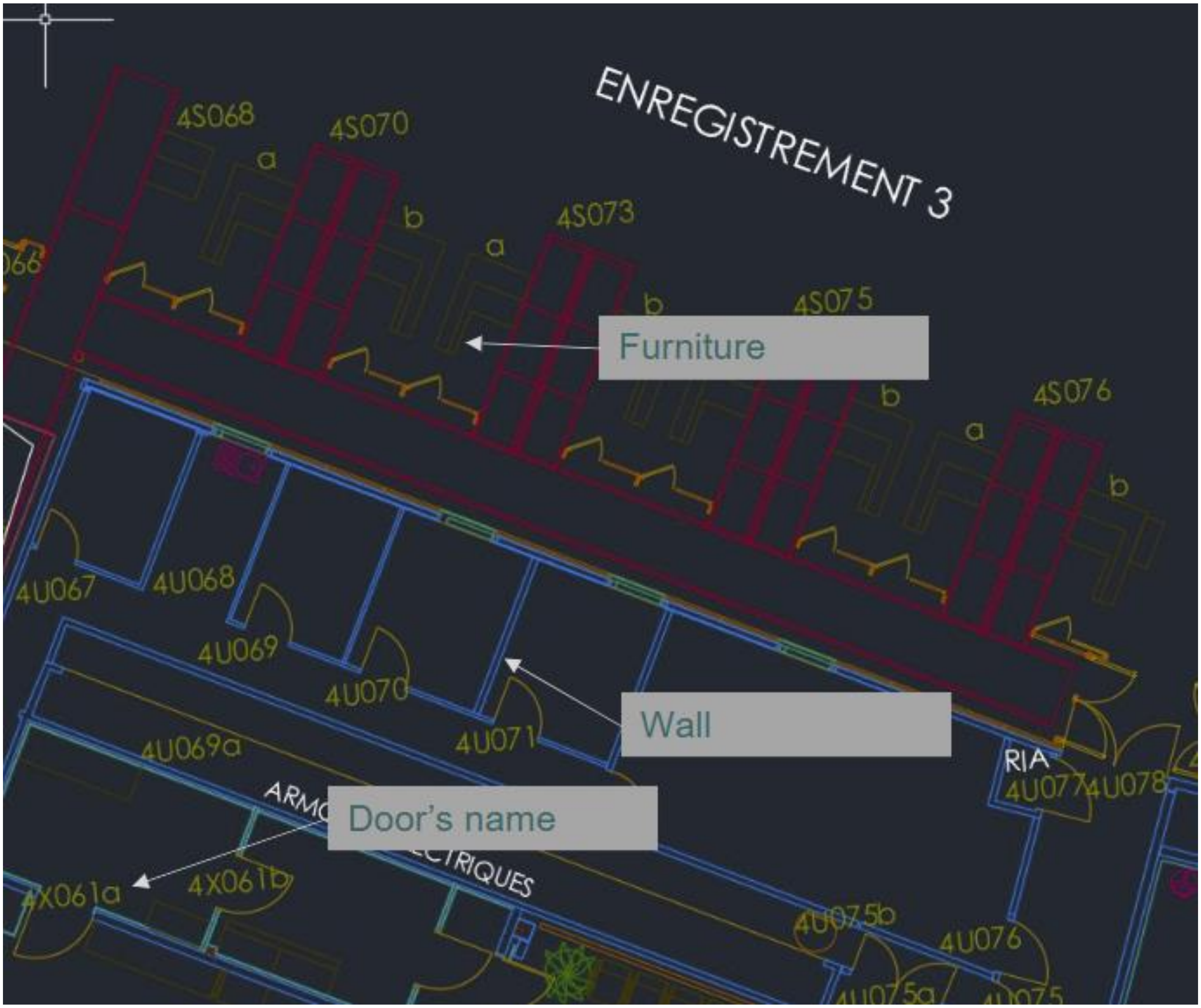


Figure 4:DWG floorplan

3.2.2 Geographical Information System used for Airport Assets inventory

A geographic information system (GIS) is a software that stores, manages, analyzes, edits, outputs, and visualizes geographic data. The data is stored within a spatial database. GIS is utilized in various technologies, processes, techniques, and methods and is attached to operations and applications related to engineering, planning, management, transport/logistics, insurance, telecommunications, and business. GIS and location intelligence applications form the foundation of location-enabled services, which rely on geographic analysis and visualization. By using location as the 'key index variable', GIS allows for the correlation of previously unrelated information. Earth-based spatial-temporal locations and extents can be recorded by specifying the date and time of occurrence, along with x, y, and z coordinates representing longitude, latitude, and elevation. It is important that all references to Earth-based spatial-temporal locations and extents are related to each other and ultimately to a physical location or extent.

Groupe ADP uses this technology to manage the patrimonial information: Patrimonial GIS tool that is the central tool and project master system. This tool aggregates all mapped data into a common database, storing both the geometry and data. To achieve this, CAD objects are converted into GIS objects and facility management drawing technicians add alphanumerical data on these geometries. A unique GIS ID is automatically generated during this operation. This ID is used to link different IT systems and identify the constituent objects of the works, such as buildings, rooms (e-rooms), doors, or airport equipment like remote display screens. This is achieved through attributes and a graphic representation, with surfaces representing rooms and points representing technical objects. The data analysis is enabled through the superposition of different layers. Objects and structures are located using XY coordinates based on the geographic projection system, such as Lambert 93-CC49 or NTF Lambert I. The attributes of each object, such as buildings, rooms, and technical objects, vary. Additionally, the GIS data can be exported to a CAD format. The list of object qualifications is provided in the Appendix. The principle of this common nomenclature is shared by all. It is gradually being implemented. Changes are made locally, such as the addition of an extra level, without being uniformly deployed.

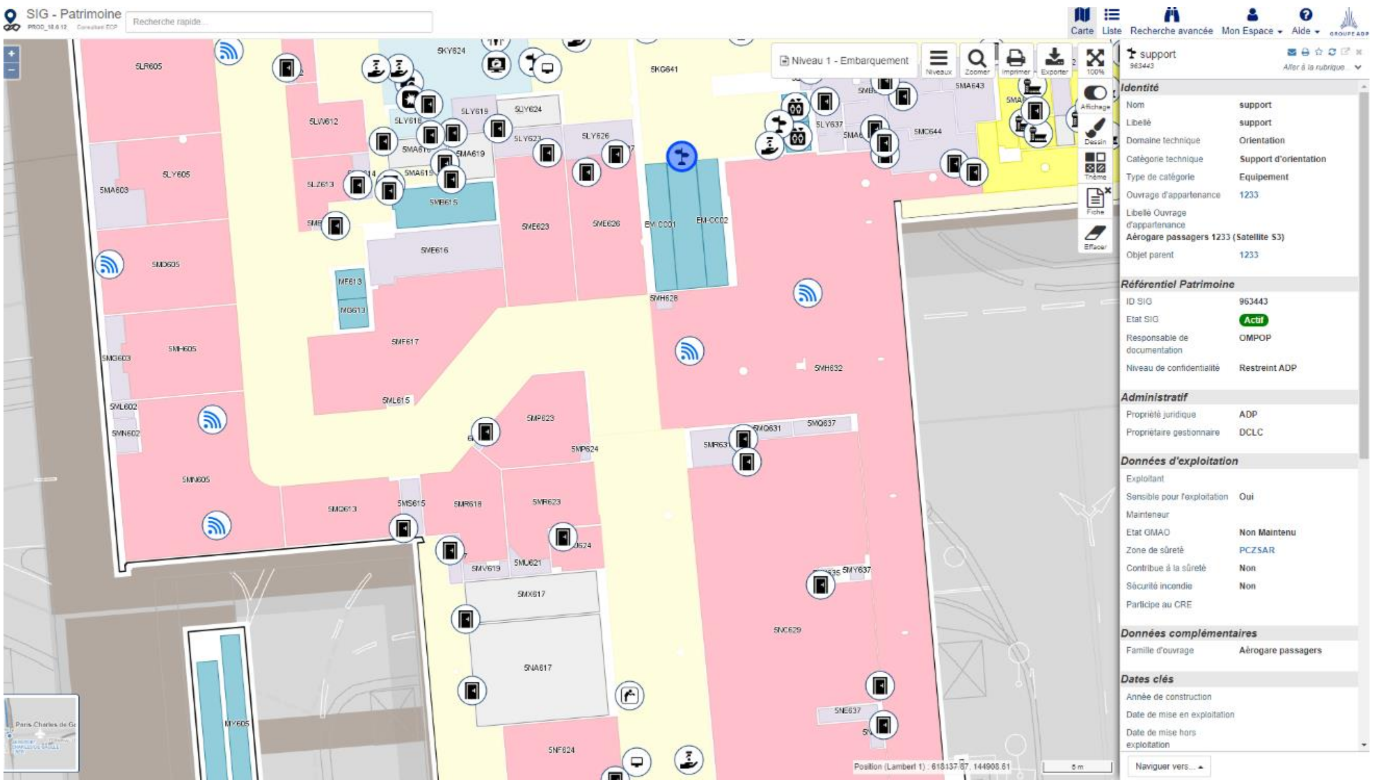


Figure 5: Screenshot of the ADP Patrimonial GIS.

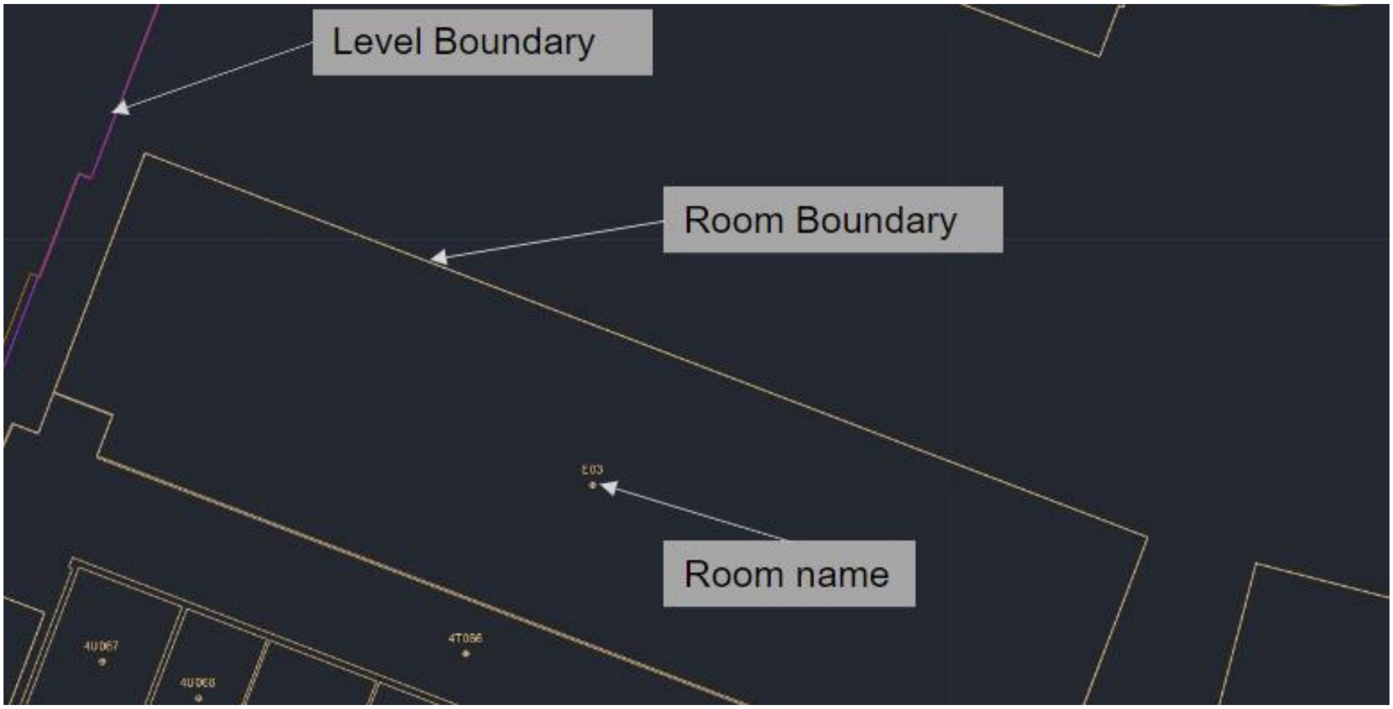


Figure 6: Screenshot of the ADP Patrimonial GIS room's boundaries export in CAD format.

3.2.3 Building Information Model

BIM is a work process used on large projects to create a 3D mock-up, draw blueprints, and produce schedules (equivalent to a Bill of Materials). BIM improves communication by reducing unnecessary back-and-forth between stakeholders, which would otherwise take months. The model is composed of objects enhanced with data. The Building Information Modelling (BIM) is utilised throughout the various stages of a building project, including design, construction, and post-delivery for the operation and maintenance (O&M) system and operational planning. Each stage generates new data that may partially or completely modify the previous stages. ADP, like many other actors in the construction sector, has adapted its software to accommodate this process change. The design teams now use Revit (Autodesk), which requires specific methods of work. The room is a specific object in Revit and architectural design teams create this object to fulfil program requirements. This object is gradually replacing the current methodology that uses CAD to update the room object in the heritage GIS. As a result, the GIS ID differs from the unique ID code present in the BIM digital models (Revit or IFC). Depending on the GIS or BIM source, the unique identification is carried by different data. A reflection is currently being conducted on the feasibility of enriching patrimonial repositories with a unique ID when using the digital model as a source of supply. When relevant, ADP integrates the GIS Unique ID in a Revit Object's specific data properties to facilitate exchanges with the GIS. If the 3D model of the object does not exist, it is the responsibility of the master GIS to create it. The 3D mock-up is composed of objects based on families. A family in Revit refers to a group of elements that share identical use, common parameters, and similar geometry. For instance, a desk model should have different sizes of desks, all of which can belong to the same desk family. The size is set with parametric data. In Revit, objects follow a structured model where the head is the 'Category' (e.g. door) composed of 'Family' (e.g. Porte_bois.rfa), and the family is also composed of 'Type' (e.g. BP 0.83mx2.04m). Each object placed in the project is assigned a category and type. Groupe ADP has begun creating its own collection of Revit object libraries (.rfa) to standardise their data, such as elevators, and promote the consolidation of Revit objects (.rfa) with a focus on the circular economy. This collection contains both generic objects, which do not have any commercial reference, and commercial objects that were obtained through a furniture tender, in order to comply with public procurement regulations. The technical documentation for the collection is stored in the corresponding folder. The inventory of objects is managed based on operational performance considerations.

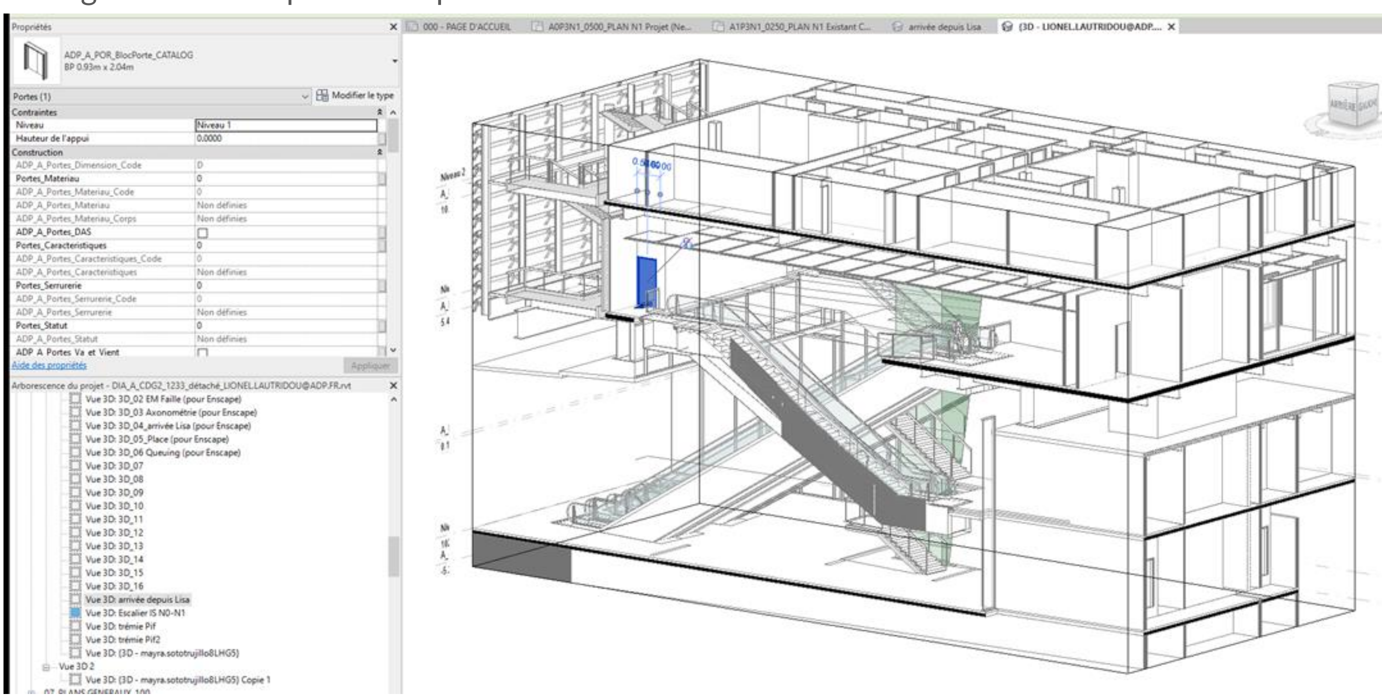


Figure 7: Digital Mock UP open with the edition software Autodesk Revit©.

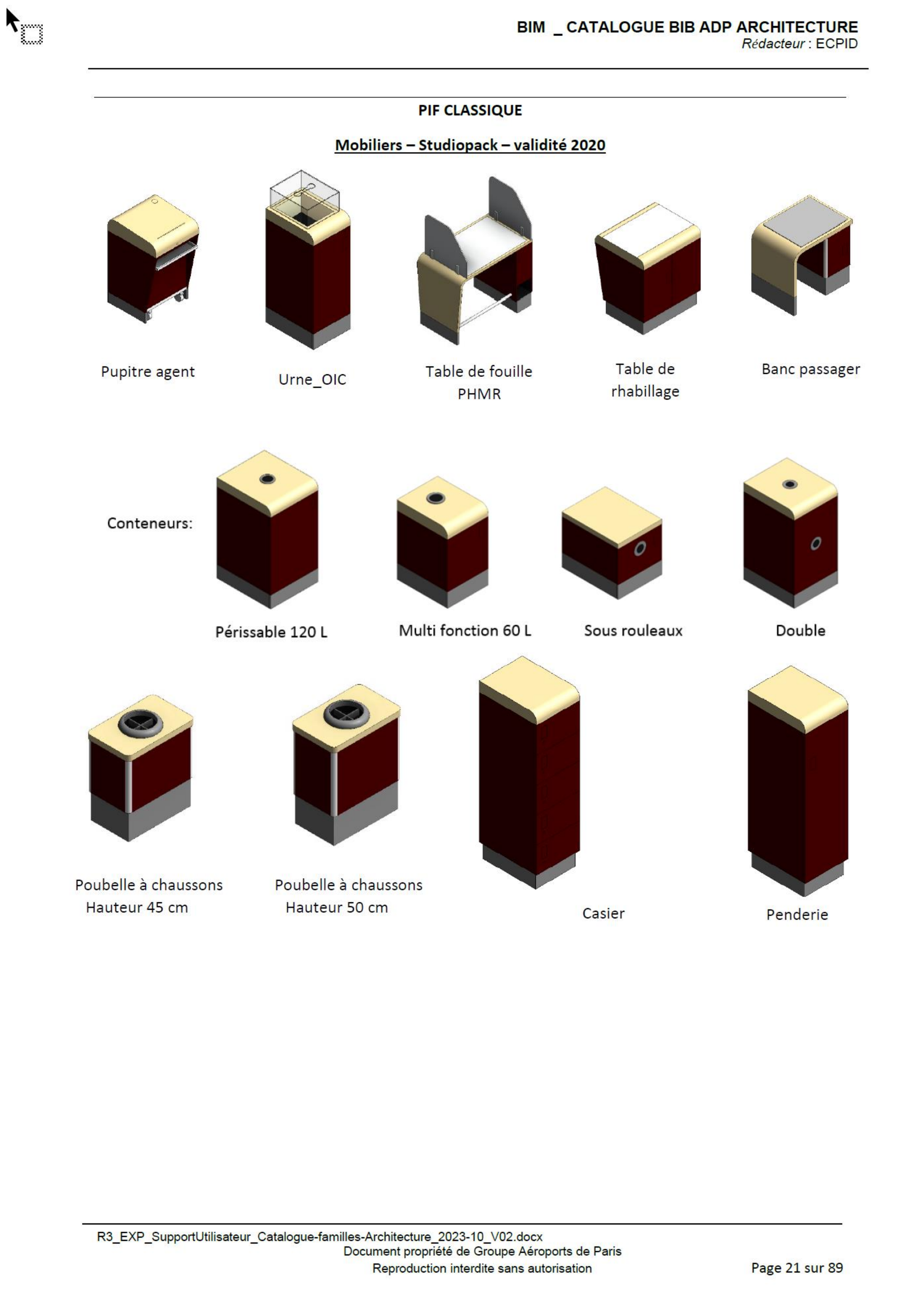


Figure 8: Example of collection: security check point furniture.

3.2.4 Other airport data

Other systems are also used to manage airport assets. The Computerized Maintenance Management System (CMMS) tool allows for the management of maintenance. Generally, the source of the objects to be maintained is extracted from the Patrimonial GIS of the Project Owner (ADP-CDG in the present situation). Specific tools are also used for the management of operational incidents, such as those related to airport operating equipment, or the management of IT incidents. All of these systems are connected to the Patrimonial GIS, which sets the location (building, level, room, X&Y) of each object. These systems can send work orders with accurate location and system function information to the maintenance provider or operational crews. The CMMS or operational system workflows focus on the technical functions within a room. However, these systems do not have a complete product inventory and do not have the function to manage data concerning the composition of materials. It was concluded that the data available from these systems was not relevant and could not be suited for use in Batirim's tool due to its lack of precision.

3.2.5 Data exchange between CAD, GIS, BIM and BatiRIM

The key element for locating the data on which ADP's IT relies is the room identifier. Each area of the airport is inventoried and assigned a unique identifier. The identifier is used to locate elements on site and is common to both GIS (operational use) and BIM (project use). Rooms have various properties, such as function, occupancy, and floor finishing. Groupe ADP has established a methodology that combines the use of room identifiers with an optional geographical coordinate system to locate devices such as screens and commercial desks. Each object in the patrimonial GIS inventory has a position data that defines the building, level, and room, and optionally includes XY coordinates. The design process, whether in BIM or CAD, uses the same geographical coordinate system as the GIS. BATIRIM® does not, but instead, it develops a process that allows for the addition of located information in the model using the BatiRIM® tool. The software should be able to locate the objects that will be modelled. At this stage of BIM maturity, the 3D mock-up model is rarely up to date (if it exists at all) in the early stages of design.

In addition, Batirim has some limitations in data exchange:

- The BatiRIM® location system does not conform to the Geographical Coordinate System.
- BatiRIM® cannot graphically export the position of each item in its inventory.
- The compliant file format for floor plans is limited to PDF.
- Impossible to switch 3D to floor plans when BIM model feeds Batirim.

Batirim input

Finally, a simpler approach was jointly validated as a turnaround solution to realize the field inventory: to use a floor plan with room identifiers and to export the result of the inventory in Excel format. The main information needed to carry out the diagnostic with the Batirim solution is:

- a floor plan,
- the classification to organise the Bill of materials (BOM),
- the list of locations (rooms).

Batirim output

BatiRim creates the objects according to the most appropriate BOM. The elements created are then injected into ADP's BIM or GIS with their coordinates. The georeferencing system must be homogeneous with the BatiRim input data.

The table below compares the advantages and drawbacks of the file's formats used by ADP to respond to this new process.

	CAD	GIS	BIM	PDF
Benefit	Commonly used by assets owner All ADP's Building are drawing with a CAD tool Originally design for printing task Cost efficiency Can export into PDF format	Used by many owner of large infrastructure (harbor, airport,...). Fuel by CAD drawing Design to manage spatial data Can export into PDF format	Technology up to date for design, construction. Official Standard for building information model Compatible with CAD data 3d model, floorplans and Section in the same file Can export into PDF format	Can be used with a lot electronical device (computer, smartphone, ...) Compatible with 3D models
Drawback	Not efficient in data management Section view must be created manually by a skill drawing technician.	No data standards for building information model Shapes are less accurate than CAD or BIM Section view aren't supported	Methodology control is necessary Higher cost ifc export is complex from Revit	The graphical objects don't have properties Need another software to update graphics. The geographical coordinate system is lost
Compatible with Batirim	No	No	Partial	Yes

Table 1: Review of the benefits and inconvenient of each data format available.

3.2.6 Airport assets classification

No official asset classification is applied in France or Europe. Several classifications are used in the airport information system to organize data. For the construction design, ADP-CDG uses an internal adaptation of UNIFORMAT II. UNIFORMAT II was published in 1992 by the National Institute of Standards and Technology, a department of the US Commerce. It is a breakdown structure for classifying building elements and related site work. Elements are fundamental components found in most buildings. They typically serve a specific function, regardless of the design specifications, construction methods, or materials used. This format can be used to manage the project specifically for reporting at all stages of the building life cycle, including planning, programming, design, construction, operations, and disposal. The most recent version of the official UNIFORMAT II proposes a fourth level definition. Beginning with Level 1, the largest group of elements, this system identifies Major Group of Elements such as Substructure, Shell, and Interiors. Level 2 further divides Level 1 elements into Group of Elements. For example, the Shell comprises the Superstructure, Exterior Closure, and Roofing. Level 3 breaks down the Group of Elements even further into Individual Elements. Exterior Closure, for instance, includes Exterior Walls, Exterior Windows, and Exterior Doors. The proposed Level 4 subdivides individual elements into smaller sub-elements, including wall foundations, column foundations, perimeter drainage, and insulation. However, this subdivision may not be suitable for airport-specific systems or furniture, such as signage for passengers, baggage handling systems, and security checkpoints. ADP should complete the nomenclature Uniformat 2 version 2017 with add-on structures that are specific to the airport's needs. This classification will provide several benefits, including faster economic analysis for evaluating alternatives at the early design stage, structured and organized BIM object library, and a standardized format for collecting and analyzing data for maintenance or reuse processes.

The figure below displays some examples of the required complement for an airport.

