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RESEARCH ARTICLE

Smart Data Management in Circular Construction: A Sustainable Business Model for Stakeholder-Material Coordination

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Abstract

The transition of the construction sector toward a circular economy requires overcoming market fragmentation, weak data infrastructures, and persistent coordination gaps. This study investigates how a digital platform can support circular (de)construction by prioritizing smart data management over transactional material exchange. Through participatory action research involving 58 professionals from the French construction ecosystem, we co-designed a sustainable business model aligned with practitioner workflows and regulatory requirements. We characterized 21 user personas, identified eight value propositions, and proposed a freemium strategy to reduce adoption barriers. Using a quantified sustainable business plan, we evaluated economic, environmental, and social performance over a nine-year horizon. Results indicate that each €1 invested is projected to generate €5.10 in environmental value, €2.10 in social value, and €1.70 in economic return, with sensitivity analyses identifying pricing and market reach as key viability thresholds. By embedding compliance automation, secure data exchange, and coordinated logistics into existing routines, the findings demonstrate how digital infrastructures can operationalize circular economy principles within the French context and beyond.

Keywords Circular Economy · Built Environment · Digital Platform Design · Data Management · Participatory Action Research · Sustainable Business Model

1. Introduction

1.1. Background

The transition to a circular economy (CE) is increasingly recognized as a pathway to mainstream sustainable production and consumption, as it reduces demand for virgin resources and enables strategies such as reduce, reuse, and recycle (Geissdoerfer et al., 2017; Schroeder et al., 2019). In 2022, the European construction sector consumed 34% of raw materials and generated 38% of waste (Eurostat, 2024a, 2024b), making the sector a priority for CE implementation (Nikolaou & Tsagarakis, 2021). However, industry fragmentation (Hossain et al., 2020), poor material flow documentation (Ipsen et al., 2021), and price competition (Sanchez & Haas, 2018) continue to hinder progress toward circularity (Martin et al., 2024).

Recent policy developments in France and the EU reinforce the push toward circularity (Diemer et al., 2022). Since 2023, the French Extended Producer Responsibility for Products and Materials from the Construction Industry (REP PMCB) mandates pre-demolition audits and structures the collection of products, equipment, materials, and waste (PEMD) (Ministère de la Transition Ecologique, 2022). At the EU level, such

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directives as the European Green Deal, Circular Economy Action Plan, and Clean Industrial Deal aim to standardize sustainable resource management in construction (European Commission, 2020a, 2020b, 2025). These frameworks have catalyzed the demand for new digital solutions, aiming to enable traceability, facilitate compliance, and foster integrated data ecosystems to accelerate circular practices (Çetin et al., 2021).

In response to these regulatory pressures, digital platforms are emerging not only as logistical tools for waste valorization but also as catalysts for behavioral change, helping to make secondary materials more accessible, trusted, and competitively integrated into procurement (Konietzko et al., 2019). However, most existing platforms focus on transactional matchmaking (connecting buyers and sellers of reused materials) without addressing upstream coordination challenges, such as defining collection and procurement strategies, connecting qualified partners, and sharing pre-demolition audit data for reinsurance and regulatory compliance (Digital Deconstruction - Interreg North-West Europe, 2022a, 2022b). Without smart mechanisms to manage this information before materials circulate, even the most advanced trading systems face low adoption and scalability limits (Yu et al., 2022a).

Implementing CE strategies for construction materials requires, first and foremost, implementing CE principles in (de)construction data infrastructures. In line with this guiding principle, researchers designed an alternative digital platform concept called the Butterfly Matchmaking Model (BMM), which aims to facilitate the matching of stakeholders with material information throughout (de)construction processes. Rather than merely brokering two-sided material trades between building owners (as existing marketplaces do), this platform type enhances upstream coordination by managing multi-sided information exchange among auditors, designers, contractors, collectors, and suppliers (Menny et al., 2024).

1.2. Research Gap and Question

Although digital platforms are increasingly recognized as CE enablers (Chiaroni et al., 2021; Nussholz et al., 2024; Adholiya, 2025; Petrik et al., 2025), few studies have validated their alignment with real-world through participatory and practice-based research (Cambier et al., 2020; Coenen, 2022; Amarasinghe et al., 2025). As a result, many academic digital tools risk misalignment with real-world challenges, particularly regarding the structuring of information and coordination across actors (Van Den Berg, 2024), thereby limiting their usability, practical integration, and potential to trigger systemic change. In parallel, most business modeling efforts in real-world practice, including those in circular construction, remain economically focused and sideline social and environmental metrics (Svensson & Wagner, 2015; Baldassarre & Calabretta, 2024; De Angelis & Vesci, 2025). Consequently, digital innovations that may seem technically and financially promising may ultimately produce more ecological and social costs than benefits if their broader impacts are not critically assessed and mitigated.

To address the dual gap in platformization and sustainable business modeling for circular construction, participatory action research (PAR) was selected as the methodological framework because it enables iterative problem-solving and deep engagement of key stakeholder groups across the ecosystem, two crucial aspects in complex and fragmented sectors such as construction (Wielopolski & Bulthuis, 2023). Following the conceptual development of the BMM (Menny et al., 2024), this study advances the transition of this model toward a market-ready digital platform by adopting a strategic approach grounded in three interconnected objectives:

1. Develop a user-centered understanding of the (de)construction ecosystem,
2. Build a sustainable business model (SBM) that integrates circular economy principles,
3. Develop a sustainable business plan (SBP) that assesses the anticipated economic, environmental, and social outcomes.

These objectives structure the research design and are operationalized through three research questions:

- *RQ1: Who are the platform's user personas, and what are their specific challenges in the circular (de)construction ecosystem?*
- *RQ2: What SBM best addresses the identified needs and challenges of the platform's users?*
- *RQ3: How can a SBP effectively evaluate the long-term implementation conditions of such a platform?*

1.3. Research Contribution and Novelty

This paper presents a holistic roadmap for transitioning the BMM from concept to implementation. More broadly, the study contributes to the literature on circular business models by demonstrating how digital infrastructures can operationalize circular strategies through coordination mechanisms rather than transactional exchange. By structuring data coordination as a prerequisite to material circulation, the BMM-guided platform tackles systemic obstacles to scaling (de)construction practices. It demonstrates how digital infrastructure, when aligned with stakeholders' needs and sustainable business logic, can enhance the interplay between behavioral change and platform operations for CE deployment.

To the best of the authors' knowledge, no published research in the construction management literature provides a participatory business design of a digital infrastructure that manages the matching of stakeholders with material information for circular (de)construction. Key contributions include:

- a characterization of 21 user personas and the analysis of 56 user stories;
- a SBM structured around eight value propositions and a freemium revenue strategy;
- a data-informed SBP evaluating market feasibility, economic viability, environmental and social returns, and sensitivity to key adoption variables.

Beyond its contribution to CE in construction, this work demonstrates how innovative digital services can close the loop between recovery and procurement systems, making circular strategies the default in project planning and execution. This user-oriented approach ensures that the platform's primary impact is behavioral and systemic, not just technological. While grounded in the French context, the method and insights are transferable to other regions and sectors facing similar challenges in mainstreaming circular and sustainable practices.

The remainder of this paper proceeds as follows: Section 2 presents a concise overview of related works and relevant literature, establishing the theoretical foundations for the study. Section 3 outlines the research methods and design. It summarizes the approach used to characterize the platform's user personas, define an SBM, and project its SBP. Section 4 presents and discusses the results of the analysis, including their limitations and implications for future research. Section 5 concludes the paper by synthesizing the key findings and contributions.

2. Related Works

The following section presents the theoretical foundations and practical challenges associated with digital matchmaking platforms, persona-based design, sustainable business modeling, and sustainable business planning. It establishes the conceptual framework of the study.

2.1. Digital Matchmaking Platforms

The transition toward CE aims to decouple economic growth from raw material extraction via strategies like reduce, repair, reuse, and recycle (Potting et al., 2017; Sukhdev et al., 2017). In construction, however, CE remains hard to scale due to fragmented supply chains and weak coordination (Kirchherr et al., 2018). Digital platforms could help overcome these barriers by facilitating the matching of stakeholders with material information. Well-designed matchmaking mechanisms have the potential to standardize information exchange and enable ecosystem-wide collaboration (Eisenreich et al., 2021; Oluleye et al., 2023; De Wolf et al., 2024a). In this way, matchmaking does more than accelerate material circulation: it actively shapes how materials are specified, selected, collected, and (re)consumed, embedding circular principles into day-to-day procurement and project planning.

However, recent systematic reviews show that circular economy platforms remain largely transaction-oriented and weakly integrated with coordination mechanisms and sustainability outcomes (Blackburn et al., 2025). Most digital matchmaking platforms in Europe and comparable markets are defined as business-to-business (B2B) online marketplaces focused on helping the exchange of reused materials (Fortuna & Diyamandoglu, 2017; Digital Deconstruction - Interreg North-West Europe, 2022a, 2022b; Rückert et al., 2024). The two-sided transactional model often fails due to misalignment with construction-deconstruction timelines and logistical complexity (Yu et al., 2024). Limited supply volumes and high-cost uncertainty reduce the scalability of these platforms and their founders' openness to collaborative innovation (Rayna & Striukova, 2015; Sanchez & Haas, 2018; Hossain et al., 2020).

BMM offers an alternative. Instead of directly synchronizing material supply and demand, BMM links professionals and their data flow across (de)construction value chains. Its principle is based on two distinct but connected matchmaking loops, one dedicated to deconstruction and the other to construction, with collectors and dealers acting as central hubs. This approach shifts attention from short-term project-centered trades to longer-term profession-centered collaboration, thereby strengthening coordination and autonomy in circular practices (Menny et al., 2024).

2.2. User Persona Characterization

User personas, evidence-based profiles that capture user goals, challenges, and digital habits (Pruitt & Adlin, 2006), are an essential tool in human-centered design. They are commonly used in digital platform development (Miaskiewicz & Kozar, 2011) because they center real usage scenarios, and therefore foster user empathy and relevance (Kouprie & Visser, 2009; Heck et al., 2018; Tomlin, 2018).

In circular (de)construction, personas reflect a complex stakeholder ecosystem, from PEMD auditors and designers to contractors and regulators (Coenen et al., 2023). Understanding how these profiles interact, differ, and depend on each other is critical to identifying pain points and value creation opportunities (Ardolino et al., 2020). This persona diversity shapes platform functionality, engagement strategies, and business modeling (Ali et al., 2019).

Beyond their role as a design tool, personas provide a framework for mapping collaboration pathways across diverse stakeholder groups in multi-sided platforms (Salminen et al., 2022). When translated into user stories, personas offer concrete inputs for prioritizing features and aligning platform services with the industry's specific workflows (Cohn, 2004). They also identify complementarities and tensions among user roles, which can then be used to build the exclusive and shared value propositions that form the basis of SBM (Sinansari et al., 2023).

2.3. Sustainable Business Modeling

SBM integrates economic value with environmental and social returns (Evans et al., 2017). They go beyond shareholder profits to create value for a broader stakeholder set (Stubbs & Cocklin, 2008). The Business Model Canvas (BMC) (Osterwalder et al., 2010) has accordingly evolved to include sustainability layers. It consists of the nine original building blocks (customer segments, value propositions, channels, customer relationships, revenue streams, key resources, key activities, key partners, and cost structure) complemented by two additional ones: eco-social costs and eco-social benefits (Osterwalder et al., 2010).

