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Bridging Construction and Manufacturing: Digital Product Passports for Circular Timber Waste Remanufacturing

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Abstract

This paper investigates the role of Digital Product Passports (DPPs) in enabling circular economy practices in the construction sector, with a specific focus on the transformation of timber waste into remanufactured materials for use in the manufacturing industry. By enhancing automation, data transparency, and lifecycle traceability, DPPs serve as critical enablers for optimizing resource recovery, supporting Life Cycle Assessment (LCA), and reducing inefficiencies in construction waste management. Using timber waste as a case study, this research presents a comparative analysis of traditional and DPP-enhanced processes, evaluated through key performance indicators such as material recovery rates, carbon footprint, and energy consumption. The study demonstrates how recovered timber, tracked and qualified through DPP systems, can be remanufactured into high-performance construction materials, effectively linking the construction and manufacturing sectors in a closed-loop system. Data is collected through DPP-enabled monitoring, industry sources, and stakeholder feedback, and environmental impacts are quantified using LCA tools. The findings highlight the environmental and operational benefits of DPP adoption, while also identifying challenges related to digital standardization and implementation. This work contributes a replicable framework for integrating DPPs in construction workflows and supports broader industrial efforts toward sustainable, data-driven circularity.

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Keywords: Digital Product Passport; DPP; circular economy; construction; timber waste management; remanufacturing .

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1 Introduction

The construction industry is one of the largest global consumers of raw materials and a major contributor to waste generation, accounting for approximately 36% of total waste in the European Union (EU). This high resource intensity and linear approach to material flows pose critical sustainability challenges. In response, the circular economy has emerged as a transformative framework that emphasizes resource efficiency, waste reduction, and material reuse across product life cycles. However, despite growing awareness, the implementation of circular economy principles in construction remains limited due to several persistent barriers, including poor data availability, lack of transparency, and fragmented supply chain communication [1].

Digital Product Passports (DPPs) offer a promising technological solution to address these gaps. As digital systems that compile and communicate product lifecycle information—such as material origin, usage history, embedded emissions, and end-of-life options—DPPs can support more sustainable decision-making at every stage of the construction process [2]. They enable improved traceability, enhanced data accessibility, and greater accountability for material flows, all of which are essential to transition from traditional linear processes to circular practices. Initially deployed in industries such as electronics and batteries, DPPs are now gaining traction in other sectors, with the European Commission identifying them as a core element of upcoming regulatory frameworks, including the Ecodesign for Sustainable Products Regulation (ESPR) [3].

Despite these developments, the application of DPPs in the construction industry is still at an early stage. Most studies focus on theoretical potentials, with limited research addressing their practical implementation, integration with existing tools (e.g., BIM), or value in specific material streams [4]. One material with particularly high circularity potential is timber, which, if managed properly, can be reused, remanufactured, or upcycled into high-performance construction products. Timber waste is a valuable case study to assess how DPPs can bridge the gap between digital infrastructure and sustainable material management.

This paper investigates how DPPs can be effectively integrated into construction waste management practices to enable circular economy outcomes, using timber waste as a representative case. Through a combination of theoretical modeling, stakeholder insights, and life cycle assessment (LCA), we present a structured framework for implementing DPP systems to support transparency, traceability, and material recovery. The study compares traditional and DPP-enhanced processes using key performance indicators (KPIs) such as material recovery rates, carbon footprint, and energy consumption. It also highlights the opportunities and challenges associated with DPP integration in the construction context, offering practical insights into their scalability and digital maturity requirements.

By addressing a critical gap in both research and practice, this study contributes to the advancement of digital circular economy tools in construction and offers a replicable model for broader adoption across material streams and industry domains.

2 State of the Art

2.1 Digital Product Passport in Circular Economy

The DPP is a database that contains information about the lifecycle of materials, products, that provides transparency, traceability, and of the ability to share data across the value chain [5]. This digital tool plays an important role in solving circular manufacturing challenges such as data fragmentation and limited stakeholder collaboration [6]. Recent research by Psarommatis and May (2024) emphasizes that DPPs serve not only as information repositories but as lifecycle-enabling tools that support traceability, reuse, and optimized end-of-life processing in modern manufacturing environments [7].