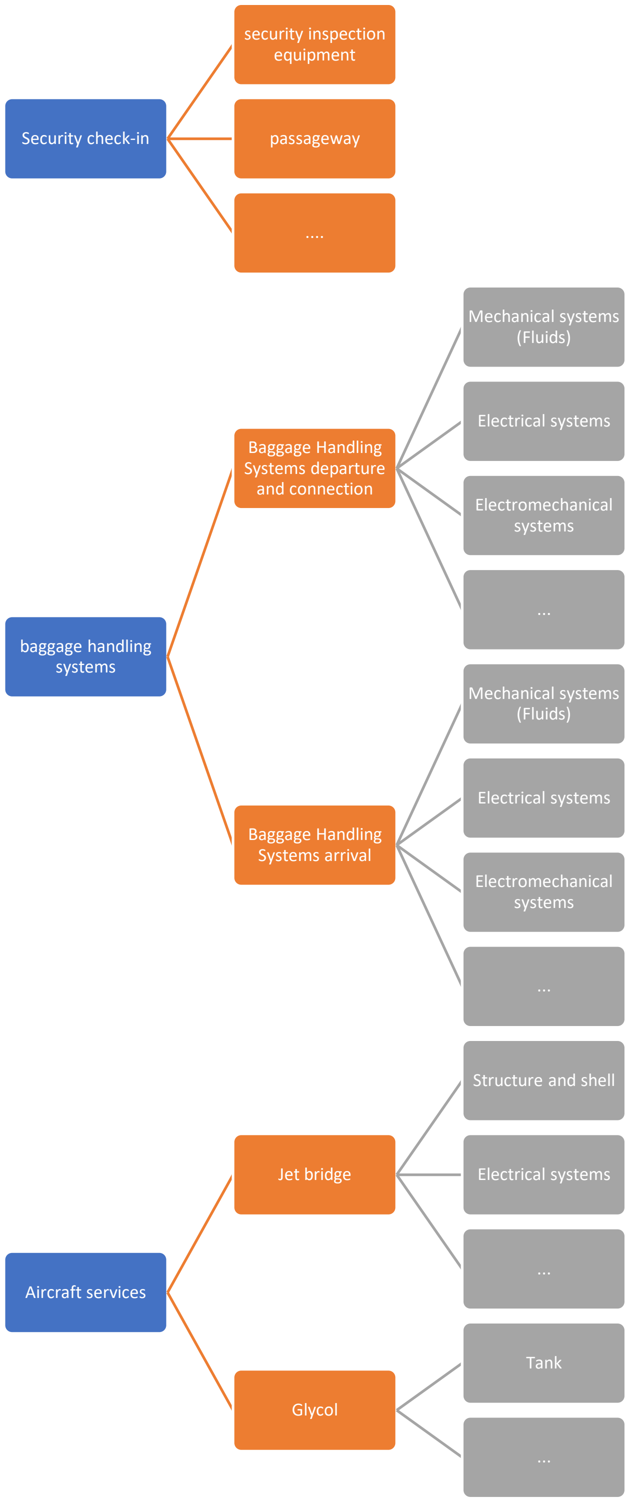


Figure 9: Example of complements on the Uniformat II asset classification.

3.2.7 Batirim

SUEZ has set up BatiRIM®, a company dedicated to work on the problems of the building and public works sector and its circular economy. BatiRIM® offers "POA CE" (Project Owner Assistant Circular Economy) support services for project owners and contractors, local authorities and industry. BatiRIM® is developing the RIM® (Resource Information Modeling) digital tool, a kind of "reverse BIM" and a data management platform tailored to the renovation and deconstruction sector of the building and public works sector. Diagnosticians can thus produce a "Products, Equipment, Materials, Waste" diagnostic, as required by the AGEC Act, passed in February 2020, so-called “PEMD” in French but referred as RMW diagnostic in the present report. BatiRIM® is specialized in carrying out the following tasks:

- Supporting project owners throughout the process, from the design of the organisation of their building and public works-related constraints in a given area, right through to post-construction feedback;
- Developing digital tools to diagnose products, equipment, materials, waste and selective dismantling, anticipating projects and budgets, monitoring operations and ensuring traceability;
- Monitoring and coordinating the execution of worksites in conjunction with the designated prime contractors, and anticipating their efforts to adapt to the circular economy;
- Supporting restructuring projects by managing the services provided by the various parties involved, while guaranteeing that the client complies with its requirements in terms of the circular economy;

In addition to this, BatiRIM® can act as a trusted third party because of its independence :

- Legal advice and regulatory monitoring for public-sector clients who are not obliged to take out property damage insurance;
- Re-appropriation of technical, geographical and physical data on the buildings to be demolished, as well as the sources of products and components they contain;
- Assistance with the operational organisation of selective dismantling worksites, platforms and 3R channels for "reuse - re-employment - recycling".

Depending on the circumstances and the needs, this approach also enables BatiRIM® to position as a consultancy specialized in the reuse of construction materials, and to provide comprehensive advice on the implementation, in design and execution, of a circular economy strategy applied to any restructuring projects.

To meet this demand, BatiRIM® has developed a digitalized Raw Materials and Wastes Diagnostic, which synthesizes all French legal and operational requirements.

This solution is based on a very precise characterization of the Project Owner's resources (and no longer on simple site "waste") taking into account, in particular:

- Identification of the products, equipment and materials present in the works;
- Their location floor by floor, room by room;
- Their physical mass, count and volume;
- Their more or less good state of preservation;

This approach allows the establishment of an original proposal for the reuse and selective deconstruction of the project's structures.

As an example, the application allows the insertion of 2D plans of all or part of the structure to be diagnosed. This insertion, rendered from BatiRIM®'s tablet application, takes the following form:

Figure 10: BatiRIM® Screenshoot.

Following this first step, the application can digitally integrate the nomenclature of the various components inside the structure. This nomenclature is more or less detailed, depending on the needs expressed, and lists the equipment, finishing or structural elements, furniture, etc. that will be quantified, located and qualified on the 2D digital plan during the diagnostic phase. It should be noted that a 3D approach can also be envisaged, depending on the site and requirements.

BatiRIM®'s experts draw up an exhaustive resource diagnostic of the elements to be dismantled, removed or restructured, in the form of a table summarising the existing elements with their characteristics, quantities, location and recommended treatment, and location maps (showing the location of the elements).

The application is then able to edit the resource identity card associated with the location maps (2D) for each of the elements thus identified. The following parameters are specified digitally, using dots and associated comments corresponding to each of the elements present in the nomenclature:

- The type of element;
- Location;
- Its current use;
- Quantity and mass;
- Its geometry;
- Its construction, assembly or installation system, in the case of partitions for example;
- Its date of construction and installation (or an estimate);
- Its condition and quality;
- Pollution levels, if any.

These RMW diagnostic reports therefore specify the reuse and recycling potential for each component identified on site. This potential is assessed on the basis of a number of criteria, taking into account the condition and quality of the item, the complexity of removal, its financial and symbolic value, demand from the ecosystem, local outlets, and so on. These are all objective elements on the basis of which any project owner or its partners can define and validate a circular economy project.

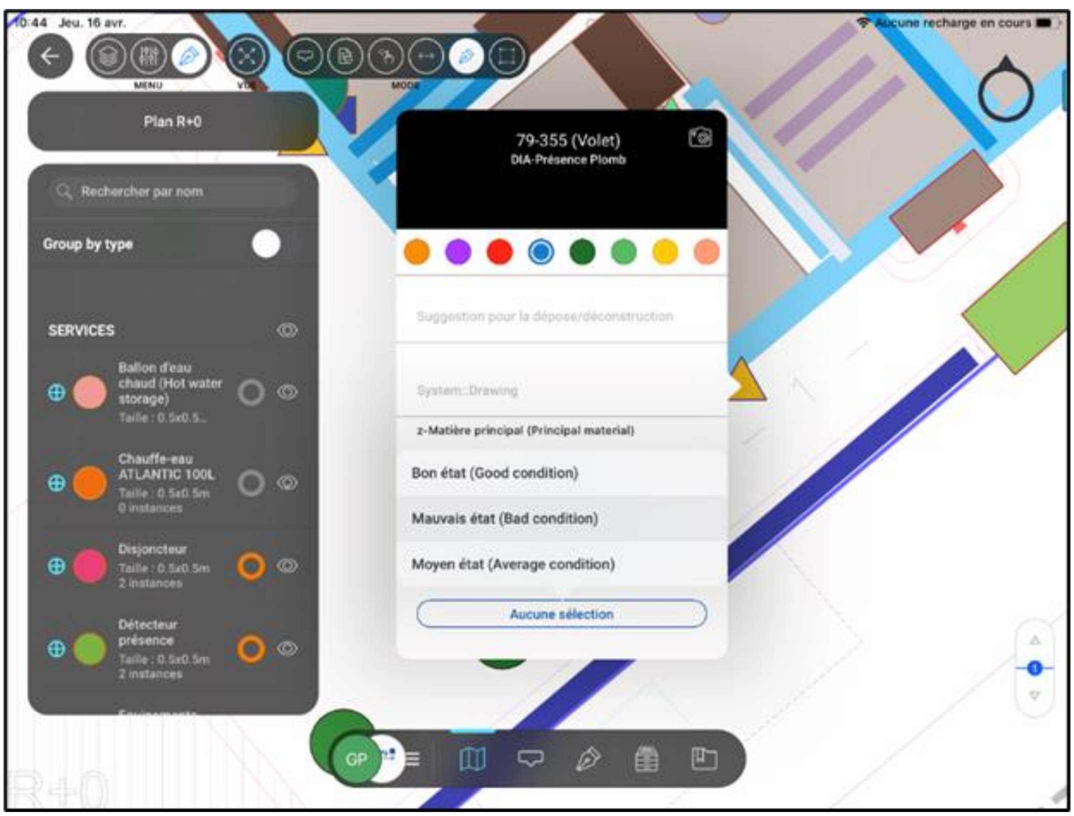


Figure 11: BatiRIM® product status data entry form.

As regard to ADP's special request, the point was indeed to interface a RMW diagnostic on plans, combining data coming from ADP's BIM databases and uniformats with a reuse referential, updated by an onsite intervention of consultants at Roissy CDG S3 terminal using a digital app in order to:

- Quantify the equipment eligible to a reuse policy
- Assess their general condition
- Enrich the referential with possible pictures or comments on site
- Deduce a 2D data model containing the information displayed below and related to a unique ID
- A mapping with the room SIG name and ID provided by ADP

3.3 Prototyping

Based on the data inventory, several tests were carried out to define the most efficient process of work.

Initially, the intention was to use the 3D model produced by the BIM process. However, it appears that the Revit model of the building proposed for diagnostic was incomplete because the rooms were incomplete or not up to date. On the other hand, the patrimonial GIS contained all the parts and was up to date. Nevertheless, this data source could not be used directly to fuel Batirim's application. The solution implemented was to cross-reference the two data sources with the aim of sharing the official GIS information that defines the location (building>level>room). To achieve this, the first attempt was to create a 3D model from GIS data by extruding the room contours to create a volume object. A script was produced to transform the GIS data of the parts using FME (Safe software) to create an extrusion from a predefined part height. The output of this script is a 3D model in IFC format, associating the main characteristics of the parts (number, function).

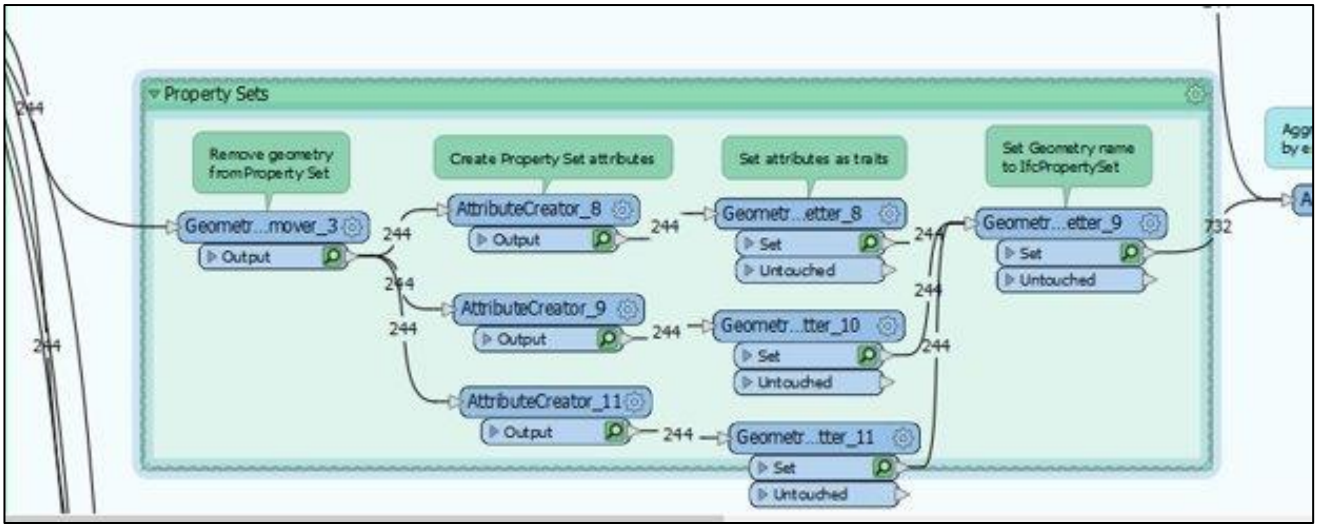


Figure 12: Sample of FME script.

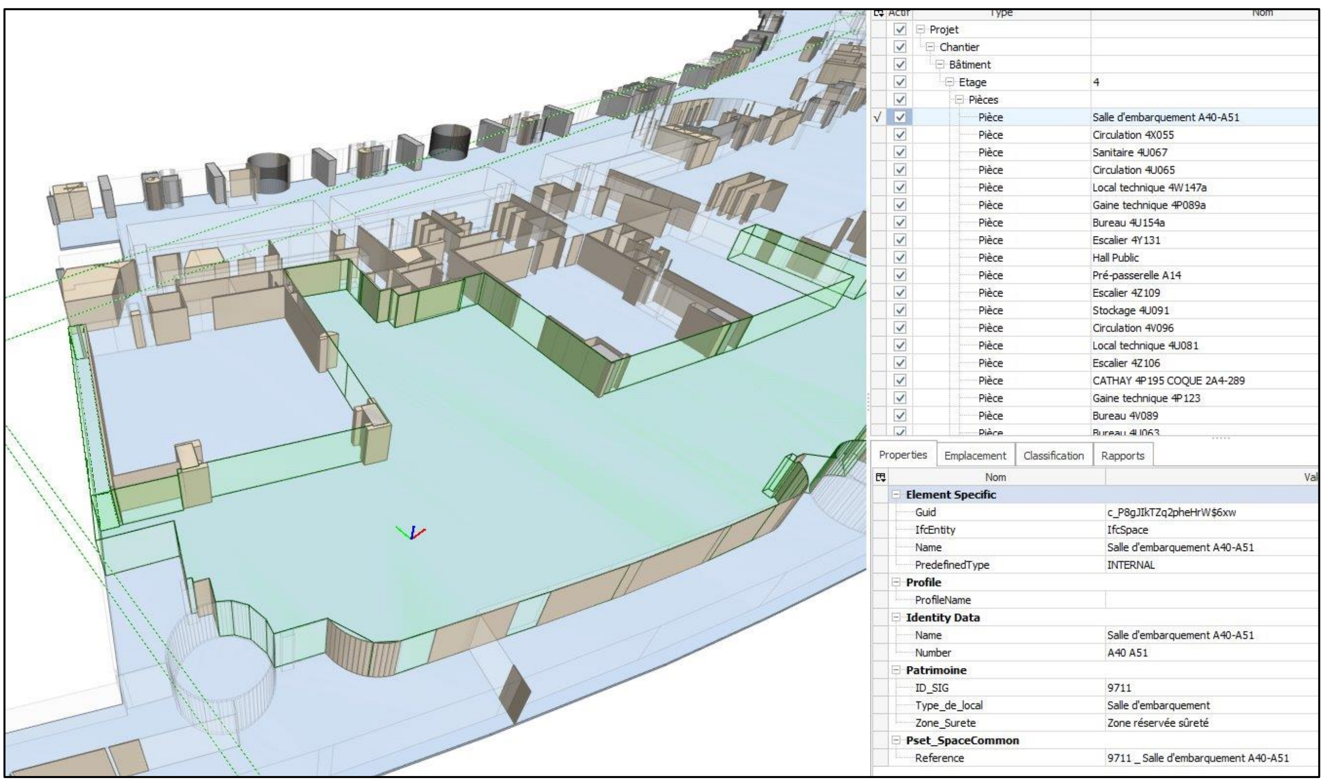


Figure 13: IFC Result after processing the FME script.

The result of this process was not as expected, as the transformation of the walls of the room into 3D objects generated numerous artefacts during the generation of the walls. In the absence of geometrically consistent walls, the algorithm was unable to generate geometrically consistent room objects. Given the results, it was not feasible to use this method.

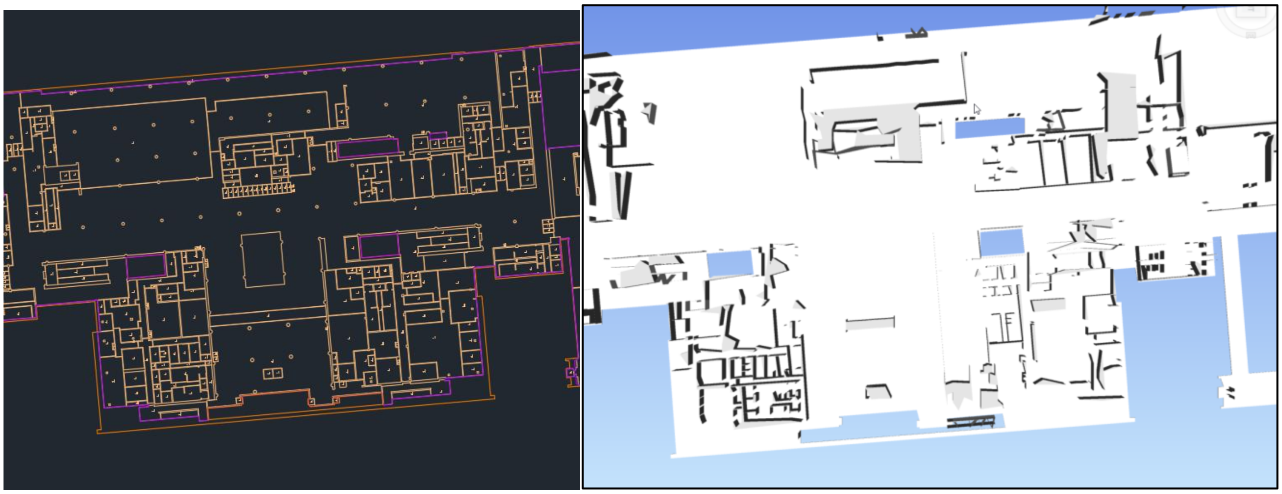


Figure 14: Comparison between the initial dwg plan and the result in IFC format.

At this level of maturity of BIM in the asset management phase, the following conclusion appears: it is not possible to systematically have an up-to-date mock-up with up-to-date information about the space. Therefore, the next decision was to use plans as a data source. All of the CDG airport terminals are drawn with CAD plans. ADP-CDG has architectural plans detailing the building's partitions, doors and vertical corridors, as well as plans with a room reference system showing the outline and number of the room according to the patrimonial GIS. Thus, a specific plan was prepared that combines the architectural plan with the patrimonial plan.

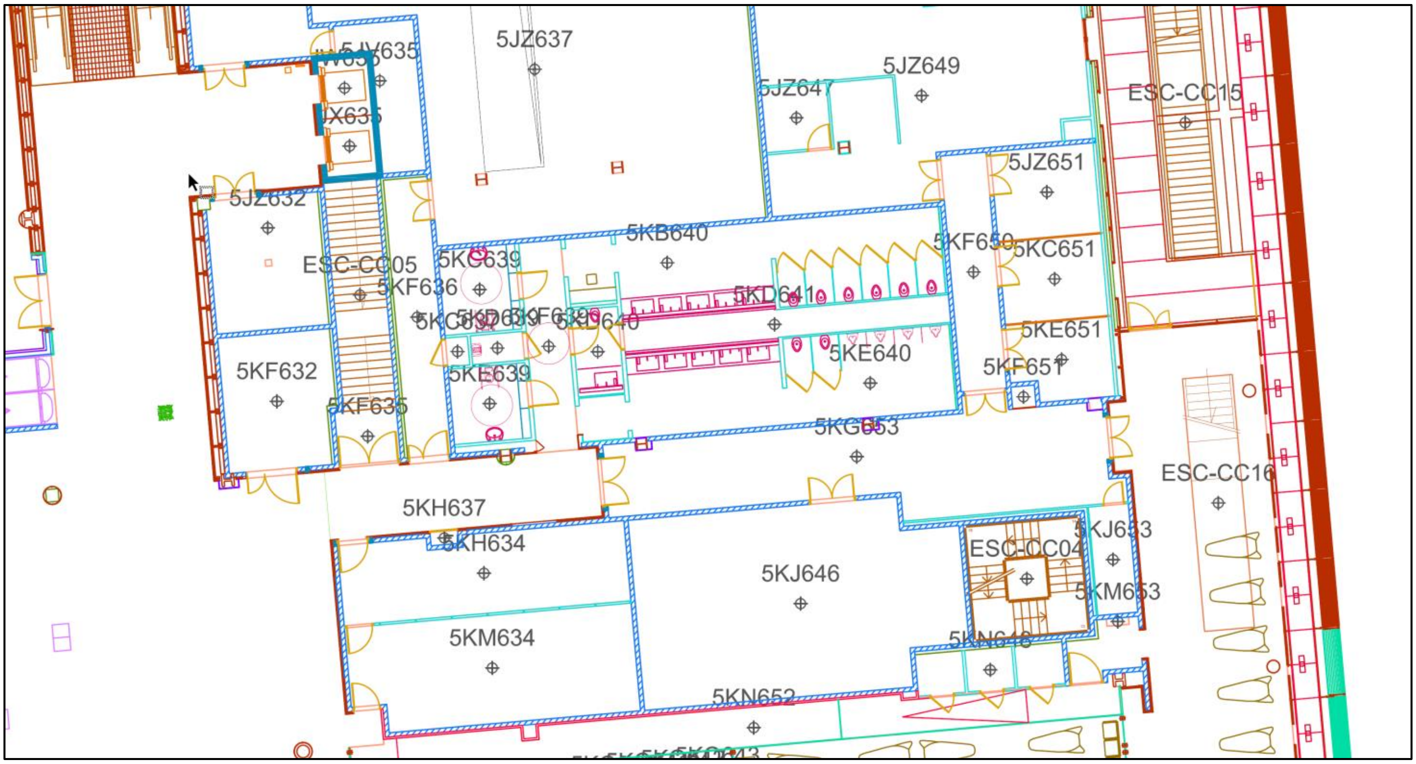


Figure 15: Architectural floor plan with room number (from GIS).

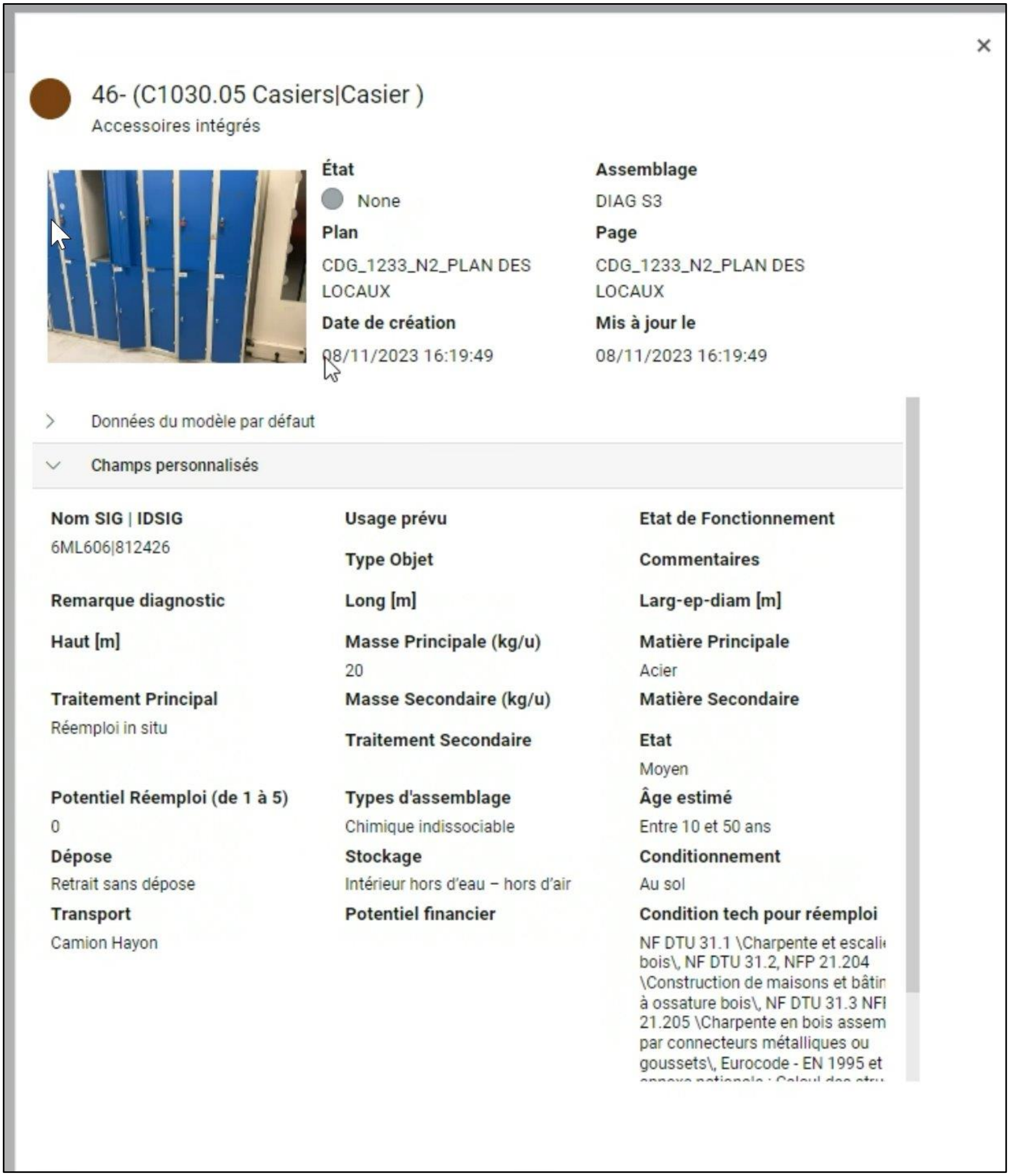
This plan is imported into the BatiRim application to enable the diagnostician to pinpoint each object found on-site. On the sheet for each object, the operator indicates the number of the room in which the object is located. To do this, the list of rooms was extracted in Excel format and imported into the BatiRim form.

An Excel export template was created to facilitate data analysis by the members of the diagnostic team. The template includes the room number of the inventoried object. The table below shows the data exported from BatiRim.

Data	Example
Id unique	0cf0ff6d-9518-49e7-906a-aa8ff1ca62a1
Date de mise à jour	06-11-2023
assemblage	DIAG S3
Plan	CDG_1233_N1_PLAN DES LOCAUX
type	lineaire
categorie	Habillage mur
nom	C3010.02 Finition de murs intérieurs|Panneau sandwich|métal + laine de roche
Quantité	2,38
Unité	ml
Matière Principale	Multi-matériaux non dangereux - panneaux sandwich
Masse Principale (kg/u)	66,4
Traitement Principal	Réemploi in situ
Matière Secondaire	--
Masse Secondaire (kg/u)	--
Traitement Secondaire	--
Potentiel Réemploi (de 1 à 5)	2
Dépose	Manuelle avec ou sans outil
Stockage	Intérieur hors d'eau – hors d'air
Conditionnement	Au sol
Transport	Camion Hayon
Potentiel financier	--
Condition tech pour réemploi	NF DTU 31.1 "Charpente et escaliers en bois", NF DTU 31.2, NFP 21.204 "Construction de maisons et bâtiments à ossature bois", NF DTU 31.3 NFP 21.205 "Charpente en bois assemblée par connecteurs métalliques ou goussets", Eurocode - EN 1995 et annexe nationale : Calcul des structures bois.
Haut [m]	3,32
Larg-ep-diam [m]	0,02
Long [m]	--
Etat	Moyen
Types d'assemblage	Par gravité
Âge estimé	Entre 10 et 50 ans
Etat de Fonctionnement	--
Usage prévu	Réemploi
Nom SIG | IDSIG	5KG641|282601

Nota: Not translated in English. Using another language requires a specific development of the software.

