

Article

A Digital Framework for the Implementation of the Circular Economy in the Construction Sector: Expert Opinions

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Abstract: The construction sector plays a significant role in resource consumption and waste generation, making the transition to a circular economy (CE) imperative for sustainability in this sector. This paper focuses on developing a framework for implementing CE principles in the construction sector, guided by expert opinions and insights. The main objective of this study was to enhance existing theoretical frameworks by incorporating feedback from construction experts to improve practical utility and applicability in real-world construction practices. By addressing key areas for enhancement, the revised framework facilitates the adoption of CE practices throughout the asset lifecycle, considering buildings from cradle to cradle. This research's methodology involved a comprehensive literature review to identify gaps in current frameworks related to CE implementation in the construction sector. Unstructured interviews with twenty construction experts were conducted to gather insights and recommendations for framework improvement. Data analysis highlighted the importance of integrating CE principles at various stages of the asset lifecycle, such as design, construction, and end-of-life phases. The key recommendations from experts include incorporating sustainable approaches, aligning with BIM models, and considering whole-life design aspects to promote circularity in the construction sector. By incorporating expert feedback and industry insights, the framework aims to guide practitioners toward more sustainable and resource-efficient construction practices, contributing to the broader field of CE implementation in the built environment.

Keywords: circular economy (CE); construction sector; sustainability; whole-life design; BIM models; expert opinions; digital framework; Materials Passports



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1. Introduction

1.1. The Circular Economy Approach in the Construction Sector

The circular economy (CE) concept has increasingly gained attention in recent years as a way to achieve more sustainable development and resource efficiency. CE aims to close the material loops and minimize waste generation by reducing, reusing, and recycling resources [1]. The construction sector is one of the most resource-intensive and waste-generating sectors in the world, accounting for 37.5% of the total waste generation in the EU [2]. Therefore, applying CE principles in the construction sector can have significant environmental and economic benefits, such as saving materials, energy and costs, enhancing innovation and competitiveness, and reducing greenhouse gas emissions [3].

The European Union proposed a CE model aimed at transforming production chains and consumption habits by converting waste into resources, effectively closing the production loop [4]. European Directive CEN/TC 350 mandates member states to legislate for the whole-life design of new buildings, considering operational and embodied carbon emissions, necessitating comprehensive assessments [5]. The “CEN/TC 350 Sustainability of Construction Works” committee focuses on developing standardized methods for assessing sustainability in alignment with the United Nations Sustainable Development Goals (UN SDGs) and the CE concept. Internationally, the ISO/TC 323 Circular Economy [6], established in 2019, provides transversal standards for the CE, potentially serving as a

foundation for specific activities. Within CEN/TC 350, the European Commission instituted a subcommittee on the circular economy (CEN/TC 350/SC1) to provide circular principles, guidelines, and requirements for the construction sector, facilitating the transition to a more sustainable CE in the built environment. This includes covering all stages of construction, from design to deconstruction and end-of-life scenarios.

However, the transition from a linear to a circular model in the construction sector is not straightforward and requires a holistic approach that involves multiple stakeholders and levels of analysis.

Several studies have explored the challenges facing and opportunities provided by the CE in the construction sector from different perspectives. For instance, some authors assessed the implementation of a CE in China, and identified some barriers and recommendations for improvement [7]. Others conducted a comprehensive literature review and proposed a framework to classify and understand the CE from three levels: micro (product or company), meso (industrial symbiosis or eco-industrial park), and macro (city or region) [8]. Pomponi and Moncaster (2017) critically reviewed the existing literature on the CE in the construction sector and highlighted the need for interdisciplinary research and collaboration among different disciplines and actors [9]. Through a critical review, some researchers conducted a thorough analysis of the barriers to implementing the circular economy (CE) in construction. They found common obstacles across approaches, mainly linked to organizational concerns. In particular, some studies referred to project–player coordination in digitalization and sustainability [10,11]. A study provided a detailed map for aiding construction sector stakeholders with developing strategies for a successful shift to a CE [12]. Others explored the socio-economic and environmental barriers to a holistic asset lifecycle approach to achieve a CE and suggested a pattern-matching method to identify the best practices and solutions [13]. Lastly, some authors studied construction-related concerns regarding the CE [14].