The EU decided that DPP has a critical role in achieving sustainability goals outlined in the Circular Economy Action Plan. By recording detailed lifecycle information, DPP promotes transparency and supports decision-making across the supply chain [8]. For example, DPPs have improved electronic waste management by increasing recycling rates and facilitating the recovery of valuable materials [9,10]. Psarommatis and May (2024) further argue that the European Commission's ESPR Regulation (published on 28th of July 2024) is relying on DPP frameworks to enforce sustainable product transparency, including component tracking, embedded emissions, and compliance throughout product life [7].

Research shows that DPPs increase resource efficiency by allowing accurate material tracking and quality control. In the battery manufacturing industry, DPP integration has reduced environmental impacts and supported closed-loop systems [11]. Moreover, technologies like blockchain and artificial intelligence are increasing DPP capabilities by improving data security and real-time decision-making [4].

Recent studies expand on these roles. Wan and Jiang (2025) highlight that DPPs are evolving from static information containers to dynamic platforms that support active decision-making throughout the product lifecycle [12]. These advanced DPPs can guide reuse, disassembly, and recovery by incorporating live operational data. In line with this, Jensen (2025) show that machine learning applied to DPP data can predict reuse potential, failure probability, and optimize recycling pathways [13]. This predictive capability is essential for achieving higher-value circularity.

The CIRPASS initiative has also proposed digital infrastructure for scalable implementation of DPPs across industries. This includes standardization of product identifiers, traceability templates, and data-sharing protocols, which will soon influence how DPPs are adopted in construction materials [14].

2.2 Circular Economy in Construction

The construction sector is one of the largest waste generators globally, producing around 36% of total waste in the EU. This shows the urgent need for innovative solutions to reduce waste and increase circularity [15]. Timber waste, in particular, shows a significant opportunity for high-value recycling and upcycling.

DPP helps to track timber products during their lifecycle, starting from their origin and usage to the final recycling and repurposing. By having detailed data on material composition, origin, and quality, DPP helps to take better decisions to reduce material waste [12]. Moreover, the application of advanced sorting and processing techniques improves the waste management as it is shown in different projects across the EU [16].

One of the key challenges in introduction of circular economy principles in construction is the difference in material quality and the complexity of waste streams. DPP can solve these problems by providing real-time data on material conditions, level of contamination, and potential reuse options [15]. This opportunity will help to align eco-design principles and bring new sustainable construction materials, such as cross-laminated timber (CLT) and glulam [17].

New pilot projects have shown that DPPs are now entering the construction domain beyond theory. De Wolf et al. (2024) reported the successful implementation of a five-step digital circular workflow that included DPPs to record embedded carbon, moisture content, and prior use data of reclaimed materials [18]. Their case studies in Switzerland, including the reuse of timber components in dome construction, demonstrate how digital tracking systems such as DPPs can be integrated across detection, disassembly, distribution, design, and deployment phases. These projects validate the functionality of DPPs in field conditions and show how circular construction can benefit from digital innovation and material traceability.

Furthermore, Iyiola et al. (2024) reviewed digital innovations in construction and demolition waste management and concluded that DPPs, when combined with mobile data entry, AI, and sensor technologies, can reduce uncertainty in demolition planning and material assessment [19]. Their systematic review highlights that DPPs, alongside technologies like BIM, blockchain, and IoT, are gaining traction as viable tools in the industry's transition from linear to circular models, although practical adoption remains limited by integration and data standardization barriers.

2.3 Advances in DPP Technologies

Recent innovations in DPP technologies aim to enhance scalability, interoperability, and decision-making capabilities. For example, blockchain solutions improve data security, traceability, and stakeholder collaboration, while artificial intelligence integration enables automated material sorting and prediction of optimal recycling or upcycling pathways based on real-time data [9]. Sector-wide initiatives such as the European Battery Alliance are also developing standardized DPP data models that could be adapted for construction materials [10], offering a harmonized framework for consistent data collection and analysis.