As a subset of SBM, circular business models operationalize CE principles, like product-as-a-service, reuse, and closed-loop design, to achieve sustainable outcomes (Bocken et al., 2018; Geissdoerfer et al., 2018; Bocken et al., 2021). By embedding circular practices, circular business models help organizations contribute to sustainable development by maximizing resource efficiency, reducing environmental impact, and promoting social equity (Pieroni et al., 2019). Frameworks like the Ecocanvas have been developed to advance these models (Lewandowski, 2016; Daou et al., 2020).

Within the circular business model literature, strategies are often categorized according to their contributions to narrowing, slowing, or closing resource loops (Bocken et al., 2016), sometimes complemented by strategies aimed at regenerating natural systems within broader circular economy frameworks (Geissdoerfer et al., 2017). This typology provides a useful analytical lens for examining how digital infrastructures may support circular value creation, for instance by improving resource efficiency, extending product lifetimes, facilitating material recovery, or enabling restorative practices.

Researchers have attempted to integrate the SBM and circular business model frameworks into a unified canvas (Antikainen & Valkokari, 2016; Schaltegger et al., 2016). However, most remain overly academic or too abstract for practical implementation (Morioka et al., 2018; Martina & Oskam, 2021; Pepin et al., 2023). This study uses Osterwalder's Triple Bottom Line (TBL) BMC (Osterwalder et al., 2010) because it is accessible and has proven to be effective in participatory environments.

2.4. Sustainable Business Planning

While often assimilated, business models and business plans serve distinct and complementary purposes within an organization (Fui-Hoon Nah et al., 2001). A business model offers a strategic vision for how a company creates, delivers, and captures value (DaSilva & Trkman, 2014), while a business plan outlines the roadmap for operationalizing this vision over time (Delmar & Shane, 2003). This roadmap typically includes financial forecasts, market analyses, and execution strategies. The purpose of the business plan is to guide organizations, particularly early-stage ventures, through launch and growth challenges (Blank & Dorf, 2020).

SBP extends this logic by integrating the TBL framework, broadening traditional business planning to encompass social and environmental performance alongside economic metrics. In doing so, TBL encourages businesses to balance profit with considerations of people and the planet (Elkington, 1998). This approach enables organizations to project the cost of their operations and strategically guide decisions that minimize negative impacts while optimizing value across all three dimensions (Muzamwese et al., 2024). However, reviews of digital and sustainability-oriented business modeling highlight that SBM integration often remains partial or weakly operationalized, particularly when translating strategic sustainability ambitions into concrete planning and decision-support tools (Khan et al., 2021).

Startups benefit from assessing their environmental and social impacts alongside economic performance (Bocken, 2015; Carle & Rayna, 2024). In markets driven by exemplary action in regard to the environment, society, and governance, this 360-degree perspective is likely to attract impact-oriented investors and enhance a business's competitiveness (Serio et al., 2020). By modeling sustainable business practices early, startups can demonstrate leadership in advancing sectoral transitions; they can reinforce confidence among stakeholders now and set benchmarks for others to follow as the CE transition moves forward (Kasana et al., 2024).

3. Methods & Research Design

The following section presents the PAR methodology and three-stage research design of the study. A detailed description of the computational methods used to assess the business plan is provided in the supplementary material (Menny et al., 2026).

3.1. Participatory Action Research

To co-design the SBM of the digital matchmaking platform, this study engaged PAR with key stakeholders in the French circular construction ecosystem (Whyte et al., 1989; Greenwood et al., 1993; Fellows & Liu, 2021). PAR supports iterative refinement grounded in real-world feedback and advances open innovation principles by collaboratively engaging stakeholders across organizational boundaries (Füller et al., 2011; Fruijtier, 2018; Cornish et al., 2023). By integrating stakeholder insights into every iteration of the platform's development, we ensured that the design remained practical, aligned with market demands, and was validated (Otto & Jarke, 2019).

PAR is sometimes criticized for the challenges that the method faces, including maintaining institutional commitment and managing power imbalances (Wittmayer & Schäpke, 2014; Cornish et al., 2023). Moreover, due to its case-specific nature, PAR may be difficult to reproduce. However, the ability of PAR to foster mutual learning and contribute to broader theoretical debates makes it a valuable co-design methodology (McNiff, 2014). To address reproducibility concerns, we embedded PAR within a structured three-stage research design (Figure 1).

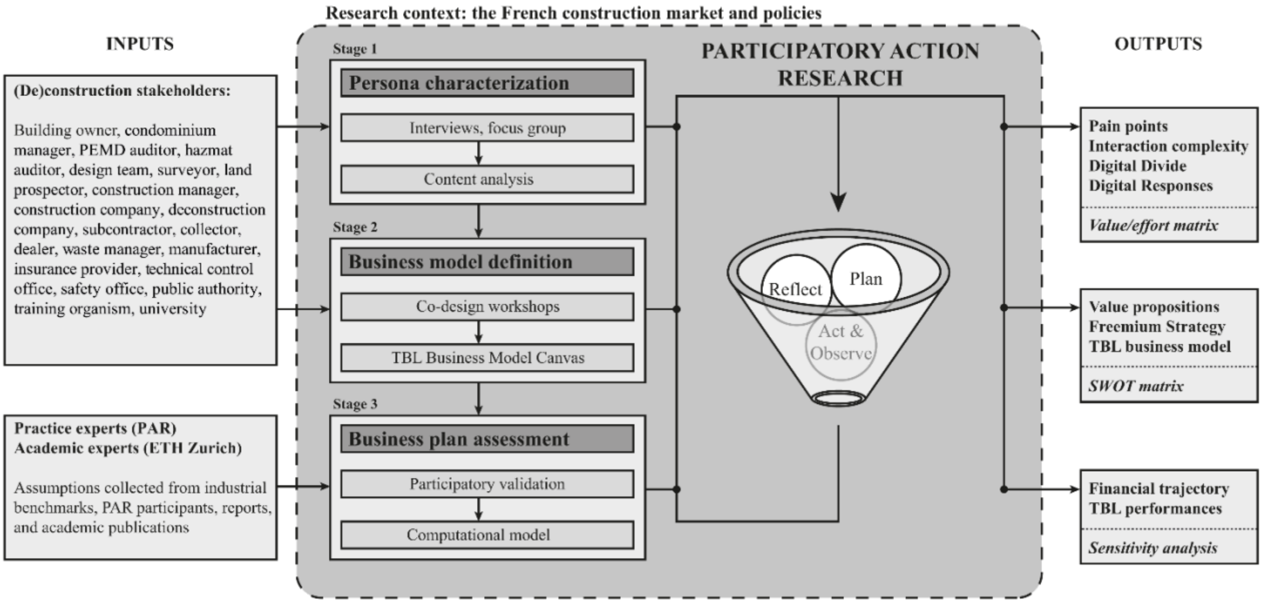

Figure 1. Research Design

The research took place within the French construction context and is grounded in the REP PMCB policy (Ministère de la Transition Ecologique, 2022). The PAR methodology was conducted with a project advisor in circular construction (often designated as a technical assistance provider in France). It was applied within the industrial partner's work environment, which includes its internal team members, as well as its clients (other companies).

Table 1 summarizes the composition of the PAR participant group, which included 58 professionals from across the (de)construction ecosystem.

Table 1. Participatory Action Research Participants

Number of participants	Organization type	Roles	Years of experience (mean)
3	Building ownership entity	CEO, economist, project leader	17
2	Condominium management firm	CEO, management supervisor	15
3	PEMD* diagnostic firm	CEO, project leader, auditor	4
2	Hazardous materials inspection	Project leader, auditor	11
4	Architectural and civil engineering firm	CEO, project leaders, BIM manager	14
3	Surveying agency	Project leaders, geographic information system manager	14
2	Land prospecting agency	Land development specialists	15
3	Construction management firm	Construction project managers, lead developer	18
4	Construction company	CEO, project leaders, craftsperson	18
2	Deconstruction company	CEO, project leader	17
3	Subcontracting firm	CEO, project leader, craftsperson	23
2	Material collection service	CEO, partnership manager, information system manager	12
3	Material distribution firm	Retail manager, account executive, warehouse manager	16

* "PEMD diagnostic" stands for product, equipment, material, and waste audit. It is the French equivalent of the term "pre-demolition audit" used in other countries.

Table 1 (cont.). Participatory Action Research Participants

Number of participants	Organization type	Roles	Years of experience (mean)
3	Waste management company	CEO, commercial manager, information system manager	18
3	Manufacturers	CEO, product managers	15
2	Insurance provider	Insurance product manager, policy administrator	15
2	Technical control office	CEO, compliance inspector	13
1	Safety oversight office	Safety manager	12
3	Public authority	Project leader, regulatory officials	13
3	Training organization	Trainers	6
5	University	Teacher, researchers, students	11

3.2. Three-Stage Research Design

3.2.1. Stage 1: Persona Characterization The first research stage focused on characterizing 21 user personas from the circular construction ecosystem. Personas were derived from stakeholder engagement sessions and defined according to participants' roles, objectives, current habits, pain points, and interactions within the system. Data were collected through semi-structured interviews, during which participants discussed their experiences, challenges, and needs related to implementing circular practices. The research team analyzed the collected data using qualitative content analysis and subsequently shared the resulting personas with participants for validation during focus groups and bilateral feedback sessions.

During the analytical phase, recurring operational barriers and coordination challenges were coded and associated with the professional roles represented in the ecosystem. Data collection and coding continued until thematic saturation was reached, meaning that no substantially new coordination challenges emerged from additional analysis. These coded themes were then translated into user stories using the standard formulation "As a [persona], I want [function], so that [outcome]," thereby operationalizing empirical insights into functional narratives that were then used to guide platform design. Overlapping needs were consolidated during participatory workshops, resulting in a final set of 56 user stories capturing the primary coordination challenges identified across personas. These user stories were subsequently discussed and prioritized with stakeholders using a value/effort prioritization matrix to identify the most impactful and feasible functionalities for platform development (Trieflinger et al., 2021). An illustrative example of the analytical transformation from personas and their pain points to user stories is presented in Table 2.

Table 2. Example of transformation from persona pain points to user stories

Persona	Pain point (from Table A1)	Derived user story (from Table A3)	Functional brick
Building owner	Difficulty finding contractors with circular construction expertise.	As a building owner, I want access to an online directory of professionals with verified circular construction experience and certifications, so that I can build a reliable team with proven expertise.	Professional Finder
PEMD auditor	Time-consuming documentation production.	As a PEMD auditor, I want a document generator that can automatically draft the Cerfa (PEMD) from various import file formats (PEMD diagnostic raw files) to various export file formats (txt, csv [CSTB]), so that I can minimize manual formatting and focus on verifying the accuracy of the information.	Data Editing & Document Generator.

Table 2 (cont.). Example of transformation from persona pain points to user stories

Persona	Pain point (from Table A1)	Derived user story (from Table A3)	Functional brick
Design team	Low visibility on circular products availability and performance: sourcing circular materials is difficult due to excessively fragmented information.	As a design team, I want access to a dedicated, searchable catalog that aggregates most of circular products available on the market, including reused items and those with circular economy certifications, so that I can efficiently adapt my design choices and prescribe sustainable products whenever possible, thereby enhancing the circularity of the project.	Material Finder
Deconstruction company	Coordination challenges with collectors, manufacturers, and waste managers.	As a deconstruction company, I want a collaborative online platform to coordinate schedules, logistics, and material handovers with collectors, manufacturers, and waste managers, so that I can minimize delays, reduce costs, and ensure a smooth workflow from deconstruction to material reuse or disposal.	Logistic & Event

To ensure transparency, the complete datasets generated during this stage, including persona descriptions, digital maturity assessments, and the full list of user stories, are provided in the supplementary material associated with this study (Menny et al., 2026; Tables A1–A3).

