Report on collection and reverse logistics optimization: KPIs identification

Deliverable D 5.1 (Part A)

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## Circular Approach for Eco-Composite Bulky Product

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Executive Summary

Looking at the circular economy boost, and with the aim of enhancing recycling activities in three industrial sectors, this report studies the reverse logistics chain.

In particular, the three sectors involved (automotive, furniture and building) have low levels of reuse, except for the first, mainly linked to old vehicles repair.

The reverse logistics chain has a greater complexity in comparison with the forward logistics mainly because its higher level of uncertainty and higher costs. On the contrary, products obtained are low-value. Thus, consequently, most of the companies in these sectors do not develop recycling and reusing activities.

In order to change this scenario, the first task is to develop a deep analysis of the different activities involved in the reverse logistics, which will allow identifying the key performance indicators (KPIs) in each case.

As a result, the most critical activities are linked to collection, inspection and sorting, and product recovery. In each case, a list of KPIs has been identified, considering the stakeholder’s point of view.

Specifically, some of them are related to costs, process complexity, traceability, final product value (linked to quality), regulation and legislations and user behaviour, the latter being understood as the need of change to a more sustainable and efficient consumption pattern.

From these results, a new reverse logistics model will be developed by addressing all the critical activates involved (transport means, monitoring activities, identification and sorting, etc.) This is the task to be completed in the following months, with the challenge of defining an optimal reverse logistics chain for each sector.
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1. Introduction

1.1. Description of the document and pursue

The objective of this work is to analyse and optimise the reverse logistics chain, by first identifying the different activities involved in this process. Thus, it will allow to identify the critical tasks and key performance indicators to be considered in order to define the optimal reverse logistics chain. To this end, the first part of this report addresses the definition and identification of the reverse logistics chain and its comparison to the forward logistics. Specifically, the three industrial sectors involved in the project (automotive, furniture and building) are studied in order to identify their specific reverse logistics activities.

Afterwards, the Supply Chain Operations Reference-model (SCOR) model is described, since it will be the pattern to follow for the operational analysis of the different reverse logistics to address in the task 5.1 of the project.

Finally, the main key performance indicators (KPIs) of the reverse logistic chain are identified, taking into account the main activities involve in this process, and specifically for each of the industrial sectors addressed.

1.2. WPs and Tasks related with the deliverable

This deliverable is included in WP5, and more specifically, within the task 5.1, of which the main objective is to optimise the reverse logistics chain of the three sectors analysed (automotive, furniture and building), specifically the collection activity, to deploy the most appropriate tools for smooth and streamlined transportation and logistics processes.

Since this task lasts until M24, the D5.1 has distributed in two sub-deliverables: first, addressing the tasks of identifying and defining the appropriate KPIs (Key Performance Indicators) in collection and reverse logistics (M18); second, including the definition of measures and strategies to optimise the collection and logistics chain and the developing of a Multi-Criteria Decision Analysis tool to evaluate them considering technological, environmental, economic and social aspects(M24)
This way, its main aim is to analyse the reverse logistics for each industrial sector and identify the critical activities involved considering aspects such as associated costs, ease of the processes, obtaining of valuable products that allow recovering the investment made, health and safety requirements and environmental issues. Afterwards, and related to these activities, the most important KPIs (Key Performance Indicators) have been identified in order to optimise the entire reverse logistics chain efficiency.

The next step (second sub-deliverable – M24-) is the identification of strategies and technologies for transport and logistics optimisation (adequate means of transport, route planning, traceability and monitoring, demand planning and forecasting, location of collection points, warehouse positioning and management, safeguard product quality and safety and other). This activity is being developed in parallel with the WP6, and more specifically with activities 6.1 and 6.2, and will be included in the updated version of this report in M24.
2. Characterization of reverse logistics chain of materials and products

As mentioned in Section 1, this WP aims to characterise each phase involved in the supply chain and inverse logistics related to the three sectors addressed in the project: automotive, furniture and constructions. Thus, this task implies the identification of the main activities in each case.

In general, logistics indicates how the products are transported from producer to customer, while reverse logistics works in an opposite way (Autry, 2005). Specifically, reverse logistics may be defined as a process of moving goods from their place of use, back to their place of manufacture for reprocessing, re-filling, repairs or recycling / waste disposal. It was presented at first in 1992 by Stock (Autry, 2005). With the increasing people’s awareness in environmental protection and progressive regulatory constraints in some countries (e.g. Japan or European Union countries), the economic value of reverse logistics is gradually increasing.

In this project context, the main objective of reverse logistics is to foster and boost recycling and reuse (material reuse and remanufacturing / refurbishing) and reduce the hazardous materials disposal.

More specifically, reverse logistics process involves the following activities:

- Handling of return merchandise (collection and transportation)
- Increasing recycling and reuse rates
- Decreasing hazardous materials disposal

When compared the reverse logistics process to forward logistics, the main differences identified are shown in Figure 1.
As mentioned previously, reverse logistics substantially differ from forward logistics. In fact, first one is more complex and harder to predict, mainly because customers are the ones who initiate the process.