Table 2: Example of data exported from BatiRIM's application.



×

46- (C1030.05 Casiers|Casier)

Accessoires intégrés

État

None

Assemblage

DIAG S3

Plan

CDG_1233_N2_PLAN DES LOCAUX

Page

CDG_1233_N2_PLAN DES LOCAUX

Date de création

08/11/2023 16:19:49

Mis à jour le

08/11/2023 16:19:49

Données du modèle par défaut

Champs personnalisés

Nom SIG | IDSIG

6ML606|812426

Usage prévu

Etat de Fonctionnement

Type Objet

Commentaires

Remarque diagnostic

Long [m]

Larg-ep-diam [m]

Haut [m]

Masse Principale (kg/u)

20

Matière Principale

Acier

Traitement Principal

Réemploi in situ

Masse Secondaire (kg/u)

Matière Secondaire

Traitement Secondaire

Etat

Moyen

Potentiel Réemploi (de 1 à 5)

0

Types d'assemblage

Chimique indissociable

Âge estimé

Entre 10 et 50 ans

Dépose

Retrait sans dépose

Stockage

Intérieur hors d'eau – hors d'air

Conditionnement

Au sol

Transport

Camion Hayon

Potentiel financier

Condition tech pour réemploi

NF DTU 31.1 \Charpente et escali
bois\, NF DTU 31.2, NFP 21.204
\Construction de maisons et bâtir
à ossature bois\, NF DTU 31.3 NFI
21.205 \Charpente en bois assem
par connecteurs métalliques ou
goussets\, Eurocode - EN 1995 et

Figure 16: Screenshot of a component's form.

ADP IT Department used the exported Excel file to create an application that demonstrates how the data can be used in a spatial context. The application cross-references the data with the geometry of the parts and assigns an approximate X,Y coordinate to each object. The demonstrator includes geostatistical functions that facilitate the identification of areas with high potential for re-use.

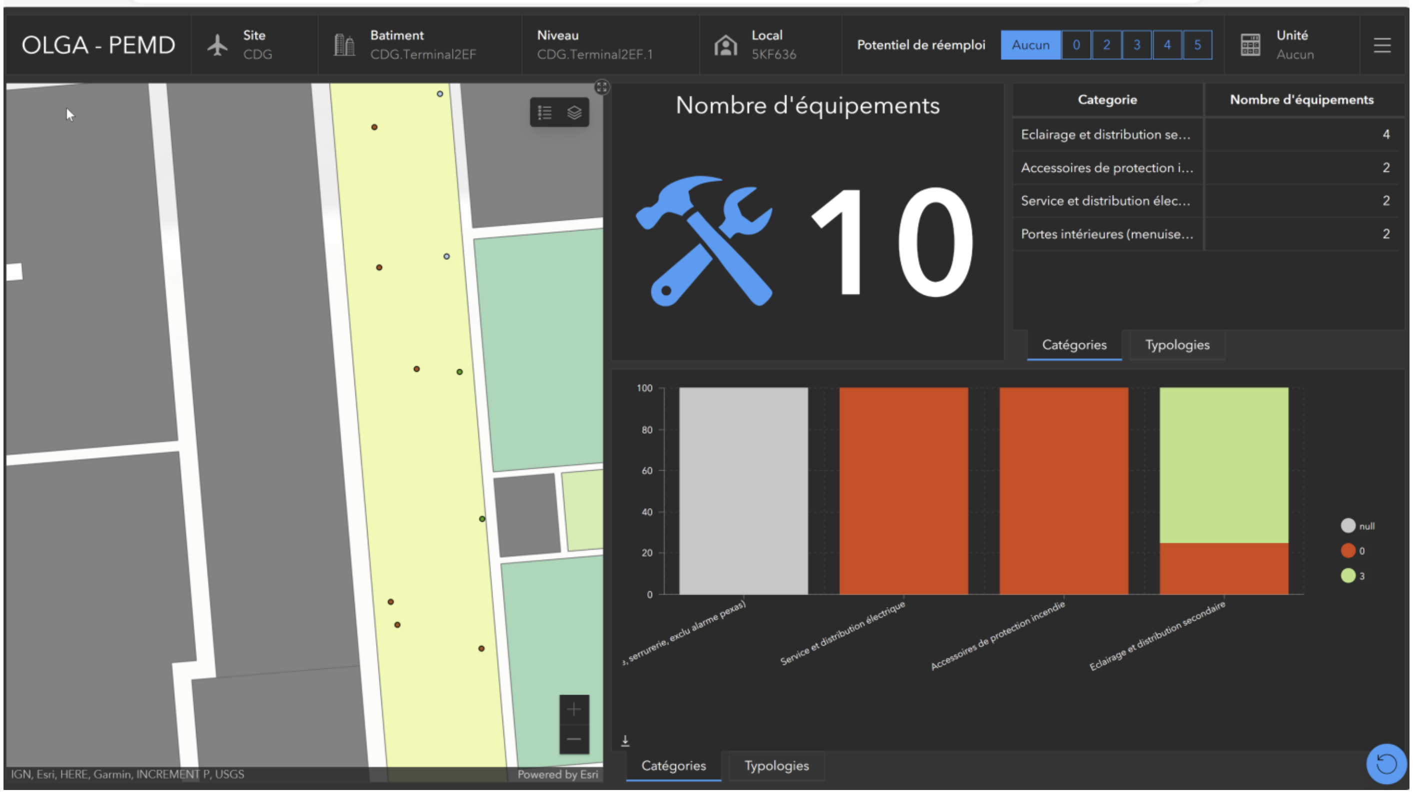


Figure 17: Demonstrator developed during the OLGA project for spatial analysis of the elements surveyed.

4 Results for the case study

4.1 Presentation of the case study

Terminal "Gate L" (aka Satellite 3) was constructed between 2004 and 2007 with a total surface area of over 150,000 m². It is 750 m long and 80 m wide, located to the east of Terminals 2E and 2F, and is dedicated to fast connections between short-haul and long-haul aircraft. The airport has increased its passenger capacity by 8.5 million a year with the addition of twenty-two boarding gates, including six gates that allow simultaneous boarding of 6 Airbus A 380s. The total surface area, which includes 3,200m² of shops and 1,400m² of bars and restaurants, is of 150,000m². The experiment was conducted on a surface area of approximately 9,000m², spread over two floors, encompassing the SIS and their upstream waiting halls, located at the top of the LISA escalators[1]. The facilities have remained largely unmodified since their inception and are of excellent quality. As of 2023, they remain in good general condition. The purpose of a RMW diagnostic is to assess and categorise all components of a structure in order to facilitate its complete or partial reconstruction (rehabilitation). This RMW Diagnostic simulation is grounded in actual project studies. In 2021, a feasibility study was conducted on the area under consideration for complete redevelopment. The study proposed relocating the SIS area to the waiting areas, resulting in fewer but larger SIS and higher passenger throughput per unit. This relocation would benefit the downstream retail areas. This RWM diagnostic only takes into account finishing materials, such as visible elements, products, equipment, furniture, and materials, including technical terminals at the level of the ceiling mesh. This also includes air vents, cameras, lighting, fire extinguishers, etc. The closed and covered areas, as well as the structure, have not been considered.

[1] LISA is a local Airport People Mover connecting Terminal 2E to Satellites 3 and 4 also named as S3 and S4.

Figure 18: Level 1 - Area considered.

Figure 19: Level 2 - Area considered.

4.2 Field survey operation

The on-site assignment involved performing the following tasks:

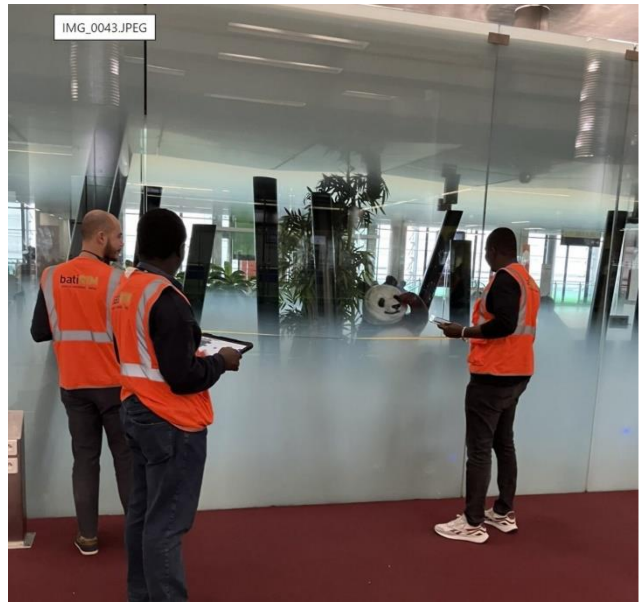
- identifying elements and their composition through visual and/or surface investigations, qualifying,
- quantifying, and locating products, equipment, and materials on a scale drawing in the RIM® tool (creating a digital mock-up of the structure).

The assessment of elements in a 2R logic (reuse and recycling) should be conducted in relation to the project's ambitions, the resource's potential, and in compliance with the hierarchy of treatment methods.

It is important to note that performing a diagnostic in an occupied airport environment creates special working conditions. Conventional diagnostic equipment such as hammers and screwdrivers are not permitted, only meters and magnets are accepted. Destructive testing and dismantling are also not possible due to the permanent and substantial passenger flow. When passing through PIFs, it is important to wear appropriate clothing to ensure quick passage through the controls. Personal Protective Equipment (PPE) is not required, but comfortable clothing and trainers are essential.

The work is carried out zone by zone, and lunch breaks are taken on-site to account for the distance from ADP canteens (which requires a 40-minute return journey).

The field survey took place over four days in early November 2023. It was conducted by three technicians from Bâtirim, accompanied by one ADP employee each day to comply with regulations for this controlled access area. The survey was conducted between 9am and 6pm with breaks interspersed throughout the day. The teams covered approximately ten kilometers each day during the survey. More than 2,300 items were identified, including more than 5,200m² of suspended ceiling, 334 cameras and more than 300 items of security checkpoint.



4.3 Results of re-using potential analysis

The PEMD inventory delivered by the on-site diagnostic that took place at Roissy's S3, from the 6th to the 10th of November 2023 enabled us to identify approximately 2,400 products and equipment and assess a potential of ≈ 519 tons of materials. The complete analysis is integrated into the document as "Part II" and the full report is attached to this document as "Part III". An extract of the analysis is displayed below:

RESEAU D'EAU POTABLE						
Produit	Quantité	Unité	Matières	Masse(kg/u)	Masse totale (Tonnage)	
D2020.01 Tuyauterie et raccords|	1,00	u	Polyéthylène - PE (HD, mousse, etc.)	151,0	0,15	0,15
HABILLAGE MUR						
Produit	Quantité	Unité	Matières	Masse(kg/u)	Masse totale (Tonnage)	
C3010.02 Finition de murs intérieurs|Bois	17,88	ml	Bois B - Contreplaqué	10,0	0,18	0,18
C3010.02 Finition de murs intérieurs|Bois avec finition	31,44	ml	Bois B - Contreplaqué	10,0	0,31	0,31
C3010.02 Finition de murs intérieurs|Bois avec finition laiton	8,79	ml	Bois B - Medium (MDF) Laiton	16 ,0 3,0	0,14 0,03	0,17
C3010.02 Finition de murs intérieurs|Bois lisse	6,27	ml	Bois B - Contreplaqué	10,0	0,06	0,06
C3010.02 Finition de murs intérieurs|Faïence	98,12	ml	Céramiques	30,0	0,03	0,03
C3010.02 Finition de murs intérieurs|Grille décoratif	4,92	ml	Acier	67,0	0,33	0,33
C3010.02 Finition de murs intérieurs|Panneau grillagé	51,48	ml	Acier Fibres synthétiques	33,0 5,0	1,70 0,26	1,96
C3010.02 Finition de murs intérieurs|Panneau sandwich|métal + laine de roche	113,88	ml	Multi-matériaux non dangereux - panneaux sandwich	58,32	10,62	10,62

Figure 20: Extract of the analysis of the PEMD inventory.

These data enable us to precise a strategic approach on the reuse operation. There are 3 ways of reusing elements with potential:

- On-site re-use/re-utilisation - the re-use of elements removed from the existing structure for use during the construction phase.
- Internal re-use - the re-use of components on other projects for the Owner. The elements are offered either for direct re-use on another site in progress, or for storage to meet future needs.
- Off-site re-use/re-utilisation - For elements that cannot be re-used or re-utilised on site, an off-site outlet will be sought. This outlet may be the reuse channel (platform or transformation players) or a project in the area or use by SSE (Social and solidarity Enterprise) players or local residents.

The methodology of reuse operations must be built through specific actions through the main phases of the project:

- During the preliminary and design phases, an in-depth study of the existing building and its potential for reuse should be conducted. The design logic should take into account the existing elements that will be removed or deconstructed and be based on the available resources. Additionally, the project should identify elements that can be reused, with the possibility of searching for elements from other sources during the construction phase. This approach allows for a design that is open to opportunities. During the detailed design phase, objectives (results and/or means) should be established, along with recommendations for deconstruction and implementation operations.
- During the dredging phase, clean-out and removal operations should be carried out to extract elements with re-use potential (on and off site), followed by transformation, packaging, storage, and transport operations.
- During construction phase, supply and re-use of re-used elements (on site or from other sources).

During the diagnostic, indicators and quantities related to waste volumes and potential pollutants were implemented, in addition to reuse. To highlight the largest volumes of waste on construction sites, the typology has been structured into 5 classes:

  - Inert waste: concrete and non-concrete,
  - Non-hazardous non-inert waste (NHINW) excluding metal waste,
  - Metal non-hazardous waste (ferrous and non-ferrous metals),
  - WEEE (hazardous and non-hazardous),

- Hazardous waste.

4.4 Proof of concept for an application

To analyse the data, a complementary spatial vision is necessary due to the size of airport facilities. Therefore, decision was embraced to develop a prototype solution to support the general thinking on this issue. The prototype enables to import Excel diagnostic data in batches and associate them with asset data. Each line in the Excel file corresponds to a physically surveyed object, and the GIS Name | IDSIG data is interpreted to link it with the local object in the Heritage GIS. The object will be randomly positioned within the room using a coordinate system identical. The coordinate system used will be identical to that of the patrimonial GIS (RGF93-CC49). The data structure will also be identical to that of the Excel export. The application was developed using the existing infrastructure of the geographic information portal, which already includes a function for browsing and viewing floor plan data. The application includes a thematic display for data consultation and simple analysis tools to define relevant indicators of reuse potential, specifically geostatistics.

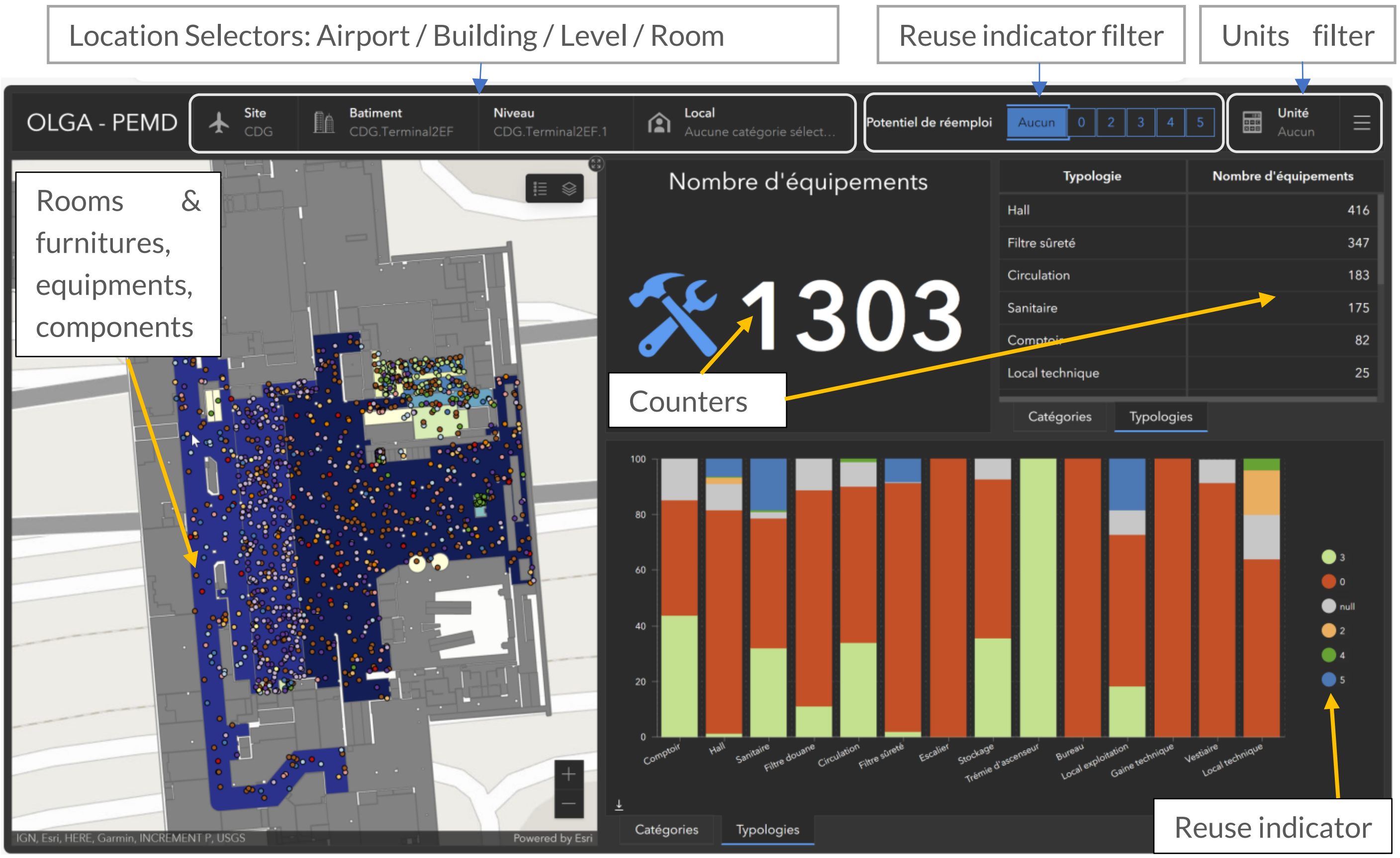


Figure 21: Demonstrator developed during the OLGA project for spatial analysis of the elements surveyed.

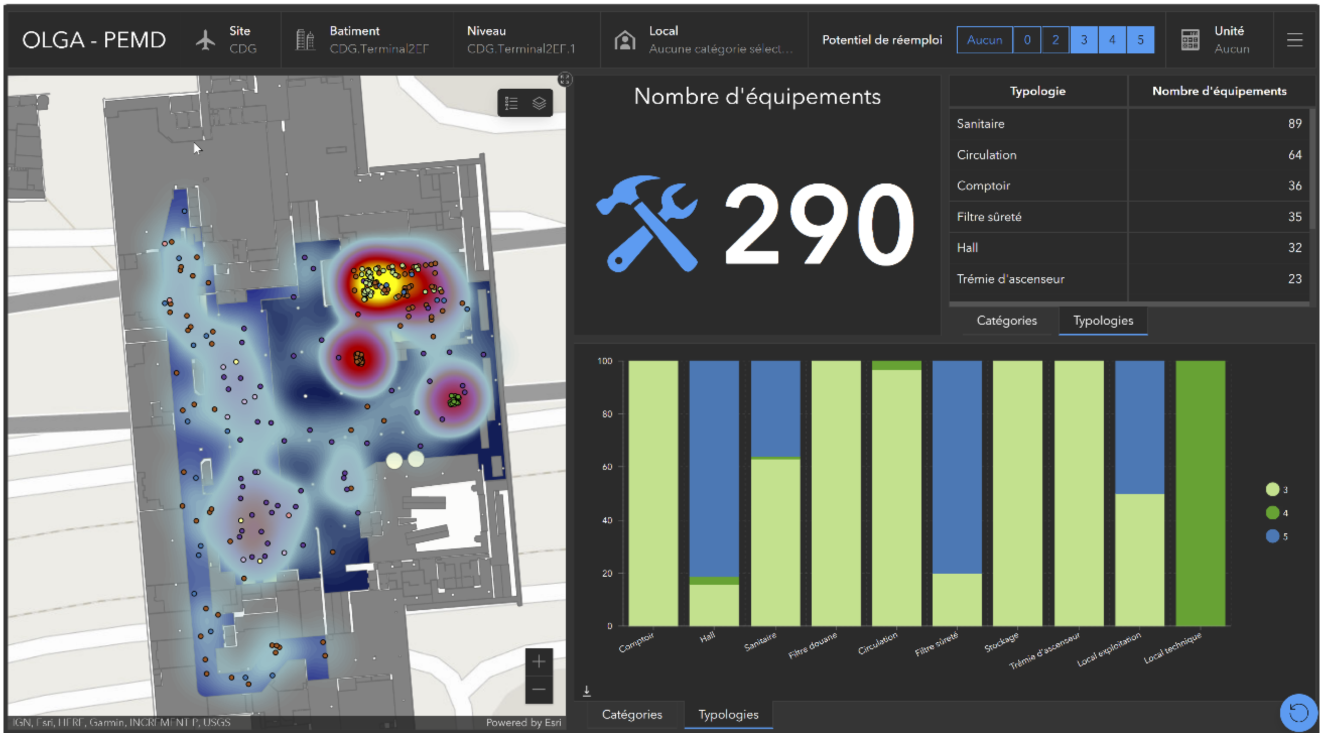


Figure 22: Illustration of a filter use with a hotspot map.

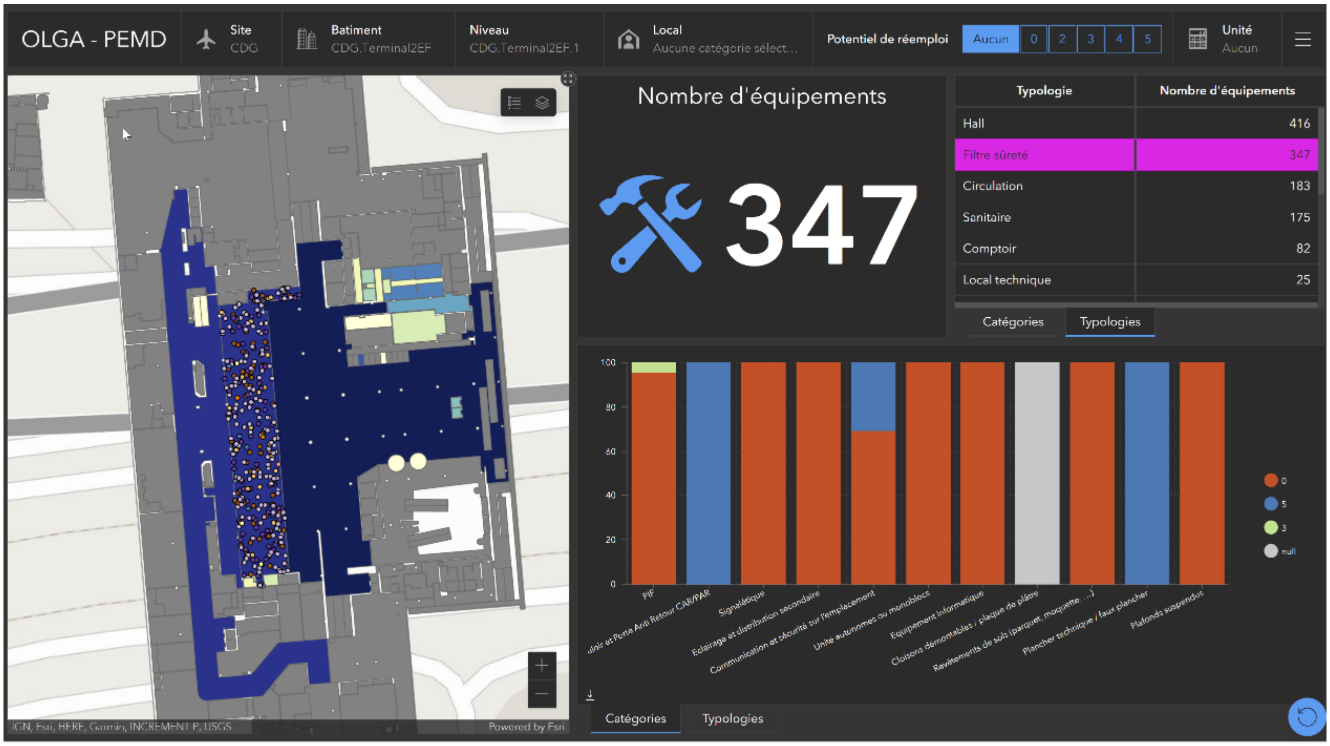


Figure 23 : Illustration of a filter use by type of object.

5 Lessons learned from this experiment

5.1 Key indicators proposal

Each product/material includes an assessment of its potential based on two predictive indicators:

1) The reuse potential of the product/equipment/material,
2) The economic potential of the potentially reusable product/equipment/material.

These predictive indicators consider both the characteristics of the element and the parameters of the context of the operation. They aim to provide a clear picture of the impact of the re-use of these products or equipment on the clearance/deconstruction operation.

These indicators aim to help with the decision on the strategy to be implemented in terms of the overall circular economy approach applied to the project.

At the RMW diagnosis stage, the assessment of these indicators is based on a visual inspection of the site and, where possible, on a documentary analysis and more in-depth complementary studies (surveys, etc.). In the case of this test, no destructive surveys were carried out.

The evaluation of the indicators can be refined and deepened as the studies and the site progress.

To assess the potential for reuse (first Key Performance Indicator), products and materials are rated according to the following three criteria, from 1 (poor) to 5 (very good):

1) **Condition of the product/equipment/materials:**
   - ⇨ Good = reusable as is,
   - ⇨ Average = minor refurbishment required,
   - ⇨ Poor = restoration or transformation required.

2) **Complexity of removing the product/material for re-use, preserving its components** - high, medium and low complexity.

3) **Possibility of finding an outlet for the product/material**, assessed on the basis of the level of development of re-use practices in the project area, the existence of demand (outlets on site or in other projects in the area) and channels for taking charge of the elements removed for re-use (assessed by a score out of 3): high, medium and low possibility.

5.2 Strategy proposal for increasing circular economy

Once the targets are clearly defined and the subcontractors designated, the project owner must mobilize all the necessary resources (material and human) to carry out the removal of the identified elements, to control the risks during the removal itself (electrical risk, working at height, others to be defined according to the nature of the material and the location context, etc.) and to preserve the physical integrity and quality of the elements. The removal methods are left to the discretion and responsibility of the subcontractors, which will be responsible for their reconditioning.

Removal tests must be carried out in order to define the correct removal methodology and achieve the desired objective. The packaging of the items removed, preserving their physical integrity and quality must also be defined. Depending on the case, this may involve putting them on pallets, in big bags, on specific racks, etc. Storage must be organised in identified storage areas on site. The components will be sorted into batches, ensuring that the batches are uniform, protected from the weather and secured against theft.