3.2.2. Stage 2: Business Model Definition The second research stage identified eight value propositions through co-design workshops with the PAR participants. These sessions maintained an open process, enabling participants to evaluate and refine emerging propositions iteratively. To translate the value propositions into SBM, we used the TBL BMC (Osterwalder et al., 2010). From this analysis, the platform's revenue model was defined. The final output of this stage was a consolidated TBL business model, which was then evaluated with participants using a strengths, weaknesses, opportunities, and threats (SWOT) matrix (Osterwalder et al., 2010).

3.2.3. Stage 3: Business Plan Assessment In the third and final stage, we evaluated the SBM in a scenario-based SBP. A computational model was developed to assess key dimensions, including the market potential, user acquisition rates, data and human resource needs, organizational carbon footprint, and TBL performance. The economic dimension focused on traditional financial metrics like the break-even period, payback period, and cash burn. The environmental dimension projected the platform’s direct organizational carbon footprint and the enabled emissions reductions associated with circular (de)construction projects impacted through platform adoption. The social dimension assessed both direct outcomes linked to platform operations (e.g., internal employment needs) and enabled outcomes associated with workforce upskilling and broader job creation. The three dimensions were compared using economic, environmental, and social return on investment (ROI) indicators, which were then combined into a sustainable ROI indicator that provides an integrated view of the platform’s long-term impact. Assumptions and risks were addressed and discussed using sensitivity analyses.

To clarify attribution, the model distinguishes between three types of outcomes. First, direct platform impacts (e.g., internal employment and organizational emissions) are calculated from the operational requirements of the platform itself. Second, platform-enabled user outcomes, such as professional certification and associated income gains, are modeled based on user participation rates and platform-supported training pathways. Third, system-level circular economy outcomes, including emissions reductions and reuse-related indirect job creation, are treated as shared ecosystem outcomes that depend on multiple actors and enabling conditions. For these system-level outcomes, impacts are modeled using a project-based unit of analysis, where the number of projects impacted by platform adoption is derived from projected active users and sectoral activity rates. Environmental and reuse-related impacts are then estimated using project-level proxies (e.g., average floor area per permit and material intensity) and attributed to the platform through an allocation factor

$AF_{benefits_{platform}}$. This factor represents the share of benefits attributable to the platform within a broader multi-actor system and is tested through sensitivity analysis.

The organizational carbon footprint was quantified following ISO 14064-1:2018 (International Organization for Standardization, 2018) and the Greenhouse Gas Protocol Corporate Standard, covering Scope 1, Scope 2, and relevant Scope 3 emissions (WBCSD & WRI, 2004). Emission factors were sourced from recognized French and EU databases. Details of the computational model, equations, system boundaries, data sources, and assumptions are provided in the supplementary material (Menny et al., 2026).

4. Results and Discussion

The following section summarizes and discusses the results that emerged from the PAR methodology and three-stage research design. The comprehensive results for each subsection can be found in the supplementary material (Menny et al., 2026).

4.1. Persona Characterization

4.1.1. Pain Points The analysis of the 21 user personas reveals substantial pain points in adopting circular practices across professions in the construction ecosystem (Menny et al., 2026; Table A1). These pain points cluster around four structural dysfunctions that hinder the implementation of the BMM.

First, pervasive knowledge gaps hinder ecosystem readiness. Circular practices remain poorly understood across many roles, especially regarding secondary material logistics and regulations. While training needs are recognized among professionals in the construction industry, scattered and low-visibility offerings block the upskilling needed for system-wide participation.

Second, a lack of standardization disrupts coordination. Critical documents, including PEMD diagnostics, tracking forms, and tender clauses, tend to be produced and shared in noninteroperable formats and through insecure and informal channels. These fragmented exchanges introduce inconsistencies and transaction costs that discourage circular experimentation and delay substitution of primary materials by secondary ones, weakening the environmental effectiveness of CE policies.

Third, regulatory fragmentation weakens enforcement. Public tenders rarely integrate circularity indicators, and stakeholders face diverging rules across regional jurisdictions. Without shared contractual references or audit benchmarks, building owners and project managers must navigate opaque and time-intensive procedures that discourage circular ambition.

Fourth, market immaturity inhibits adoption. Traceability concerns, insurance liabilities, and weak reverse supply chains reduce confidence in secondary products. The lack of centralized platforms to aggregate inventories and specifications further complicates circular procurement at scale. This market opacity inhibits recovered material flows, limiting circular product volumes and emissions reductions.

These pain points are not isolated. Even with clear project ambitions, these misalignments erode implementation, not from reluctance but from repeated failures to coordinate value loops across actors, processes, and tools. While the study focused on France, these dysfunctions confirm similar challenges previously reported in European, North American, Asian, and Oceanian contexts (Mahpour, 2018; Guerra et al., 2021; Yu et al., 2022b; Hossain et al., 2024; Ababio et al., 2025), and therefore suggest broader relevance.

4.1.2. Interaction Complexity Stakeholder interaction maps (Menny et al., 2026; Figures A1–A2) reveal two barriers to coordination: fragmented contracting relationships and unstructured information flows.

The contractual map indicates that the building owner must be the CE initiator; however, implementation is spread across loosely aligned downstream contracts involving auditors, designers, and executors. The late involvement of intermediaries (e.g., dealers, collectors) further undermines recovery efforts.

The information map highlights operational inefficiencies: identical documents, such as audit reports or technical specs, circulate through multiple intermediaries who often manually rework those documents to satisfy role-specific compliance. Without automation, version control, or secure exchange, delays make CE workflows impractical.

Mismatched authority and data flows prevent system coherence. Digital matchmaking platforms could help, but only if they are grounded in the stakeholders' everyday realities. Smart data management interventions cannot simply promote openness; they must align with practical routines.

4.1.3. Digital Divide Digital capabilities are uneven across the ecosystem (Menny et al., 2026; Table A2). Some professions, including surveyors, designers, and insurers, have adopted Building Information Modeling (BIM), Geographic Information Systems (GIS), and analytics. Other professions, such as (de)construction companies, collectors, and waste managers, continue to rely on manual routines. Three obstacles deepen the digital divide: poor interoperability, high adoption costs, and limited support for digitalization. Future digital infrastructures must offer modular integration and be led by actors who bear both technical and financial risks while providing free access opportunities and embedded support services.

4.1.4. Digital Responses Analysis of 56 user stories (Menny et al., 2026; Table A3) identifies four digital responses to the personas' needs (Figure 2):

1. Automated document generation alleviates the burden of compliance tasks for planning, auditing, and reporting.
2. Professional networking directories build reliable project teams and counter market fragmentation.
3. Secured data-sharing tools streamline document flow, improve traceability, and ensure regulatory alignment.
4. Logistics management dashboards coordinate site access, reuse events, and material handovers in real time.

These functions are not disruptive innovations; rather, they reflect the need for simple, interoperable, and persona-specific services. Their value lies in translating sustainable principles into operational practice within existing project routines, enhancing coordination rather than reconfiguring it.

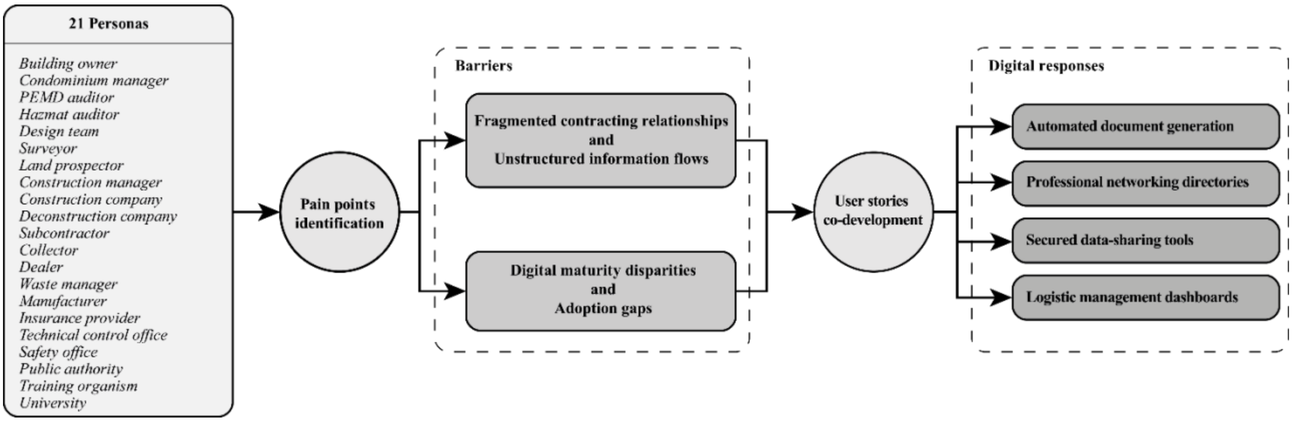

Figure 2. From Personas' Pain Points to Digital Responses

4.1.5. User Stories Prioritization for Strategic Rollout To facilitate discussion of how to best implement the various features of the platform, the 56 user stories were plotted on an impact–effort matrix with PAR participants (Menny et al., 2026; Figure A3)[3].

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[3] The numbering of user stories (e.g., #X) follows the convention used in (Menny et al., 2026; Table A3), which provides the full list and descriptions.

Four strategic priorities emerged:

1. Low-effort, high-impact features should lead development: the PEMD channels inventory (#12) and automated Waste Management and Organization Plan (SOGED) generator (#30–31, 47–49) offer immediate regulatory value and broad applicability, justifying their inclusion in early premium services.
2. Conversely, high-effort, low-impact features, such as material-taxonomy harmonization (#40) and circular safety coordination plans (#51), should be co-developed with institutional partners or deprioritized to avoid costly overhead.
3. Low-effort, low-impact features, including shared file drives (#2) and basic learning resources (#6, 11, 14), are ideal for a freemium offering that encourages user onboarding and platform familiarity.
4. High-effort, high-impact features, such as AI-driven circular product sourcing (#20, 27, 38, 39) and automated tender generators (#5, 25), are longer-term investments. They should be phased in progressively through iterative pilots once user adoption reaches maturity.

This sequencing reflects a pragmatic approach: build trust with simple tools, demonstrate value, and scale selectively through progressive onboarding. Priority should be given to services that ease compliance and enable cooperation among fragmented actors. These priority services tangibly save time while reinforcing ecosystem alignment by activating previously disconnected value loops.

4.2. Business Model Definition

4.2.1. Value Propositions Eight value propositions distilled from the user stories respond to entrenched inefficiencies in circular (de)construction operations. More than digital features, they strategically align data, materials, and workflows to facilitate traceability, compliance, and collaboration in B2B contexts. Collectively, they form a modular yet interdependent infrastructure that shifts circular (de)construction from aspirational policy to executable routine. Sequenced according to implementation priorities, these value propositions activate foundational data enablers that unlock higher-order functions such as networked coordination, collection, and procurement. The propositions are described in detail within the TBL BMC (Menny et al., 2026; Figures A4–A11) and summarized in Table 3.