One of the main differences refers to collection and transportation since products are moved from several origins to the main destination (in case of assuming the centralised point to collect products before their sorting and treatment processes). This situation involves not clear routes, which means more time needed to decide on destination of recycled products.

Furthermore, packaging is also different in reverse logistics since recycled products are usually not packaged or improperly packaged, which results in damages to them. In addition, this involves that they can be stacked.

In general, costs in reverse logistics are higher due to several reasons:

➢ Lower vehicle utilisation, linked to lower volume of products;
Lower utilisation rates, as a result of low level of standardisation; and,  
Longer time in inspecting, sorting and process the different types of products.

Likewise, and after analysing both processes, other serious barriers link to the reverse chain are:
- Legal issues:
  - This is a very cumbersome and time-consuming process and non-compliance may mean that the manufacturer will have to face legal action.
  - Many organizations consider reverse goods as waste and they don’t want to spend their resources on processing waste.
- The goods are considered unworthy of any investment.

Furthermore, waste treatment is another priority measurement for nowadays environmental protection and maintains the sustainability for future, which refers to the methods that have to be done to guarantee that the waste has the least negative impact and hazardous influences to the environment. Waste treatment has also been divided into many specific forms in different areas in worldwide due to the law. The main way of controlling of the environmental pollution and waste which are harmful to human health is to impose on waste resources harmless reduction treatment processes. In this sense, the recycling of industrial waste must be developed according to the specific characteristics of a given industry production, as well as pay attention to the technical feasibility, the competitive product and economic benefits among other factors.

In this context, the concept of circular economy arises as “resource-product-litter-renewable resources” process, be based on three main activities: reduce, reuse and recycle.

Then, this section aims to study and analyse the current status and development of reverse logistics in the three sectors: automotive, furniture and construction. In other words, its scope is to answer the following questions:

- What is the importance of reverse logistics?
- What are the exiting problems in reverse logistics?
2.1. Automotive sector

Currently, forward logistics of automobile industry have been developed in a good stage and this is the key area of focus for third-party logistics companies at the moment. However, with the mature of automotive consumer market competition, innovation and the rise of global environmental awareness, the car reverse logistics must be given due attention as well.

The concept of recycling has arisen since more and more people have been realised the importance of sustainability. Not only because recycling can provide the decreasing of waste but can also effectively revalue this waste, which implies a better use of resources and more sustainable processes.

Related to the recycling process of materials from the end-of-life vehicles, Cui & Roven (2010) defined a model which shows the typical structure for this activity:

![Figure 2: Automotive sector reverse logistics process. Cui and Roven (2010)](image)

Based on this scheme, the disassembly of automotive vehicles usually is a selective process, in which selecting out the hazardous or usable parts is a necessary step in automotive recycling. More specifically, this methodology allows to take a part a series of components or the
sub-components of a product; or to break down a product in small little parts based on the provided goal.

The mentioned methodology involved different steps:

- **Step 1**: Analysis of input and output product, to figure out the reusable, valuable and hazardous parts and resources of the product.
- **Step 2**: Analysis of assembly, to identify participate components, elements level and former assembly queue.
- **Step 3**: Analysis of uncertainties and risks, related to defective components and joint parts.
- **Step 4**: Establishment of the disassembly strategy (non-destructive way or a destructive way).

### 2.2. Furniture sector

The European furniture industry faces a variety of economic and regulatory challenges – including manufacturing growth in emerging markets, improved logistics (reducing export costs from India, China etc.), declined tariffs on foreign trade, increased demand for low-cost items within the EU, increased costs of raw material, labour and energy within the EU and increasing consumer demand for sustainable products\(^1\).

More specifically, addressing the concept of circular economy into the furniture industry could help this sector to reduce the waste and environmental impact by recapturing the remaining value of products at the end of lifecycle.

Traditionally, this sector has been linear focused and is lacking the transition towards a circular economy. One of the main reasons is that furniture is generally spoken big and heavy, thus hard to handle and represents a relatively low residual value, therefore, it makes the industry hard to transform towards the Circular Economy model. Additionally, there are not many previous experiences that encourage companies to shift towards Circular Economy.

Currently, this industry generates huge amounts of waste which is mainly sent to landfills. In fact, many furniture products are disposed although they are not at the end of their lifecycle and the conditions of materials are appropriate to be reused again.

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\(^1\) European Remanufacturing Network Market Study (2015)
According to European Federation of Furniture Manufacturers (UEA) statistics, in the EU furniture waste accounts for more than 4% of the total municipal solid waste, of which 80-90% is incinerated or dumped in landfills, with 10% recycled. Where reuse does occur, it is mostly through commercial second-hand shops, social enterprise companies or charities.