Despite these advancements, the application of DPPs in construction—particularly in construction and demolition waste management—remains underdeveloped. Existing research is largely theoretical, with limited empirical studies demonstrating how DPPs function in operational environments for specific material streams such as timber. Key gaps include:

- **Lack of practical implementation frameworks** showing how DPPs integrate with existing digital tools (e.g., BIM, ERP) in the construction sector.
- **Absence of empirical performance data** quantifying environmental and operational gains in real-world waste processing.
- **Limited material-specific research** addressing the variability, contamination, and quality grading challenges of reclaimed timber.

Some recent developments point toward progress. For instance, Matarneh et al. (2022) demonstrate that DPPs can now align with open BIM standards such as IFC, enabling seamless integration with design and facility management systems [20]—a capability critical for long-term adoption. Similarly, predictive analytics applied to DPP datasets, as described by Voulgaridis et al. (2024), can support automated quality grading, failure risk forecasting, and identification of optimal reuse pathways [21].

This study directly addresses the identified gaps by presenting a detailed, case-based framework for integrating DPPs into timber waste management in the construction sector. It combines theoretical modeling, stakeholder insights, and life cycle assessment to demonstrate not only technical feasibility but also quantifiable environmental and operational benefits, thereby moving the discourse from conceptual potential to evidence-based practice.

3 Methodology

The study focuses on the role of DPP in improving circularity in the construction sector through timber waste management. The methodology proposed in this paper uses DPP to monitor and improve transparency, traceability and up/re-cycling processes. DPP will have a direct impact on circular practices through the following aspects:

3.1 Research Design

A comparative analysis evaluates waste management practices with and without DPP using KPIs such as material recovery rate, carbon footprint, and energy savings. To assess practicality and scalability, we gathered qualitative input via semi-structured interviews and a focus group with representatives from key stakeholder groups: recyclers/material recovery facilities, demolition contractors, general contractors, timber remanufacturers, equipment OEMs, architects/BIM managers, and public authorities/regulators (including EPD/ESG compliance actors). Sampling was purposive to cover the full value chain (collection, processing, design/specification, and compliance) and a range of firm sizes; the objective was breadth of perspectives rather than statistical representativeness. The comparative framework considers processing efficiency, contamination reduction, and final product quality, and integrates quantitative results with stakeholder insights to contextualize implementation opportunities and risks.

The study demonstrates the scalability of DPP systems in a variety of construction settings: small-scale demolition projects and large-scale urban initiatives. By covering these diverse contexts, the research provides a comprehensive understanding of the benefits of DPP across the entire construction industry.

3.2 Data Collection

Data collection in this study is designed to ensure comprehensive and reliable tracking of timber waste across its entire lifecycle, from deconstruction to reuse. The primary data source is the DPP platform, which automatically records a wide array of material and process-specific attributes at each stage of the circular workflow. These include information on the material's origin, prior use (e.g., construction or demolition source), composition, contamination level, and physical properties such as dimensions, moisture content, and density. This data is collected through advanced technologies integrated within the processing chain, including IoT sensors, RFID/NFC tags, and AR-based scanning tools. In addition to passive data capture, DPP systems facilitate the active input of certification data, quality assessments, and process metadata by operators. This combination ensures that all relevant lifecycle stages are documented in a standardized and traceable format.

The DPP platform used in this study is AeonTrace, a proprietary, cloud-based solution designed for real-time material tracking and lifecycle data management. AeonTrace supports interoperability with external systems such as ERP, BIM, and LCA tools through REST APIs and standardized JSON file exchange, enabling seamless integration into existing digital workflows. This architecture allows the platform to function as a central data hub, ensuring that lifecycle information remains synchronized across design, construction, waste management, and sustainability assessment processes.

To validate the robustness of the data collected via DPP, additional sources were triangulated, including site inspection reports, semi-structured interviews with industry stakeholders, and archival data from recycling facilities. A standardized protocol was followed across all test sites to reduce variability and enhance comparability. Tools such as mobile data entry platforms, automated sorting records, and material testing outputs were harmonized to feed into a centralized DPP repository. This enabled real-time synchronization and cross-verification of data streams, ensuring that any discrepancies could be flagged and corrected promptly. Furthermore, the integration of sensor-based monitoring allowed for the collection of dynamic process data—such as energy consumption during treatment or ambient conditions during storage—which was used to enhance the fidelity of subsequent life cycle assessments. Altogether, this approach supports a high-resolution, real-time overview of material flows and circular performance metrics, laying a solid foundation for evaluating the benefits of DPP integration in construction waste management. In the current paper "real-time" means DPP data are available within the equipment cycle time (seconds to <1 minute) and linked to the active batch/lot. This low-latency feed lets DSS update routing and treatment set-points while the line runs, triggering quality gates or maintenance actions. It also preserves data integrity and context by time-stamping sensor and operator inputs to the same batch record end-to-end.