From a theoretical perspective, the platform's value propositions can be interpreted through the circular strategy framework proposed by (Bocken et al., 2016), which distinguishes business model contributions to narrowing, slowing, and closing resource loops. Using this framework as an analytical lens helps clarify how the platform's digital functions support different circular mechanisms within the construction ecosystem. The platform primarily contributes to closing resource loops by facilitating the identification, coordination, and sourcing of reclaimed construction materials across projects. Other functions contribute to narrowing resource loops by reducing inefficiencies in documentation production and data exchange. In addition, training, professional networking, and circular procurement mechanisms support slowing resource loops by strengthening long-term circular competencies and embedding reuse practices within project governance. Overall, the platform's value propositions span several circular strategies, with three functions primarily supporting closing loops, three supporting slowing loops, and two contributing to narrowing loops. Regenerative strategies are not directly addressed, as the platform focuses on coordinating material recovery and reuse within the built environment rather than restoring natural ecosystems. Table 3 summarizes the dominant circular strategy associated with each value proposition.

Table 3. The Eight Value Propositions

Value proposition	What it does?	Why it matters?	Circular strategy contribution
Circular Channels Map	Aggregates regulatory references into a verified material-routing schema for PEMD auditors and building owners.	Simplifies navigation, anchors the ecosystem, and provides the foundation for reverse logistics.	Close resource loops
Circular Documents Generator	Automatically produces core regulatory and operational outputs (e.g., SOGED, PEMD tracking forms).	Reduces compliance bottlenecks, addresses project-owner risk aversion, and enables standardization, which is critical for multi-actor coordination.	Narrow resource loops
Circular Data Box	Transforms informal document workflows into auditable, interoperable data exchanges.	Enforces traceability across a fragmented ecosystem while providing secure data storage and exchange.	Narrow resource loops
Circular Training Matchmaker	Matches supply and demand for circular economy skillsets, beyond just listing courses.	Generates metadata that strengthens the credibility and growth of the networked user base.	Slow resource loops
Circular Professional Network	Builds a verified collaboration layer from onboarding and task histories.	Helps users find and retain trusted partners, especially valuable in tendering and procurement phases.	Slow resource loops
Circular Clauses Library	Provides jurisdiction-aware, legally-sound tender clauses.	Fills procurement's regulatory blind spots, enhances institutional confidence, and standardizes circular commitments.	Slow resource loops
Circular Material Sourcer	Integrates second-life products into digital procurement catalogs alongside conventional options.	Operationalizes circularity at the point of transaction, provided upstream systems are ready.	Close resource loops
Circular Events “Too Good to Recycle”	Opens professional demolition projects to reuse opportunities for individuals (B2C context).	Extends the platform's functionality beyond professionals, scaling circular logistics to the public once earlier layers are mature.	Close resource loops

4.2.2. Freemium Strategy The platform's freemium model is designed not simply for monetization but as a structural catalyst for digital inclusion and circular activation. It acknowledges two core barriers in the construction ecosystem: uneven digital maturity and low willingness to pay, especially among small and medium enterprises (SME) and waste operators. By prioritizing ecosystem enablement over immediate revenue, the model supports broad onboarding without forcing early behavioral or technological shifts.

All features may be made accessible free of charge during the initial deployment phase, both to reduce adoption barriers and to enable iterative refinement of product–market fit. Monetization is introduced once usage frequency demonstrates that specific tools have become routine and deliver measurable efficiency gains. In practice, empirical research on freemium design shows that the calibration of free usage limits and conversion barriers is critical for long-term viability: overly generous free tiers depress premium conversion, while poorly calibrated limits undermine perceived value (Kato & Dumrongsiri, 2022). This analytical insight reinforces the decision to structure the platform's freemium staircase around usage thresholds that signal habitual adoption before monetization. At this point, premium tiers can justifiably capture a portion of the resulting time and cost savings, aligning revenue with verified value creation.

This staircase approach ensures that monetization emerges only once utility is evident, which strengthens the platform's credibility in a regulatory landscape where compliance is increasingly a cost center and efficiency a competitive advantage. In this role, the platform positions itself as both enabler and buffer in the transition, helping under-digitized actors meet new demands while gradually building a user base for premium services.

Alternative revenue models were rejected due to their misalignment with the sector's structure and goals. Commission-based approaches disincentivize reuse by inflating costs in a margin-sensitive market. Advertising erodes trust in a compliance-oriented environment. Licensing shifts risk to early adopters, hindering diffusion. Freemium instead reflects delayed reciprocity: if access precedes monetization, then the platform can scale through relevance and system fit rather than extraction.

4.2.3. TBL Business Model The TBL BMC (Menny et al., 2026; Figure A12) consolidates the platform's value propositions and freemium strategy into a cohesive framework that generates economic, environmental, and social value. It is designed for infrastructural realism rather than market disruption, sequencing services according to ecosystem readiness and user maturity. By embedding modularity, the model ensures that digital interventions can be phased in progressively while maintaining coherence across different stakeholder groups.

Phased activation reduces friction for early adopters while enabling later sophistication through accumulated data and workflows. This stepwise growth avoids the binary logic of "scale-or-fail" that dominates many VC-backed Software-as-a-Service (SaaS) ventures, where short-term expansion is prioritized over long-term fit. Instead, the platform matures alongside sectoral rhythms and operational constraints, fostering resilience rather than dependency.

The model rejects transactional centralization typical of marketplaces, opting instead for infrastructural facilitation through its SaaS-based design. Rather than commodifying material flows or prioritizing volume over value, both of which undermine sufficiency-oriented strategies such as material reduction and avoidance, the platform provides data scaffolding and workflow orchestration to save time in circular processes. By avoiding a transaction-driven business model that incentivizes material throughput, the platform design also reduces the risk that efficiency gains translate into higher material turnover or demolition activity. Such design choices help address coordination costs and information asymmetry in fragmented construction supply chains while supporting informed decisions on material reuse and recovery.

While improved coordination can enable circular practices, digital platforms may also generate unintended systemic effects if efficiency gains trigger rebound dynamics. For example, reduced coordination costs and improved logistics could increase transport volumes, accelerate demolition activity, or promote higher material turnover rather than sufficiency-oriented strategies. Therefore, the platform design integrates several mitigating mechanisms. First, material sourcing tools prioritize geographically proximate reuse opportunities, thereby limiting transport-related rebound effects. Second, the platform's data infrastructure supports traceability and documentation of reuse decisions, encouraging project teams to prioritize renovation and material recovery over demolition and landfilling where feasible. Third, by embedding circular clauses, training, and professional networking into procurement and governance processes, the platform promotes longer-term capability building and responsible material stewardship rather than purely transactional exchange. These design choices position the platform as a coordination infrastructure that supports sufficiency-compatible circular practices rather than simply accelerating material circulation.

The freemium staircase further strengthens this position by enabling equitable participation, especially from under-digitized actors facing new regulatory obligations. Beyond economic accessibility, equity and inclusion also relate to the distribution of capabilities and opportunities within the circular transition. In the construction sector, smaller firms, subcontractors, and actors with limited digital resources often face structural barriers to participating in emerging circular practices. By providing shared coordination infrastructure, standardized documentation tools, and accessible training pathways, the platform lowers entry barriers and enables a broader range of actors to engage in circular construction processes. In this sense, the platform contributes not only to environmental performance but also to a more inclusive circular transition by redistributing access to information, coordination mechanisms, and CE competencies across the construction ecosystem, a dimension increasingly emphasized in research on spatial justice (Gonçalves et al., 2025).

Finally, embedded feedback loops enable the monitoring and steering of the platform's impacts, including emissions, inclusion, and data governance. These tools ensure that the platform's growth remains aligned with sustainability goals. However, achieving sufficient network density and managing the lag between activation and monetization remain key challenges for the platform's long-term viability.

Figure 3 illustrates how the value propositions and the freemium revenue strategy converge into the TBL business model, highlighting its economic, environmental, and social contributions.

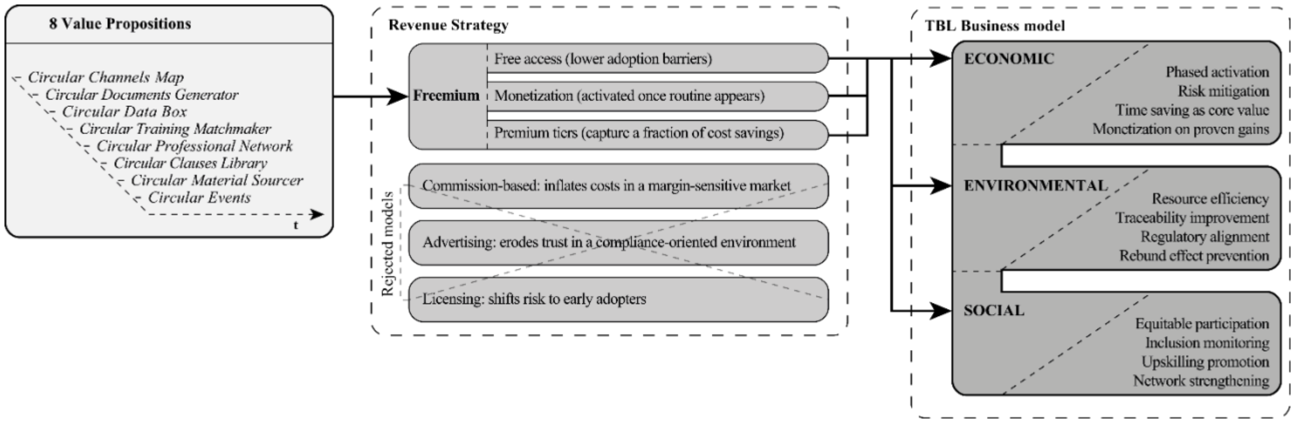

Figure 3. From Value Propositions to a TBL Business Model

4.2.4. SWOT Matrix The platform's SWOT matrix highlights a dynamic interplay of internal strengths, external contingencies, and emergent opportunities (Menny et al., 2026; Figure A13).

Strengths such as compliance automation, modular design, and traceable data flows provide infrastructural stability. They reduce operational friction while enabling interoperability across diverse value chains. By embedding CE workflows into digital routines, the platform serves as an intermediary that accelerates alignment between regulation and practice for material recovery.

Opportunities are equally significant. Policy instruments, emerging data standards, and shifting procurement models create windows where the platform can position itself as a trusted digital backbone. By capturing early PEMD data and facilitating transparent reporting, the platform has the potential to become indispensable to both regulators and enterprises navigating circular transitions.

At the same time, weaknesses such as low digital maturity or underdeveloped supply chains reflect systemic gaps rather than intrinsic limitations. Here, the platform can act recursively: early data capture and standardized signals can strengthen circular procurement and build confidence in secondary materials markets.

Threats remain concentrated in the volatility of policy frameworks. While regulatory shifts can accelerate adoption, they may also reverse momentum if political priorities change. Strategic resilience therefore depends on balancing institutional partnerships with grassroots adoption, ensuring the platform is embedded both top-down and bottom-up.

Ultimately, the platform's success depends on aligning governance, user practices, and technical capabilities. Rather than adding features in isolation, it must orchestrate legitimacy, ensure auditability, and distribute participation equitably.

4.3. Business Plan Assessment

The computational model, along with all calculations and assumptions, is given in the supplementary material (Menny et al., 2026).

4.3.1. Financial Trajectory The model indicates that the platform could reach financial breakeven in three years with the support of a lean operational model and pricing structure accessible to SME (€49/month for premium services). Breakeven is achieved with approximately 3,700 recurring premium users, a threshold considered to be attainable within an addressable market of 560,000 companies. This projected breakeven is driven by a total estimated cash burn of €2,700,000, which includes development, early operations, and freemium onboarding costs spread over the initial ramp-up phase.