For that reason, this industry is one of the sectors which have future potential by developing a circular economy business model, by creating new revenue streams by reusing and refurbishing furniture products. However, it largely depends on the financial feasibility of the process (it seems to be the first step to change the current pattern). In this context, an efficient management of reverse logistics is fundamental to enable furniture companies to shift towards Circular Economy. This should enable them to develop a viable supply chain of collection, repairing, refurbishing, remanufacturing and reselling. More specifically, there are major concerns with regards on handling logistics and transportation.

Pokharel and Mutha (2009) developed an overview on reverse logistics that can be summarised in the following framework:

![Figure 3: Furniture reverse logistics process. Pokharel and Mutha (2009)](image)

In general, in the reverse logistics processes different categories are identified: general, inspection and consolidation, integrating...
manufacturing and remanufacturing and product modularity. More specifically, the process above also includes more activities: disassembly, remanufacturing, supply chain planning, coordinating, inventory control and, in many cases, after-sales services. In the final sections, reverse logistics outputs diversify between product pricing and competition and customer relation.

In order to foster and boost this model, several identified barriers to circular furniture have to be broken down:

- Lower quality materials and poor design: the current move away from solid wood and metal furniture to cheaper materials, restricts the potential for a successful second life;
- REACH Regulation (on Registration, Evaluation, Authorisation and Restriction of Chemicals): the lack of information on chemicals contained in products and on ways how to deal with them appropriately joins to the overrun of hazardous substances treatment;
- Poor consumer information and availability of spares: consumers are rarely given guidance on how to maintain and repair furniture, and the lack of availability of spare parts encourages the purchase of new furniture;
- Limited collection and reverse logistics infrastructure: currently there are weak drivers and underinvestment in the collection and logistics for furniture take-back;
- High cost of repair and refurbishment: transport and labour costs are high, making any significant repair and refurbishment costly;
- Weak demand for second-hand furniture: the price differential between new furniture against the cost of second-life furniture, is not significant enough to drive more sustainable purchasing behaviour;
- Poor offer for recycled materials: end markets for recycled materials, post deconstruction, are underdeveloped. Some second-hand channels are Ebay and Freecycle, however, the number of items traded in this way is difficult to quantify;
- Weak over-arching policy drivers: typically, furniture is not managed in accordance with the waste hierarchy, with reuse failing to be prioritised over recycling, incineration and landfill.

### 2.3. Building sector

The application of circular economy to the building sector is less than straightforward. In fact, existing frameworks frequently express
principles, but it is needed to both the appropriate ecosystem and the individual components to change. In this case, issues such as governance, regulation and business models could potentially be more important than design and engineering.

Effectively, the regulatory framework is one of the aspects that most affects in this context, identifying different administrative obstacles that cause not to promote the circular economy but quite the opposite. First, a significant percentage of the waste generated is illegal dumping derived from small works, renovations, etc. that are not properly managed and that the lack of control does not allow the application of the appropriate sanctions. In addition, official production statistics are not available, which makes traceability difficult, and does not favor selective collection, which is critical to improving the quality of the recycled material. Furthermore, the main problem is associated to the difficulties derived from the legislation when carrying out the reuse of land and waste between different works. This regulation often introduces many administrative requirements that complicate and delay such reuse.

Moreover, cooperation between companies or entities of the same or different value chain, through which they develop exchanges (materials, waste, by-products, energy, water, information, etc.) is a great opportunity.

In parallel, the change of ownership model by the use or service model is, in many sectors, one of the most successful strategies to promote the circular economy (“servitisation”). There are therefore possibilities and opportunities to explore within the construction sector, the application of this type of business models in different construction products and facilities.

Related to the value chain, consumption and use of natural resources have generally followed a linear approach. Materials are sourced, used and finally disposed of as waste. Known as the take-make-use dispose model, this produces negative externalities that include rising carbon emissions, increased pressures on landfill, unsustainable levels of water extraction and widespread ecosystem pollution.

The built environment comprises the man-made elements of our surroundings such as buildings as well as infrastructure including transportation, telecommunications, energy, water and waste systems. Design, planning, and construction contribute to the quality of the built environment, which has a significant impact on human health, well-being and productivity.
Currently, this sector is the world’s largest consumer of raw materials. It accounts for 50% of global steel production and consumes more than 3 billion tonnes of raw materials\(^2\).

In this context, a circular approach could help the sector to reduce its environmental footprint, and to avoid rising costs, delays, and other consequences of volatile commodity markets. Considering the technical cycle, man-made products are designed so that at the end of their service life – when they can no longer be repaired and reused for their original purpose their components are extracted and reused or remanufactured into new products. This avoids sending waste to landfill and creates a closed-loop cycle.

In order to prolong product life, it is fundamental to design for long-term durability, utilisation and value of assets. Durable materials and robust construction standards can reduce maintenance costs and extend the economic viability of a building or structure. Standardised components manufactured off-site to higher quality control standards can minimise the risk of structural faults and reduce long-term maintenance requirements.

With this aim, a closed-loop supply chain is defined in which the life of the materials would extend beyond the lifespan of the buildings, and they could be used again in other buildings or secondary markets.