1.2. Improving the Understanding of the CE

Kirchherr et al. (2017) provided an overview of the current understanding of the CE concept by analyzing 114 CE definitions. They found that the CE is most frequently defined as a combination of reduce, reuse, and recycle activities and that it has few explicit linkages to sustainable development. They also critically discussed the various CE conceptualizations and their implications [15]. In 2022, Kirchherr et al. updated and extended the previous analysis of those 114 circular economy definitions. Kirchherr et al. found that the concept has seen both consolidation and differentiation in the five prior years and that definitional trends were emerging that may have more meaning for scholars than in practice. They also proposed a new framework for categorizing CE definitions based on their scope, rationale, and enablers [16]. Another area where clarity is required is the waste hierarchy and the “3 Rs” (reduce, reuse, and recycle). Authors provided clarification on the different ways of retaining the value of the resources and products in a CE by proposing a 10 Rs typology that covers both the production and consumption phases: refuse, rethink, reduce, reuse, repair, refurbish, remanufacture, repurpose, recycle, and recover [17]. They also aimed to provide clear and consistent terminology for CE concepts, such as downcycling and upcycling, and to show how they can be applied in practice. More recently, a study tried to clarify how businesses can apply CE principles to improve their environmental and social performance. The authors provided a list of 60 CE principles grouped into four categories: reduce, reuse, recycle, and reverse logistics [18].

Another way to improve the understanding of the CE is by providing frameworks to practitioners, such as to small and medium enterprises (SMEs) [19], for traceability [20], assessing circularity, or implementing the CE approach. Indeed, Rahla et al. (2021) proposed a framework for assessing the CE for buildings based on two segments: circular processes and circular impacts [21]. Circular processes are the actions that retain the value of products and systems, while circular impacts are the outcomes that reflect the goals of the CE. They also provided a comprehensive review of indicators for measuring both segments. The

framework was developed for the construction sector, dealing with the design, use, and end of life (EOL) of buildings and their components. The paper suggests three innovative aspects for implementing CE strategies in buildings: wise resource management, building design approaches, and digitalization of the building industry [21]. Another study provided a framework for using digital product passports (DPPs) and knowledge graphs (KGs), which represent the relationships between different entities, such as products, materials, processes, and stakeholders. The authors claimed that DPPs and KGs can help with information sharing, traceability, and transparency in the construction sector. The paper also discusses the main components and limitations of the framework [22].

1.3. Digitalization As an Enabler

Several studies argue that digitalization is another key factor that can enable and support the transition to a CE in the construction sector through building information modeling (BIM), the Internet of Things (IoT), artificial intelligence (AI), machine learning (ML), blockchain, cloud computing, and augmented reality (AR) [23]. These technologies can enable the collection, analysis, and exchange of data and information throughout the life cycle of buildings and infrastructure, from design and planning to construction, operation, and EOL management. This can facilitate the implementation of CE principles, such as designing for durability, adaptability and disassembly, optimizing resource use and waste management, extending the service life and functionality of products and components, and recovering and reusing materials at the end of their lives [24]. Some authors provided a comprehensive review of the uses of BIM to overcome barriers to the CE in the construction sector [25]. The outcome was the development of seven new BIM uses to guide and support practitioners in CE implementation. Others systematically reviewed the literature on the interplay between the CE and digital technologies and proposed a framework for digitalization-enabled CE. The study revealed that IoT and AI are crucial for the CE transition, that there are various barriers to overcome, and that a product-service system (PSS) is a key business model innovation for the CE [23].

Charef 2022 [26] explored the potential and challenges in applying the CE concept to the construction sector, especially in the context of the digitalization of the construction industry. The paper presents some arguments for and against the CE and the digitalization of the sector and proposes some recommendations for future research and practice. Another author argued that CE and digital technologies can help the construction sector reduce its environmental impact and achieve system change. A network governance model that fosters collaboration and innovation among various stakeholders in the building sector was proposed [27].

The existing theoretical frameworks based on BIM for implementing the CE approach show the asset phases and the stakeholder roles throughout the asset lifecycle [28]. Based on these previous theoretical works, the current study aimed to develop an improved digital framework for the implementation of the CE approach based on interviews with experts. Three objectives were fulfilled to achieve this aim:

- (i) To undertake an extensive literature review on the use of the circular economy (CE) approach for the built environment, with digitalization as an enabler,
- (ii) To identify and discuss improvements suggested by 20 experts interviewed to develop a theoretical BIM-based framework,
- (iii) To construct an improved BIM-based framework for the adoption of the CE approach.

This paper is structured into four sections: After having explored the CE and its application within the construction sector (Section 1), Section 2 briefly presents the methodology for the improvement in the theoretical framework, used as a basis for this study 2. In Section 3, the interview results, classified into five areas of improvement, are presented. Lastly, the conclusion and areas for further research are proposed in Section 4.