3.3 Life Cycle Assessment

The LCA is a core component of this study, providing a cradle-to-grave assessment of timber waste management with and without DPP integration. It follows ISO 14040 and 14044 standards and covers both direct impacts (on-site emissions, energy use) and indirect impacts (embodied carbon in recovered materials, avoided emissions from virgin timber substitution). The analysis focuses on key metrics—GHG emissions (CO_2-eq), energy demand (kWh), material recovery rate (%), and resource depletion potential—using data from standardized databases (Ecoinvent, GaBi), literature benchmarks, and industry partners. In DPP-enabled scenarios, real-time monitoring and traceability enhance data granularity, reflecting material-specific factors such as contamination, processing intensity, and moisture content. Sensitivity analyses assess how variables like reuse rates and process efficiency influence overall environmental performance.

The inclusion of DPP in the LCA process enhances not only data precision but also process accountability. By linking each recovered timber batch to a complete digital history, LCA outcomes can be disaggregated by material quality, origin, and treatment method. This allows for scenario-based evaluations, such as assessing the impact of reusing treated glulam in structural versus non-structural applications. The integration of DPP data also facilitates more dynamic environmental accounting by capturing temporal and spatial variations in performance, which are typically overlooked in static LCA models. Ultimately, the LCA demonstrates that DPP-supported workflows can lead to substantial reductions in environmental burden, improved data transparency for sustainability reporting, and better-informed material choices across the construction value chain.

4 Circularity in construction using the DPP

The DPP is a key enabler of circular economy principles in construction, providing a unified, structured data flow across the entire material lifecycle—from sourcing to final reuse or manufacturing. As shown in Figure 1, the DPP captures and links stage-specific datasets that improve transparency, efficiency, and sustainability.

In the materials sourcing phase, it records origin, type, compliance with sustainability standards, and environmental footprint, ensuring traceability from the outset. During construction, it monitors material usage, documents waste generation, and flags inefficiencies for corrective action. At demolition, the DPP maps recoverable materials and captures pre-quality control and resource consumption data, reducing landfill waste. The sorting stage uses these records alongside automated, data-driven technologies to classify materials, identify contaminants, and increase recovery rates. In recycling and upcycling, the DPP logs processing details, upcycling specifications, and associated environmental impacts, enabling higher material utilization and carbon footprint reduction. Finally, at the reuse/manufacturing stage, products re-enter the market with full lifecycle documentation, including performance metrics, safety certifications, and sustainability data, ensuring trustworthy material information for downstream users.

By integrating these functions into one platform, the DPP supports material traceability, optimized resource use, high-quality decision-making, and measurable reductions in environmental impact, aligning directly with global sustainability objectives.