In this regard, a series of networks are established to prolong the life of materials:

- **Recycling networks**: simple structure network that is characterised by requiring a high number of products recovered, but of little unit value. Products go from the consumption phase to the raw materials phase.
- **Remanufacturing networks**: networks used to recover parts or components of products with a high value added. The products go from the consumption phase to the manufacture phase.
- **Reuse networks**: simultaneous circulation networks of original and reused products, in which the cost of transportation is the most significant. Products go from the consumption phase to the distribution phase.

The next figure shows the reverse logistics flow scheme in the building sector:

In short, recovering and recycling valuable materials reduces resource use and minimises waste, and it can cut costs and earn revenues for stakeholders in the built environment.

Buildings and structures can be designed to allow component parts to be easily separated and recycled. Standardisation of components will also facilitate this process and increase recyclability. Designing for reuse has the potential to significantly reduce carbon emissions and mitigate fluctuating materials prices.

In this regard, the European Union, through the new Waste Directives, as well as the Management Protocol for construction and demolition waste in the EU, is promoting the concept of Circular Economy in order to achieve more ambitious waste recycling objectives, such as "recycling 70% of construction and demolition waste in 2020, thus closing the life cycle of products by increasing recycling and reuse."
As a result of the analysis carried out so far of the reverse logistics chain, and its effects on the circular economy, several critical factors should be taken into account for its development effectively, and therefore, its successful implementation: associated costs, ease of the processes, obtaining of valuable products that allow recovering the investment made, health and safety requirements and environmental issues. Objectively, three activities have a special effect in the factors mentioned: **collection, inspection and sorting and product recovery processes**. Therefore, the efficiency, effectiveness and economic viability of the entire reverse logistics are largely dependent on different methods to carry out them. For this reason, the key indicators to be identified in the next section will refer to those ones that have a maximum incidence in the optimisation of these activities.
3. Definition of KPIs in reverse logistics

After analysing the reverse logistics chain, the next step is to identify the most critical activities involved and their key performance indicators (KPIs) that have critical influence in the process success and its efficiency levels.

The development of the new reverse logistics flow will be based on the SCOR (Supply Chain Operations Reference) model. This will ease the diagnosis of the current flow, characterizing its processes and providing references for the formulation of metrics and best practices to achieve the best-in-class performance. This activity will be addressed in the second report within the task 5.1.

Specifically, The SCOR Green model proposes ways to monitor the environmental impact, based on the measure of factors such as carbon footprint, emissions and recycling.

For that reason, this section aims to describe this model and its development process.

3.1. SCOR model definition

The Supply Chain Operations Reference-model (SCOR) has been developed and endorsed by the Supply-Chain Council (SCC), an independent not-for-profit corporation, as the cross-industry standard for supply-chain management. Its main objective is to establish a Process Reference Model.

In fact, the SCOR-model is a Reference Model; it does not have a mathematical description or heuristic methods, instead, it standardises the terminology and processes of a Supply Chain to model and, using specific parameters, compares and analyses different alternatives and strategies of the entire supply chain.

The SCOR model allows describing the business activities necessary to satisfy the demand of a client. The Model is organized around the five main management processes: Plan, Source, Make, Deliver and Return.
As shown in the graph, the Supply Chain contemplated within the Model includes from the suppliers of our suppliers, to the customers of our customers, that is, it considers the Supply Chain understood in a broad sense. The following describes the basic processes in general lines. The following table defines each of these five processes.

<table>
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<tr>
<th>SCOR Process</th>
<th>Description</th>
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<tr>
<td>Plan</td>
<td>It analyses how to balance resources with requirements and how to establish and publicise the plans for the entire chain. In addition, it also addresses the general operation of the company and how to align the chain strategic plan with the financial plan.</td>
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<tr>
<td>Source</td>
<td>It analyses how to carry out the scheduling of deliveries, the identification, selection and valuation of suppliers or the inventories management.</td>
</tr>
<tr>
<td>Make</td>
<td>It involves the activities related to: production programming, product characteristics, testing stage and product preparation for its passage to the next stage of the logistics chain.</td>
</tr>
<tr>
<td>Delivery</td>
<td>In this area all management processes related to customer.</td>
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requests and shipments are analysed, including warehouse management, product reception and verification by the client and its installation if necessary. Finally, it also involves the customer's invoicing.

**Return**

This phase involves all the processes related to the return of the product and post-delivery service.

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Moreover, SCOR contains three levels of process detail (see Figure 6): Higher Level (types of processes), Level of Configuration (categories of processes) and Level of Processes Elements (decomposition of processes). In all these three levels, SCOR provides KPIs, and systematically divided into five Performance Attributes: reliability, flexibility, responsiveness, cost and assets.

In a fourth level (level of implementation), the elements are decomposed of processes in tasks. At level 4, companies incorporate improvements in their processes and systems, not being part of the SCOR model. This level is usually started with one or several pilot projects, then evaluate them and then extend them to the entire Supply Chain, adapting their organisation, technology, processes and people to achieve competitive advantage.

