

# Digital Chain of Custody for a Blue Circular Economy

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**Abstract:** Discarded fishing equipment and other fishing waste are thought to account for 27% of all ocean litter. To achieve a sustainable circular blue economy, working closely with all stakeholders to eliminate waste and preserve marine ecosystems is crucial. By integrating data, technology, and waste reduction into business processes, businesses can adopt more sustainable practices and reduce the impact of plastic pollution in the ocean. This paper promotes circularity and recyclability through a blue circular economy approach. The primary objective is to establish a digital chain of custody that traces the transformation of marine debris from fishing operations into secondary raw materials. A case study is presented, highlighting the active involvement of fishermen in the recycling process. The paper introduces a framework for evaluating organisational collaboration in adopting circular economy strategies and incorporating knowledge into their business processes. The solution encompasses a data governance approach and a digital chain of custody, facilitating stakeholder collaboration towards a shared objective.

**Keywords:** Data governance, KPI, Blue circular economy, Digital chain of custody, Social awareness

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## 1. Introduction

Marine plastic pollution (MPP) poses significant environmental and socio-economic challenges, impacting the marine ecosystem and posing risks to biodiversity, food security, and human health (Barboza et al., 2019). In response to this issue, the European Union (EU) has committed to adopting a sustainable blue circular economy approach that addresses the recyclability of plastics and lost or abandoned fishing gear, thus tackling marine litter (COM240, 2021; Brink et al., 2018). This commitment has led to implementing measures to mitigate the cumulative impact of MPP, including visible pollution like plastic litter and invisible pollution such as microplastics.

The EU emphasises the importance of engaging stakeholders in waste prevention and preserving marine ecosystems to establish a sustainable blue circular economy. By promoting collaboration and implementing strategic actions, the EU strives to reduce the adverse effects of MPP and work towards a cleaner and more sustainable marine environment. An example of such an initiative is the Single-Use Plastics Directive<sup>1</sup>, which specifically targets single-use plastic products and fishing gear that currently contribute to 70% of marine litter in the EU (EIA2022).

The circular economy (CE) paradigm provides opportunities to move toward circular production models (Jonker et al., 2022). These models facilitate the transformation of value chain activities, creating new avenues for growth and maintaining competitive advantage. Manufacturers can devise eco-friendly initiatives by comprehending the circular relationships within the value chain. Organisations can adopt more sustainable practices by integrating data governance and waste reduction into their business processes (Awan, U., 2022).

Within the Blue Circular Post Branding Project (BCpBP) scope, this paper presents a case study conducted in Portugal, which outlines a digital chain of custody (dCoC) combined with a data governance approach. The objective is to foster social awareness regarding MPP by involving stakeholders from different areas, including fishermen, local authorities, associations, and industry. The case study scenario establishes a value chain that facilitates collaboration between fishermen and industrial partners, who incorporate the collected marine litter into new products. The case study also provides guidelines for fishermen to deposit the marine debris they encounter during fishing operations into designated ecopoints. Each ecopoint is associated with an identified collector assigned to a specific fishing community. Figure 1 shows one of these ecopoint containers equipped with a Bigbag.

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<sup>1</sup>Directive (EU) 2019/904, the reduction of the impact of certain plastic products on the environment.



Figure 1: Example of a BCpbP Ecpoint Container

The project aligns with the EU strategy for plastics in a circular economy (ESPCE 2018), which aims to transform how plastic products are designed, produced, used and recycled in the EU.

The blue circular economy is a growing field of study, with an increasing number of scholarly activities exploring the relationship between sustainability and ocean economy growth (Martínez-Vázquez et al., 2021). Indeed, the blue economy operates as a dual-loop regenerative system, optimising environmental and economic performance (Ziegler et al., 2023). It aims to transform the marine economy into a sustainable solution by optimising resource utilisation (recycling), revalorisation, and rethinking production and consumption. This means that the blue economy encompasses commercial, research, and innovative activities (Alhawari et al., 2021). Many authors also sustain that leveraging the potential of science and innovation is crucial for ocean sustainability (Awan et al., 2020; Alcalde-Calonge et al., 2022; Heras-Saizarbitoria et al., 2023). This paper is aligned with these research findings in exploring co-creation approaches for a sustainable blue economy, fostering skills-building and interdisciplinary dialogues between industry sectors. The case study scenarios provide examples of such practices by joining concepts related to self-sustaining communities, promoting societal engagement, embracing digitalisation, harnessing ecosystem services, and fostering collaborative research.