Yet it is the seven-year payback horizon that signals the platform's transition from a catalytic intervention to a self-sustaining infrastructure. While breakeven confirms immediate viability, payback reflects the cumulative recovery of invested capital and the emergence of sustainable value flows. This temporal asymmetry between early breakeven and longer-term payback reflects a deliberate strategy of financial sustainability. This strategy avoids the fragility of premature scaling. After seven years of activity, the model is embedded in compliance, procurement, and reporting systems. At this point, it transitions from user acquisition to value extraction and retention. Ultimately, this cash flow structure reinforces the platform's positioning as a long-term coordination mechanism, rather than a high-growth speculative asset.

4.3.2. Triple Bottom Line Performances The platform's financial model generates a cumulative economic ROI (CEcoROI) of 169% after nine years of activity, with annual EcoROI reaching 204%. This growth is driven by the scaling of premium subscriptions and increased operating efficiency. Economic value creation rises from €66,000 in Year 1 to over €16,000,000 in Year 9, while total costs follow a proportional but manageable curve, peaking at €7,960,000. These trends demonstrate robust financial resilience without sacrifice of accessibility or modularity.

On the environmental side, the model forecasts over 530,000 tons of CO_2e avoided after nine years, with annual reduction peaking at 157,000 tons of CO_2e. The platform's cost per ton of CO_2e saved drops from €796 in Year 1 to just €56 in Year 9, surpassing parity with the French social cost of carbon (SCC) in Year 4 (Quinet et al., 2019). This inflection point positions the platform as a cost-effective carbon avoidance mechanism, opening eligibility for sustainable finance instruments and public subsidies. The cumulative environmental ROI (CEnvROI) reaches 513%, underscoring carbon mitigation as the most significant component of value creation.

Socially, the platform enables both upskilling and job creation. By Year 9, 1,600 professionals will have completed a certified training program designed to enhance their circular (de)construction skills. This upskilling is expected to generate an average salary increase of €4,000 per year, resulting in an estimated €8,500,000 in cumulative certification-linked income. Additionally, the platform supports 37 direct and 165 indirect sustainable jobs. The cumulative social ROI (CSocROI) reaches 207%, slightly outperforming the CEcoROI and reflecting strong labor-market externalities.

Taken together, these dimensions yield a cumulative sustainable ROI (CSusROI) of 889% after nine years of activity, equivalent to nearly €9 in public and private returns per euro invested. The breakdown of economic, environmental, and social ROIs is shown in Figure 4, where environmental ROI dominates, but social returns also exceed financial ones. This suggests that while the platform is economically sound, its true added value lies in accelerating systemic decarbonization and workforce transformation through embedded digital infrastructure.

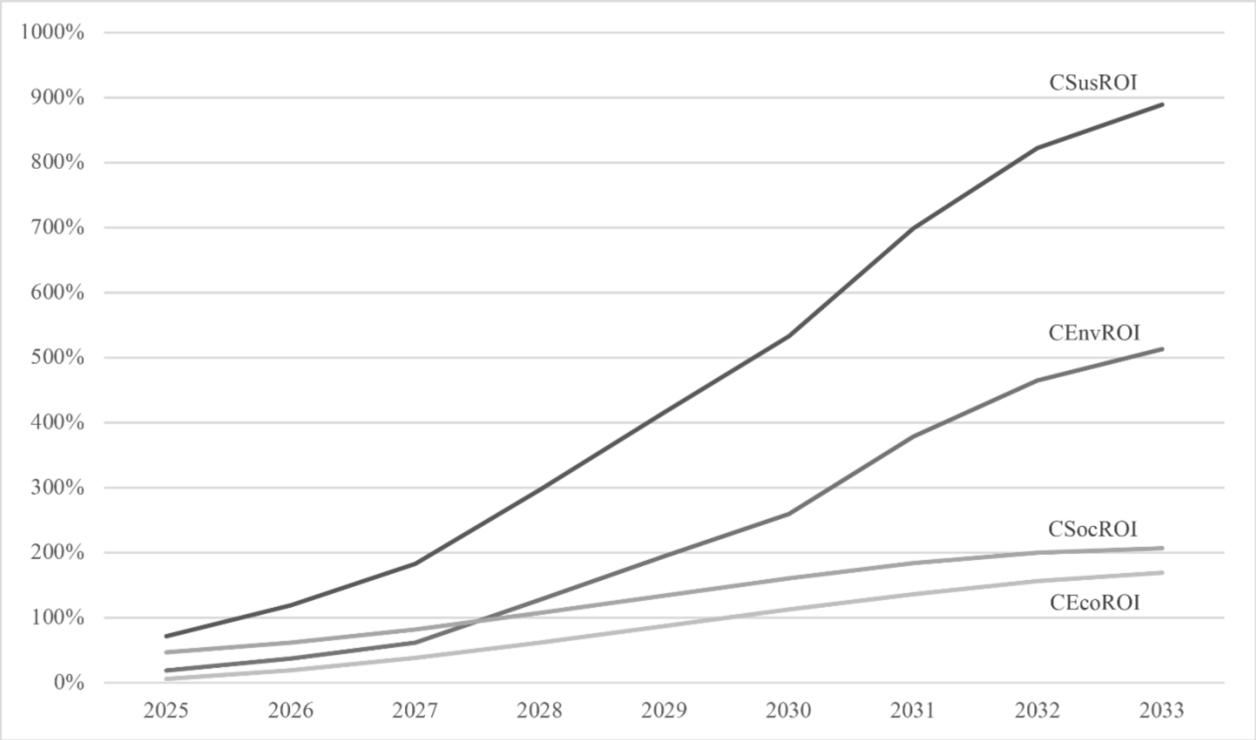

Figure 4. Comparison of Triple Bottom Line ROIs

4.3.3. Sensitivity Analysis A key dimension of the business model evaluation lies in understanding how platform-attributed benefits influence its sustainability profile. The analysis reveals that the CEnvROI remains positive over the nine-year horizon as long as the platform accounts for at least 2% of the carbon reductions associated with projects impacted by platform adoption. In the model, environmental benefits are estimated at the project level and aggregated annually based on the number of projects impacted by active platform users. Because these outcomes depend on multiple enabling conditions beyond the platform itself, only a share of these benefits is attributed to the platform through the allocation factor $AF_{benefits_{platform}}$. This parameter represents the proportion of environmental and reuse-related benefits that can reasonably be attributed to the platform's coordination functions within a broader multi-actor ecosystem. Digital infrastructures are widely recognized as critical enablers of CE scaling in the construction sector (De Wolf et al., 2024b). Accordingly, the attribution factor is treated as an allocation parameter rather than a causal estimate, and its baseline value of 10% represents a conservative share of benefits attributed to the platform.

For the social dimension, the sensitivity landscape shifts. The CSocROI is shown to be more dependent on the certification rate ($\alpha_{certification}$) than on the allocation factor $AF_{benefits_{platform}}$, because the latter only affects reuse-related indirect job creation in the model. Even under low-benefit attribution assumptions, CSocROI remains positive if just 2% of users obtain certified training, a threshold below the modeled 3% reference target. This result highlights a clear design implication: maximizing social value is less about reaching all users and more about ensuring robust certification pipelines. Investment in training infrastructure and recognition frameworks becomes a critical lever for not only real social impact but also derisking the model's social narrative.

Further insights emerge from comparative market-size scenarios. Modeling Switzerland, France, and the EU as distinct total addressable markets reveals a strong inverse correlation between market size and required subscription fees. In Switzerland, where the market is limited (~50,000 companies), a three-year breakeven requires a €443/month premium fee. France, with its 560,000 firms, offers a more accessible price point of €49/month, while a fully accessible EU market (~3,400,000 firms) would enable the same performance at €19/month. Though all three cases yield similar economic outcomes, their CSusROI profiles diverge sharply: smaller markets result in lower aggregated environmental and social gains, which limit systemic returns. This modeling data underscores why France is an optimal launchpad for the platform. France combines viable economics with scalable impact. The data further validates EU expansion as a second-stage growth vector once operational maturity is achieved.

In parallel, the need for dynamic pricing strategies is demonstrated by the model's sensitivity to marketing performance, reflected in conversion, churn, and win-back rates. Under pessimistic conditions (high churn, low conversion), a €58/month fee is required to maintain viability. In optimistic scenarios (low churn, high conversion), the fee can drop to €35/month. These outcomes validate the reference fee of €49/month as both strategically sound and adaptable. Notably, the CSusROI remains stable across these scenarios, indicating that engagement dynamics primarily influence financial metrics, not systemic returns. This resilience suggests that price flexibility is crucial for maintaining platform openness while ensuring financial self-sufficiency.

Taken together, these results reveal a key advantage of the platform model: its capacity to absorb ecosystem uncertainties through modular design and flexible monetization while maintaining strong sustainability profiles under a wide range of adoption and attribution scenarios. By explicitly quantifying thresholds for environmental, social, and economic viability, the business plan offers a transparent basis for investor confidence, public-sector alignment, and adaptive governance.

4.4. Limitations and future work

Despite its methodological and computational rigor, the study acknowledges some limitations regarding business design and generalizability. Real-world adoption may diverge from model projections due to competitor behavior and regulatory volatility, especially under evolving REP PMCB policy in France and similar legislation elsewhere. Business plan assumptions, while conservatively framed, warrant further validation via pilot testing.

The empirical setting of this research is the French construction sector and its associated regulatory environment. In particular, elements of the model rely on parameters derived from the REP PMCB policy framework and related documentation requirements such as PEMD diagnostics and SOGED procedures. These regulatory structures influence both the operational workflows considered in the platform design and the assumptions used in the sustainable business plan.

At the same time, the coordination challenges identified through the participatory action research are not unique to the French context. Fragmented contracting relationships, inconsistent documentation practices, limited interoperability between actors, and uneven digital maturity across the construction value chain have been widely reported in circular construction research across multiple regions. In this regard, the platform should be understood as a coordination infrastructure whose core logic (facilitating structured data exchange, professional matchmaking, and circular material sourcing) can be adapted to different regulatory environments. Context-specific elements such as regulatory documentation formats, market size assumptions, or national carbon accounting benchmarks would require adjustment when implementing the model in other jurisdictions.

Regional variation in CE maturity, legal frameworks, and cultural practices may therefore affect implementation pathways and adoption dynamics. Future research should test the adaptability of the proposed platform model through pilot implementations in different national contexts and compare how regulatory environments influence adoption and performance outcomes.

Although the TBL framework enabled stakeholder engagement and early-stage sustainability assessment, it may not fully capture the systemic and qualitative benefits of circular construction (Rambaud & Richard, 2015; Wuni, 2022). Building on these limitations, future work should focus on cross-country adaptation trials, hybrid revenue models, and the integration of broader sustainability metrics, including those related to water and land use.

5. Conclusion

This paper has presented a comprehensive roadmap for transitioning the Butterfly Matchmaking Model (Menny et al., 2024) from concept to implementation. Through a participatory action research methodology, we translated stakeholder pain points into user stories and value propositions, ultimately converging into a freemium-based Triple Bottom Line business model. These results demonstrate how digital infrastructures can act as enabling backbones, facilitating collaboration, compliance, and traceability while streamlining circular workflows.