A process reference model contains:

- A standard description of process management
- A framework of relationships between standard processes
- Standard metrics to measure the performance of the processes
- Management of best practices of its kind
- Standard alignment for features and functionalities

The different levels of SCOR are presented and characterised by: the elements and processes that are identified in each one of them; the content of each one of the levels as well as the areas that they cover; and, their decomposition and interrelation upstream and downstream.
Level 1: At this level the scope and content of the SCOR model is defined by analysing the bases of competition and establishing the objectives of competitive performance, related to provisioning, production and supply.

Level 1 performance metrics are high-level measures that run through multiple SCOR processes. Some of the most commonly used first level key indicators are those represented in the following figure.
Subsequently, the values of the first level indicators are compared in a table with other companies’ ones in its sector and other sectors, and qualify as Equals, with Advantage or Superiors. In this way, it is possible to analyse in which aspects the Supply Chain is disadvantaged, identify the necessary improvements, prioritise the necessary improvement projects and plan their execution at a global level.

**Level 2:** at this level, each SCOR level can be further described by process type.

<table>
<thead>
<tr>
<th>SCOR Process Type</th>
<th>Characteristics</th>
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| **Planning**      | A process that aligns expected resources to meet expected demand requirements. Planning processes:  
|                   | o Balance aggregated demand and supply  
|                   | o Consider consistent planning horizon  
|                   | o (Generally) occur at regular, periodic intervals  
|                   | o Can contribute to supply-chain response time |
| **Execution**     | A process triggered by planned or actual demand that changes the state of material goods. Execution processes:  
|                   | o Generally, involve  
|                   | ▪ Scheduling/sequencing |
Circular Approach for Eco-Composite Bulky Product

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<th>Enable</th>
<th>A process that prepares, maintains, or manages information or relationships on which planning and execution processes rely</th>
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|        | ▪ Transforming product, and/or  
|        | ▪ Moving product to the next process  
|        |   o Can contribute to the order fulfillment cycle time |

Table 3: SCOR processes type characterisation.

In the second level, 26 processes categories are considered, which are the main categories that allow to configure the chain of practically any company: 5 to Plan, 3 to Procurement, 3 to Manufacturing, 4 to Distribution, 6 to Devolution (3 of Procurement and 3 of Distribution), and 5 to Enable. The first five are related to the planning type, the 16 intermediate ones to the executing type and the last 5 to the support type (enabling). The Enabling ones support planning and executing: they prepare, preserve and control the flow of information and the relationships between the other processes.

Next, all the tools of level 2 are shown. At this level, all possible configurations of a Supply Chain, as well as each of the participating links, are included and drawn. It is determined what type of plan or strategy is associated with each of the operations dependent on them, the provisioning policy of each of the members, the type of manufacturing if any, the selected distribution mode and the reverse logistics concerning the processes of return of products in case of defect, repair or excess.
**Level 3**: At this level the different processes of the Supply Chain are represented in a more detailed way by decomposing the Categories in Process Elements. They are presented in logical sequence (with rectangles and arrows) with information and materials inputs and outputs. Furthermore, the performance of each process and element is evaluated through indices, which allows to identify the different performance levels among the processes and elements of the Supply Chain.
**Level 4:** This stage involves the implementation of Supply-Chain Managing Practices within the company

### 3.2. Application to Ecobulk products and KPIs definition

After describing the SCOR model, the next step is to implement it in the three different reverse supply chain involved in the ECOBULK project: automotive, furniture and building sectors.

It follows from previous sections that reverse logistics may have a narrow or broad scope:

- The narrow scope refers to the actual movement and management of reverse flows of products/parts/materials from customers to suppliers. The focus then is on logistics issues such as transportation modes and routing, pick-up scheduling, and the use of third-party logistics providers to optimize the logistics capability (Kumar and Dao, 2006)

- The broader scope includes activities that support the management of used products including picking them up, sorting them out, and reusing them in different ways (Dowlatshahi, 2000)

First, as a result of the section 2, after analysing the processes involved in the reverse logistics chain, the three major activities of reverse logistics are: **collection, inspection and sorting, and product recovery.**

As previously mentioned, with the aim of optimise the operation, i.e, minimising enforcement costs, easing and boosting processes development and obtaining valuable products, in a healthy, safe and sustainable environment for each of these activities have been identified a list of parameters with an outstanding importance and relevance for their design and development. For this purpose, the different tasks that make up these activities have been considered

1. **Collection:** it refers to all activities rendering used products availability and moving them physically to some point where further treatment is conducted for product recovery (Sasikumar and Kannan, 2008).
Related to this activity, two decision criteria are identified: location-allocation of collection centres and methods of collection.