The buildings have mechanical limits to be considered. In order not to overload the floors, the contractor must take all necessary measures to distribute the loads when storing the deposed elements on site.

A storage area will be provided by the Owner until the contractor takes over the construction contract. These elements must be packaged and labelled with the completed "Product Sheet".

The acceptance of these elements must be carried out and validated in the presence of the Owner, the Contracting Authority, and the Project Management Team in charge of reuse process.

Transport of the elements to the reconditioning workshop and then to the storage location defined by the project owner must be provided by the contractor. It must take all measures to ensure that the means of transport envisaged are adapted to the packaging, quantity, size and nature of the elements in order to preserve the quality of the elements throughout the journey and in compliance with the regulations.

Reconditioning by cleaning, using a process and product suited to the surfaces and materials of the components. ADP must recondition elements in the flooring and sanitary category.

The components must be checked to guarantee that they are in good working order. This inspection and verification may concern:

- The physical condition - integrity of the product for all items identified for reuse in situ;
- Checking that equipment and electrical appliances are in good working order (electrical and electronic equipment, HVAC safety appliances).

If it is impossible to restore or guarantee the correct operation of an item identified for on-site re-use, the reasons must be justified. Elements that do not comply with the project requirements should be taken in charge for re-use off-site.

The traceability of all elements that are re-used in situ must be carried out with the provision of a Product Sheet.

In the event that it is no longer possible to re-use or re-purpose items in situ, preference will be given to re-use or re-purposing them ex situ, followed by sorting and single-stream disposal for recycling and recovery, in accordance with regulations, and, as a last resort, disposal.

Appendix

Example of GIS DATA

For the type of object "room"

ID SIG	9711
Nom	A40 A51
Libellé	Salle d'embarquement A40-A51
Type de local	Salle d'embarquement
Ouvrage d'appartenance	1200A
Niveau	4
Etat SIG	Actif
Responsable de documentation	CDG9
Propriété juridique	ADP
Zone de sûreté (locaux | réseaux)	Zone réservée sûreté
Site	Paris-Charles de Gaulle
Commune	TREMBLAY-EN-FRANCE
Surface (m²)	3917,23

For the type of object "level"

ID SIG	7526
Nom	4
Libellé	Niveau 4 - Etage (Trafic)
Famille de niveau	Etage
Ouvrage d'appartenance	1200A
Etat SIG	Actif
Responsable de documentation	CDG9
Niveau de confidentialité	Restreint ADP
Site	Paris-Charles de Gaulle
Surface (m²)	18052,4
Type d'occupant	Mixte
Plan de base	Trafic
Delta X	616516,951
Delta Y	144823,075
Rotation	4,999935

Surface de plancher	16271,3
SHOB	17282,45
SHON calculée	15923,11
Somme des SHON estimées	15923,11
Créateur	ADP-NT\XXX
Date de création	13/03/2008
Dernier modificateur	ADP-NT\XXX
Date dernière modification	30/08/2021

For the type of object "Technical object"

ID SIG	1630303
Nom	Poutre 1 S40 Dép A40.2
Libellé	Poutre 1-5s-Salle A40-Dép Elec A40.2
Domaine technique	Architecture
Catégorie technique	Siège
Type de catégorie	Equipement
Ouvrage d'appartenance	1200A
Propriété juridique	ADP
Site	Paris-Charles de Gaulle
Ouvrage localisant	1200A
Niveau	4
Local	A40 A51
Complément de localisation	
Etat de localisation	Géolocalisé
Coordonnée X	616419,179
Coordonnée Y	144719,486
SRID	27561
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6 Part 2 "Resources-materials-waste diagnostic and circular economy methodology" of the Report including a methodology proposal for increasing the circular economy in refurbishing airport terminals projects. Trial on Satellite S3 (Terminal 2E) and feedbacks. Paris-Charles de Gaulle Airport, 95700 Roissy-en-France.

7 Context and issues

7.1 Introduction

As part of the OLGA research project, Group ADP is investigating technical and methodological solutions for reducing the environmental footprint (resource footprint) of construction, renovation and rehabilitation projects carried out on airport platforms. This document describes **the BATIRIM Resource, Material, Waste (RMW) diagnostic** test carried out in an area of approximately 9,000 m². Located in the satellite S3, this test was carried out in November 2023, on a surface area spread over 2 floors, at the level of the Screening Inspection Stations (SIS) (PIFs in French) and their upstream **waiting halls, at the top of the LISA (fully automated metro system) escalators.**

S3 (with a total surface area of over 150,000 m²) was delivered in 2007. Little or no changes have been made to the facilities since they were built, and the interior fitting are of very good quality. In 2023, they were in good condition overall.

The aim of a RMW diagnostic is to quantify and qualify all the elements that make up a building with a view to its total or partial dismantling (rehabilitation).

This Resource Diagnostic simulation is based on actual project studies. The area studied is the subject of a feasibility study realized in 2021 for a complete redevelopment involving the relocation of the Screening Inspection Stations (SIS) area (fewer but larger SISs allowing a higher passenger throughput per unit) into the waiting areas to the benefit of the retail areas downstream.

For this Resource approach, only finishing materials have been considered: visible elements, products, equipment, furniture, and materials have been counted, including technical terminals in the ceiling mesh; this includes air vents, cameras, light fittings, fire extinguishers, etc. (neither the building envelope, nor the structure, nor the façade elements (glazing) have been considered).

Figure 24- Charles de Gaulle Airport aerial view.

7.2 Regulations overview

In France, regulations have profoundly revaluated the responsibility and management of resources and materials (RM) and waste (W) on building sites. Re-use is a management priority, and waste must be sorted at source for at least 7 regulatory streams:

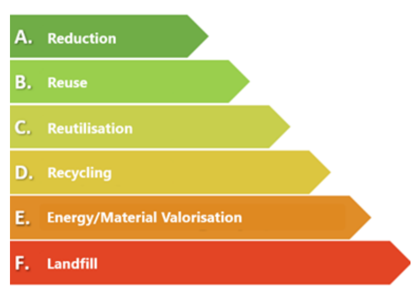
- The **Environment Code** specifies that producers are responsible for their waste until it is disposed of (framework law of 15th of July 1975).
- **Energy transition law for green growth (LTECV in French) of 17th of August 2015** sets a recovery target of 70% of all construction and public works waste and 55% of non-hazardous non-inert waste from 2020. New obligations for local authorities regarding the use of recycled materials on construction or road development sites.
- The **Anti-waste for a circular economy (AGEC in French) law of 10th of February 2020,** relating to the fight against waste and the circular economy, reinforces the objectives of the LTEC; it introduces:
  - **Priority given to re-use for RMW,** with removal from waste status.

- **Mandatory** Resource, Material, Waste (**RMW**, PEMD in French) **diagnostics as** of the decree of 25th of June 2021.
- **Sorting of 7 streams** from decree no. 2021-950 of 16th of July 2021, which amends article D543-278 of the 5 streams. *Failure to comply with this obligation is now directly referred to in article L541-46, which clearly makes it a **criminal offence punishable by two years' imprisonment and a fine of €75,000 in France**.*
- **Extended Producer Responsibility** (*Responsabilité Elargie du Producteur*, REP in French) by Decree no. 2021-1941 of 31st of December 2021: extended producer responsibility for construction products and materials in the building sector (*produits et les matériaux de construction du secteur du bâtiment*, PMCB in French) takes up the objectives for setting up recovery rates by material recommended by **European Directive 2018/851 of 30th of May 2018.**
- **Circular of 15th of February 2000** on planning the management of "building and public works" (BTP in French) waste in each department, with the aim of:
  - Preventing and reducing waste at source.
  - Respecting the principle of proximity by limiting waste transport.
  - Waste recovery through re-use, material recycling, organic recovery, and energy recovery.

- **The French Thermal Building Regulation RE 2020** comes into force for residential buildings on 1st of January 2022, with the date on which planning permission is submitted serving as proof.

Offices and educational buildings will be subject to this requirement from 1st of July 2022, followed by other types of building between late 2024 and early 2025.

In the case of deconstruction, the objective of re-use enables to reduce the Carbon Footprint of the project with the CO_2 avoided when the building is rebuilt. This list of regulations presents the main texts but is not exhaustive. A regulatory watch is necessary throughout each operation.



The diagram below summarizes the different treatment options for the elements available on site.

Priority is given to re-use and, if sorted in a controlled manner, building products, equipment and materials can escape the status of waste.

Priority must be given to the most virtuous methods of treatment, in accordance with the hierarchy of waste treatment and disposal methods set out in article L541-1 of the Environment Code.

7.3 Study's scope

At the heart of Paris Charles de Gaulle Airport, the diagnostic covers an area of 9,000m² located on levels 1 and 2 of Hall 2E - Waiting Hall and Screening Inspection Stations, Gate L - Satellite 3, on the level of the Screening Inspection Stations (*Poste d'Inspection Filtrage*, PIF in French) and their upstream waiting halls, at the top of the LISA (fully automated metro system) escalators.

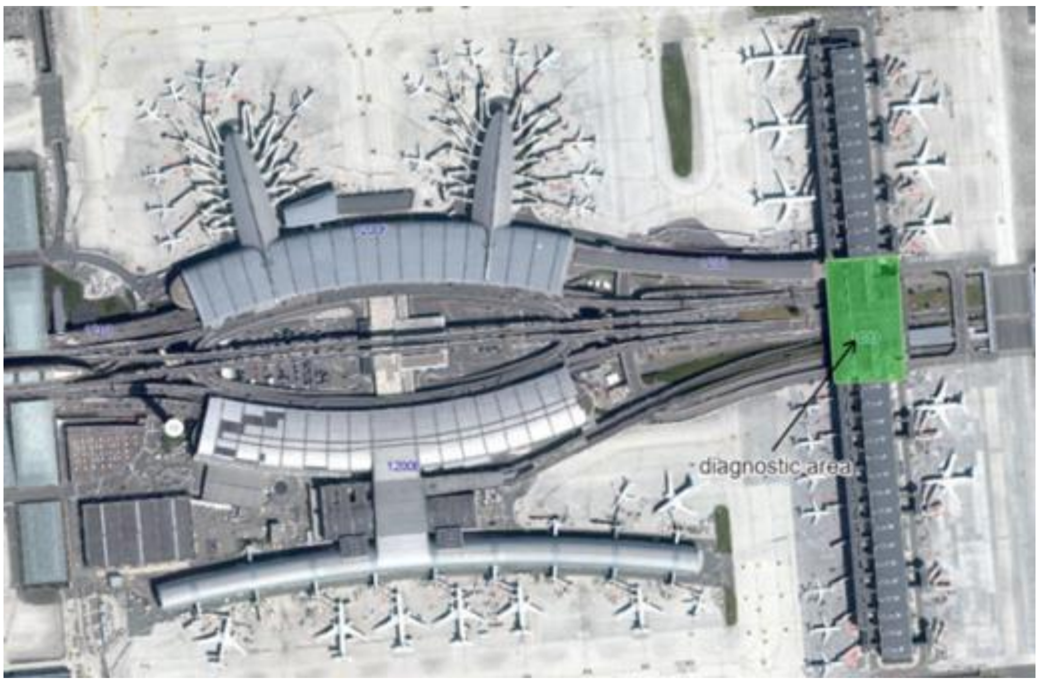


Figure 25: Terminal 2E aerial view.

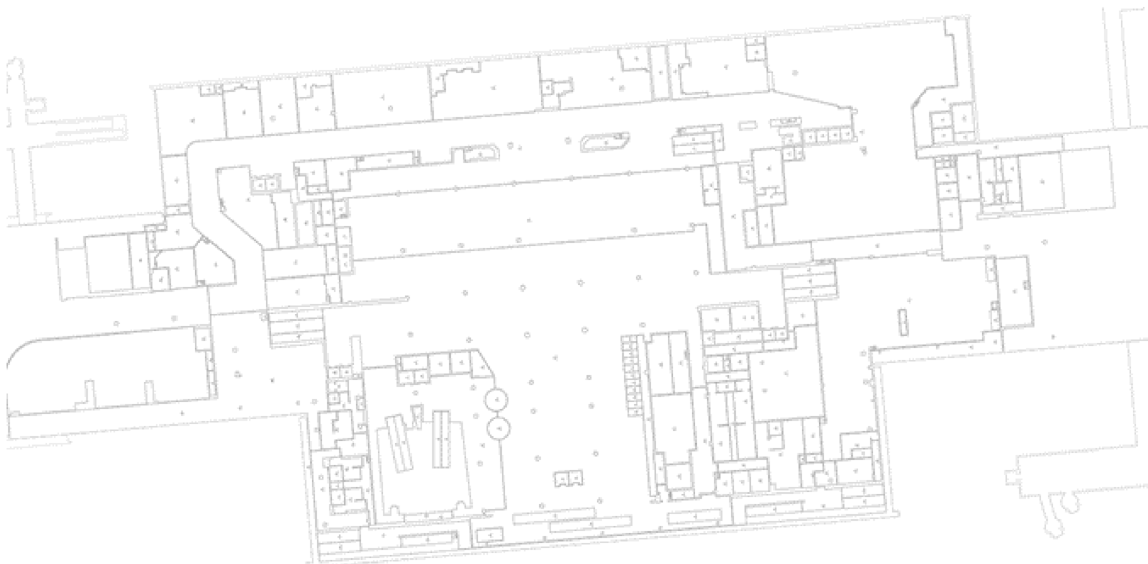


Figure 26: First floor plan.

Figure 27: 2nd floor plan.

9 Circular economy approach: field of possibilities

A glossary of circular economy terms is provided at the beginning of the document.

9.1 A dual approach to integrating circular economy principles.

As part of the OLGA research project, Groupe ADP is investigating technical and methodological solutions to implement a circular economy approach.

The approach is based on the principle of a construction, renovation or refurbishment project that should enable to:

- Significantly reduce the production of waste by encouraging re-use and/or recycling.
- Maximize the recycling and recovery of materials through selective clearance - with a focus on both the inert fraction and non-inert waste.

The implementation of the circular economy process methodology is based on the results of the Resource, Material, Waste analysis. This diagnostic makes it possible to classify **the elements into different categories and to assign them a treatment method**, in accordance with the hierarchy of treatment methods, as defined by the regulations.

This note focuses on the diagnostic results, presenting:

- **A waste-reduction approach** - through a process of re-use operations throughout the project, which enables resources and materials deposited to avoid the status of waste.
  This is the treatment favored by the proposed strategy. However, when re-use is not possible, the items will be taken care of by the waste re-use and recovery circuits.
- **A waste recovery approach** - this applies to the materials resulting from the cleaning process, which can be re-used, recycled and recovered from materials or energy.

9.2 Resources & materials analysis and the French resources, materials, and waste diagnostic

9.2.1 Carrying out the RMW diagnostic: methodology

As this was a partial diagnostic of the building, a site visit was carried out prior to the days dedicated to the data collection to precisely define the scope of the work in terms of plan and volume.

The work was carried out in a restricted part of the terminal under special security conditions. Working in this specific area means several organizational constraints:

- Requires a full search with the impossibility of taking tools with you
- Needs to anticipate requests for authorizations (at least two weeks in advance) and ensure that duly authorized ADP staff are available,
- Ensures that the ADP authorized staff is present every time with the declared people for the operation: people must work in group because they are under the responsibility of the authorized ADP staff member.

At the time of the trial, the ADP authorized staff were not trained to enter data collected during the diagnostic. Therefore, due to security special constraints, data entry for this trail requires constant communication between the members of the diagnostic team to coordinate the distribution of items to be entered from the same room. Generally, during a conventional diagnostic, the diagnosticians divide up the rooms or levels, making this a solitary exercise.

The RMW diagnostic was carried out using RIM® (Resource Information Modeling) technology developed by BATIRIM, which enables data to be inventoried directly on a scale plan from a library of nomenclature elements, thus creating a 2D digital model of the existing building.

Figure 28: Circular economy in building scheme.

The digitized RMW diagnostic was carried out according to the methodology described below and presents all the information required by the regulations:

- How to prepare,
- On-site diagnostics,
- Data processing,
- Drafting of deliverables.

Please note that BATIRIM carried out the surveys only in accessible premises and areas of which it was aware, either from the plans or from the project owner, and to which its personnel had access under normal safety conditions. No removal tests or material analyses were carried out.

The RMW diagnostic is carried out using a digital tool that allows to get as close as possible to the composition of the structures and the quantities measured. Nevertheless, certain elements had to be approximated based on plans, and some of the tonnages calculated based on ratios and densities. At the diagnostic stage, **the quantities supplied remain estimates**; they are usually confirmed by the companies when they draw up their bids and validated at the site phase by monitoring the actual quantities submitted.

9.2.2 The RMW diagnostic: limits of the implementation

This document makes it possible to estimate the re-use potential of existing structures based on a visual inspection on site and provides indicators with help with the decision on the strategy to be implemented in terms of the overall circular economy approach applied to the project.

The document presents:

- **The RMW diagnostic carried out on all the elements**, usually carried out prior to the feasibility study for the reconstruction work and the acceptance of estimates or the awarding of contracts for the work;
- **Information on the potential for re-use** of products, equipment and materials;
- In the absence of re-use, **information on waste management and recovery methods**, in particular local methods, with a view, in descending order of priority, to re-use, recycling or other material recovery, energy recovery or disposal;
- **Information on precautions to be taken when removing, storing, and transporting** products, equipment, materials, and waste.

The methodology for re-use operations must be built up through specific actions and through the major phases of the project: Preliminary design (PD), Operations implementation program (OIP), Construction and equipment department (CED), Execution (EXE), Cleaning/dredging and construction. A chart presenting the circular economy approach through these phases is presented in the appendix.

9.2.3 The RMW diagnostic: mission preparation

The diagnostic carried out by BATIRIM was based on data provided by ADP's BIM and GIS systems. These ADP information systems carry the source data. The aim was to enhance the data identifying and locating the terminal's RMW with the re-use data collected by BATIRIM as part of its diagnostic.

To achieve such an objective, a nomenclature of items integrated into the BATIRIM database was created on behalf of ADP. This nomenclature is available both via a web client and via a mobile client, such as an IOS tablet.

The data transmitted by ADP was structured based on a "part number" type reference providing a unique reference intended to apply to each of the parts, (open) zones or objects tracked by ADP in its GIS database, with 2 key elements:

- GIS_NAME (of the room) to GIS_ID (of the room) to function of the room (for example: security, retail or passenger reception);
- ID_SIG à Heritage reference for the object.

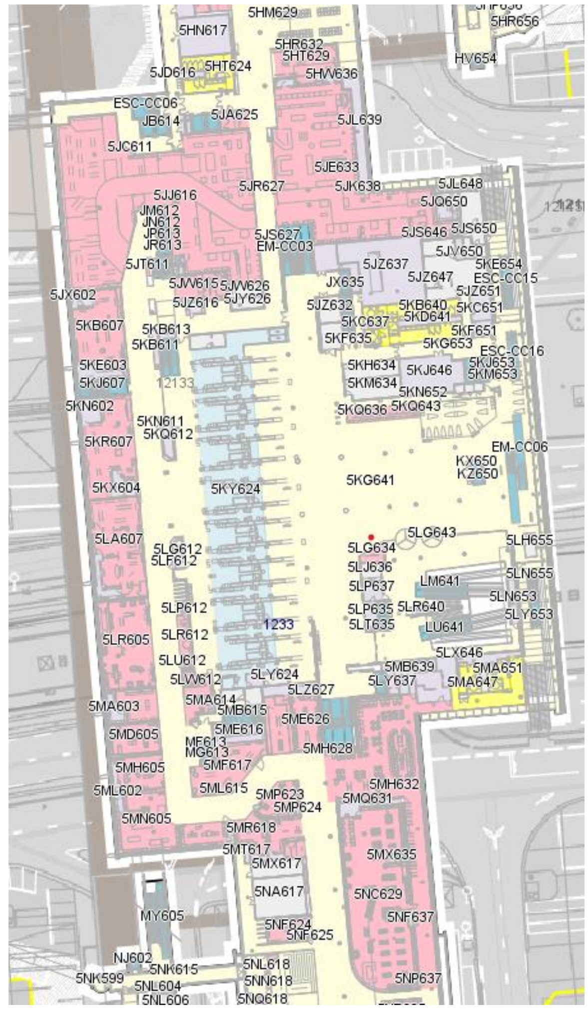


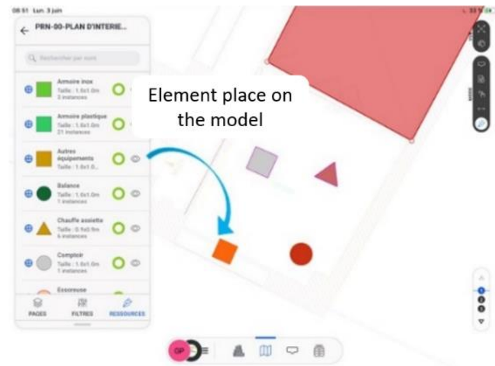
Figure 29: Plan with name of the rooms.

Indeed, it is important for ADP to enrich the value of the "GIS ID" field, as it remains the key to the computerized asset object to be applied to any equipment whose re-use potential BATIRIM had to detail following its intervention in the area as part of a digitized diagnostic operation held between 6 and 9 November 2023.

An ad-hoc import file was compiled manually by BATIRIM to assign to each item of equipment data a complement derived from these 2 ADP fields NOM_SIG on the one hand and ID_SIG on the other. In this way, each piece of equipment was listed, inventoried, and identified in terms of its potential for re-use, together with the information from this part reference system. This file was then injected into the project numerically created.

Before the BATIRIM teams began their on-site diagnostic, the following steps were implemented:

- Initialization of a project in the database entitled "20-12 OLGA - GREEN DEAL volet airport".
- Injecting PDF plans into this project;
- Injection of the article nomenclature, itself taken from:
  - BATIRIM standard reference articles;
  - List of ADP equipment;
  - Standard characteristics for re-use and materials from BATIRIM;
  - GIS ID and value defined for each piece of equipment;
  - NOM_SIG and value defined for each piece of equipment given priority by ADP.
- Plans scaled by BATIRIM's experts;
- Start of diagnostic.



Note that on the plans supplied by ADP, the ID_SG and NOM_SIG information can be read directly and assigned to each of the rooms where BATIRIM's diagnosticians will be working.

9.2.4 The RMW diagnostic: on-site data gathering

The diagnostic took place with the following constraints:

- No conventional diagnostic equipment (hammers, screwdrivers, etc.);
- Only meters and magnets are accepted;
- No destructive testing possible;
- No dismantling possible;
- Diagnostic in an occupied environment, with a permanent and substantial flow of passengers;
- Zones with Screening Inspection Stations: diagnosticians had to pass through the Screening Inspection Stations like a normal passenger including their equipment. It requires bringing appropriate clothing to pass through the controls quickly;
- PPE (Personal Protective Equipment) not required, but trainers and comfortable clothing essential;
- Working zone by zone;
- Breaks and lunches : Water bottle (empty for security screening), lunch on site (take away) and break in the passenger waiting areas.

9.2.5 The RMW diagnostic: data processing

The data processing phase is designed to ensure business consistency and effective management of non-compliance.

This breaks down as follows:

- **Retrieval of the inventory database from the BATIRIM® data management platform**

Once the field diagnostic is complete, the diagnostician can consult the data entered on the platform. If all the products and materials have been entered, the raw data is exported for the first time.

- **First generation of RMW summary tables**

It is only at this stage that the operator has complete visibility of the total quantities present on his facilities. He is now able to assess the resulting summaries and, if necessary, make the corrections required to adjust these quantities.

- Retrieval of the inventory database from the BATIRIM® data management platform,
- Automatic calculation, quantitative and qualitative analysis of RMW with the BATIRIM® platform,
- Generation of RMW summary tables,
- Search for recovery channels within the project perimeter, according to 2 criteria: capacity to process flows and proximity of the future worksite.

10 Circular economy methodology into the project management

10.1 Criteria for assessing re-use potential.

Each product/material includes an assessment of its potential based on two predictive indicators:

- the re-use potential of the product/equipment/material,
- the economic potential of the potentially reusable product/equipment/material.

These predictive indicators consider both the characteristics of the element and the parameters of the context of the operation. Their aim is to provide visibility of the impact of the re-use of these products or equipment on the clearance/deconstruction operation.

They are indicators to help in the decision on the strategy to be implemented in terms of the overall circular economy approach applied to the project.

At the RMW diagnostic stage, the assessment of these indicators is based on a visual inspection of the site and, where possible, on a documentary analysis and more in-depth complementary studies (surveys, etc.). (PM: no destructive testing has been carried out on the terminal).

The evaluation of the indicators can be refined and deepened as the studies and the project progress.

10.2 Re-use potential

To assess the potential for re-use, the RMW are rated according to **the following three criteria, with a score out of 5**, from 1 (poor) to 5 (very good):

- **Status of the RMW:**
  - good = reusable as is,
  - medium = light refurbishment required,
  - poor = restoration or conversion required.
- **Complexity of removing the** RMW for re-use, while preserving its components (high, medium, and low).
- **Possibility of finding an outlet** for the RMW, assessed based on the level of development of re-use practices in the project area, the existence of demand (outlets on site or in other projects in the area) and channels for landfilling items deposited for re-use: high, medium, and low possibility.

Depending on their re-use potential, there are **2 use cases**:

- **Ready for re-use**: RMW with a potential of **3**, **4** and **5** have the following characteristics: they are in good condition, easy to use, and can be dismantled and reconditioned at little or no cost.

The re-use of these elements in ADP projects can be envisaged in the **short** (potential 5 and 4) and **medium term** (potential 3).

- **Complex to re-use**: RMW with a potential of **1** and **2** have the following characteristics: average or poor condition, difficult to implement and costly (complex removal, immature re-use and reconditioning market); they require a more in-depth study with re-use players. The re-use sector for these elements is not structured or is in the process of being structured.

The re-use of these elements in ADP projects can be envisaged in the **long term** (potential 1 and 2).

11 Scenarios for re-use as part of a new airport development project

11.1 Principles.

Our analysis, presented in this document, focuses on the **re-use potential of an airport terminal** (located in France), considering the possible treatment scenarios according to the ease or complexity of re-use. The points considered in establishing the treatment scenarios and methodology are as follows:

- building configuration,
- characteristics of the project,
- context close to the project,
- local context - ecosystem and material flows,
- scale of work on existing structures,
- construction schedule.

Based on the data collected during the RMW diagnostic, an initial selection and classification of products, equipment and materials is carried out, considering the parameters linked to the project and the maturity of the ecosystem to receive these sources.

The classification characteristics of these elements are as follows:

- **Easy**: These RM are easy to re-use, as they benefit from an already structured re-use sector, and some components are not subject to insurance constraints.

The re-use of these elements in ADP projects can be envisaged in the **short and medium term.**

- **Ambitious**: RM with the complexity of re-use at this stage of the study. The re-use sector for these elements is not structured or is in the process of being structured.

The re-use of these elements in ADP projects can be envisaged in the **long term,** as they require a more in-depth study with those involved in re-use to put in place a re-use methodology.

Typically, the scenarios proposed at this stage of the study must then be validated during the conception phase (Detailed Desing/Tender Document Production phase or PRO-DCE phase in French) and during the execution phases (conception phase once the execution company has been designated or EXE phase in French). During each stage, analysis are carried out in consultation with the Project Owner (PO), the project manager, the Control Office (CO), contractors and those involved in re-use. For example, it is advisable to validate the scenarios again after carrying out removal tests, before the actual removal phase.