Beyond its empirical grounding in practitioners' routines, the study advances the academic debate on sustainable business models in two distinct ways. First, it demonstrates that digital platforms can move beyond transaction-driven logics to serve as upstream coordinators, thereby supporting a broader range of circular strategies and stakeholders. Second, it operationalizes the Triple Bottom Line in both design and evaluation phases, offering one of the first quantified assessments of economic, environmental, and social returns of a freemium-based digital platform in circular construction. More broadly, by combining participatory action research, platform design methodologies, and computational sustainability assessment within a single framework, the study demonstrates a replicable approach for developing and evaluating digital coordination infrastructures that support circular transitions.

While the computational model and return on investment projections are tailored to the French regulatory and market context, particularly under the REP PMCB policy framework, the underlying coordination challenges of contractual fragmentation, limited traceability, and uneven digital maturity are consistently reported across both European and non-European regions, including in low- and middle-income countries. This suggests that the proposed platform architecture is not nationally bound but internationally transferable, provided it is adapted to local regulatory and market environments. Its core mechanisms (i.e., structured data exchange, professional matchmaking, and integration of circular materials into procurement workflows) can be recalibrated to different policy frameworks, market structures, and sustainability metrics. Importantly, the platform's non-transactional coordination architecture reduces incentives that would promote material throughput, thereby supporting informed reuse decisions and more sufficiency-compatible circular practices.

The study, therefore, contributes both a viable platform blueprint and a conceptual foundation for scaling digital infrastructures that enable systemic circularity in diverse contexts. More broadly, the findings suggest that the scaling of circular practices in complex sectors such as construction may depend less on isolated material innovations than on the development of shared coordination infrastructures that align fragmented actors and information flows. Digital platforms designed as coordination infrastructures, rather than transactional marketplaces, may therefore play a critical role in enabling systemic circular transitions across industries characterized by high fragmentation and information asymmetries.

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Authors' Contributions Thibaut Menny: Conceptualization; Data curation; Formal analysis; Funding acquisition; Investigation; Methodology; Project administration; Resources; Software; Validation; Visualization; Writing - original draft; Writing - review & editing. **Stéphane Le Guirriec:** Conceptualization; Funding acquisition; Resources, Supervision; Validation; Writing - review & editing. **Catherine De Wolf:** Conceptualization; Funding acquisition; Resources, Supervision; Validation; Writing - review & editing.

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Data availability The datasets generated and analyzed during the current study are openly available in Zenodo at https://doi.org/10.5281/zenodo.17215530. Essential figures and tables are included in the manuscript; extended materials are provided in the repository to ensure transparency and reproducibility.

Declarations

Competing Interests The authors declare no competing interests.

Ethics Statement Ethical considerations were addressed in accordance with institutional research ethics guidelines. Participation was voluntary and conducted in professional roles within a participatory action research framework. No personally identifiable or sensitive personal data were collected.

AI Use During the preparation of this work, the authors used Grammarly and ChatGPT in order to improve the readability and language of the manuscript. After using these tools, the authors reviewed and edited the content as needed and take full responsibility for the content of the published article.

References

Ababio, B. K., Lu, W., Agyekum, K., & Ghansah, F. A. (2025). Enhancing circular construction through procurement: A conceptual stakeholder-centric collaborative framework for sustainable outcomes. Environmental Impact Assessment Review, 112, 107784. https://doi.org/10.1016/j.eiar.2024.107784

Adholiya, A. (2025). Evaluating the Impact of Digitalization on Circular Economy Growth: Insights from Structural Equation Modelling. Circular Economy and Sustainability. https://doi.org/10.1007/s43615-025-00685-2

Ali, F., Stewart, R., Boks, C., & Bey, N. (2019). Exploring "Company Personas" for Informing Design for Sustainability Implementation in Companies. Sustainability, 11(2), Article 2. https://doi.org/10.3390/su11020463

Amarasinghe, I., Stewart, R. A., Sahin, O., & Liu, T. (2025). Enhancing construction material circularity: An integrated participatory systems model. Sustainable Production and Consumption, 57, 106–120. https://doi.org/10.1016/j.spc.2025.05.012

Antikainen, M., & Valkokari, K. (2016). A Framework for Sustainable Circular Business Model Innovation. Technology Innovation Management Review, 6, 5–12. https://doi.org/10.22215/timreview/1000

Ardolino, M., Saccani, N., Adrodegari, F., & Perona, M. (2020). A Business Model Framework to Characterize Digital Multisided Platforms. Journal of Open Innovation: Technology, Market, and Complexity, 6(1), 10. https://doi.org/10.3390/joitmc6010010

Baldassarre, B., & Calabretta, G. (2024). Why Circular Business Models Fail And What To Do About It: A Preliminary Framework And Lessons Learned From A Case In The European Union (Eu). Circular Economy and Sustainability, 4(1), 123–148. https://doi.org/10.1007/s43615-023-00279-w

Blackburn, O., Ritala, P., Keränen, J., & Bocken, N. (2025). Circular Economy Platforms: A Systematic Review. Business Strategy and the Environment, 1(32). https://doi.org/10.1002/bse.70307

Blank, S., & Dorf, B. (2020). The Startup Owner's Manual: The Step-By-Step Guide for Building a Great Company. Wiley.

Bocken, N. (2015). Sustainable venture capital – catalyst for sustainable start-up success? Journal of Cleaner Production, 108, 647–658. https://doi.org/10.1016/j.jclepro.2015.05.079

Bocken, N., de Pauw, I., Bakker, C., & van der Grinten, B. (2016). Product design and business model strategies for a circular economy. Journal of Industrial and Production Engineering, 33(5), 308–320. https://doi.org/10.1080/21681015.2016.1172124

Bocken, N., Schuit, C., & Kraaijenhagen, C. (2018). Experimenting with a circular business model: Lessons from eight cases. Environmental Innovation and Societal Transitions, 28, 79–95. https://doi.org/10.1016/j.eist.2018.02.001

Bocken, N., Weissbrod, I., & Antikainen, M. (2021). Business Model Experimentation for the Circular Economy: Definition and Approaches. Circular Economy and Sustainability, 1(1), 49–81. https://doi.org/10.1007/s43615-021-00026-z

Cambier, C., Galle, W., & De Temmerman, N. (2020). Research and Development Directions for Design Support Tools for Circular Building. Buildings, 10(8), Article 8. https://doi.org/10.3390/buildings10080142

Carle, A., & Rayna, T. (2024). Where to start? Exploring how sustainable startups integrate sustainability impact assessment within their entrepreneurial process. Journal of Management & Organization, 30(1), 148–164. https://doi.org/10.1017/jmo.2023.46

Çetin, S., De Wolf, C., & Bocken, N. (2021). Circular Digital Built Environment: An Emerging Framework. Sustainability, 13(11), 6348. https://doi.org/10.3390/su13116348

Chiaroni, D., Orlandi, M., & Urbinati, A. (2021). The Role of Digital Technologies in Business Model Transition Toward Circular Economy in the Building Industry. In D. R. A. Schallmo & J. Tidd (Eds.), Digitalization: Approaches, Case Studies, and Tools for Strategy, Transformation and Implementation (pp. 39–58). Springer International Publishing. https://doi.org/10.1007/978-3-030-69380-0_3

Coenen, J. (2022). Improving circular building under uncertainty and complexity: Exploring recent trends in the Netherlands. In A. Stefanakis & I. Nikolaou (Eds.), Circular Economy and Sustainability (pp. 337–357). Elsevier. https://doi.org/10.1016/B978-0-12-821664-4.00025-X

Coenen, J., van der Heijden, R. E. C. M., & van Riel, A. C. R. (2023). Expediting the Implementation of Closed-Loop Supply Chain Management: A Facilitated Case Study on Re-using Timber in Construction Projects. Circular Economy and Sustainability, 3(1), 93–124. https://doi.org/10.1007/s43615-022-00186-6

Cohn, M. (2004). User Stories Applied: For Agile Software Development (1st edition). Addison-Wesley Professional.

Cornish, F., Breton, N., Moreno-Tabarez, U., Delgado, J., Rua, M., de-Graft Aikins, A., & Hodgetts, D. (2023). Participatory action research. Nature Reviews Methods Primers, 3(1), Article 1. https://doi.org/10.1038/s43586-023-00214-1

Daou, A., Mallat, C., Chammas, G., Cerantola, N., Kayed, S., & Saliba, N. A. (2020). The Ecocanvas as a business model canvas for a circular economy. Journal of Cleaner Production, 258, 120938. https://doi.org/10.1016/j.jclepro.2020.120938

DaSilva, C. M., & Trkman, P. (2014). Business Model: What It Is and What It Is Not. Long Range Planning, 47(6), 379–389. https://doi.org/10.1016/j.lrp.2013.08.004

De Angelis, R., & Vesci, M. (2025). Circular Economy Business Models, Value Creation and Humane Entrepreneurship: A Micro-Sized and Social Enterprise Perspective. Circular Economy and Sustainability, 5(1), 147–160. https://doi.org/10.1007/s43615-024-00419-w

De Wolf, C., Cetin, S., & Bocken, N. (2024a). Can Digital Matchmaking Boost Circular Construction? Lessons from Reusing the Glass of Centre Pompidou. In M. R. Thomsen, C. Ratti, & M. Tamke (Eds.), Design for Rethinking Resources (pp. 667–675). Springer International Publishing. https://doi.org/10.1007/978-3-031-36554-6_42

De Wolf, C., Çetin, S., & Bocken, N. (Eds.). (2024b). A Circular Built Environment in the Digital Age. Springer International Publishing. https://doi.org/10.1007/978-3-031-39675-5

Delmar, F., & Shane, S. (2003). Does business planning facilitate the development of new ventures? Strategic Management Journal, 24(12), 1165–1185. https://doi.org/10.1002/smj.349

Diemer, A., Nedelciu, C. E., Morales, M. E., Batisse, C., & Cantuarias-Villessuzanne, C. (2022). Waste Management and Circular Economy in the French Building and Construction Sector. Frontiers in Sustainability, 3, 840091. https://doi.org/https://doi.org/10.3389/frsus.2022.840091

Digital Deconstruction - Interreg North-West Europe. (2022a). Analysis of digital trading platforms for construction products in North-Western Europe (p. 17). https://vb.nweurope.eu/media/20548/ddc_analysis-of-digital-trading-platforms-for-reused-materials_report.pdf. Accessed 15 January 2026

Digital Deconstruction - Interreg North-West Europe. (2022b). Digital trading platforms for reclaimed construction materials (p. 2). https://vb.nweurope.eu/media/20549/ddc_analysis-of-digital-trading-platforms-for-reused-materials_summary-and-platform-list.pdf. Accessed 15 January 2026

Eisenreich, A., Füller, J., & Stuchtey, M. (2021). Open Circular Innovation: How Companies Can Develop Circular Innovations in Collaboration with Stakeholders. Sustainability, 13(23), Article 23. https://doi.org/10.3390/su132313456

Elkington, J. (1998). Cannibals with Forks: The Triple Bottom Line of 21st Century Business. New Society Publishers.