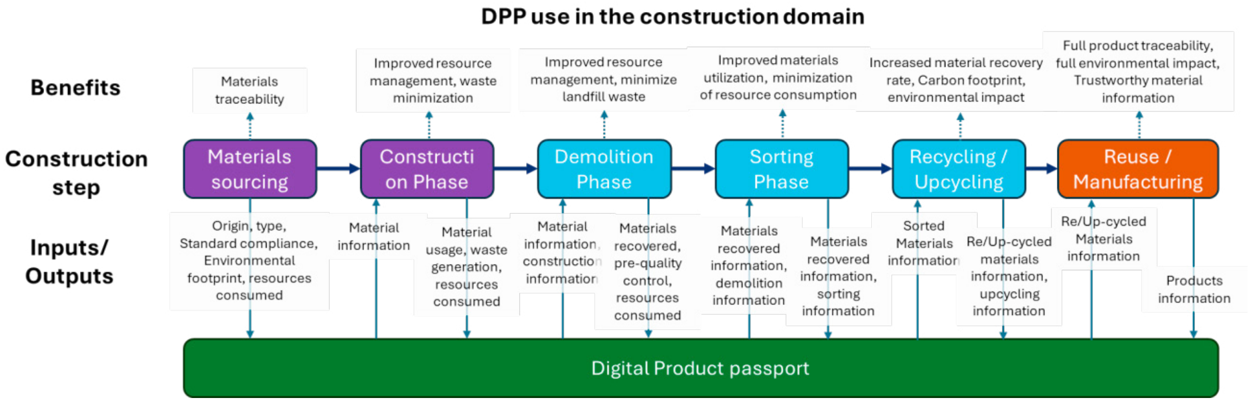

Figure 1 Schematic representation of Digital Product Passport integration and its benefits for construction processes

5 Case Study: Timber Waste Management

To illustrate the effectiveness of DPP usage, we provide an example of DPP application in timber waste management in the construction industry.

5.1 Material source and composition

In the first stage of waste management, timber is categorized into different groups based on its source (construction, demolition, or manufacturing waste) and type (hardwood or softwood).

DPP records the origin of the material, history of a building usage if material came from demolition site, types of detected materials using AR tool (pure timber or mixture), condition of timber, contamination level (if nails or varnish are present), and physical characteristics (dimensions, density). Sustainability metrics are also recorded, including information about equipment used, energy consumption, duration of the processes, and used labor. These metrics are captured at each step of the waste management process.

5.2 Sorting

Timber waste is initially pre-sorted on site based on categorization results and transports to the processing site. At the processing unit, more precise quality control steps are applied, like Vision/Optical-based robotic system pre-sorting that differentiate timber into three groups: low-quality timber, small-sized timber parts and medium/high quality timber.

At this point, DPP records results of visual inspection, detected physical defects, presence of contaminants, amount of usable waste after inspection, volume of timber in each classified group, detailed classification of medium/high-quality timber by type, length, performance, presence of nails, screws, cement, paint, or varnish.

5.3 Processing and treatment

The DPP system also records detailed metrics during this phase, such as processing time per batch, percentage of material lost during decontamination, the quantity and type of removed contaminants, and the final recovery yield. These insights provide valuable feedback for optimizing treatment parameters and aligning them with sustainability

KPIs, such as minimizing resource loss and energy input. Moreover, by linking each treated timber batch with its contamination profile and transformation history, the DPP facilitates smarter downstream decisions, such as selecting suitable reuse pathways or directing materials for further refinement. The integration of automated scanning tools (e.g., 3D vision, X-ray, and AR-enabled devices) enhances the consistency and accuracy of the treatment process while reducing human error. Ultimately, this phase plays a pivotal role in transforming waste into valuable material inputs for construction, reinforcing the role of DPP as a digital enabler for sustainable material recovery. Post-treatment and quality control

At this stage, advanced techniques are applied to assess the quality of the processed timber, checking for knots, cracks, contamination, or defects (e.g., fungal or insect damage). Afterwards, the final sorting and classification for the upcycling will be employed, including toxicological analysis.

Here, DPP records images from scanning (X-Ray CT), reports on detected defects (with images of defects, knots, cracks, contaminants, etc.), reports on fiber direction/orientation, density, moisture content, etc., quality grade of each piece. At this stage the DPP will also include information on the strength and durability of the final material, chemical contamination remaining in the timber, confirmation of the absence of fungal or insect contamination. Similar to the previous stages, the DPP will include information on the methods used for final sorting and classification, the amount of timber that passed the final quality control and the amount of timber to be further processed, as well as potential applications for upcycling. Finally, for the toxicological analysis, the methods used, and the results of the tests performed will be recorded, as well as the identified potential risks to workers' health, the handling of contaminated timber and proposed safety protocols to mitigate risks when working with timber waste.

5.4 Remanufacturing and new recirculates creation

In this final phase, new timber products are developed and characterized and with suggestions for future reuse or repurposing at their end-of-life stage.

The DPP collects information on the production of developed prototypes (e.g. glulam, CLT lamellas), data on product characteristics: timber size, type, material composition and properties, laboratory test results for recycled products (e.g. strength, moisture content, durability). For the product, the DPP will include information about type, purpose, specifications and suggested uses. Information on the user manual, potential users, sustainability, health and safety will also be included in the DPP, as well as performance data, packaging and certifications. Data on reuse and repurposing will be collected in the form of reports on the scalability and environmental performance of new products and data on lab-tested circular solutions for timber reuse and repurposing.