## 2. Data Governance in the Circular Economy

A CE is an economic model that aims to efficiently use resources, minimise waste, retain long-term value, and operate within environmental limits. In contrast, a linear economy follows a "take-make-dispose" plan, transforming raw materials into products that eventually become waste. The circular economy offers an alternative approach, considering waste a valuable resource. It follows the principles of reducing, reusing and recycling (i.e., the 3R approach); value is created by prioritising value preservation, minimising resource use, and recycling materials to a high standard. Figure 2 illustrates the difference between circular and linear systems, highlighting the challenge of implementing circular business models.

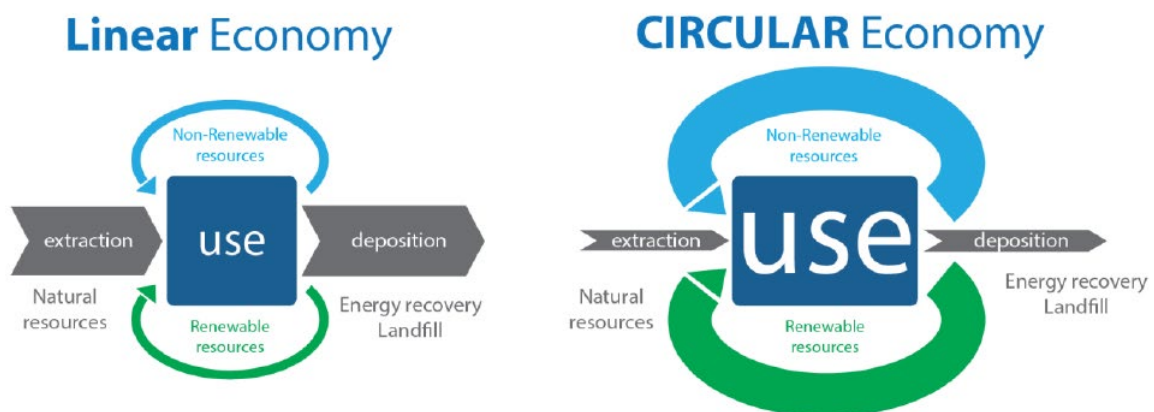


Figure 2: The Fundamental Differences Between Circular and Linear Economies (PBL, 2017)

The concept of a Blue Circular Economy is commonly applied to address marine litter, emphasising the importance of collecting and reintroducing materials like plastics and fishing gear into the economic system to promote resilience and minimise waste. In line with this, the BCpbP has developed a business process that facilitates a recycling journey, where marine litter and fishing gear are collected and transformed into valuable resources for the manufacturing industry. The following examples highlight industrial partners who are interested in being recognised as eco-friendlier producers in this context.

- [Biedronka](#), one of the biggest supermarkets in Poland, is leading a movement to replace its shopping carts, baskets and trolleys with innovative alternatives made with 25% of plastic from fishing ghost nets. The remaining 75% comes from recycled plastic.



- [ZOURI](#), a well-known brand in the footwear sector in Portugal, is willing to cooperate in using fishing ghost nets and recycled plastic in the production of their shoe soles



These two examples show how traditional industrial partners can contribute to circularity and reduce the carbon emissions of producing new plastic by around 20%. The social recognition of eco-friendlier companies is a differentiation factor that consumers cherish.