European Commission. (2020a). The European Green Deal. https://ec.europa.eu/info/strategy/priorities-2019-2024/european-green-deal_en. Accessed 15 January 2026

European Commission. (2020b). Circular Economy Action Plan. https://eur-lex.europa.eu/legal-content/EN/TXT/?qid=1583933814386&uri=COM:2020:98:FIN. Accessed 15 January 2026

European Commission. (2025). Clean Industrial Deal. https://commission.europa.eu/topics/eu-competitiveness/clean-industrial-deal_en. Accessed 15 January 2026

Eurostat. (2024a). Material footprints—Details by final use of products [Dataset]. https://doi.org/https://doi.org/10.2908/ENV_AC_RMEFD. Accessed 15 January 2026

Eurostat. (2024b, September). Waste statistics. https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Waste_statistics. Accessed 15 January 2026

Evans, S., Vladimirova, D., Holgado, M., Van Fossen, K., Yang, M., Silva, E. A., & Barlow, C. Y. (2017). Business Model Innovation for Sustainability: Towards a Unified Perspective for Creation of Sustainable Business Models. Business Strategy and the Environment, 26(5), 597–608. https://doi.org/10.1002/bse.1939

Fellows, R. F., & Liu, A. M. M. (2021). Research Methods for Construction. Wiley.

Fortuna, L. M., & Diyamandoglu, V. (2017). Optimization of greenhouse gas emissions in second-hand consumer product recovery through reuse platforms. Waste Management, 66, 178–189. https://doi.org/10.1016/j.wasman.2017.04.032

Fruijtier, E. (2018). Action Research and Open Innovation: A Synergy? In Cross-Disciplinary Approaches to Action Research and Action Learning (pp. 19–39). IGI Global Scientific Publishing. https://doi.org/10.4018/978-1-5225-2642-1.ch002

Fui-Hoon Nah, F., Lee-Shang Lau, J., & Kuang, J. (2001). Critical factors for successful implementation of enterprise systems. Business Process Management Journal, 7(3), 285–296. https://doi.org/10.1108/14637150110392782

Füller, J., Hutter, K., & Faullant, R. (2011). Why co-creation experience matters? Creative experience and its impact on the quantity and quality of creative contributions. R&D Management, 41(3), 259–273. https://doi.org/10.1111/j.1467-9310.2011.00640.x

Geissdoerfer, M., Savaget, P., Bocken, N., & Hultink, E. J. (2017). The Circular Economy – A new sustainability paradigm? Journal of Cleaner Production, 143, 757–768. https://doi.org/10.1016/j.jclepro.2016.12.048

Geissdoerfer, M., Vladimirova, D., & Evans, S. (2018). Sustainable business model innovation: A review. Journal of Cleaner Production, 198, 401–416. https://doi.org/10.1016/j.jclepro.2018.06.240

Gonçalves, J. E., Rocco, R., Sitzoglou, M., Michail, N., Kupper, D., Grafakos, S., Djuraskovic, M., Veeckman, C., Pantelidis, N., Gkatsikos, A., Vrochidis, S., Dieguez-Seoane, A., Jover, A., Guerrero-Hidalga, M., Jelmini, A., Dommerholt, T., Amin, S., Visconti, C., & Francis, L. (2025). Spatial justice in participatory planning: An integrated framework and lessons from practice. Frontiers in Sustainable Cities, 7. https://doi.org/10.3389/frsc.2025.1656745

Greenwood, D. J., Whyte, W. F., & Harkavy, I. (1993). Participatory Action Research as a Process and as a Goal. Human Relations, 46(2), 175–192. https://doi.org/10.1177/001872679304600203

Guerra, B. C., Shahi, S., Mollaei, A., Skaf, N., Weber, O., Leite, F., & Haas, C. (2021). Circular economy applications in the construction industry: A global scan of trends and opportunities. Journal of Cleaner Production, 324, 129125. https://doi.org/10.1016/j.jclepro.2021.129125

Heck, J., Rittiner, F., Meboldt, M., & Steinert, M. (2018). Promoting user-centricity in short-term ideation workshops. International Journal of Design Creativity and Innovation, 6(3–4), 130–145. https://doi.org/10.1080/21650349.2018.1448722

Hossain, M. S., Lopa, N. Z., Khatun, M., & Rahim, S. T. (2024). Enablers of Circular Economy Implementation in Built Environment Sector of Developing Countries—Evidence from Bangladesh. Circular Economy and Sustainability, 4(3), 2287–2311. https://doi.org/10.1007/s43615-024-00392-4

Hossain, Md. U., Ng, S. T., Antwi-Afari, P., & Amor, B. (2020). Circular economy and the construction industry: Existing trends, challenges and prospective framework for sustainable construction. Renewable and Sustainable Energy Reviews, 130, 109948. https://doi.org/10.1016/j.rser.2020.109948

International Organization for Standardization. (2018). ISO 14064-1: Greenhouse gases—Part 1: Specification with guidance at the organization level for quantification and reporting of greenhouse gas emissions and removals. https://www.iso.org/obp/ui/en/#iso:std:iso:14064:-1:ed-2:v1:en. Accessed 15 January 2026

Ipsen, K. L., Pizzol, M., Birkved, M., & Amor, B. (2021). How Lack of Knowledge and Tools Hinders the Eco-Design of Buildings—A Systematic Review. Urban Science, 5(1), Article 1. https://doi.org/10.3390/urbansci5010020

Kasana, S., Chavan, M., Sedera, D., Cheng, Z., & Ganzin, M. (2024). Unlocking circular start-ups: A model of barriers. Business Strategy and the Environment, 33(3), 2546–2577. https://doi.org/10.1002/bse.3608

Kato, T., & Dumrongsiri, A. (2022). Designing freemium with usage limitation: When is it a viable strategy? Electronic Commerce Research and Applications, 53, 101153. https://doi.org/10.1016/j.elerap.2022.101153

Khan, I. S., Ahmad, M. O., & Majava, J. (2021). Industry 4.0 and sustainable development: A systematic mapping of triple bottom line, Circular Economy and Sustainable Business Models perspectives. Journal of Cleaner Production, 297, 126655. https://doi.org/10.1016/j.jclepro.2021.126655

Kirchherr, J., Piscicelli, L., Bour, R., Kostense-Smit, E., Muller, J., Huibrechtse-Truijens, A., & Hekkert, M. (2018). Barriers to the Circular Economy: Evidence From the European Union (EU). Ecological Economics, 150, 264–272. https://doi.org/10.1016/j.ecolecon.2018.04.028

Konietzko, J., Bocken, N., & Hultink, E. J. (2019). Online Platforms and the Circular Economy. In N. Bocken, P. Ritala, L. Albareda, & R. Verburg (Eds.), Innovation for Sustainability: Business Transformations Towards a Better World (pp. 435–450). Springer International Publishing. https://doi.org/10.1007/978-3-319-97385-2_23

Kouprie, M., & Visser, F. S. (2009). A framework for empathy in design: Stepping into and out of the user's life. Journal of Engineering Design, 20(5), 437–448. https://doi.org/10.1080/09544820902875033

Lewandowski, M. (2016). Designing the Business Models for Circular Economy—Towards the Conceptual Framework. Sustainability, 8(1), Article 1. https://doi.org/10.3390/su8010043

Mahpour, A. (2018). Prioritizing barriers to adopt circular economy in construction and demolition waste management. Resources, Conservation and Recycling, 134, 216–227. https://doi.org/10.1016/j.resconrec.2018.01.026

Martin, H., Chebrolu, D., Chadee, A., & Brooks, T. (2024). Too good to waste: Examining circular economy opportunities, barriers, and indicators for sustainable construction and demolition waste management. Sustainable Production and Consumption, 48, 460–480. https://doi.org/10.1016/j.spc.2024.05.026

Martina, R. A., & Oskam, I. F. (2021). Practical guidelines for designing recycling, collaborative, and scalable business models: A case study of reusing textile fibers into biocomposite products. Journal of Cleaner Production, 318, 128542. https://doi.org/10.1016/j.jclepro.2021.128542

McNiff, J. (2014). Writing and Doing Action Research. SAGE. https://books.google.fr/books?id=uNzSAwAAQBAJ

Menny, T., Le Guirriec, S., & De Wolf, C. (2024). The butterfly matchmaking model for circular construction: Towards a digital matchmaking platform tailored to French policy. Sustainable Production and Consumption, 49, 130–143. https://doi.org/10.1016/j.spc.2024.06.011

Menny, T., Le Guirriec, S., & De Wolf, C. (2026). Integrated Research Dataset for Smart Data Management in Circular Construction: Computational Modeling, Multi-Stakeholder System Mapping, and Platform Design Architecture [Dataset]. Zenodo. https://doi.org/10.5281/zenodo.17215530. Accessed 15 January 2026

Miaskiewicz, T., & Kozar, K. A. (2011). Personas and user-centered design: How can personas benefit product design processes? Design Studies, 32(5), 417–430. https://doi.org/10.1016/j.destud.2011.03.003

Ministère de la Transition Ecologique. (2022, June 10). Arrêté du 10 juin 2022 portant cahier des charges des éco-organismes, des systèmes individuels et des organismes coordonnateurs de la filière à responsabilité élargie du producteur des produits et matériaux de construction du secteur du bâtiment. Légifrance. https://www.legifrance.gouv.fr/jorf/id/JORFTEXT000045940429. Accessed 15 January 2026

Morioka, S. N., Bolis, I., & Carvalho, M. M. de. (2018). From an ideal dream towards reality analysis: Proposing Sustainable Value Exchange Matrix (SVEM) from systematic literature review on sustainable business models and face validation. Journal of Cleaner Production, 178, 76–88. https://doi.org/10.1016/j.jclepro.2017.12.078

Muzamwese, T. C., Heldeweg, M. A., & Franco-Garcia, L. (2024). Financing and Business Models for Scaling Up Sustainable Business Networks—Building a Circular Economy. Circular Economy and Sustainability, 4(3), 1655–1667. https://doi.org/10.1007/s43615-024-00348-8

Nikolaou, I. E., & Tsagarakis, K. P. (2021). An introduction to circular economy and sustainability: Some existing lessons and future directions. Sustainable Production and Consumption, 28, 600–609. https://doi.org/10.1016/j.spc.2021.06.017

Nussholz, J., Assmann, I. R., Kelly, P., & Bocken, N. (2024). Circular Business Models for Digital Technologies in the Built Environment. In C. De Wolf, S. Çetin, & N. Bocken (Eds.), A Circular Built Environment in the Digital Age (pp. 245–258). Springer International Publishing. https://doi.org/10.1007/978-3-031-39675-5_14

Oluleye, B. I., Chan, D. W. M., & Antwi-Afari, P. (2023). Adopting Artificial Intelligence for enhancing the implementation of systemic circularity in the construction industry: A critical review. Sustainable Production and Consumption, 35, 509–524. https://doi.org/10.1016/j.spc.2022.12.002

Osterwalder, A., Pigneur, Y., & Clark, T. (2010). Business model generation: A handbook for visionaries, game changers, and challengers. Wiley.

Otto, B., & Jarke, M. (2019). Designing a multi-sided data platform: Findings from the International Data Spaces case. Electronic Markets, 29(4), 561–580. https://doi.org/10.1007/s12525-019-00362-x

Pepin, M., Tremblay, M., Audebrand, L. K., & Chassé, S. (2023). The responsible business model canvas: Designing and assessing a sustainable business modeling tool for students and start-up entrepreneurs. International Journal of Sustainability in Higher Education, 25(3), 514–538. https://doi.org/10.1108/IJSHE-01-2023-0008

Petrik, D., Hiller, S., & Morar, D. (2025). Digital platforms for circular economy: Empirical development of a taxonomy and archetypes. Electronic Markets, 35(1), 60. https://doi.org/10.1007/s12525-025-00792-w

Pieroni, M. P. P., McAloone, T. C., & Pigosso, D. C. A. (2019). Business model innovation for circular economy and sustainability: A review of approaches. Journal of Cleaner Production, 215, 198–216. https://doi.org/10.1016/j.jclepro.2019.01.036

Potting, J., Hekkert, M. P., Worrell, E., & Hanemaaijer, A. (2017). Circular Economy: Measuring innovation in the product chain. https://www.pbl.nl/uploads/default/downloads/pbl-2016-circular-economy-measuring-innovation-in-product-chains-2544.pdf. Accessed 15 January 2026

Pruitt, J., & Adlin, T. (2006). The Persona Lifecycle: Keeping People in Mind Throughout Product Design. Elsevier.