6 Expected Results

The integration of DPPs into timber waste management processes is expected to significantly enhance the circularity and sustainability of construction workflows. Based on theoretical modeling and existing best practices, we estimate that optimized sorting and treatment guided by DPP data can improve material recovery rates by up to 30% compared to traditional, non-digitized methods. These improvements stem from more accurate classification of reusable timber, contamination identification, and the minimization of material loss during mechanical processing. Additionally, DPPs enable better pre-processing decisions by linking material origin and condition to suitable recovery strategies, thus reducing overprocessing and misclassification. Such enhancements not only support environmental performance but also improve the economic viability of timber recovery by maximizing usable output from the same input waste stream.

In terms of energy efficiency, the automated and data-informed nature of DPP-enabled workflows is projected to reduce energy consumption during sorting and treatment phases by approximately 20%. This reduction is achieved by minimizing redundant steps, optimizing machine settings, and enabling predictive maintenance for energy-intensive equipment based on material type and batch characteristics. Critically, structured, upfront characterization data shortens the time needed to identify and classify incoming materials and prevents re-characterization or repeating the same process as material moves downstream—thereby avoiding idle machine time and unnecessary run time that drive up energy use. Furthermore, DPP-driven transparency allows operators to monitor energy and emissions per processing cycle, creating feedback loops for continuous refinement. By structuring data in standardized formats, DPPs also raise the level of automation—streamlining compliance and generating automated reports (e.g., ESG, EPD) while reducing manual data handling and errors. These capabilities align with industry sustainability metrics and support regulatory compliance with forthcoming EU Green Deal and Circular Economy Action Plan measures. Improved energy efficiency and reporting automation translate into lower operating and administrative costs, which—together with savings from increased material recovery and reduced landfill fees—can offset initial DPP implementation expenses over time; preliminary estimates from comparable digitalization projects suggest payback periods of 2–4 years, with additional gains possible when monetized carbon savings are considered.

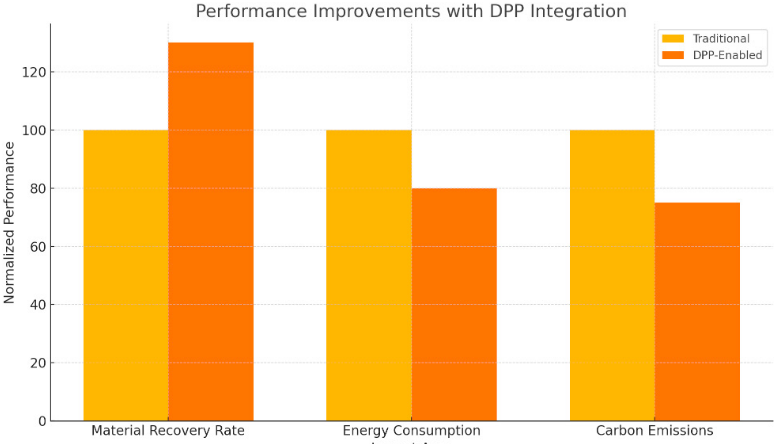

Figure 2: Comparison of performance indicators between traditional and DPP-enabled timber waste managements

From an environmental perspective, DPP adoption is expected to reduce GHG emissions associated with timber waste management by up to 25%, primarily due to higher recovery rates that displace virgin timber extraction and more targeted upcycling efforts that extend product lifecycles. The same structured data foundation enables automated and higher-quality operational decisions (e.g., real-time sorting rules, treatment set-points, procurement choices), improving consistency and auditability across projects. By providing stakeholders with real-time information on carbon footprint, embedded material emissions, and process-related impacts, DPPs can inform greener procurement decisions and facilitate the creation of carbon-optimized construction products. These benefits—especially when viewed in relation to their costs—highlight the potential for DPPs to serve as a financially viable and scalable enabler of circular transformation in the construction sector, offering tangible gains in efficiency, transparency, automation, decision quality, and sustainability. These benefits are amplified when DPP data is integrated with other digital platforms, such as Building Information Modeling (BIM) and LCA tools, enabling whole-project sustainability assessments. Overall, the expected results of this study point to DPPs as a high-impact enabler of circular transformation in the construction sector, offering tangible gains in efficiency, transparency, and sustainability.