Tracing the data to know the origins of materials and products is an essential step, meaning that data plays a vital role in achieving traceability, supply chain transparency, and optimising production processes (Patel et al., 2020). However, sharing data among stakeholders poses challenges due to the need for a common language with standardised semantics, ontologies, and taxonomies. Additionally, since these data are primarily computed by machines, fostering interoperability of IT systems using this common language becomes essential. A digital chain of custody (dCoC) with a data governance approach is required to operationalise these goals and establish a functional ecosystem (Ladley 2019).

Sharing data throughout a value chain unlocks new insights that can enhance the efficient utilisation of resources. This knowledge brings value to companies across four dimensions: cost reduction, improved brand image, risk reduction, and increased revenue. In addition, a data governance framework for dCoC provides the structure to leverage these four dimensions, offering opportunities for brand enhancement and consumer recognition. In this approach, a data lineage culture is essential for fostering trust and ensuring transparency within a dCoC.

Within the BCpbP case study context, we will see that the Matrioskas Sequence Framework (MSF) application helps employ a circular data flow approach to expedite the development of data products that aid stakeholder decision-making. This offers a standardised methodology for measuring data cycles and provides visibility into environmental considerations.

### 3. Overview of the Digital Chain of Custody for the BigBag

The dCoC incorporates metadata, providing comprehensive contextual information for efficient digital management throughout the custody chain. The chain of custody is divided into two phases to ensure simplicity and readability and facilitate auditing stakeholder involvement, including the fishing community's contributions. The scope of the dCoC encompasses all resources involved in the acquisition, collection, transportation, analysis, division, and storage of the collected materials, along with contextual information and timestamp records. Data sharing between links in the dCoC is foreseen as a driving force for circular value creation and innovation in the proposed approach.

Exploring the role of technology as an enabler for implementing a standardised record of digital evidence custody is an essential aspect to consider for dynamically gaining insights into stakeholders' opinions, attitudes, and behavioural intentions. The value chain diagrams in Figures 3 and 5 offer a comprehensive overview of the process landscape for data management within the dCoC. These diagrams follow the guidelines outlined by ISO (2020). The value chain diagrams visually depict the CE business model and illustrate the interconnectedness of

processes throughout the data lifecycle. Each link in the value chain represents a series of business processes that transform input resources into value-added outputs for the following link in the dCoC. This value chain framework aids management in categorising circularity models, assigning ownership and accountability, identifying process integration and hand-off points, and ultimately defining organisational roles and responsibilities.

### 3.1 Scenario I: Collection and Delivery to the Central Hub

The process initiates by the local authority (e.g., Fishing Port) extending an invitation to the fishing communities to participate in the initiative. The communities are then registered into the system, and ecopoint collectors are assigned to them, as shown in Figure 3. Each ecopoint is associated with metadata that georeferences its location and monitors its fill level, which is manually observed by checking if the collectors are packed. This task is performed by each participant within the BCpbP community.

The fishing community is instructed to deposit nets, fishing gear, and other marine litter, including undifferentiated plastic, into designated collectors aboard their vessels. They are encouraged to consistently fill their assigned collectors, fostering a healthy competitive environment. Each time a complete BigBag is removed from the collector, the achievement is recorded for the respective fishing community. This indicator serves as social recognition of their dedication and active involvement in cleaning the sea of marine litter.