2. Methodology

This paper is extracted from a larger research project and more information about the method used could be found in previous publications, in particular, the boxes with the references ([28–30]) in Figure 1 have been achieved and described in three previous articles developed by the author (see Figure 1). The methodology process adopted for this paper is split into three stages. The first stage aims to prepare the interviews. It refers to the literature review ending in 2019, extracted from [29], who proposed a theoretical BIM-based framework that integrates the EOL as a phase in its own right, (illustrated as stage 1 in Figure 1).

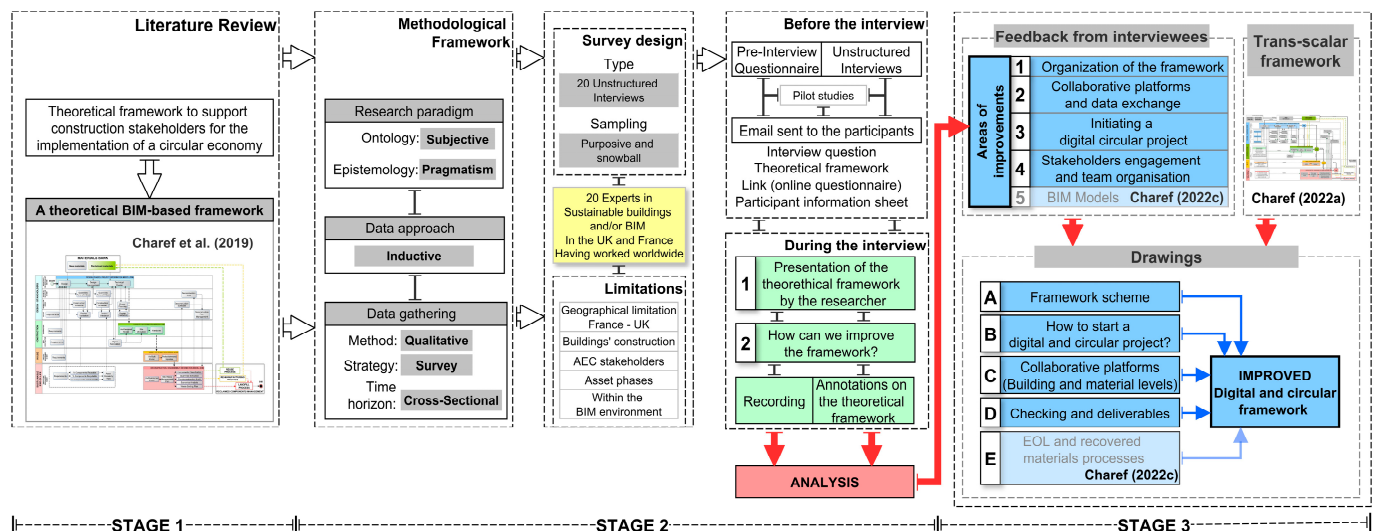


Figure 1. Details of the study methodology. The figure is designed by the author, but it includes three references [28–30].

2.1. Unstructured Interviews (Stage 2)

A pre-interview questionnaire (PIQ) was followed by unstructured interviews. The PIQ specifically aimed to assess the comprehension and the level of the application of sustainable approaches by the twenty construction experts selected for participation in the interviews. This preliminary information served as a valuable foundation allowing the author to gain a comprehensive understanding of the participants' backgrounds.

The unstructured interviews were conducted with the overarching objective of identifying areas for improvement in the theoretical BIM-based framework extracted from [29], which is reproduced in Figure 2, to enhance its practical utility for construction practitioners. To solicit expert opinions on the theoretical framework, unstructured interviews, characterized by their flexible and exploratory nature, were chosen as the preferred method. This approach was intended to establish rapport and foster a comfortable environment for interviewees, aligning with the advantages highlighted by some scholars, such as the flexibility and boundaryless exploration inherent in unstructured interviews [31].

For the collection of data, the author used two methods: annotating the theoretical framework sheet and recording the interviews. The use of recordings not only enabled the comprehensive review of discussions but also facilitated interaction with participants, ensuring a focus on the objectives of this investigation. The strategic recording of sessions to facilitate subsequent analysis and ensure accuracy and objectivity was notified by [32]. Participants were encouraged to actively engage with the theoretical framework sheet, adding or removing arrows and boxes, providing a tangible way for them to contribute to the discussion. The theoretical framework was employed for each interview, serving both as a dynamic tool for discussion and a means for the researcher to document pertinent notes.