11.2 Implementation process

There are 3 ways to re-use part, equipment or component:

- **On-site re-use (and/or spare parts),** re-use of parts or totality of an equipment identified during the RMW diagnostic within the new project forecasted on the footprint of the old building. This process requires storage space, aligned timings, and compatible phasing.
- **Internal re-use,** re-use of parts or totality of an equipment identified during the RMW diagnostic within a new project forecasted outside of the footprint of the old building but within the Project Owner premises. This process requires storage spaces and the capacity of reconditioning.
- **Off-site re-use,** re-use of parts or totality of an equipment identified during the RMW diagnostic within a new project forecasted outside of the footprint of any projects of the Project Owner. Generally, the parts are sold using marketplaces dedicated for re-use elements.

Based on the resources and materials identified on site, their characteristics, and their potential, 2 treatment methods are envisaged, in the following order of priority:

- **Off-site re-use** - planned in the **short and medium term,**
- **Internal re-use - a medium- to long-term** approach.

11.3 Specific airport equipment and associated re-use potential

The list of airport-specific categories and equipment was drawn up with the ADP team and is attached in the Appendix (Table 2.2). However, a validation of these statements on the equipment with an ADP expert is necessary.

The analysis of the potential for re-use was carried out on the following 4 categories of specific airport equipment:

- Airport furniture (counters, banks, etc.) ,
- Corridor and Anti-Return Door CAR/PAR ,
- Screening Inspection Stations,
- Signage.

The graph below shows the average re-use potential for these categories. Note that the Screening Inspection Stations (SIS) and Signalitique categories have a higher potential of **2.5** and can be considered for re-use on ADP projects in the short and medium term.

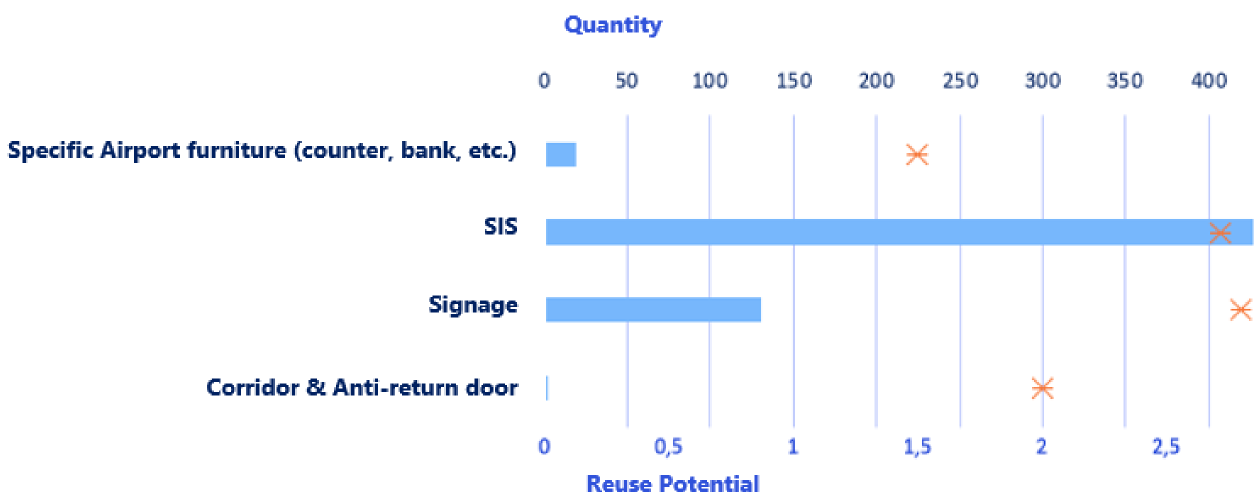


Figure 30- Average re-use potential by category - Airport equipment

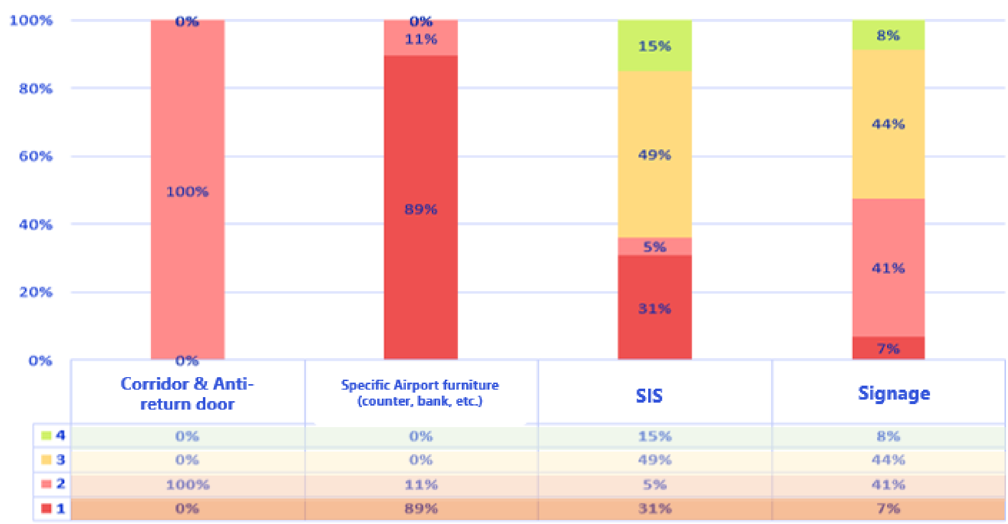


Figure 31: Potential for re-use of specific airport components.

The graphs above shows the potential for re-use on a scale from 1 to 5 of the elements in each category, the following details can be underligned:

- On one hand, around **55%** of the elements in the **Screening Inspection Stations** and **Signage** categories are in good condition and are easy to remove;
- On the other hand, the items listed above are more complex for re-use :
  - around **40%** of items in these 2 same categories **(Screening Inspection Stations** and **Signage**) and,
  - **100%** of the category **Corridor and Anti-return door** and **Specific furniture.**

The potential of re-use of these elements is assessed by:

- the unsatisfactory condition of certain components,
- the cost of reconditioning them, and
- the level of complexity for other elements, in particular the cost of removal and logistics.

These results will provide ADP with a decision-making tool for implementing a policy of reusing the RMW in its portfolio in the short, medium and long term.

Re-use of these components is **ambitious** at this stage. Feasibility studies and research need to be carried out for those components (manufacturers and/or installers) to define a methodology for removal, handling and repackaging that will guarantee proper functioning, to encourage and industrialize re-use. The short- and medium-term ex situ re-use of these components can be envisaged through various sales channels: the second-hand airport equipment sales platform, Airport Market Place, or directly by second-hand equipment buying and selling companies.

The following paragraphs present in a more detailed way the re-use potential of the specific airport products, equipment, and materials.

11.3.1 Specific airport products with an ambitious re-use level

11.3.1.1 Screening Inspection Station (SIS)

The diagnostic included the dismantlement of 2 large zones of Screening Inspection Stations. Figure 32 below indicates the types of equipment available in those areas.

Figure 32: Example of Screening Inspection Station furniture's and equipment's.

The RMW diagnostic identified **19 element typologies** (423 units - all units combined: m², ml, u) with re-use potential. According to the analysis of the RMW diagnostic results, the Screening Inspection Stations category has a re-use potential with a higher average of **2.5** (Figure 33) defined at this stage of the project.

The graph below shows that for the Screening Inspection Stations category, the RMW diagnostic identified **14 element typologies** with a potential equal to or greater than **3**, i.e. **55%** of all RM in the category (15% of RM with a potential of **4** and 35% with **3**).

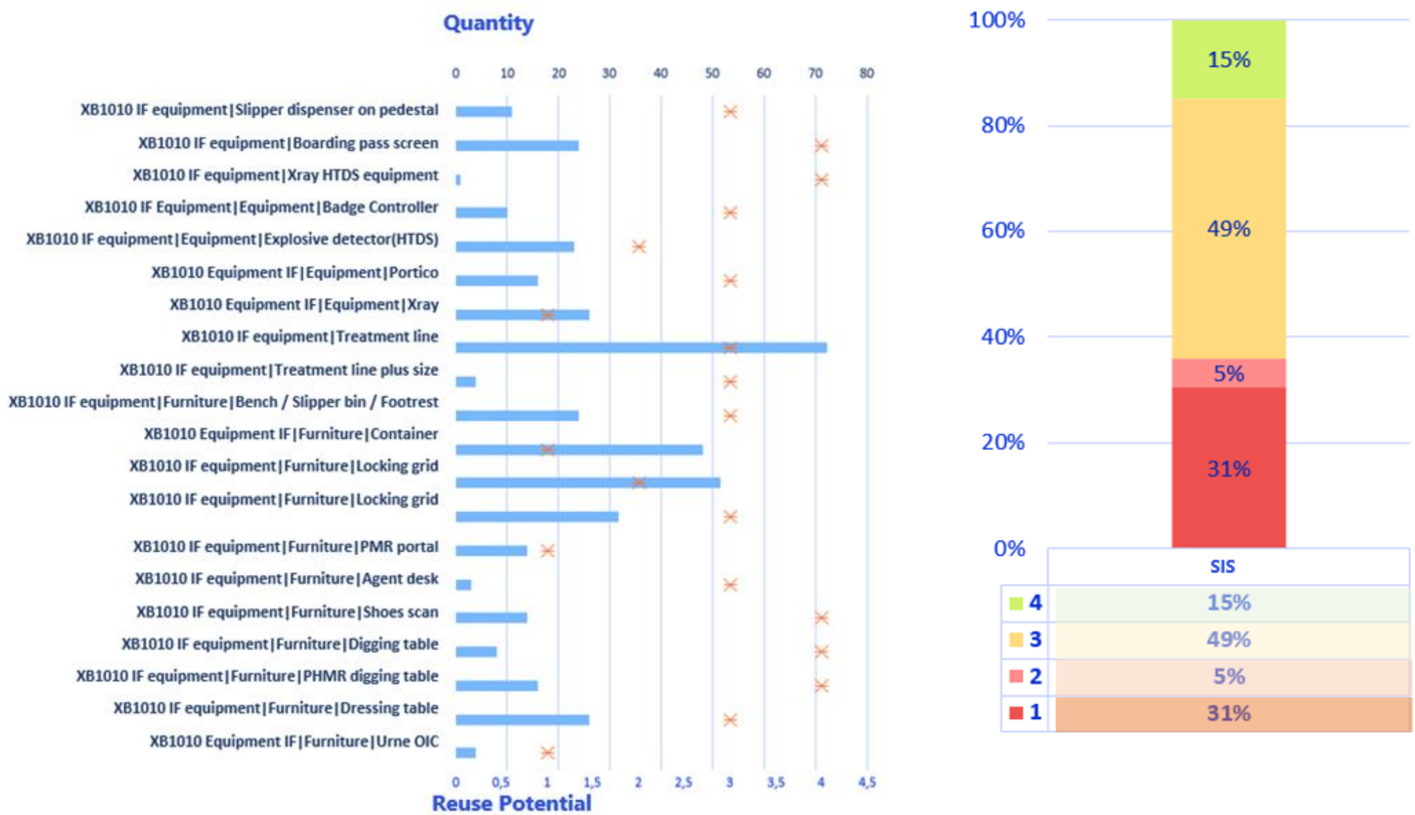


Figure 33: Re-use potential for each component from the SIS category.

These results provide inputs for reflexion with a view to ADP's own strategic choices for implementing a re-use approach at :

- **In the short and medium term around 55%** of all RMW in this category are reusable,
- **Long-term an additional 45%** of all RMW from this category are reusable.

The short- and medium-term re-use of these items can be envisaged through various sales channels: the second-hand airport equipment sales platform, Airport Market, or directly by second-hand equipment buying and selling companies.

11.3.1.2 Signage

The diagnostic included the analysis of large waiting areas, operational zones and orientation spaces. All those areas need an important signage. However, this signage furniture is generally very specific to each airport as they support the brand of the company. The Figure below offers some examples of signage material.

Figure 34: Example of material and equipment part of the signage category .

The RMW diagnostic identified **9 typologies of elements** (130 units - all units combined: m², ml, u) with re-use potential. According to the analysis of the RMW diagnostic results, the Signage category has a re-use potential over **2.5** (Figure 35) defined at this stage of the project.

The graph below shows that for the Signage category the RMW diagnostic identified **5 element typologies** with a potential equal to or greater than **3**, i.e. around **50%** of all the RMW in the category (15% of RMW with a potential of **4** and 35% with a potential of **3**).

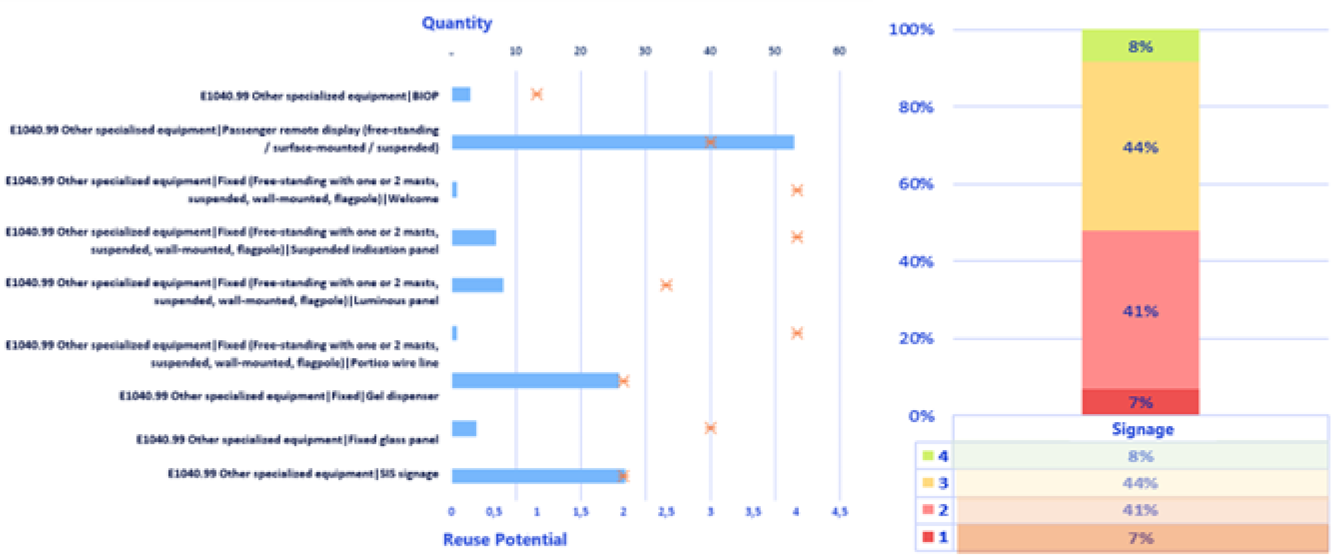


Figure 35: Re-use potential for each component from the signage category.

These results provide inputs for reflexion with a view to ADP's own strategic choices for implementing a re-use approach at :

- **In the short and medium term**, **50%** of all RM in the category are re-usable,
- **In the long term**, **50%** of all RM in the category are re-usable.

The short- and medium-term re-use of these items can be envisaged via various sales channels: the second-hand airport equipment sales platform, Airport Market, or directly by second-hand equipment buying and selling companies.

11.3.1.3 Anti-return corridor

The RMW diagnostic identified **1 typology of elements** (comprising 2 units) with re-use potential with equal to 2: the anti-return corridor.

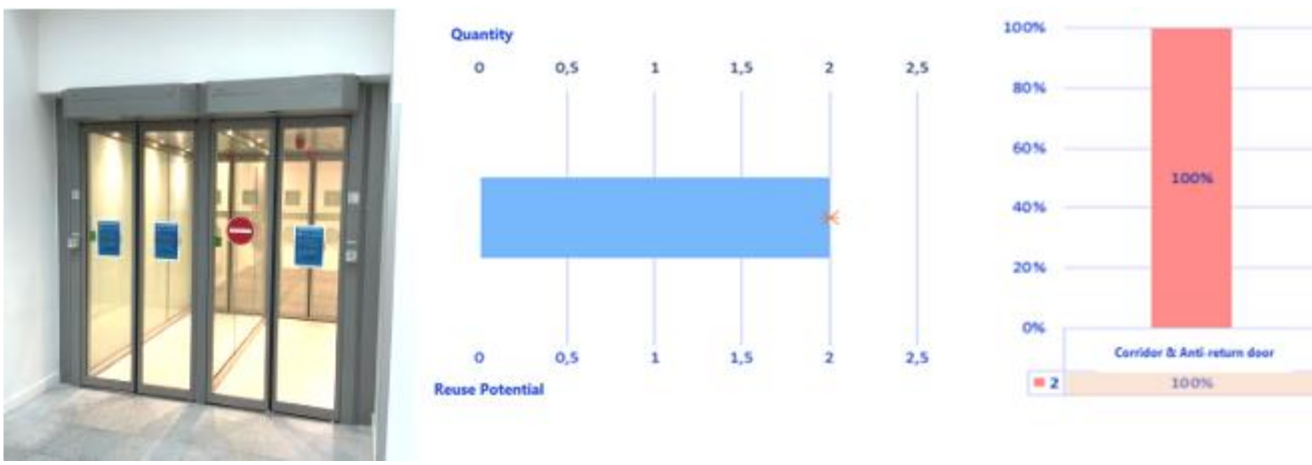


Figure 36: Example of material and equipment part of the anti-return corridor typology & re-use potential graph.

The graphs above shows that the **short- and medium-term** re-use of these items identified during the RMW analysis is <u>complex</u> due to the cost of removal and logistics (complex removal, immature re-use, and reconditioning market). However, removal tests could be envisaged to study the implementation of a process.

11.3.2 Specific airport products with an easy re-use level

11.3.2.1 Specific airport furniture (counters, reception desks, etc.)

The diagnostic included the analysis of some waiting area comprising specific airport furniture such as armchairs. Airline counters were also located in the area, those counters are generally used to ensure the care of all passengers, and specifically connecting passengers. Figure 37 below illustrates the type of furniture available in the area.

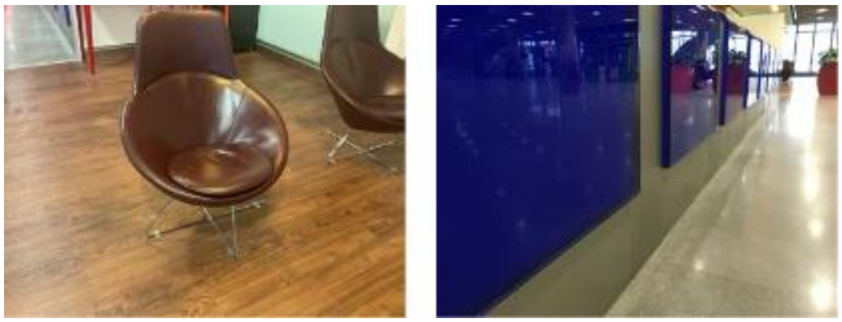


Figure 37: Example of material and equipment part of the airport furniture category.

The RMW diagnostic identified 2 **types of elements** (19 units - all units combined: m², ml, u) with re-use potential.

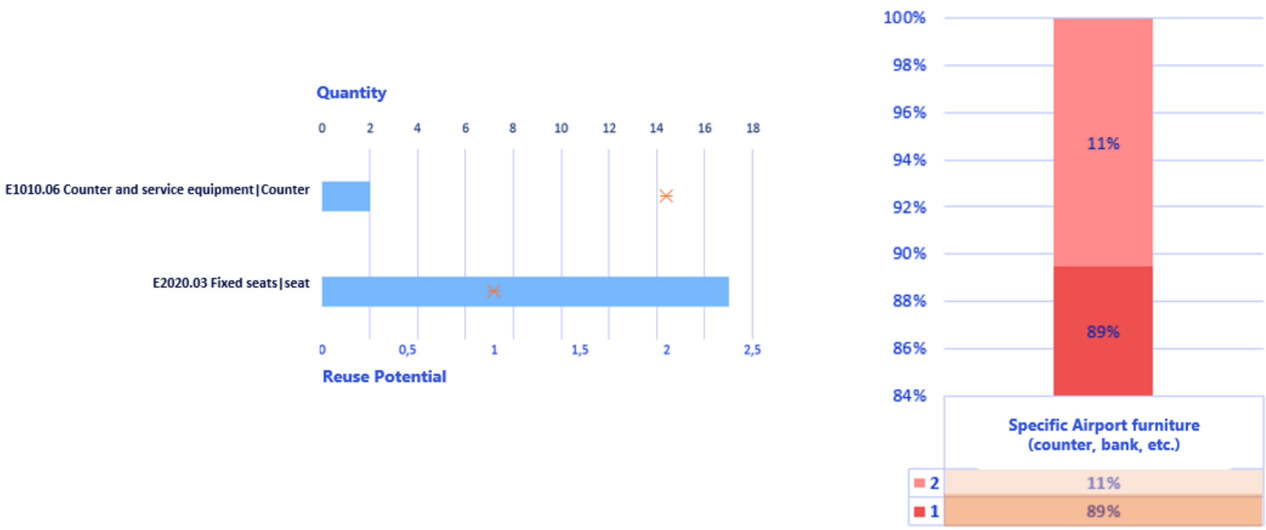


Figure 38: Re-use potential for each component of the airport furniture category.

The graphs above shows that the **short- and medium-term** re-use of these elements identified during the RMW diagnostic is complex due to:

- the unsatisfactory condition of certain components and the cost of reconditioning them,
- complexity for other elements, in particular the cost of removal and logistics.

However, the re-use potential of **furniture items** can be enhanced by improving their condition (by going through a reconditioning stage). Furniture items in general are easy to re-use, as they benefit from an already well-structured re-use channel, with several identified companies or associations.

Counter and service elements can be re-used on site as spare/replacement elements. In cases where short-term re-use is not possible at the present time, the re-use solution can be explored with players in the ecosystem who are already mature on the subject.

11.4 Standard resource and material and associated re-use potential

An analysis of the reusability of 24 categories of standard elements is presented below.

In 2023, a list of categories of products, equipment, and materials suitable for re-use was published by CSTB - French national organization providing research and innovation, consultancy, testing, training and certification services in the construction industry - as part of a research project to industrialize this type of approach.

The short- and medium-term ex situ re-use of these items can be envisaged through various disposal mechanisms: the second-hand airport equipment sales platform, Airport Market or other, or directly by the company.

11.4.1 Standard resource and material with an easy re-use level

The RMW diagnostic identified **15 categories** that can be **easily** re-used and/or re-used:

- **Plumbing fixtures and fittings**: **85%** of items in this category are identified as ready for re-use in the short term,
- **Technical floor**: **100%** of the elements in this category are identified as ready for re-use in the short term,
- **Cable trays**: **100%** of items in this category are identified as ready for short-term re-use,
- **Floor coverings (parquet, carpet, etc.)** - Carpet and resilient flooring: **100%** of items in this category are considered suitable for re-use to date (long-term re-use depending on the structure of the channels),
- **Lighting and secondary distribution**:**85%** of elements in this category are identified as ready for short-term re-use,
- **IT equipment:** **40%** of items in this category are identified as ready for short-term re-use,

- **Interior doors**: **100%** of items in this category are identified as ready for re-use in the short term,
- **Wall and post cladding**: **20%** of the elements in this category have been identified as ready for re-use in the short term,
- **Integrated accessories**: **35%** of items in this category are identified as ready for short-term re-use,
- **Other equipment**: **100%** of items in this category are estimated to be suitable for re-use to date (long-term re-use depending on the structure of the channels),
- **Institutional equipment**: **100%** of items in this category are identified as ready for short-term re-use,
- **Handrails & bottom protection**: **100%** of the elements in this category are considered to be suitable for re-use to date (long-term re-use depending on the structure of the channels),
- **Suspended ceilings: 20%** of elements in this category are identified as ready for short-term re-use,
- **Electrical service and distribution: 65%** of items in this category are identified as ready for short-term re-use,
- **Electrical panel**: **100%** of the elements in this category are identified as ready for short-term re-use.

The graph below shows the potential for re-use/recycling for each category assessed during the RMW diagnostic.

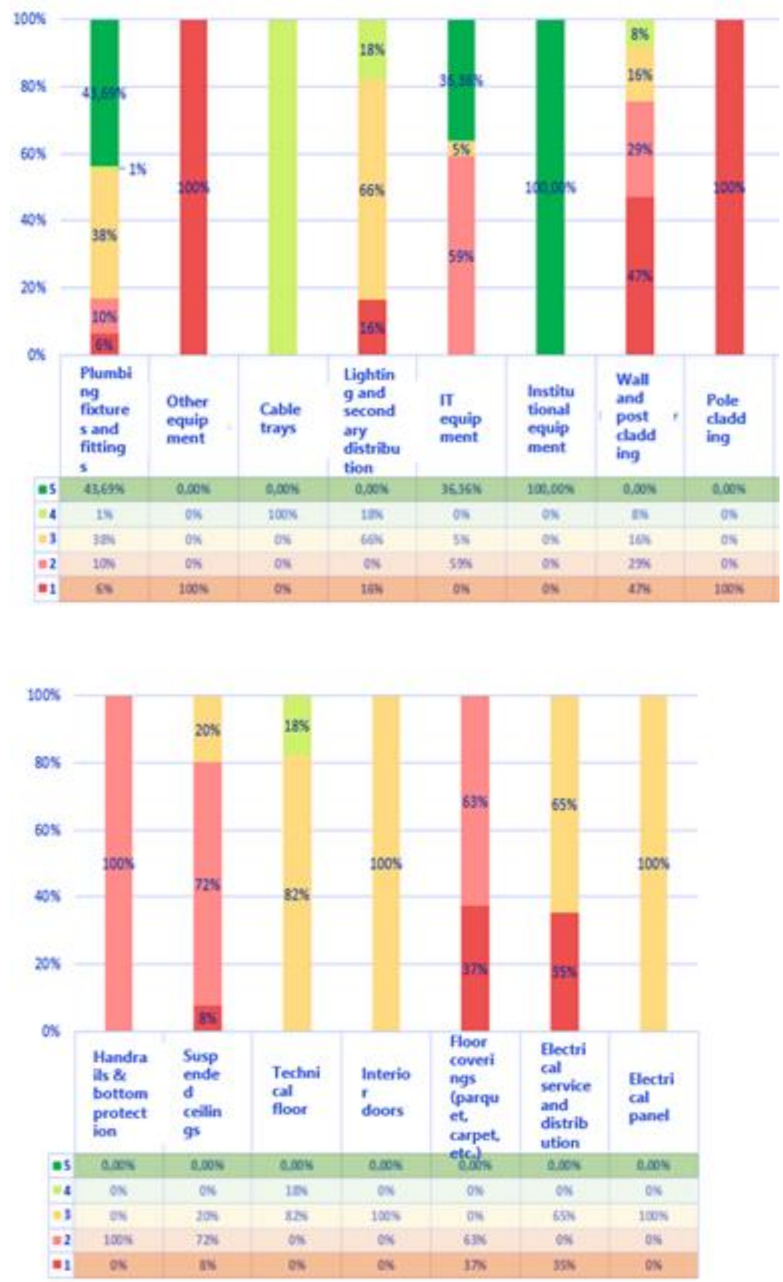


Figure 39: Re-use potential for all the component of the standard resource and material category.