Quinet, A., Bueb, J., Le Hir, B., Mesqui, B., Pommeret, A., & Combaud, M. (2019). La valeur de l'action pour le climat, une valeur tutélaire du carbone pour évaluer les investissements et les politiques publiques (Rapport de la commission). France Stratégie. https://www.strategie-plan.gouv.fr/files/files/Publications/Rapport/fs-2019-rapport-la-valeur-de-laction-pour-le-climat_0.pdf. Accessed 15 January 2026

Rambaud, A., & Richard, J. (2015). The "Triple Depreciation Line" instead of the "Triple Bottom Line": Towards a genuine integrated reporting. Critical Perspectives on Accounting, 33, 92–116. https://doi.org/10.1016/j.cpa.2015.01.012

Rayna, T., & Striukova, L. (2015). Open innovation 2.0: Is co-creation the ultimate challenge? International Journal of Technology Management, 69(1), 38–53. https://doi.org/10.1504/IJTM.2015.071030

Rückert, A., Balkute, G., & Dornack, C. (2024). Calculating the Environmental Benefit of Reuse Platforms. Circular Economy and Sustainability, 4(3), 1913–1936. https://doi.org/10.1007/s43615-024-00360-y

Salminen, J., Wenyun Guan, K., Jung, S.-G., & Jansen, B. (2022). Use Cases for Design Personas: A Systematic Review and New Frontiers. CHI Conference on Human Factors in Computing Systems, 1–21. https://doi.org/10.1145/3491102.3517589

Sanchez, B., & Haas, C. (2018). Capital project planning for a circular economy. Construction Management and Economics, 36(6), 303–312. https://doi.org/10.1080/01446193.2018.1435895

Schaltegger, S., Lüdeke-Freund, F., & Hansen, E. G. (2016). Business Models for Sustainability: A Co-Evolutionary Analysis of Sustainable Entrepreneurship, Innovation, and Transformation. Organization & Environment, 29(3), 264–289. https://doi.org/10.1177/1086026616633272

Schroeder, P., Anggraeni, K., & Weber, U. (2019). The Relevance of Circular Economy Practices to the Sustainable Development Goals. Journal of Industrial Ecology, 23(1), 77–95. https://doi.org/10.1111/jiec.12732

Serio, R. G., Dickson, M. M., Giuliani, D., & Espa, G. (2020). Green Production as a Factor of Survival for Innovative Startups: Evidence from Italy. Sustainability, 12(22), Article 22. https://doi.org/10.3390/su12229464

Sinansari, P., Salsabila, S. H., Hanoum, S., Lopatka, A., & Wlodarski, W. (2023). Identify Customer Element Through Empathy Map and User Persona. Procedia Computer Science, 27th International Conference on Knowledge Based and Intelligent Information and Engineering Sytems (KES 2023), 225, 4148–4156. https://doi.org/10.1016/j.procs.2023.10.411

Stubbs, W., & Cocklin, C. (2008). Conceptualizing a "Sustainability Business Model." Organization & Environment, 21(2), 103–127. https://doi.org/10.1177/1086026608318042

Sukhdev, A., Vol, J., Brandt, K., & Yeoman, R. (2017). Cities in the Circular Economy: The Role of Digital Technology. Google & the Ellen MacArthur Foudation. https://www.ellenmacarthurfoundation.org/topics/cities/publications. Accessed 15 January 2026

Svensson, G., & Wagner, B. (2015). Implementing and managing economic, social and environmental efforts of business sustainability: Propositions for measurement and structural models. Management of Environmental Quality: An International Journal, 26(2), 195–213. (world). https://doi.org/10.1108/MEQ-09-2013-0099

Tomlin, W. C. (2018). How to Create a Persona. In W. C. Tomlin (Ed.), UX Optimization: Combining Behavioral UX and Usability Testing Data to Optimize Websites (pp. 47–61). Apress. https://doi.org/10.1007/978-1-4842-3867-7_5

Trieflinger, S., Münch, J., Bogazköy, E., Eißler, P., Schneider, J., & Roling, B. (2021). How to Prioritize Your Product Roadmap When Everything Feels Important: A Grey Literature Review. IEEE International Conference on Engineering, Technology and Innovation (ICE/ITMC), 1–9. https://doi.org/10.1109/ICE/ITMC52061.2021.9570243

Van Den Berg, M. (2024). Digital Technology Use Cases for Deconstruction and Reverse Logistics. In C. De Wolf, S. Çetin, & N. Bocken (Eds.), A Circular Built Environment in the Digital Age (pp. 197–212). Springer International Publishing. https://doi.org/10.1007/978-3-031-39675-5_11

WBCSD, & WRI. (2004). The Greenhouse Gas Protocol: A Corporate Accounting and Reporting Standard. Revised ed. (p. 114). https://ghgprotocol.org/sites/default/files/standards/ghg-protocol-revised.pdf. Accessed 15 January 2026

Whyte, W. F., Greenwood, D. J., & Lazes, P. (1989). Participatory action research: Through practice to science in social research. American Behavioral Scientist, 32(5), 513–551. https://doi.org/10.1177/0002764289032005003

Wielopolski, M., & Bulthuis, W. (2023). The Better Building Initiative—A Collaborative Ecosystem Involving All Stakeholders as Catalyst to Accelerate the Adoption of Circular Economy Innovations in the Construction Sector. Circular Economy and Sustainability, 3(2), 719–733. https://doi.org/10.1007/s43615-022-00205-6

Wittmayer, J. M., & Schäpke, N. (2014). Action, research and participation: Roles of researchers in sustainability transitions. Sustainability Science, 9(4), 483–496. https://doi.org/10.1007/s11625-014-0258-4

Wuni, I. Y. (2022). Burden of proof beyond the triple bottom line: Mapping the benefits of circular construction. Sustainable Production and Consumption, 34, 528–540. https://doi.org/10.1016/j.spc.2022.10.006

Yu, Y., Yazan, D. M., Junjan, V., & Iacob, M.-E. (2022a). Circular economy in the construction industry: A review of decision support tools based on Information & Communication Technologies. Journal of Cleaner Production, 349, 131335. https://doi.org/10.1016/j.jclepro.2022.131335

Yu, Y., Junjan, V., Yazan, D. M., & Iacob, M.-E. (2022b). A systematic literature review on Circular Economy implementation in the construction industry: A policy-making perspective. Resources, Conservation and Recycling, 183, 106359. https://doi.org/10.1016/j.resconrec.2022.106359

Yu, Y., van den Berg, M., & Yazan, D. M. (2024). Circular (de)construction matchmaking: A matter of space and time. Journal of Industrial Ecology, 28(4), 868–884. https://doi.org/10.1111/jiec.13503

Table of abbreviations

Acronym	Definition
AI	artificial intelligence
B2B	business-to-business
B2C	business-to-consumer
BIM	Building Information Modeling
BMC	Business Model Canvas
BMM	Butterfly Matchmaking Model
CE	circular economy
CEcoROI	cumulative economic return on investment
CEnvROI	cumulative environmental return on investment
CSocROI	cumulative social return on investment
CSusROI	cumulative sustainable return on investment
GIS	Geographic Information Systems
PAR	participatory action research
PEMD	products, equipment, material, and waste
REP PMCB	Extended Producer Responsibility for Products and Materials from the Construction Industry
ROI	return on investment
SaaS	software-as-a-service
SBM	sustainable business model
SBP	sustainable business plan
SCC	social cost of carbon
SME	small and medium enterprises
SOGED	Waste Management and Organization Plan
SWOT	strengths, weaknesses, opportunities, and threats
TBL	Triple Bottom Line

Appendix

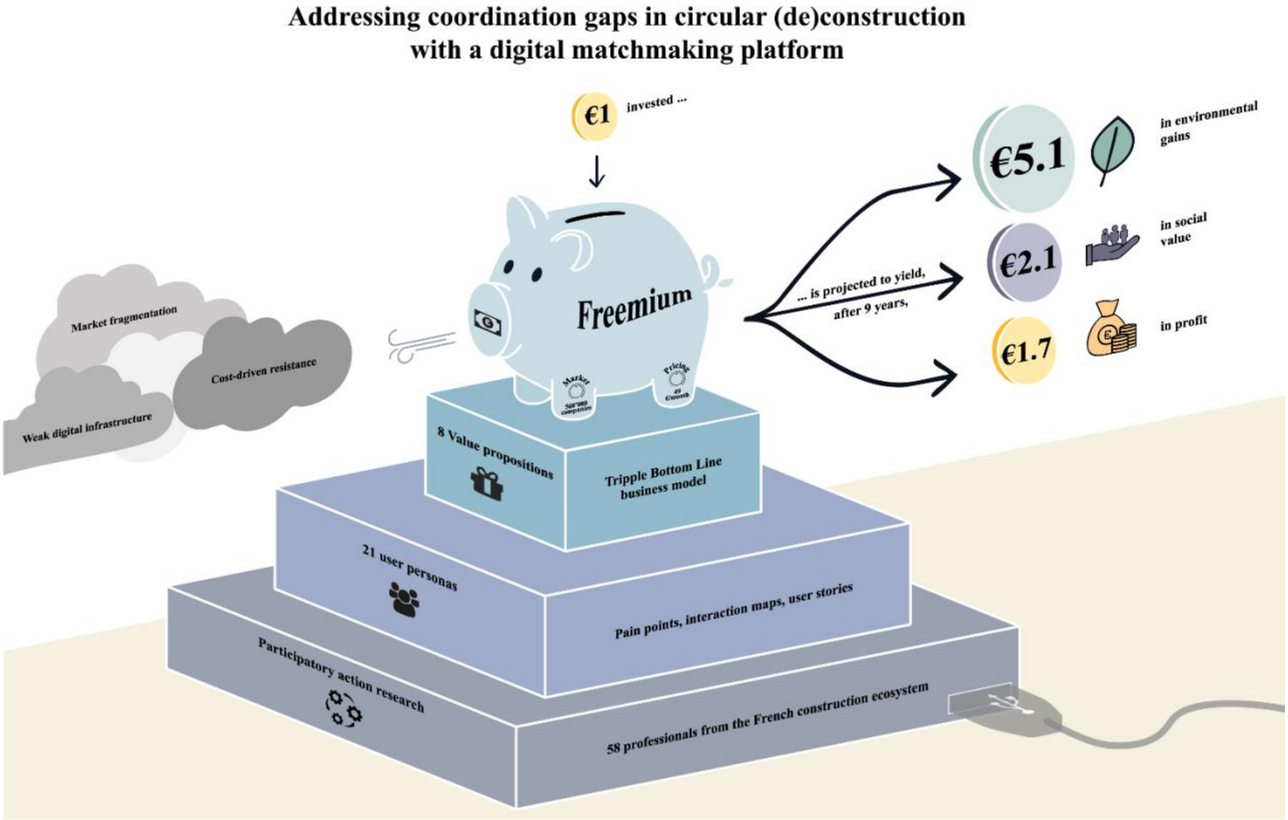

Figure A1. Graphical Abstract