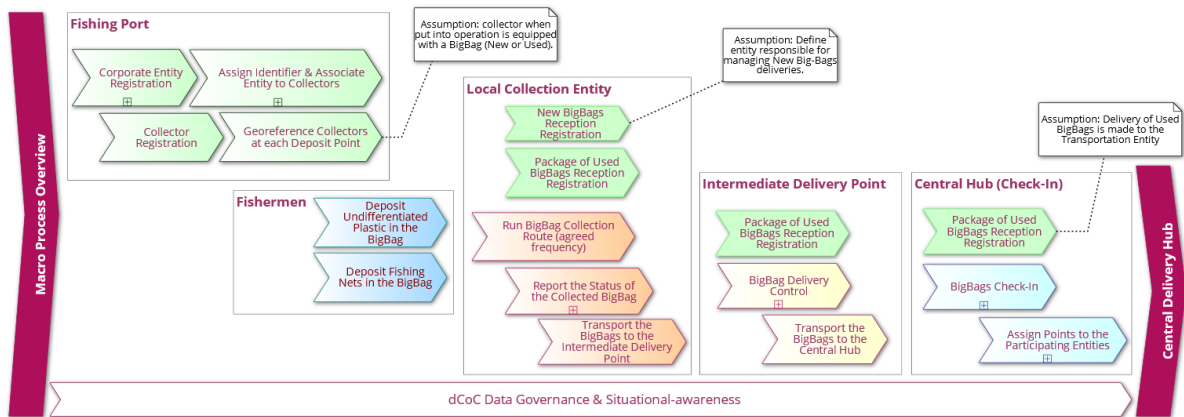


Figure 3: Phase I of the dCoC Within the BCpbP Scope

Many partnerships had to be formed to collect BigBags from each ecopoint. As a proof of concept, the local municipality, responsible for municipal waste collection, took on the responsibility of collecting the BigBags. During this process, the collector scans the QR code of both the ecopoint and the BigBag, establishing a connection between the content of the BigBag and the associated fishing community. Additionally, any damage to the BigBags must be reported, particularly if they are rendered unusable and need to be replaced. This indicator allows for monitoring the efficiency and durability of the delivered BigBags. Figure 4 shows that the BigBags are transported to an interim storage facility before being transported in bulk to a central hub for processing. The logistics carrier oversees the transportation to the central hub.

It is essential to consider the data lineage to implement a data monetisation approach based on the added value derived from tracking the custody of BigBags. The data lineage refers to the end-to-end traceability of data, documenting its origins, transformations, and movement throughout the dCoC process. Tracking the custody of BigBags generates valuable data insights regarding the stakeholders involved at each stage of the process. This data provides crucial information for implementing a sustainable circular economy business model.

In the context of the BCpbP, the data obtained from tracking the BigBags enables a gamified approach where points are assigned to relevant stakeholders, particularly the fishing communities. These data-driven insights enhance the understanding of stakeholder engagement and contribute to effectively implementing data monetisation strategies. By leveraging the data lineage and associated insights, it is possible to optimise data monetisation efforts and unlock the economic value generated by tracking and managing the custody of BigBags within the dCoC framework.



Figure 4: BigBad Deposit at the Intermediate Delivery Point

The dCoC data governance framework determines user access rights and levels of responsibility, ensuring that the same data can be shared across multiple users while maintaining data quality and data integrity. The data governance framework includes rules, processes and procedures that must be followed continuously. The main objective is to enforce and facilitate monitoring performance indicators to analyse who contributes and with what regularity and identify bottlenecks or operational constraints requiring an agile intervention.

### 3.2 Scenario II: Supply Chain to the Industry

In the second phase, the collected raw material is recycled and looped back into the production cycle (see Figure 5). In this phase, the BigBags circularity is managed at the Central Hub, where the marine litter are cleaned and processed to be used as secondary raw materials by manufacturers. Any CE business model has costs; therefore, its viability depends on the commercial value of the materials used in the circularity or any other financial agreement signed with funding entities. Although not covered within this paper, the market value of a BigBag packed with fishing nets or plastics is an essential data monetisation feature for BCpbP's financial sustainability. The market value of the BigBag is processed at the central hub before shipping to the production phase.