11.4.1.1 Sanitary fittings and taps

As any area in an airport, the diagnosed zone comprised a toilets area. The Figure bellows illustrates the types of equipment encountered in this zone.

Figure 40: Example of material and equipment part of the sanitary fittings and taps category.

The RMW diagnostic identified **15 types of elements** (78 units - all units combined: m², ml, u) with re-use potential. According to the analysis of the RMW diagnostic results, the sanitary ware and taps category has re-use potential with an average of over **3** (figure 4) defined at this stage of the project.

The graphs below shows that for the Sanitary Appliances category, the RMW diagnostic identified **12 types of elements** with a potential equal to or greater than **3**, i.e. **85%** of all the RM in the category (44% of the RM with a potential of **5** and 38% with **4**).

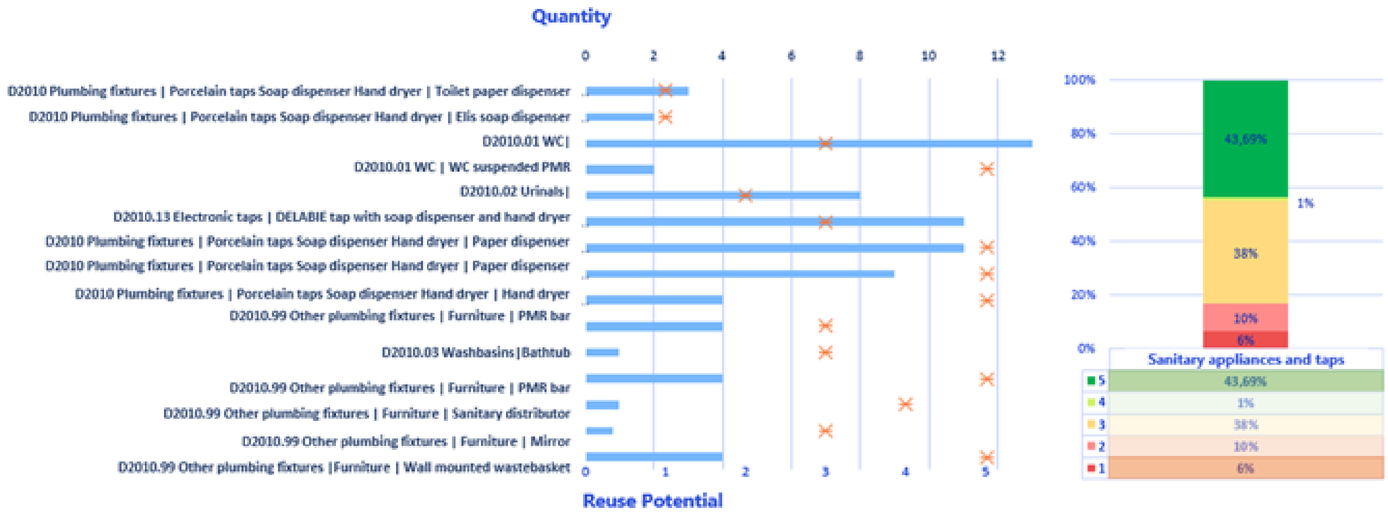


Figure 41: Re-use potential of the sanitary fittings and taps category.

These RM are easy to re-use and benefit from an already structured re-use sector, and for certain elements there are no insurance constraints.

The potential of the elements in this category is assessed as follows:

- Potential of 5, 4 and 3: RMs are in good condition, easy to remove and recondition, inexpensive and controlled by the players.
- Potential of 2 and 1: RMs are in average or poor condition; reconditioning is/or is not possible.

11.4.1.2 Technical floor

The RMW diagnostic identified 1 **typology of elements** with a surface area of 711 m² with a re-use potential indicator equal to or greater than **3.** The results show that the re-use of these elements is easy and can be envisaged in the short and medium term.

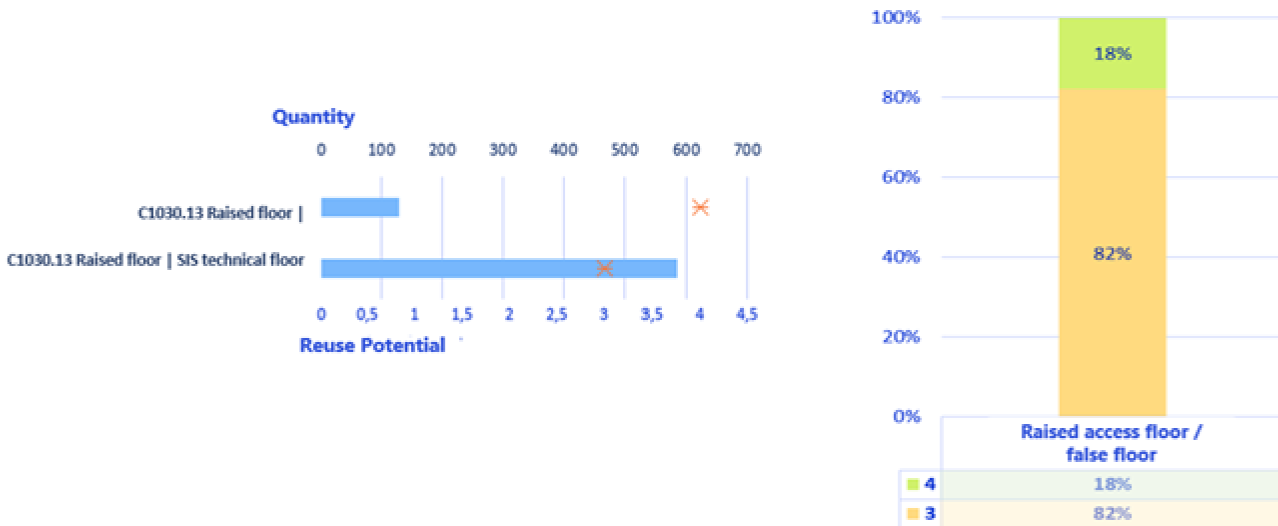


Figure 42: Re-use potential for the technical floor category.

11.4.1.3 Floor coverings (parquet, carpet, etc.) - Carpet and resilient flooring

The area studied covers more than 10 000 m², therefore component covering the floor is an important source of RMW diagnostic. Figure 43 bellow illustrates some type of floor coverings encountered by the diagnostic team.

Figure 43: Example of material and equipment part of the floor covering category.

The RMW diagnostic identified 2 **types of elements** included in this category. They cover a surface area of 350m² with a re-use potential. The result shows that the products and complex for re-use because the assessment of the potentiality of these elements depends strongly on the condition of the product (poor) established during diagnostric RMW. In some cases, reconditioning is not possible.

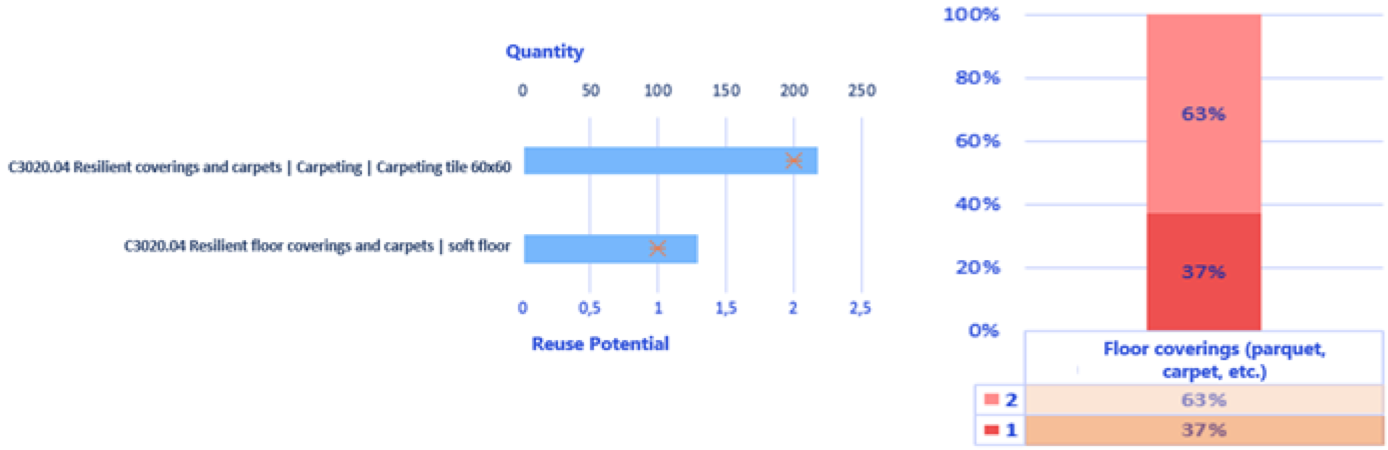


Figure 44: Re-use potential for each component of the floor covering category.

It should be noted that these items are normally easy to re-use. Indeed, they benefit from an already structured re-use sector and do not present any insurance constraints (specifically carpets). So, if their condition permits, these items could be considered for re-use in the short to medium term.

11.4.1.4 Integrated accessories

The RMW diagnostic identified 3 **typologies of elements** (29 units - all units combined m², ml, u) with re-use potential. The result shows that:

- **34%** of items in this category are ready for re-use,
- **65%** of items are complex for re-use because the assessment of the potential of these items depends mainly on the condition of the product (poor) identified during RMW diagnostics. For these items, reconditioning is little or not possible.

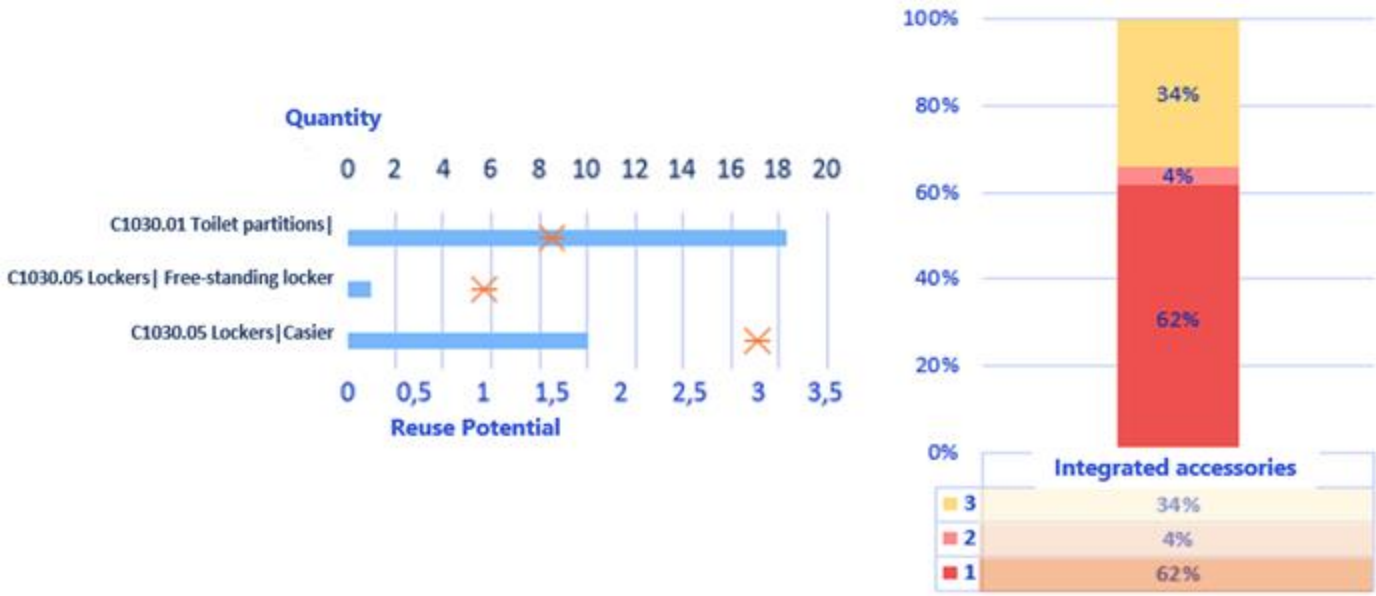


Figure 45: Re-use potential of integrated accessories category (ex: lockers, toilets partitions...).

11.4.1.5 Cable trays

The RMW diagnostic identified 2 **types of elements** (4 ml) with a **re-use potential indicator of 4**. The result shows that the re-use of these elements is easy and can be envisaged in the short term.

These components are easy to re-use and benefit from a structured re-use network.

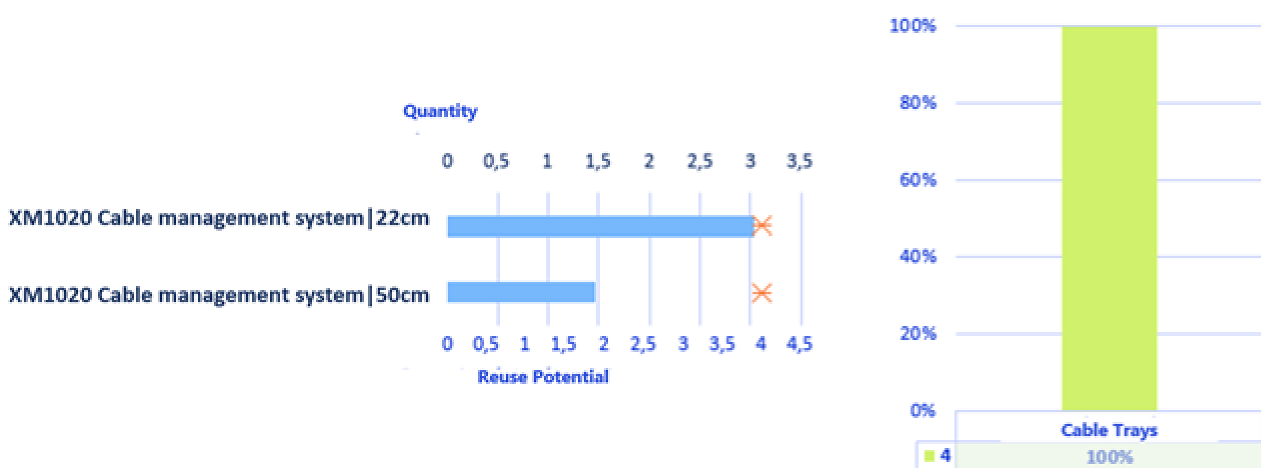


Figure 46: Re-use potential of cable trays category.

11.4.1.6 Doors

The area diagnosed included several doors. Figure 47 below indicates the types of doors currently installed in the terminal area. They are of various sizes and various types.

Figure 47: Example of doors included in the category doors.

The RMW diagnostic identified 2 **types of elements** (24 units - all units taken together m², ml, u) with **re-use potential indicator at 3.**

The re-use of doors may be possible for certain specific models, depending on the dimensions and criteria (fire safety or other) requested in the project. These elements are easy to re-use and re-purpose, and benefit from an already structured re-use network.

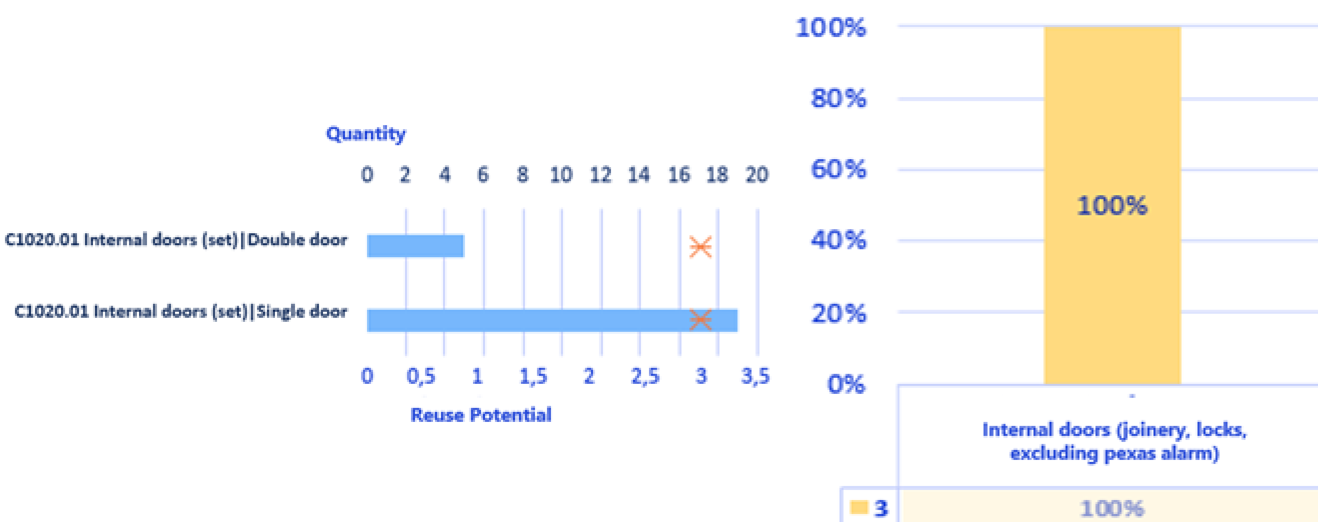


Figure 48: Re-use potential of doors category.

11.4.1.7 Suspended ceilings

Similarly, as for the floor covering, the area analysed comprise an important surface of ceiling of various types, sizes, uses and quality. Figure 49 bellow illustrates the various equipment encountered in an airport terminal.

Figure 49: Example of elements part of the ceiling category.

The RMW diagnostic identified **7 types of elements** with re-use potential, including **4 types of elements** with a potential indicator equal to **3**, i.e. **20%** of all RMWs.

Re-use of false ceilings is possible for certain specific models. In the case of non-re-use, the re-use solution can be envisaged and studied with the ecosystem players.

The graphs below shows that **20%** of the elements present on site can be re-used. However, for the remaining 80% of components that are complex to re-use, the reutilization (repurposing) solution may be considered.

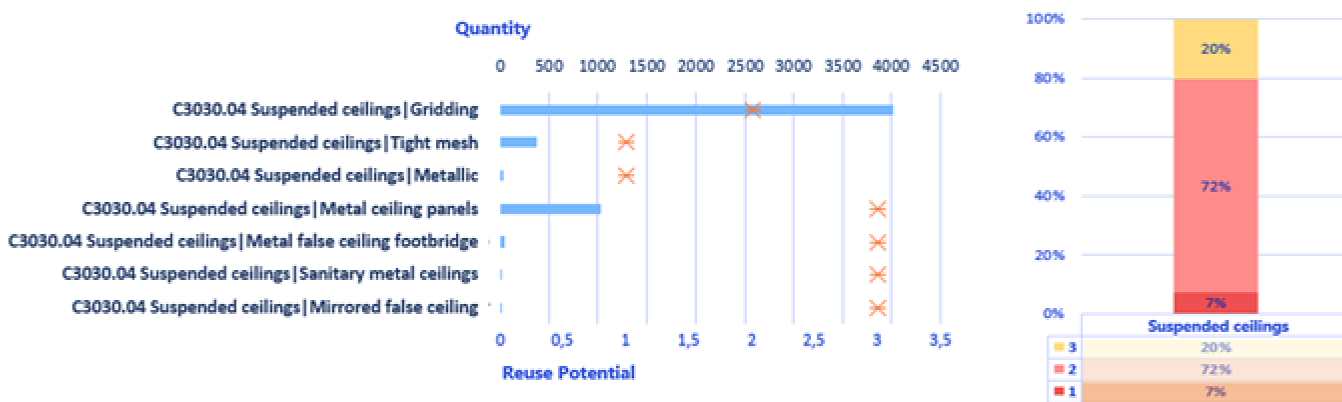


Figure 50: Re-use potential of elements part of the suspended ceilings category.

11.4.1.8 Lightning

Artificial lightning is an important element of an airport terminal. Lightning is used for operational purposes but also to generate a specific environment for the passenger. Figure 51 below gives several example of lightning types available in this airport terminal.

Figure 51: Example of material and equipment part of the lightning category.

The RMW diagnostic identified **15 typologies of elements** (1,000 units - all units combined: m², ml, u) with re-use potential. According to the analysis of the RMW diagnostic results, the Lighting and secondary distribution category has a re-use potential with an average equal to **3** (figure 4) defined at this stage of the project.

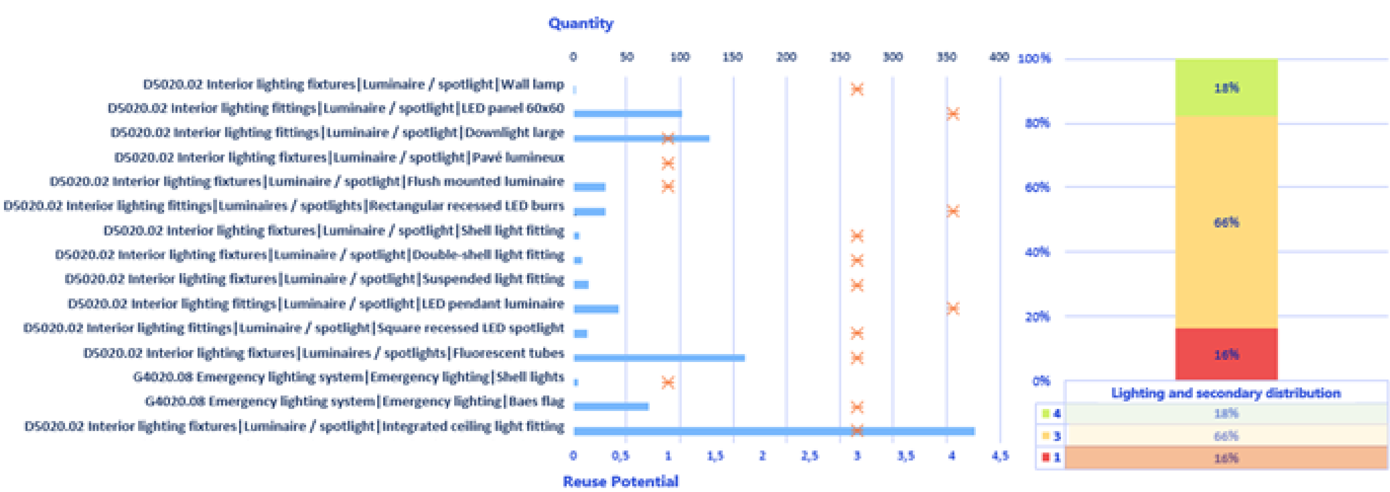


Figure 52: Re-use potential of elements parts of the lightning category.

These RMWs are easily reusable and benefit from an already structured re-use channel. The assessment of the potential of the elements in this category is as follows:

- Potential of 5, 4 and 3: RMWs are in good condition, easy to remove and recondition, inexpensive and controlled by the players.

- Potential of 2 and 1: RMWs are in average or poor condition; reconditioning is/or is not possible.

11.4.1.9 Handrails & protections

The RMW diagnostic identified 1 **type of elements** (23 ml) under this category with re-use potential of 2.

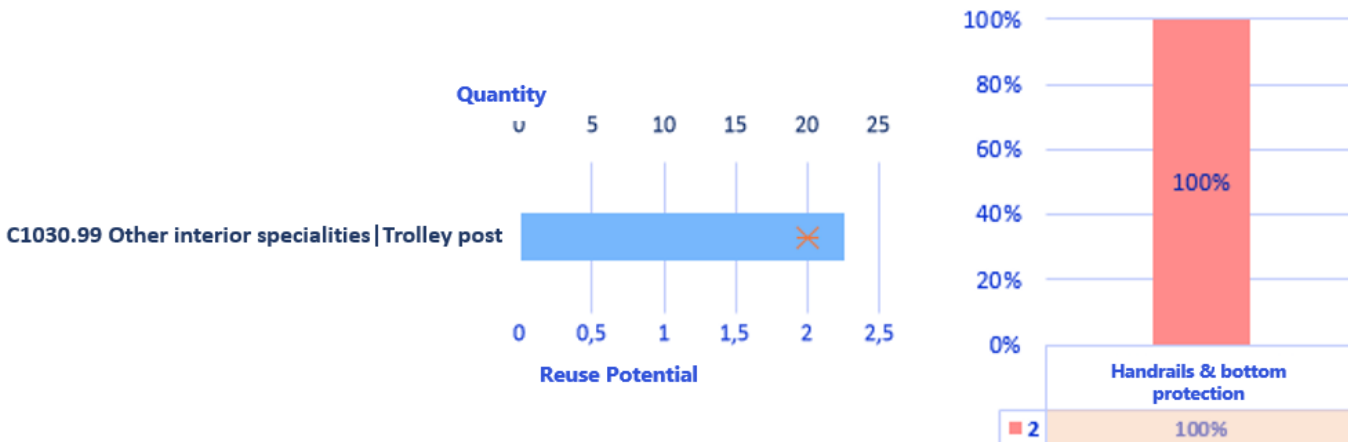


Figure 53: Re-use potential of elements part of the Handrails and protection category.

The graph above shows that the re-use of this element remains complex due to the architectural adaptation. However, the possibility of a re-use can be explored with the players in the ecosystem who are already mature on the subject.

11.4.1.10 Computer equipment

The RMW diagnostic identified **3 types of elements** (44 u) with re-use potential**.** The result shows that 40% of the elements are easy and ready to re-use in a short and medium terms.

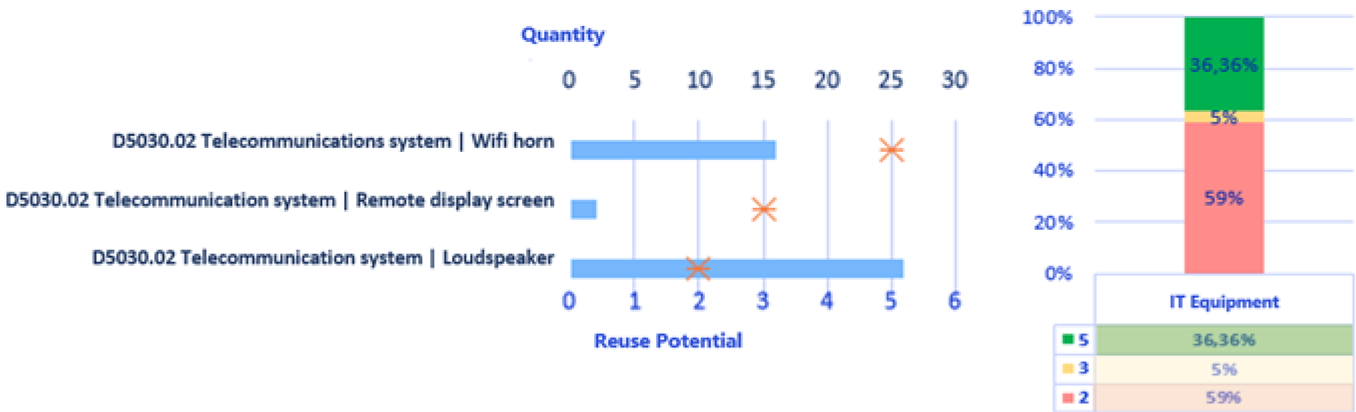


Figure 54: Re-use potential of elements part of the computer equipment category.

11.4.1.11 Electrical service and distribution

The RMW diagnostic identified **5 types of elements** (9 u) with re-use potential**.** The result shows that 65% of the elements are easy and ready to re-use in a short and medium terms.