- **Location-allocation of collection centres**: several multi-stage, multi-product and multi-level mixed-integer models (MILP) have been developed in the last two decades to optimise the distribution on this type of nodes with the aim of increasing the collection activity. Specifically, the **key performance indicators (KPIs)** identified for this issue are the following:
  
  ➢ Collection cost  
  ➢ Processing cost  
  ➢ Value added recovery  
  ➢ Energy use  
  ➢ Waste generation  
  ➢ Level of social acceptability  
  ➢ User (end-of-life) accessibility (close to home)

The following table shows the relation between the indicated KPIs and the factors identified in Section 2:

<table>
<thead>
<tr>
<th><strong>Key Indicators</strong></th>
<th><strong>Variables</strong></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><strong>Enforcement Cost</strong></td>
<td><strong>Ease of processes development</strong></td>
<td><strong>Obtention of Valuable products</strong></td>
<td><strong>Health and Safety requirements</strong></td>
<td><strong>Sustainability</strong></td>
</tr>
<tr>
<td>Collection Cost</td>
<td><img src="#" alt="Mark" /></td>
<td><img src="#" alt="Mark" /></td>
<td><img src="#" alt="Mark" /></td>
<td><img src="#" alt="Mark" /></td>
<td><img src="#" alt="Mark" /></td>
</tr>
<tr>
<td>Processing Cost</td>
<td><img src="#" alt="Mark" /></td>
<td><img src="#" alt="Mark" /></td>
<td><img src="#" alt="Mark" /></td>
<td><img src="#" alt="Mark" /></td>
<td><img src="#" alt="Mark" /></td>
</tr>
<tr>
<td>Value added recovery</td>
<td><img src="#" alt="Mark" /></td>
<td><img src="#" alt="Mark" /></td>
<td><img src="#" alt="Mark" /></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Energy Use</td>
<td><img src="#" alt="Mark" /></td>
<td><img src="#" alt="Mark" /></td>
<td><img src="#" alt="Mark" /></td>
<td><img src="#" alt="Mark" /></td>
<td></td>
</tr>
<tr>
<td>Waste Generation</td>
<td><img src="#" alt="Mark" /></td>
<td><img src="#" alt="Mark" /></td>
<td><img src="#" alt="Mark" /></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Level of social acceptability</td>
<td><img src="#" alt="Mark" /></td>
<td><img src="#" alt="Mark" /></td>
<td><img src="#" alt="Mark" /></td>
<td><img src="#" alt="Mark" /></td>
<td><img src="#" alt="Mark" /></td>
</tr>
<tr>
<td>User (end-of-life) accessibility</td>
<td><img src="#" alt="Mark" /></td>
<td><img src="#" alt="Mark" /></td>
<td></td>
<td><img src="#" alt="Mark" /></td>
<td></td>
</tr>
</tbody>
</table>

*Table 4: KPIs and factors related to location-allocation of collection centres (collection).*

- **Methods of collection**: three different methods of collection are identified: collection by original equipment
manufacturer (OEM), collection with retailers and collection with third party logistics providers. Barker and Zabinsky (2008, 2011) in their conceptual framework for decision making in reverse logistic network design identified two collection types: proprietary collection and industry-wide collection. The first one is particularly beneficial when the company has a strong direct relationship with its customer such as a lease return relationship, or when there is high customer trade-in behaviour. In any case, collection methods depend on the type of industry and size of collection in addition to the criteria of initial investment, value added recovery, return volume, operating cost, degree of supply chain control, and level of customer satisfaction. In this case, the study of activities involved in the collection phase resulted in the identification of the following indicators:

- Initial investment
- Return volume
- Operating cost (including the transport mode)
- Supply chain control
- Environmental impact
- Health and safety issues

The following table shows the relation between these KPIs and the factors identified in Section 2:

<table>
<thead>
<tr>
<th>Key Indicators</th>
<th>Variables</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Enforcement Cost</td>
</tr>
<tr>
<td>Initial investment</td>
<td>✓</td>
</tr>
<tr>
<td>Return Volume</td>
<td>✓</td>
</tr>
<tr>
<td>Operating cost</td>
<td>✓</td>
</tr>
<tr>
<td>Supply chain cost</td>
<td>✓</td>
</tr>
<tr>
<td>Environmental impact</td>
<td>✓</td>
</tr>
<tr>
<td>Health and safety issues</td>
<td>✓</td>
</tr>
</tbody>
</table>

Table 5: KPIs and factors related to methods of collection (collection).
2. **Inspection and sorting**: this activity involves the operations that determine whether a given product is reusable or not, and if yes, then to what extent. In this case, the main issues to be considered refers to: level of centralisation and degree of disassembly:

- **Level of centralisation**: sorting/testing can either be done at centralised location or decentralised location and discussed the trade-offs considerations. The first option is more suitable for high-cost testing procedures as it minimises the cost of testing equipments and specialised labor. However, the main drawback of this system is that the waste will be identified after its transportation to the testing facility, and therefore it implies a higher cost. The second option is often used if low cost testing procedures are available, such as for paper recycling machine refurbishing or reusable containers and equipment. In this system scrap is identified early and shipped to waste disposal center, thus reduces the transportation costs. However, testing procedures must be consistent and reliable at all centers. The network may be more complicated because scrap and usable return product are shipped in separate streams. Finally, it should be indicated that inspection/separation may encompass disassembly, shredding, testing, sorting, and storage steps. The main **indicators** to be considered in this phase are the following:

  - Testing cost
  - Product reliability requirement
  - Availability of skilled labour
  - Location of waste disposal sites
  - Labour cost
  - Volume of collection
  - Waste handling, storage and transportation cost

The following table shows the relation between the mentioned KPIs and the factors identified in Section 2:
Circular Approach for Eco-Composite Bulky Product
GA NUMBER: 730456
Start: 01/06/2017 - End: 31/05/2021

<table>
<thead>
<tr>
<th>Key Indicators</th>
<th>Variables</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Enforcement Cost</td>
</tr>
<tr>
<td>Testing cost</td>
<td>✔</td>
</tr>
<tr>
<td>Product reliability requirement</td>
<td>✔</td>
</tr>
<tr>
<td>Availability of skilled labour</td>
<td>✔</td>
</tr>
<tr>
<td>Location of waste disposal sites</td>
<td>✔</td>
</tr>
<tr>
<td>Labour cost</td>
<td>✔</td>
</tr>
<tr>
<td>Volume of collection</td>
<td>✔</td>
</tr>
<tr>
<td>Waste handling, storage and transportation cost</td>
<td>✔</td>
</tr>
</tbody>
</table>

Table 6: KPIs and factors related to level of centralisation (inspection and sorting).

- **Degree of disassembly**: it comprises a systematic method of separating a product into its constituent parts, components, subassemblies or other groupings and it is also used to remove the toxic elements. The most common **indicators** considered with the aim of defining this activity and increasing its efficiency are the following:

  - Value recovery
  - Disassembly cost
  - Processing cost
  - Landfill cost
  - Incineration cost
  - Environmental impact of processing
  - Environmental impact of landfill
  - Environmental impact of incineration
The following table shows the relation between these KPIs and the factors identified in Section 2:

<table>
<thead>
<tr>
<th>Key Indicators</th>
<th>Variables</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Enforcement Cost</td>
</tr>
<tr>
<td>Value recovery</td>
<td>✔️</td>
</tr>
<tr>
<td>Disassembly cost</td>
<td>✔️</td>
</tr>
<tr>
<td>Processing cost</td>
<td>✔️</td>
</tr>
<tr>
<td>Landfill cost</td>
<td>✔️</td>
</tr>
<tr>
<td>Incineration cost</td>
<td>✔️</td>
</tr>
<tr>
<td>Environmental impact of processing</td>
<td>✔️</td>
</tr>
<tr>
<td>Environmental impact of landfill</td>
<td>✔️</td>
</tr>
<tr>
<td>Environmental impact of incineration</td>
<td>✔️</td>
</tr>
</tbody>
</table>

Table 7: KPIs and factors related to degree of disassembly (inspection and sorting).

3. **Product recovery**: this activity has the objective of managing the flow of products or parts destined for remanufacturing, repairing, or disposal and to effectively use the resources. In addition, it is carried out to recover hidden economical value, to meet market requirements or to meet Government regulations. This activity involves a process including these tasks: repair, reuse, refurbish, remanufacture, cannibalize, recycle or disposal. The aim of this process is to bring the product into ‘as new’, starting a new cycle of use. Sometimes this process is not economically viable for the industry. By contrast, it is an environmentally sound way to achieve many of the goals of sustainable development. In this context, new products are reassembled from the old and, where necessary, and can produce a fully equivalent and sometimes superior-in performance and expected lifetime to the original new product.

The **indicators** to be considered in order to asset the efficiency of this activity are:

- Operating cost
Circular Approach for Eco-Composite Bulky Product
GA NUMBER: 730456
Start: 01/06/2017 - End: 31/05/2021

- Environmental impact
- Market demand
- Technical feasibility
- Green image
- Value recovery
- Health and safety issues
- Employment generation opportunities
- Law and regulation

The following table shows the relation between above KPIs and the factors identified in Section 2:

<table>
<thead>
<tr>
<th>Key Indicators</th>
<th>Variables</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Enforcement Cost</td>
</tr>
<tr>
<td>Operating cost</td>
<td></td>
</tr>
<tr>
<td>Environmental impact</td>
<td>⬤</td>
</tr>
<tr>
<td>Market demand</td>
<td>⬤</td>
</tr>
<tr>
<td>Technical feasibility</td>
<td>⬤</td>
</tr>
<tr>
<td>Green image</td>
<td></td>
</tr>
<tr>
<td>Value recovery</td>
<td></td>
</tr>
<tr>
<td>Health and safety issues</td>
<td></td>
</tr>
<tr>
<td>Employment generation</td>
<td></td>
</tr>
<tr>
<td>opportunities</td>
<td></td>
</tr>
<tr>
<td>Law and regulation</td>
<td>⬤</td>
</tr>
</tbody>
</table>

Table 8: KPIs and factors related to product recovery.

Specifically, some additional indicators have been identified in the three analysed sectors that have to be considered.