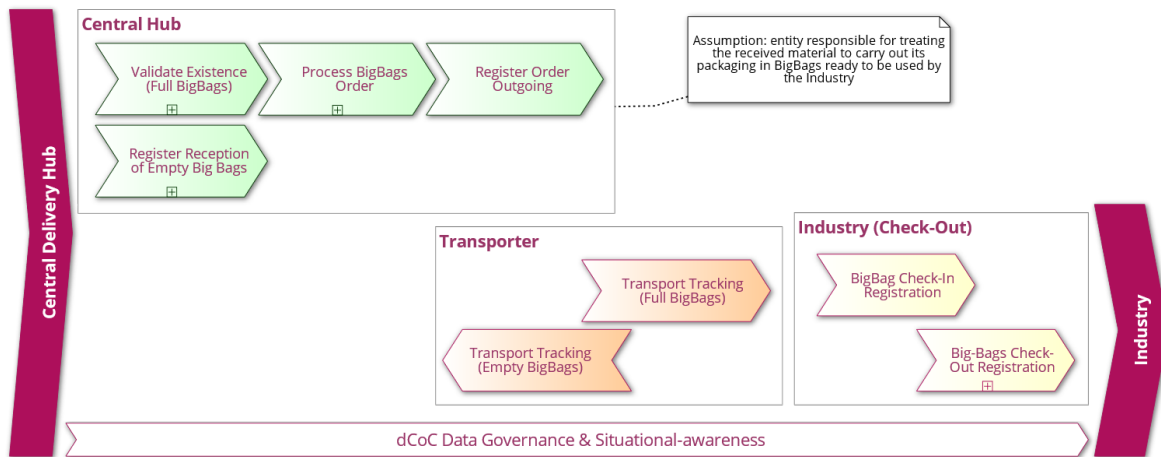


Figure 5: Phase II of the dCoC Within the BCpbP Scope

After the check-in of the received BigBags, the Industrial partner should check-out the custody of any empty BigBags. The transporter assumes the custody of those empty BigBags back to the central hub. At the central hub, available empty BigBags are put into the distribution cycle for reuse by the local collectors during their ecopoints collection circuit (see phase I in Figure 3). Within the scope of the BCpbP case study, keeping a registry of the BigBag status was considered a requirement to trace custodianship at each stage in the dCoC. A QRcode reader provided a quick solution for tracing the BigBags at each check-in and check-out, including BigBags collected by local collection entities at each ecopoint. When a BigBag is damaged, the user selects that option enabling the system to register a loss and trigger an alert when minimum stock is reached.

The two diagrams (Figure 3 and Figure 5) cover the complete circularity of the dCoC, and highlight the circular business models that typically leverage data to drive value. They provide a high-level view of the data flows between participants to standardise the data governance of the custody transfer, triggering context-awareness whenever mishandling of digital evidence is detected. The technologies rely on data exchange between actors, and data is essential for ensuring scalability and realising value from CE business models.

#### 4. The MATSKI Framework Within the Data Governance Circularity

The proposed dCoC process establishes guidelines for adopting standard operating procedures that require data governance workflows to oversee the digital custody of BigBags. It also allows for just-in-time performance control. These data controls are based on maintaining a digital log of the participating actors in the dCoC and providing digital evidence to trace information back to its source. These data controls can also be used to find trends and correlations to plan maintenance and replacement.

The Matrioskas Sequence Framework (MSF) addresses these guidelines as it was developed as a service design framework for empirically assessing how an organisation collects, measures, learns, and integrates knowledge into its culture and operations (Pestana and Rosa,2020). As part of CE's business model, MSF is committed to developing unique differentiated expertise and market share by transforming around three pillars: Processes, Technology and People & Skills. MSF also requires a higher level of digital transformation, including the automation and dematerialisation of business processes that generate more data to track goods or new capabilities that need to be handled by decision-makers. In this regard, the following indicators have been identified to assist decision-makers in taking action.

- *Registered fishing communities (RFC)*, the total number of communities collaborating in the project
- *Fishermen in each fishing community (FFC)*, the total number of fishermen associated with each fishing community
- *Stakeholder Points (SP)*, the total points acquired by a specific actor based on the achievements accomplished within the BCpbP case study (i.e., tasks performed within the dCoC)
- *New BigBag Tagged (NBBT)*, the total of new BigBags available with an identified tag (i.e., with a QR code)
- *Lost BigBag Tagged (LBBT)*, the total of BigBags reported as damaged (i.e., out of circulation)
- *Shipped BigBag Orders (SBBO)*, the total of BigBags shipped to the production line. Possibility to drill down by type of material (i.e., the content of the BigBag)
- *Average Time at the Central Hub (ATCH)*, the average time a BigBag stands at the central hub before being shipped to an industrial partner
- *Quality of Service (QOS)*: users' (e.g.stakeholders) perceptions of the quality of service supplied
- *Customer satisfaction (CS)*: users' (e.g.stakeholders) satisfaction with the service supplied
- *Loyalty & Recommendation (LR)*: users' (e.g.stakeholders) further intent and recommendation of the service

Considering the MSF, these KPIs are placed under the Technology pillar, as shown in Figure 6.