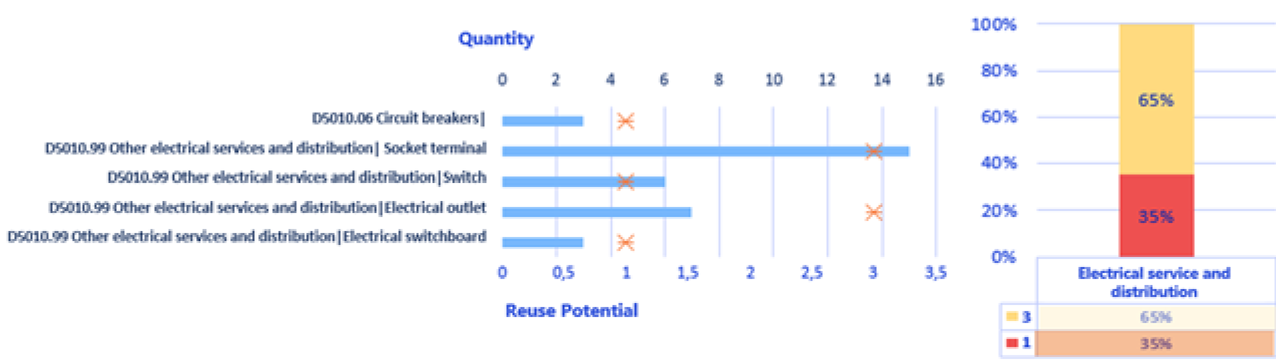


Figure 55: Re-use potential of elements part of the electrical service and distribution category.

11.4.1.12 Electrical panel

The RMW diagnostic identified 1 **typology of elements** (3 u) with re-use potential**.** The result shows that 100% of the elements are easy and ready to re-use in a short and medium terms.

Figure 56: Re-use potential of elements part of the electrical panel category.

11.4.1.13 Fire protection system

The RMW diagnostic identified 6 **types of elements** (60 units - all units combined: m², ml, u) with re-use potential.

The graphs below shows that for this category, the RMW diagnostic identified **4 types of elements** with a re-use potential indicator equal to or greater than **3,** i.e. **45%** of all RMs in the category (43% of RMs with a potential of **3** and 2% with a potential of **4**).

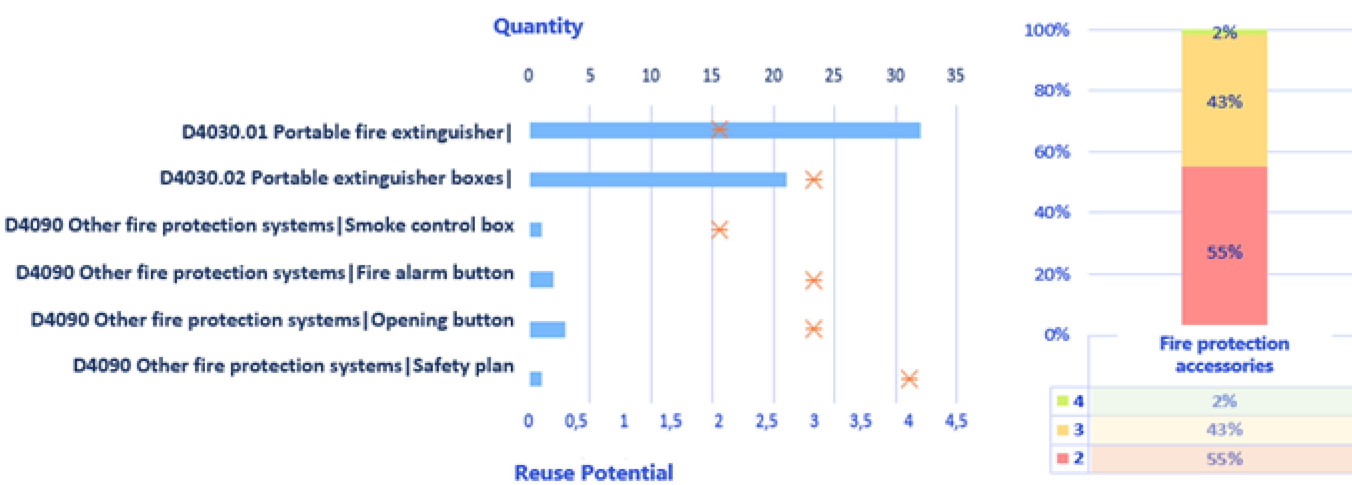


Figure 57: Re-use potential of elements part of the fire protection system category.

More than 50% of the quantity of RMW has been identified as complex to the re-use of :

- the unsatisfactory condition of certain components and the cost of reconditioning them,
- complexity for other elements, in particular the cost of removal and logistics.

11.4.2 Standard resource and material with an ambitious re-use level

In this section, the categories present elements that are still difficult to re-use, due to the lack of maturity of the re-use channels to date; however, some are in the process of being structured. The re-use of these elements in ADP projects may be envisaged in **the medium to long term**. At present, these categories require more in-depth study with re-use players to put in place the resources necessary for their re-use, including clean disposal, reconditioning and storage.

Off site re-use can be envisaged in the **short and medium term** for the elements identified as ready for re-use (potential indicators 5, 4 and 3) by various disposal channels: platforms or by second-hand equipment buying and selling companies in order to test the market.

Morevover, the re-use of the components of these items as spare parts could be envisaged in the **short and medium term** by various second-hand equipment sales platforms, including Airport Market, or directly by second-hand equipment buying/selling companies.

In this section, the RMW diagnostic identified the categories, i.e. **15 types of elements** (1,420 units - all units combined: m², ml, u):

- Escalator and walkaways,
- Lifts and goods lifts,
- Advertising screen,
- Communication and safety on site,
- Self-contained or monobloc units,
- Fire tap (French RIA).

Figure 58 : Example of non-specific material and resource with an ambitious level of re-use.

11.4.2.2 Advertising screens

The RMW diagnostic identified **2 types of elements** (2 u) with re-use potential.

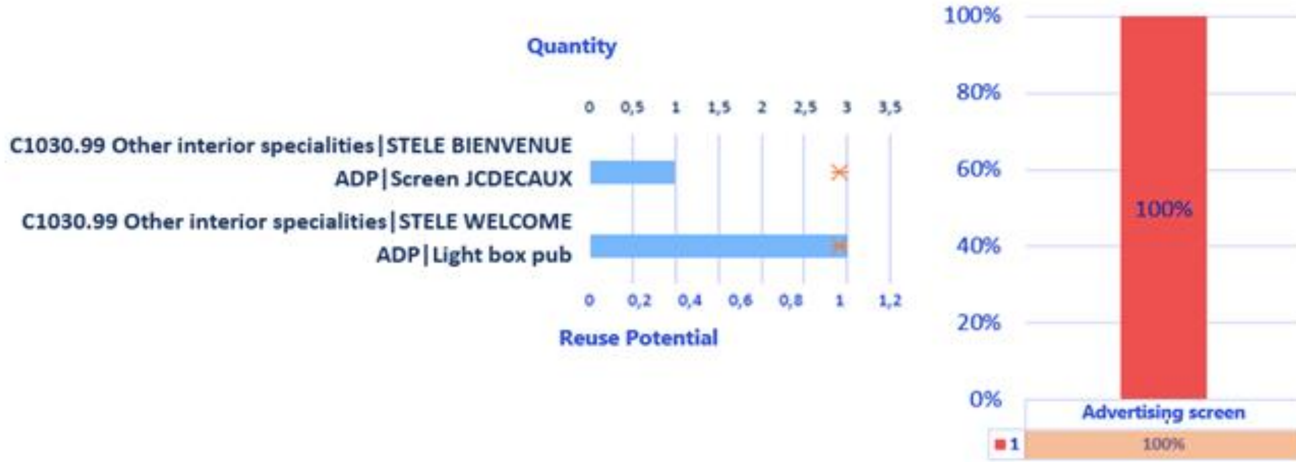


Figure 59: Re-use potential of elements part of the advertising category.

11.4.2.3 Communication and safety on site

For this category the RMW diagnostic identified 3 **types of elements** (10 u) with re-use potential. The result of the two graphs shows that the elements in this category are ready for re-use in the short and medium term. The re-use of these elements can be studied with the manufacturers and the removal companies.

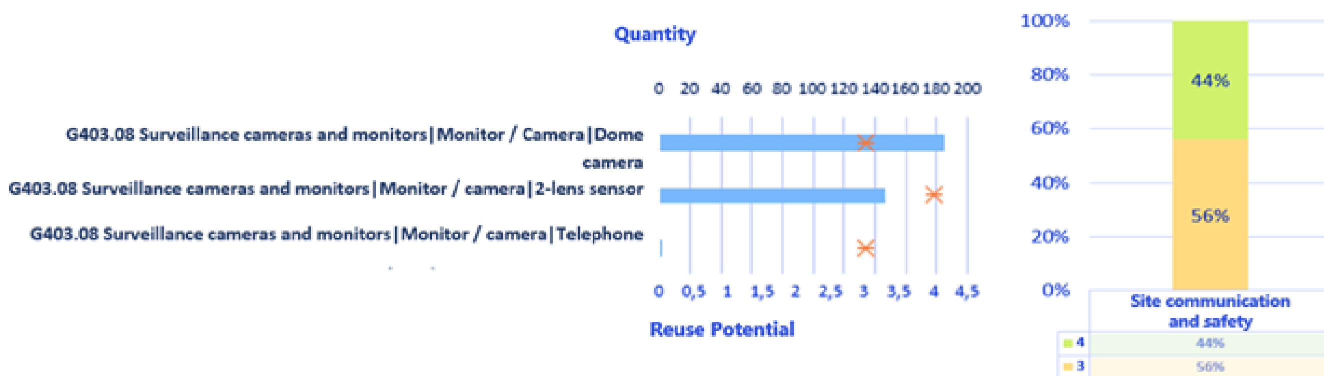


Figure 60: Re-use potential of elements part of the safety equipment category.

11.4.2.4 HVAC stand-alone or monobloc units

The RMW diagnostic identified **3 types of elements** (61 u) with re-use potential. The result of the two graphs shows that 11% of the elements in this category are ready for re-use. **Short- and medium-term** re-use of items in this category remains complex at this stage. Re-use channels for these components are currently being set up.

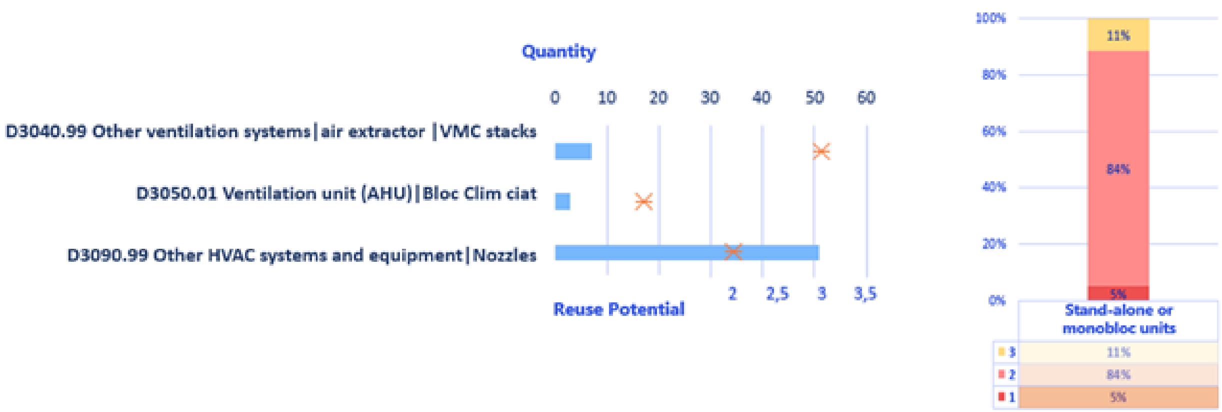


Figure 61: Re-use potential of elements part of the HVAC equipment category.

11.4.2.5 Fire hose

The RMW diagnostic identified **1 type of elements** (8 u) with a re-use potential indicator at 1. The result of the two graphs shows that the elements in this category are **complex** for re-use in a **short and medium term**.

Figure 62: Re-use potential of elements part of the fire hose category.

11.4.2.6 Escalators and walkaways & Lifts and goods lifts

Airport terminal are very specific buildings, as an example they may include escalators, travelators, lifts (see Figure 63 below). That equipment is however not specific to airport terminal as it can be encountered in other welcoming public buildings.

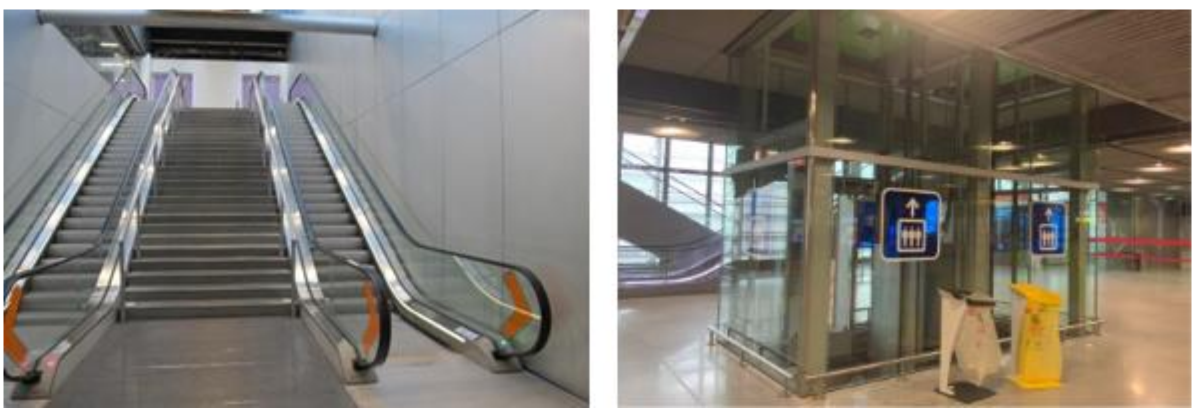


Figure 63: Example of equipment part of the escalators, travelators and lift category.

For this category, the RMW diagnostic identified **4 types of elements** with a potential equal to or less than **3.** Re-use of these components is ambitious at this stage of the project due to the complexity of removal (knowledge of this specific product) and the logistics involved. The re-use of components as spare parts may be possible in the **short and medium term** via various sales channels: second-hand equipment sales platforms, including Airport Market, or directly by second-hand equipment buying/selling companies.

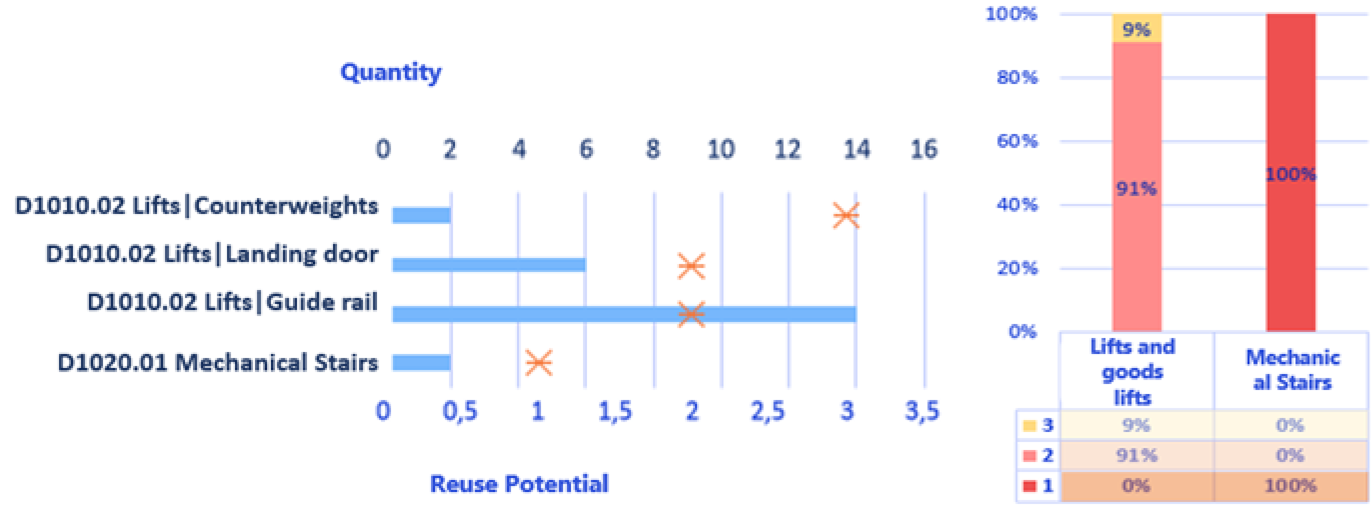


Figure 64: Re-use potential of elements part of the Handrails and protection category.

11.4.2.7 Demountable partition lining & Wall and post cladding

The project impacts the commercial area in interface with one of the Screening Inspection Stations. The Figure 65 below indicates the types of equipment available in those areas.

Figure 65: Example of elements part of the partitioning and walls category.

The RMW diagnostic identified 5 types of elements (111 units - all units combined m², ml, u) with re-use potential.The graphs below shows that for these categories, the RMW diagnostic identified **2 types of elements** with a potential equal to or greater than **3,** i.e. **24%** of all the RMs in the category (8% of RMs with a potential of **4** and 16% with **3**).

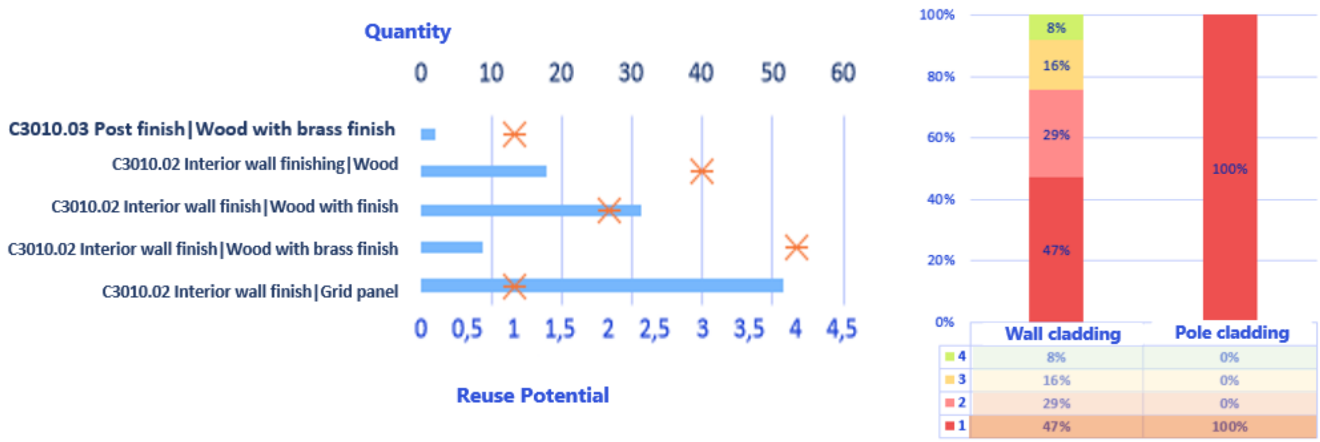


Figure 66: Re-use potential of elements part of the partitioning and walls category.

In cases where re-use is not possible for certain products and materials, other solutions can be envisaged, such as reutilization. The possibility of re-use can be explored with players in the ecosystem who are already mature on the subject.

11.4.2.8 Demountable partitions

The area evaluated is very wide and comprises several operational spaces. Therefore, several types of demountable partitions are available. They are composed of various materials and they are of various quality as exposed in Figure 67 below.

Figure 67: Example of elements of the demountable partitions category.

The RMW diagnostic identified **6 types of elements** (230 units - all units taken together m², ml, u) with a low re-use potential (1). The re-use of these elements is ambitious at this stage of the project due to the complexity of removal and/or installation.

Figure 68: Re-use potential of elements part of the demountable partitions category.

In cases where re-use is not possible for certain products and materials, other solutions can be envisaged, such as reutilization. The possibility of re-use can be studied with the players in the ecosystem who are already mature on the subject.

11.4.2.9 Ceramic, stone, or terrazzo flooring

The area comprises several floor coverings as presented upper, however, in addition to this technical floor an airport terminal comprises also some stone and ceramic flooring. The Figure 69 below shows some examples of such covering.

Figure 69: Example of ceramic, stone and terrazzo flooring.

The RMW diagnostic identified **6 types of elements** in this category, present in very large quantities.

The re-use of these elements is ambitious at this stage of the project due to the complexity and cost of removal, and their logistics.

While it may not be possible to re-use these elements, they still have a much greater potential for re-use - for a new function. The possibility of their re-use can be explored with the players in the ecosystem who are already mature on the subject.

Three treatment methods can be combined:

1. **Reconditioning**: clean removal tests should be carried out to check the feasibility and profitability of removal. The type of laying (cement/lime mortar, adhesive mortar, glue) and the characteristics of the joints (thickness, composition) have a major impact on the possibility of removing the product without damaging it.
2. **Re-use** for the manufacture of terrazzo and/or other products: the product can be sent to **re-use companies** for the manufacture of new products based on inert materials: furniture, wall and floor coverings for interiors and exteriors, etc.
3. **Recycled** by crushing as inert waste.

11.5 Implementation process for waste management

In cases where re-use and re-utilization is not possible for certain products and materials, other solutions may be considered, such as recycling.

The implementation of the circular economy approach is based on the means to respect waste treatment methods:

- materials containing pollutants that will be subject to decontamination work,
- materials from demolition operations,
- items with re-use potential that have not found an outlet.

Materials from these elements will be treated in accordance with regulations - they will be subject to:

- **Sorting** at source, single-stream evacuation and **recovery** of the **7 regulatory streams** (including wood, metals, glass, plastics, mineral waste), WEEE and streams for which recycling solutions exist;
- Handed over to an approved sector or **eco-organization**, particularly for waste covered by the Extended Producer Responsibility (EPR) scheme.

The EPR (Extended Producer Responsibility) principle is based on the "polluter pays" principle: it transfers the cost of waste management from the holder to the producer of products and materials. For construction companies, this means that building waste will gradually be taken back "free of charge" (Source: Fédération Française du Bâtiment). As this scheme was introduced on 1st of January 2023, the general contractor is asked to quote for sorting materials, to ensure that the extended producer responsibility scheme will take back the following flows: inert materials, 7 regulatory flows sorted separately.

5 Conclusion & recommandations

Since the 1st of July 2023, the French RMW diagnostic has been a regulatory requirement for all deconstruction or renovation operations exceeding 1,000 m². The simulation of an RMW diagnostic for a typical airport renovation project has enabled to put into perspective the opportunities offered by a circular economy approach to works at the heart of an airport.

On the one hand, air traffic safety standards and regulations are evolving regularly, and on the other hand, the development of the terminals, which are subject to high passenger flows, leads to frequent finishing work campaigns involving more than two technical trades (in accordance with the conditions of the French RMW regulations). Because the constraints associated with this type of works are numerous and generally involve maintaining activity, little or no consideration was given to the circular economy of materials.

In this study, the state of the art in 2024 in Ile-de-France was considered to assess the re-use possibilities for each category of elements, as well as reasonable medium-to-long-term prospects.

This theoretical and experimental study, carried out by the BATIRIM between October 2023 and March 2024 in collaboration with ADP, presents the **initial results of an estimate of the potential for re-use of products, equipment (resources) and materials (RMW) from a typical project linked to airport activity**, in passenger areas (i.e. in the most unfavorable conditions in terms of site management). The analysis was carried out based on data collected during an RMW diagnostic and feedback from the BATIRIM over the last 5 years, on the possibilities for re-use and recycling of these elements.

The aim of this study is to provide input for an internal **study by ADP for the benefit of European airport hubs, with a view to drawing up a strategic action plan to integrate re-use and recycling from the design phases through to the deconstruction and construction stages**. It considers the known risks (logistics, removal, multiplication of project stakeholders) and opportunities (resilience, reduction of the environmental footprint, reduction of flows, availability of products, etc.) according to the different scenarios studied and the different options proposed:

- Specific airport facilities: easy to ambitious RM,
- Standard RM: easy to ambitious RM.

A roadmap needs to be drawn up to examine in greater detail the methodology to be implemented for the elements identified as "typical", in conjunction with the players in the re-use ecosystem, in order to characterize off-site re-use in the short and medium term and the possibilities for in situ or internal re-use of the platform in the long term.

A few key figures from the experimental RMW diagnostic:

- The RMW diagnostic identified **123 types of** elements, i.e. **9 140 units** (all units taken together u, ml, m²) with re-use potential and the evaluation of the potentiality of the elements is as follows:
  - **Potential for 3, 4 and 5**: **72 types of** elements, or **3,550 units** (all units combined: u, ml, m²),
  - **Potential for 1 and 2: 51 types of** elements, i.e. **5,580 units** (all units combined: u, ml, m²).
- The results of our analysis show that the categories with the **best average potential** are:
  - **Institutional equipment** at indicator 5,
  - **Cable trays** at indicator 4,
  - **Raised access floors, Sanitary fittings, Communication and security and IT equipment** over indicator 3,
  - **Interior doors and switchboards** at indicator 3.
- Restructuring work on a project of this type involves a large quantity, estimated at **500 tons** of **products, equipment and ancillary materials.** These items are potentially waste for which recovery solutions can be studied. However, studies need to be carried out to propose recovery solutions commensurate with their potential for re-use.

  On the one hand, these solutions avoid waste and, on the other, save money and raw material on construction.

Therefore, based on the above element, it can be concluded that:

<u>In the short term,</u> the results of the analysis show that the re-use of **easy components (estimated at 15 categories)** can be envisaged in **the short to medium term off-site and/or within ADP platforms**. The industrialization of the re-use of these elements within ADP can be envisaged because these elements are offered by already structured re-use channels.

<u>In the medium term</u>, the on-site **re-use of easy categories** must be studied in an operational manner and in conjunction with the design team and a Circular Economy Project Owner Assistant (POA CE). The re-use of these elements on site will be accompanied by an **upstream analysis of the processes and a feasibility study** with the players in the ecosystem (the re-use channels that are already structured).

In addition, it is important to include circularity clauses into works specifications of the project.

In the long term, renovation projects within ADP must be able to incorporate more and more elements that are considered **ambitious** at this stage **for re-use in situ, but also re-use from outside sources**. Specific studies and analyses of materials must be carried out as early as possible in the programming and design process to identify the levers for accelerating re-use practices.

Numerous feasibility studies are currently being carried out between the re-use sectors and manufacturers of new materials, with a view to finding solutions that will make re-use accessible to all project owners and for all types of projects.

Recommendations

To put in place a circular economy approach with realistic re-use objectives, it is necessary to **think about an action plan** within the various activities relating to the works; indeed, a re-use strategy collides with certain current technical and financial practices. It is also necessary to integrate new stages into the design process. It seems important to question and add the circular economy approach to the following stages:

- The needs identification and programming phases: at this stage, the need of new material (or not) should be defined; for example, the toilets in the project can outcome of the re-use market.
- The design phase, particularly in the detailed design and the tender document redaction phases, incorporating specific circular economy clause;
- Materials and equipment purchasing strategy;
- The selection of demolition companies, in particular for their method of clean removal of components;
- The opportunity for logistics and/or storage of items for re-use within the airport's assets;
- Knowledge of the Re-use Ecosystem (PO and companies).

Finally, in order to inform and consolidate the thinking on the potential for re-use of the various categories, **a complementary study must be carried out with the specialist players** (manufacturers and/or installers) **of the elements identified in order, in the short term, to** establish technical methodologies for removal, handling and reconditioning that guarantee the proper functioning and durability of the elements, as well as their insurability.