The reported figures of a 30% increase in material recovery, 20% energy savings, and 25% reduction in GHG emissions are projections derived from preliminary simulations conducted during the early development of the AeonTrace-based workflow. These simulations combined baseline operational data from partner facilities with modeled process improvements based on DPP-enabled sorting, treatment optimization, and recovery routing. The assumptions included: elimination of redundant sorting steps, improved classification accuracy through automated scanning, and reduction of virgin material demand via upcycling. The reported percentages represent **best-case scenario estimates** under these modeled conditions and are intended to illustrate potential performance gains, which will be further validated in ongoing pilot trials.

7 Discussion

The findings of this study confirm the strong potential of DPP to support circular economy goals in the construction sector, particularly through the management of timber waste. The structured implementation presented here shows that DPP systems improve material traceability, process control, and quality documentation across every phase of the lifecycle. These outcomes support the model proposed by [7], who emphasize the importance of adaptable DPP structures that account for user roles, levels of automation, and different stages of a product's life. Our process-based approach applies that flexibility in practice, capturing data during contamination removal, mechanical sorting, toxicological screening, and upcycling preparation.

The case study validates that the integration of DPP into construction workflows can enhance both environmental and operational performance. When benchmarked against traditional approaches, the DPP-enabled process demonstrates higher recovery rates, more efficient sorting, and improved environmental data capture. This complements the findings of [18], which demonstrated that DPP use in modular timber components can support circular design and reuse. While their work focused on architectural reuse and structural applications, our results contribute a deeper look into the material preparation and quality control stages, which are necessary to ensure functional reuse.

However, the study also reveals several limitations. As highlighted in [19], a key barrier to implementing digital technologies in construction and demolition waste management is the lack of integration between data systems. Despite the ability of DPP to collect rich data, the absence of common standards limits interoperability with other platforms such as BIM and environmental assessment tools. Our case reinforces this point, showing that without alignment between systems, much of the DPP data remains underutilized or inaccessible during project planning and procurement. Another challenge concerns the interpretation of the data collected. The DPP framework in this study captures advanced indicators such as fiber orientation, density variation, and chemical contamination. While these offer strong potential for assessing material suitability, they also require trained professionals to interpret the results. As noted in [15], data is only useful when it is structured, accessible, and interpretable by stakeholders making product lifecycle decisions. Our study supports this view, indicating that the benefits of DPP can only be fully realized if the construction workforce is trained to use and trust the system.

While the model shows strong potential—lower emissions and higher recovery rates—its impact depends on consistent application. Deviations such as incomplete scanning or misclassification can compromise data accuracy and trust. Realizing the full benefits requires all supply chain actors to follow a transparent, standardized data protocol.

This study reinforces that DPPs can transform construction waste management but must be backed by regulatory alignment, stakeholder training, and common data frameworks. Only through this combined effort can DPPs scale as a viable solution for circular construction across regions and project types.

8 Conclusion

Integrating DPPs into construction offers a major opportunity to advance circular economy goals through digital transparency, material traceability, and data-driven decision-making. This study shows that DPPs improve timber waste lifecycle management by enabling precise tracking, quality control, and optimized recovery strategies. Real-time data embedded from deconstruction to post-treatment ensures valuable materials are identified, qualified, and reintegrated into productive cycles.

Recovered timber becomes a feedstock for engineered wood products such as CLT and glulam, produced through lamination, densification, or composite forming. With full lifecycle data attached, these products support transparency, sustainable design, and reuse—transforming construction waste into a resource for manufacturing in a closed-loop system.

Achieving this transition requires digital standardization, cross-sector collaboration, and supportive policy frameworks. Integration with existing systems (e.g., BIM, ERP), coupled with workforce training and stakeholder engagement, is essential for adoption. Future research should pilot these approaches in varied contexts to validate performance and refine scaling frameworks. Through DPP-enabled circularity, timber waste shifts from environmental liability to a driver of sustainable industrial transformation.

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