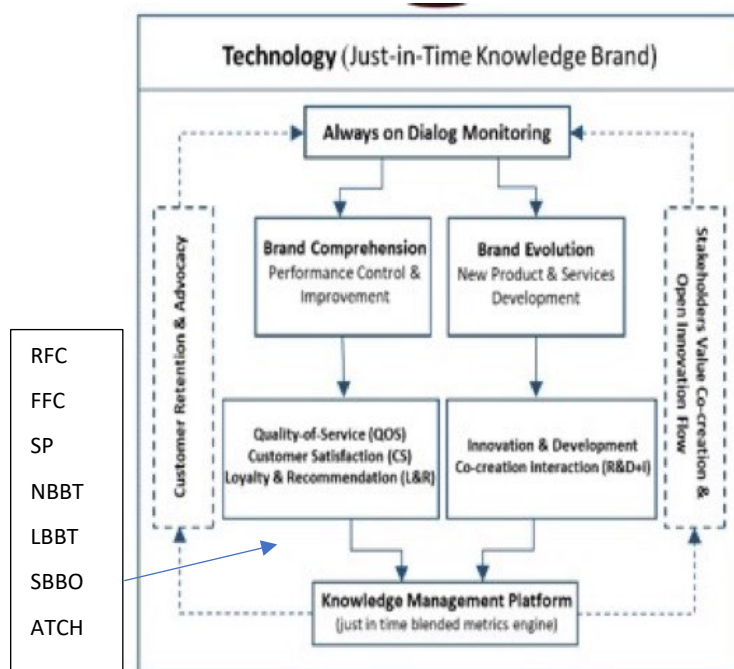


Figure 6: Matski Framework: KPI for Data Governance

It can be argued that considering the intersection of MSF with the CE allows redesigning existing business models to include innovations that can lead to strategic actions aligned with sustainable development (Rosa and Pestana, 2019). Our study expands the discussion around data sharing within dCoC by adding controls to the technological domain. Yet, more will need to be done to understand why and how firms survive industry transformations for CE sustainability. Therefore, it will be necessary for researchers to explain and predict how organisations with different business models will affect each other in the changing CE. Functional areas such as research and development, controlling, and quality assurance also utilise these data for greater accuracy, process automation, real-time analysis and reporting.

## 5. Conclusion

Combining the challenges of circularity and recyclability requires a pragmatic approach to business innovation. In a blue circular economy, marine litter such as plastics and fishing gear should be collected and reintroduced into the economic system or converted into new valuable resources at the end of the product life cycle. This can be accomplished by encouraging initiatives to implement public-private collaborative networks to work together and bring stakeholders from multiple sectors to create socially and environmentally sustainable business model opportunities.

The paper presented the BCpbP case study as a value proposition to create a robust supply chain, create value from marine litter, reincorporate these materials in the manufacturing industry, and promote sustainable design alternatives to current consumption patterns while raising awareness of ocean sustainability. This can be accomplished by encouraging initiatives to implement public-private collaborative networks to work together and bring stakeholders from multiple sectors to create socially and environmentally sustainable business model opportunities.

Our findings highlight the importance of considering the CE with a dCoC for data governance on value chain activities and how they impact existing business models, drive innovation, and enable value creation. The manufacturing industry is changing from a linear (take–make–use–dispose) model to a circular economy. In addition, technological innovation impacts the value chain as a set of primary and supporting activities necessary to deliver a valuable product to the market. This study also demonstrates how MSF can contribute to the value chain while focusing on manufacturers and providing new opportunities for future research.

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