**Automotive sector**

Related to this sector, and from the point of view of main stakeholders involved in this chain, those indicators are important:
• **Collection:**
  ➢ Traceability, in order to give greater transparency to the whole chain

<table>
<thead>
<tr>
<th>Key Indicators</th>
<th>Variables</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Enforcement</td>
</tr>
<tr>
<td>Traceability</td>
<td>✔️</td>
</tr>
</tbody>
</table>

*Table 9: Additional KPI and factors related to collection in automotive sector.*

• **Inspection and sorting**
  ➢ Easy identification and separation of different parts

<table>
<thead>
<tr>
<th>Key Indicators</th>
<th>Variables</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Enforcement</td>
</tr>
<tr>
<td>Easy identification and separation of different parts</td>
<td>✔️</td>
</tr>
</tbody>
</table>

*Table 10: Additional KPI and factors related to inspection and sorting in automotive sector.*

• **Product recovery**
  ➢ User behavior change, to increase awareness of circular economy

<table>
<thead>
<tr>
<th>Key Indicators</th>
<th>Variables</th>
</tr>
</thead>
<tbody>
<tr>
<td>User behavior change</td>
<td>Enforcement</td>
</tr>
<tr>
<td></td>
<td>✔️</td>
</tr>
</tbody>
</table>

*Table 11: Additional KPI and factors related to product recovery in automotive sector.*

**Furniture sector**

Similarly, in the case of furniture sector, those parameters are also considered:

• **Product recovery**
➢ User behavior change, to increase awareness of circular economy (e.g. through economic incentives)
➢ Establishment of quality labels/certifications, in order to enhance product liability and boost customer confidence

<table>
<thead>
<tr>
<th>Key Indicators</th>
<th>Variables</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Enforcement Cost</td>
</tr>
<tr>
<td>User behavior change</td>
<td>✓</td>
</tr>
<tr>
<td>Establishment of quality labels/certifications</td>
<td></td>
</tr>
</tbody>
</table>

*Table 12: Additional KPI and factors related to product recovery in furniture sector.*

**Building sector**

Finally, after analysing this sector, there are some specifics indicators to take into account:

- **Collection:**
  - Traceability, in order to give greater transparency to the whole chain (e.g. by using a Building Information Modelling (BIM), an innovative digital tool that communicates information relating to all phases of an asset's lifecycle and allows multiple stakeholders to collaborate more efficiently on the design, construction and operation of buildings)

<table>
<thead>
<tr>
<th>Key Indicators</th>
<th>Variables</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Enforcement Cost</td>
</tr>
<tr>
<td>Traceability</td>
<td>✓</td>
</tr>
</tbody>
</table>

*Table 13: Additional KPI and factors related to collection in building sector.*

- **Product recovery**
  - User behavior change, to increase awareness of circular economy (e.g. through economic incentives)
<table>
<thead>
<tr>
<th>Key Indicators</th>
<th>Variables</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Enforcement Cost</td>
</tr>
<tr>
<td>User behavior change</td>
<td>✓</td>
</tr>
</tbody>
</table>

*Table 14: Additional KPI and factors related to product recovery in building sector.*
4. Conclusions and next steps

The activities to be carried out in task 5.1 are aimed at analyzing the activities associated with the reverse logistics chain, identifying the critical processes and the main variables that influence them. In this way, the approach and definition of improvement strategies will be possible, allowing the optimization of all the included activities associated with the first phase of the chain, that is, collection and transport.

Since this task clearly presents two differentiated phases (characterisation and proposal of improvement solutions), and also taking into account that the activity of the same continues until the M24, it has been chosen to develop two different reports, associated with two phases.

Well then, this first deliverable addresses the first mentioned action, the characterization of the reverse logistics chain, as well as the identification of key performance indicators for its development.

As a result of this study, the reverse logistics chain differs greatly from the forward logistics. In the first case, the complexity of their activities is greater, which increases their costs. In addition, this difficulty implies less operational control.

Specifically, in relation to the activities involves in the reverse logistics chain, the most critical tasks are collection, inspection and sorting, and product recovery. Therefore, the KPIs to take greater account are those involved in these activities.

These indicators are mainly related to costs, process complexity, value recovery, health and safety, users’ behavior, regulation and legislation and environmental impact.

As mentioned, after this first analysis, the proposed activity plan until the end of the activity is as follows:

- Completion of the definition and measures and strategies that allow to improve the efficiency of the collection and transport of waste activities, associated with the selection of the appropriate mode, loading capacity, route optimization, and ease of access (both end-life users and transport operators) - M21 (aligned with the development of tasks 6.1)
- Completion of the development of the Multi-Criteria Decision Analysis (MCDA) tool, which allows the
evaluation of the proposed measures from a technological, economic, environmental and social point of view. Evaluation of its operation - M24
5. References

- European Environmental Bureau. (2017). *Circular economy opportunities in the furniture sector*. MAVA (Foundation pour la Nature) and LIFE Programme of the European Union
- European Remanufacturing Network. ((2015). *Remanufacturing Market Study*