12 Part 3 “Conclusions” of the Report including a methodology proposal for increasing the circular economy in refurbishing airport terminals projects.

13 Executive summary

13.1 Brief description of the work performed and results achieved

This work was composed of two steps. The first step aimed at defining the methodology adapted to an airport terminal. This first phase focused on the data exchange needs between the digital deconstruction solution proposed by BATIRIM and the BIM design solution. The IT connectivity requirements and the information data model were defined in this phase. The second phase implemented this forward-looking approach and its digital modelling techniques on a real on-site airport deconstruction/construction project. This second phase was implemented by BATIRIM. The information collected during this inventory was used to analyse "in vivo" the re-use potential of all construction materials and some of typical airport’s equipment. One of the objectives of this sub-task is to define simple metrics to evaluate, during the design phases, the potential of re-use of a small area of a larger building. In this document, the “Resource, Material and Waste diagnostic” is deigned after the acronym RMW diagnostic also known as PEMD diagnostic in French.

14 Conclusion

14.1 Anticipating the logistical needs of the circular economy approach

Airports buildings are very peculiar buildings. Therefore, to implement a circular economy process in the construction of a new building or the renovation of an existing one, airport owner or airport operator shall implement a specific approach and management. First, one must not forget to consider that circular economy can be implemented at various stages of construction: during the demolition phase; and during the conception phase. Those two phases could be interconnected but this requires:

- An alignment between resources, materials and waste diagnosed and future needs,
- An alignment between the timing of deconstruction and the timing of construction / reconstruction,
- Enough space on-site or close to it, to store the resources, materials and waste listed during the diagnostic,
- And the capacity of reconditioning equipment when necessary or requested by insurance for example. As such, achieving on-site re-use may be currently very difficult for airport owner or airport operator in the present timing.

Therefore, to contribute to a better understanding on how to implement circular economy in an airport building project, this OLGA task focused only on the demolition phase and the good practices to deploy to enhance a circular economy process at this stage. One of the main conclusions is that the airport owner or airport operator shall mobilize the adequate resources (material and human):

- To carry out the removal of the identified resources and materials,
- To control the risks during the removal itself (electrical risk, working at height, others to be defined according to the nature of materials and the location context, etc.) and
- To preserve the physical integrity and quality of the elements. For classical resources, the removal methods should be studied with deconstruction or re-use company. For the airport's equipment, the removal methods could be left to the discretion and responsibility of the airport owner or airport operator, which will be responsible for their reconditioning.

An airport owner / airport operator must carry out removal tests to define the optimum removal methodologies and achieve the goal for each element. As a start, removal tests could be carried out on the flooring and sanitary fittings which are equipment with a high re-use potential due to the development of an economic environment for re-use on those items.

Some other conclusions refer to packaging and storage:

- Pack of the items deposited on-site preserves their physical integrity and quality. Depending on the case, this may involve putting them on pallets, in big bags, on specific racks, etc.
- Storage must be organized in identified storage areas on site, but mostly off site[2]. The components will be sorted into batches, ensuring that the batches are uniform, protected from the weather and secured against theft.

Note that this could have structural impact, because in order not to overload the floors, the contractor may take all necessary measures to distribute the loads when storing the resources and material on site, if needed.

Those conclusions have strong consequence because it implies that a storage area should be provided by the airport owner / airport operator before the contractor takes over the construction contract like for the construction office base. These deposited elements must be then packaged and labelled with the completed "Product Sheet". The acceptance of these elements must be carried out and validated in the presence of the Project Owner, the Contracting Authority (works execution company), and the Project Management Team (including a circular economy expert or assistant to Project Owner).

Last point of the process, the preparation of the transport of the resources and materials to the reconditioning workshop and then to the storage location. The contractor must take all measures to ensure that the transportation envisaged are adapted to the packaging, quantity, size and nature of the elements to preserve their quality throughout the journey and in compliance with the regulations.

Airport owner / airport operator will request reconditioning of the resources and materials before being reemployed. This reconditioning process generally includes its cleaning (it is important to use a process and product suited to the surfaces and materials of the components reconditioned) and repairing. In addition, airport owner / airport operator will not ensure that components are compliant, it will mandate construction companies to ensure compliance. Those companies must check that the components are in good working order, to guarantee that they can be re-used. This inspection and verification may concern:

- the physical condition - integrity of the product for all items identified for re-use on-site;
- checking that equipment and electrical appliances are in good working order (electrical and electronic equipment, HVAC safety appliances, compliance with standards or norms mandatory for construction).

[2] The storage off site is to be preferred to offer better conditions to clean and restore the elements.

The traceability of all elements that are re-used on-site must be carried out with the provision of a Product Sheet. The model for these documents will be validated by the DPMT (Design and project management team). the contractor/Project Manager.

If it is no longer possible to re-use items on-site, preference will be given to re-use them off-site. Next stage of valorization would be sorting (several streams for recycling and recovery, in accordance with regulations). And, as a last resort, disposal would be the last option.

Most of these practices are new to the construction team, the decision to implement circular economy approach must then be clearly defined toward all the actors: the design team for clean disposal of element and the execution team for packaging, storage, transportation, reconditioning and traceability. As such, the use of a software to list all the resource and equipment after a RMW diagnostic appears as a necessary tool for airport asset managers. It must be underlined that implementing circular economy requires an important logistic that is not yet totally available.

14.2 Benefit and necessary improvement with software

The size and the complexity of the airport justify fully the use of a software with a tablet to collect data on field. ADP uses several specific classifications to structure the asset's elements. Each classification covers a point of view on the patrimonial (construction, operating, maintaining, real estate, …). For this experiment, it was decided to use the classification Uniformat II adapted by ADP[3] also used in BIM process. The structured inventory was directly "pinned" on the floorplan. The speed of field survey has proved the efficiency of this method.

Most of the solutions available on the market located the equipment with a text or a list field in the form, this is an unsatisfactory situation due to the airport size. Indeed, CDG (Charles de Gaulle airport) is composed of 878 buildings, 20% of those buildings have one or more rooms with an area upper than 50 000 m². There are more than 57 000 rooms referenced into the CDG patrimonial database, a dozen of buildings is composed of more than thousand rooms. Some rooms are sizing more than 350 meters length. ADP's asset data are geolocalized and unfortunately the output data from the BATIRIM software cannot be directly associated with this information. This situation highly limits the way to

[3] ADP enriched the original Uniformat II (EN1557) by merging other classification like Bridge Elements (E2103-NIST 1122), or the classification for Transportation Surface Elements (ASTM E3008M). Others specific elements for the airports (Baggage Transportation System, services for the plane, ...) were added.

federate data to have a high scale view concerning the availability of resources on a territory. To avoid that this situation become a mid-term brake for the development of circular economy outside the construction project's site, geolocalization solutions will have to be developed.

So far software recently developed to facilitate the resources and materials analysis (RMW diagnostic) use insufficiently the BIM potential at the first step of their development (lack of function like selecting the work view between 3D, floor plans, section or elevation views, filtering the view by type of object, cropping the view with a box, showing the relevant data,…). The other technologies (CAD, GIS) seem to have the same limits as the BIM technology. Airports and the other actors in charge of large infrastructures have probably the same issue to implement the circular economy and encounter the same problem. Many of them use the CAD, GIS or BIM and set-up these technologies to respond to their needs. Indeed, the software editor could not engage an investment for each client in order to connect the client's asset database with their solution. Moreover, the French market for this type of solution has not yet reached maturity and is currently driven by players offering downstream dismantling services at the current stage. It is likely that the offering will continue to evolve over the next few years.

The strategic position of airports requires the implementation of a strict data protection policy. This policy limits the sharing of data with third parties outside its boundaries. Therefore, this constraint poses a problem when it comes to connecting asset data directly to a hosted cloud-type solution. In the absence of an IT security study validating the solution, it was not possible to connect the BATIRIM solution directly to the airport asset inventory data. A solution that is regularly used is to host the application data in a datacentre that is suited to the sensitivity of the information being managed.

For these reasons, the project team chose to define an operational standard that structure the patrimonial data exchange like the COBie edited by the NBS (British) or the NIBS (American). This standard should also define the type and the structure of the location data, define the most frequent query on data, and define the requirement concerning the IT security. The return of the Resources, Material and Waste diagnostic (or RMW diagnostic) in a structured graphic is a strong expectation for the managers of major infrastructures and will also be included in this standard. This standard will guide the software editors to develop accurate connector and will secure their invest.

14.3 Discussion about the re-use indicator

Once the inventory finalized, it was analysed by BATIRIM with the airport owner support. Therefore, indicators were calculated to balance the re-use potential. Each product or material was quoted between 1(poor) to 5(good).

Three information are used to calculate this indicator:

- Product condition
  - Good: Directly useable
  - Average: small refurbishment is needed
  - Poor: restoration or transformation is needed

- Product dismantling with product preservation
  - Low complexity
  - Average complexity
  - High complexity

- Product outlet. This information assesses the level of development of the re-using methods inside the project area, the demand (outlets on site or in other projects in the area) and the channels for handling items deposited for re-use:
  - Highly demand
  - Mean demand
  - Poor demand

The products and materials evaluated "Easy" for re-use have an indicator quoted above 3. Those elements have the following characteristics: good condition, easy to implement, and a low-cost controlled process to dismantle and to refurbish. Those elements have an already organized outlet and for some of them have no insurance issue. Re-using should be considered in short term for the level 4 or 5, and in mid-term for the level3.
The products and materials evaluated "Ambitious" for re-use have an indicator quoted less than 3. Those elements have these characteristics: mean or bad condition, difficult to implement, high cost (dismantle complexity, unorganized refurbishing outlet), these elements must be analysed with re-using's actors. Re-use could be considered in long term for level 1 or 2.

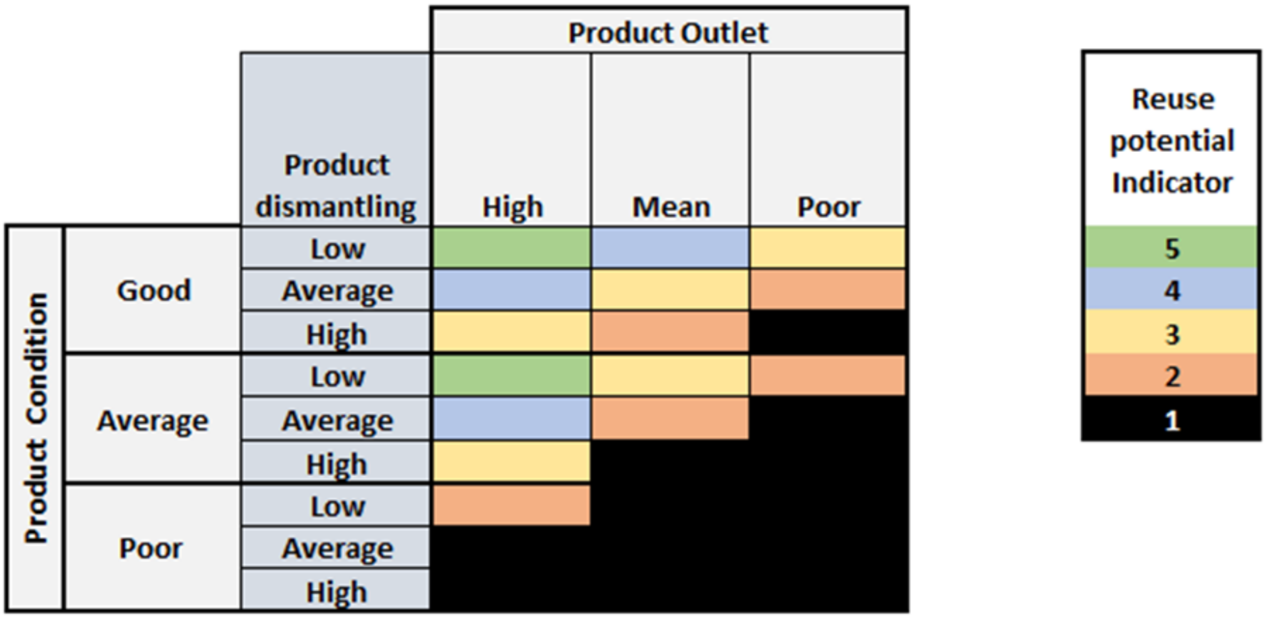


Figure 70: Re-use indicator matrix.

Following the discussions between ADP and BATIRIM this indicator was finally considered to be very effective for business analysis purposes. It allows to quickly prioritize the different types of products which have a great re-using's value, and it helps the team project member to define technical packages concerned by a dismantling with preservation of the product.

14.4 Proposition on where to add circular economy into a project workflow.

The Figure 71 illustrates the general organization in ADP construction Management Process. This process is traditional for Project Owner. Following the on-site trial for RMW diagnostic, it is interesting to visualize which steps of this construction process are concerned to implement a circular economy process.

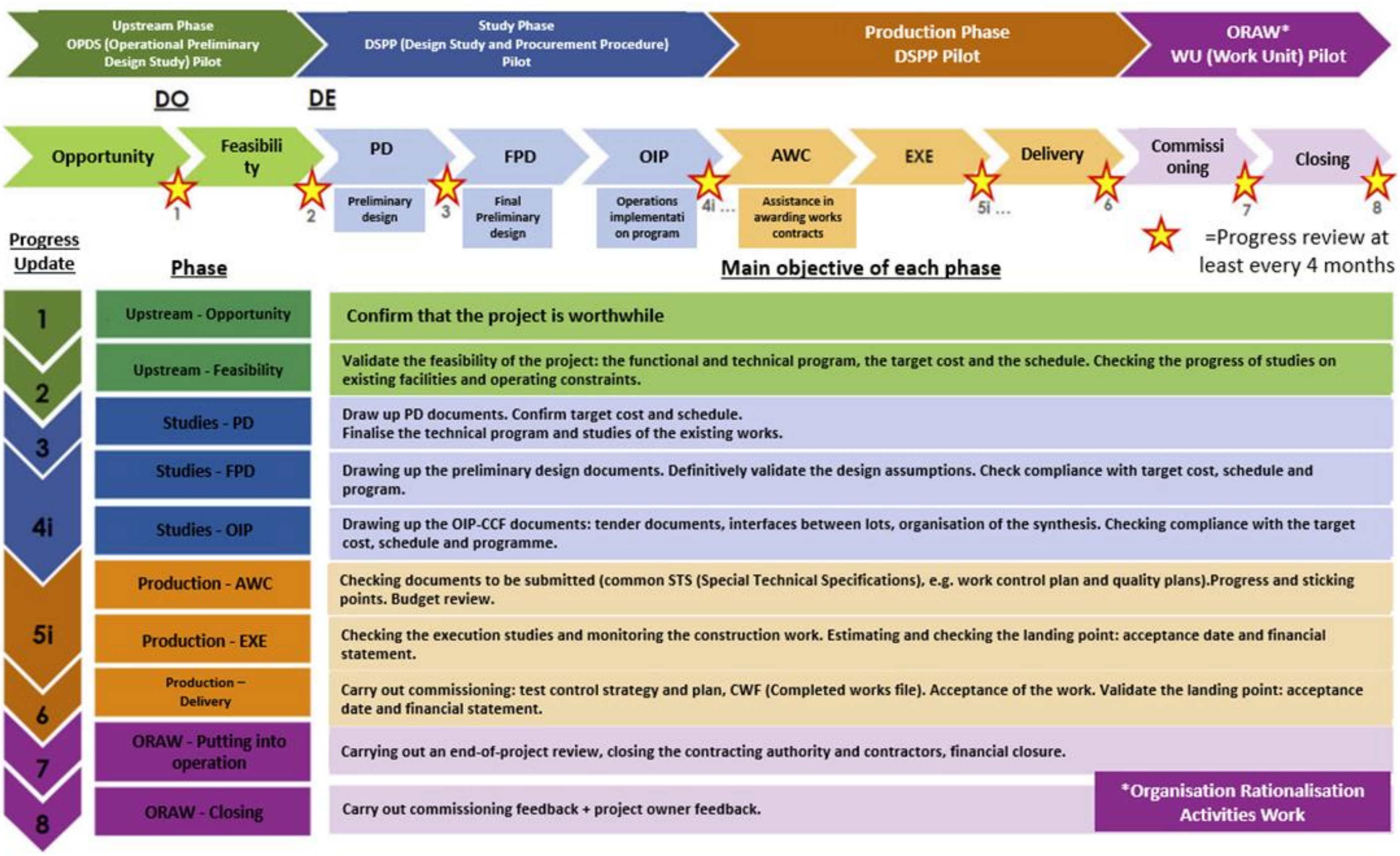


Figure 71: ADP construction project milestones.

Group ADP's Engineering department follows in the logic of the French law MOP[4], which formalizes the different stages and milestones during the project (initial, pre-design, preliminary design, design, detailed design, procurement, construction, commissioning, operating).

[4] This law No. 85-704 of July 12, 1985, determines the relationship between public construction project managers and private designer and construction structures. It explains the responsibilities of the different construction's actors.

14.4.1 Circular economy at the upstream stage

The initial stage lasts generally between 12 and 18 months. This corresponds with ADP's internal financial milestones DO (Demand of Opportunity) and DE (Demand of technical studies). The main deliverable of this stage is the technical and functional program that will guide the studies realized during the next phase. The program is essential because it enables project members to work together. It serves as a reference throughout the operation, ensuring that all specific operating requirements have been considered. This stage defines objectives that the construction will respect, the list of technical studies to produce, and the master scheduling of the construction. The documents included in the program are:

- Functional, technical, performing and quality requirement.
- Needs measurements for area, volume, equipment, functional connexion.
- Cost and delay objectives accurate with the requirements.
- List of regulatory procedures.

Several diagnostics, under owner responsibilities like asbestos or lead, are realized during this stage. Since the 1st of July 2023 (date of entry into force of the decree implementing the RMW diagnostic), the assets owner is required additionally by the French law to make a RMW diagnostic to manage the product, equipment, material and wastes from the construction for all projects greater than 1000m². This regulatory diagnostic is shared with each actor (architect, engineering firm, contractors) that makes studies or realizes demolishing works or renovation projects.

Following this on-site experimentation, it can be clearly concluded that the RMW diagnostic

- must be carried out as early as possible in the project, and
- must cover a sufficiently large area to offer the greatest potential.

In the organisation of the studies, the diagnostic will be carried out during the programming phase and must be sufficiently exhaustive. After a documentary study of the structure's data, the RMW diagnostic is required by law to ensure that a trained and qualified team carries out an on-site survey with the aim of encouraging re-use indicating the precautions to be taken when removing, storing on site and transporting these products. In the absence of re-use potential, the experts must indicate the waste management or recycling channels.

The analysis of the diagnostic by the project team will enable the definition of a re-use priority, jointly with the client and the project team. It may concur to reconciling the environmental impact of the project, the cost of careful removal, the recovery of the removed product and the timeframe.

Following the operational phase of diagnostic, it appears that there are 6 treatment options including 4 re-use options (Figure 72) for a product before it ends up as waste:

1. Re-use by the project.
2. Re-use by other projects at the airport.
3. Recovery of components to supply the spare parts shop.
4. External re-use by sale or product session.
5. Recovery of materials.
6. Disposal as a waste.

These options are decided by the project team and the client, depending on the needs and constraints of the project. It requires an adjustment to the timetable to allow for careful removal and, above all, a place to store the products. Re-use as a spare part is subject to the technical compatibility of the product with those used at the airport.

The last three options should be challenged during the call for tenders to select the contractor. Re-use performance can be included as a sub-criterion of the technical note.

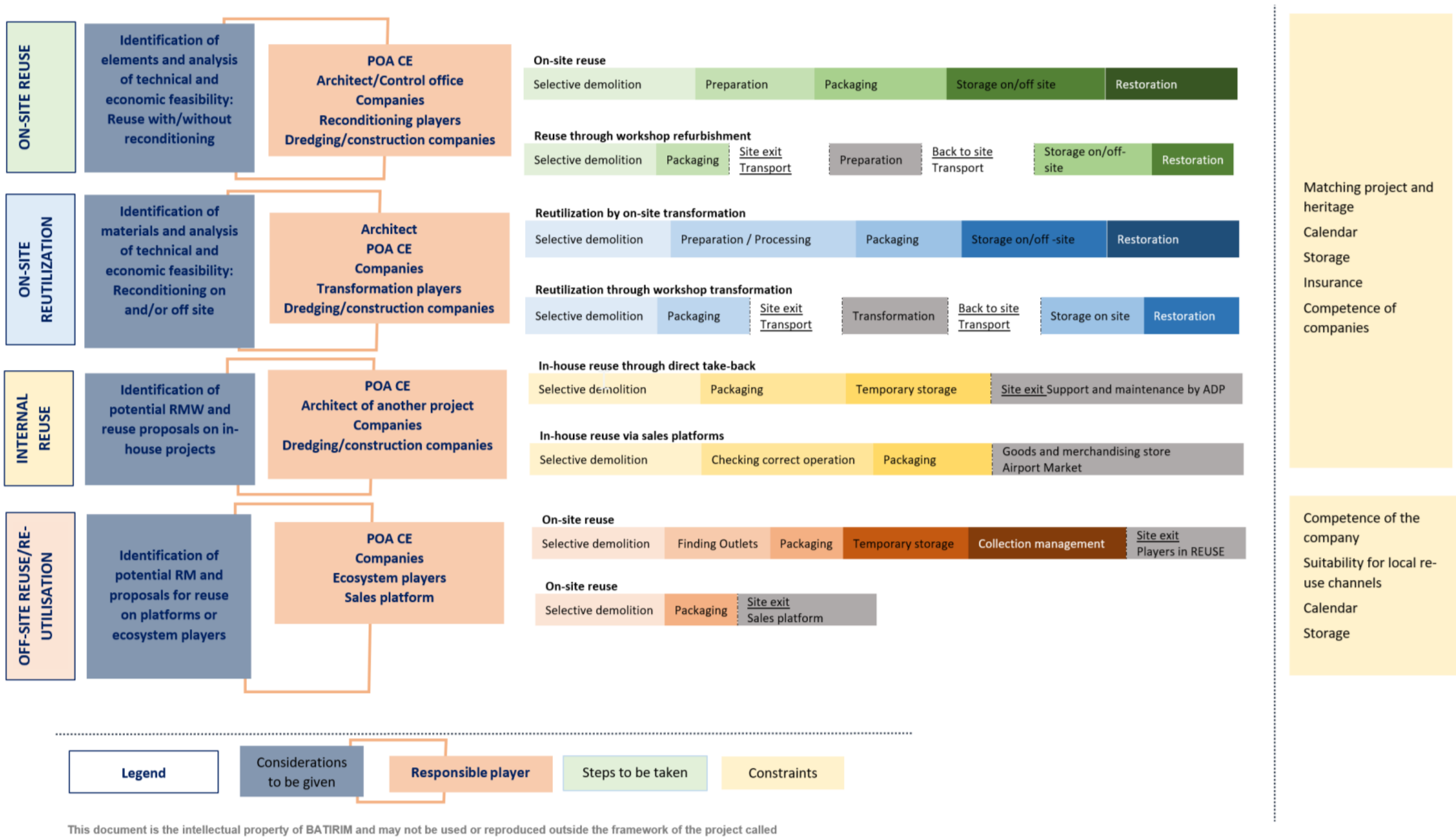


Figure 72: Synthesis of the 4 re-use options studied after au RMW diagnostic (Batirim ©).

14.4.2 Circular economy at the conception and execution phases

The present study covered only the upstream phase of a construction project. However, the analysis of the diagnostic allows to make some proposals to where the construction process should include new steps to perform circular economy.

In ADP's construction workflow, the next stages (preliminary design, design, detailed design, procurement, construction) start after the DE milestones. These steps include the design studies which, depending on the customer's requirements, lead to the preparation of one or more deliveries of studies documents (preliminary design, design, detailed design, procurement), the consultation and signature of works and project management assistance contracts, the execution studies and the work carried out by the contractors, etc. At the start of this phase, the list of tasks and their duration required to complete the project are defined. The procurement documents are made up of plans and written technical requirements compile with the tender documents (administrative, technical, and financial documents). The candidates' bids are analysed both technically and financially. The file also contains the criteria for monitoring the completion and acceptance of the works.

Figure 73 synthetise all the deliverables associated to a construction project management. It shows that although the RMW diagnostic is the first step of the process, a circular economy approach is still needed:

- During the preliminary and detailed design, with the final definition of re-use objectives;
- During the tender process, with the evaluation of the offers if they include a criterion on circular economy;
- And finally during the execution phase, with the control of the final result proposed by the contractor company.

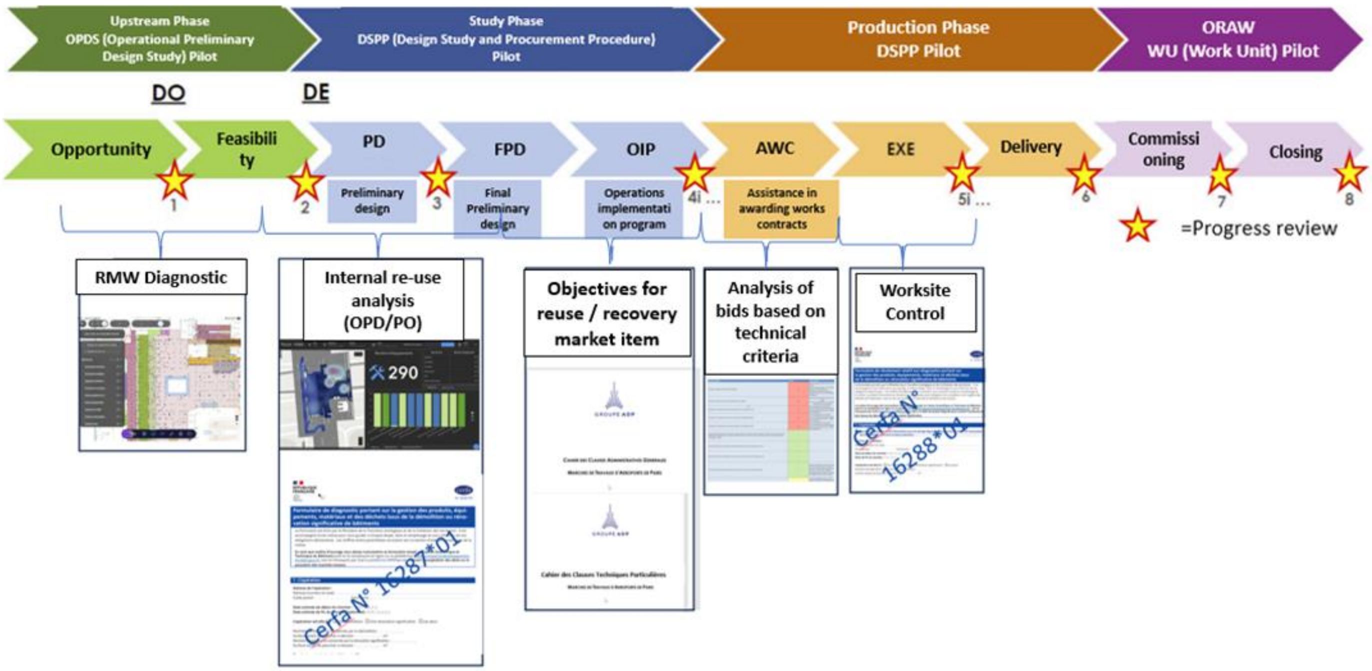


Figure 73: Re-use's process deliveries documents timeline.