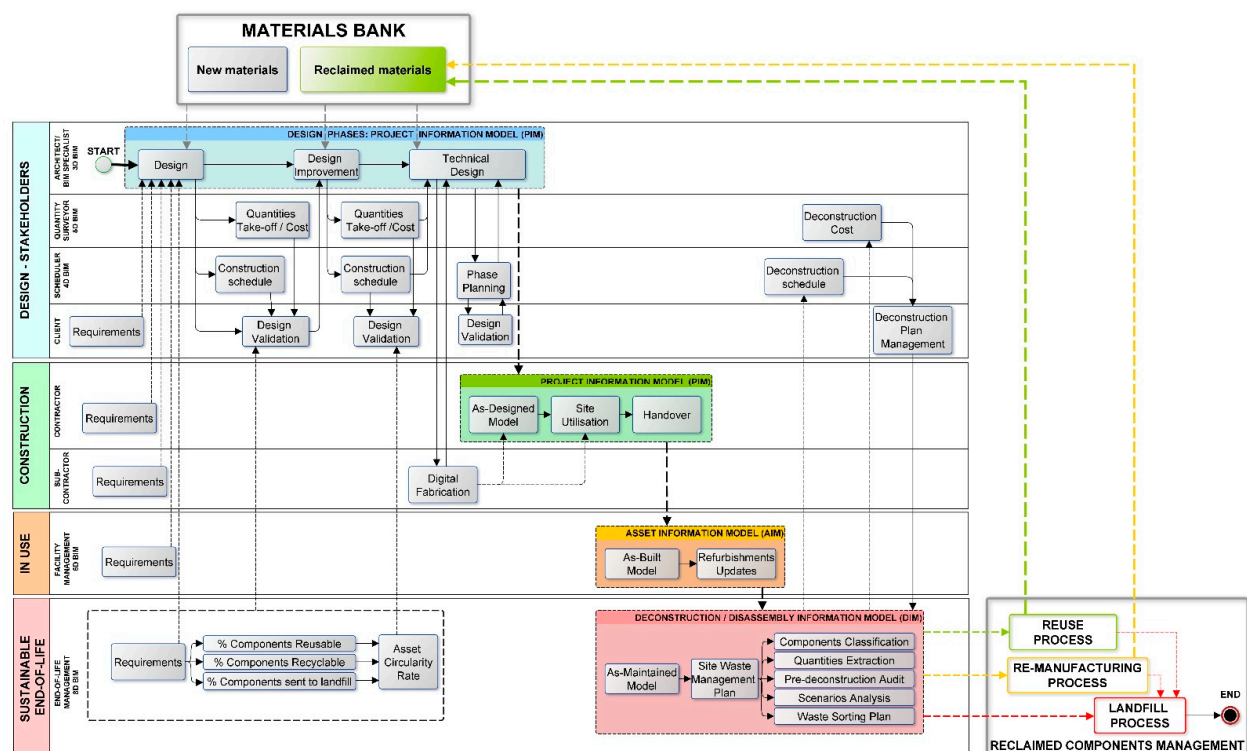


Figure 2. Theoretical framework extracted from [29] and used as a support for the interviews.

Following the presentation of the theoretical framework, the interviewer posed a single open-ended question: “How do you believe the framework could be improved to enhance its applicability in your day-to-day practice?” The ensuing interaction with experts unfolded as a natural conversation, punctuated by strategic pauses and probes such as “Would you explain further?”, “Could you provide an example?”, and “Is there anything else?” These prompts aimed to stimulate interviewees and facilitate the articulation of their responses.

The researcher employed a combination of verbal and nonverbal cues, including head nodding and concise verbal affirmations such as “ok” and “I understand” [33]. Drawing on the confidence gained through an extensive literature review, the interviewer navigated the exploration with a clear plan, ensuring interviewees remained focused on the topic. Subtle techniques were utilized to aid interviewee comprehension when deemed necessary, contributing to a well-structured and participant-engaging interview process.

2.2. Sampling, Interview Procedure, and Analysis (Stage 2)

The author employed a purposive and snowballing sampling approach to identify construction experts specialized in CE, sustainable buildings, and BIM. Interviews were conducted either face-to-face or via phone. The interview period spanned from June 2018 to April 2019.

For analysis, a descriptive approach and means’ comparison were executed utilizing NVivo 11, a qualitative tool designed to streamline the collection and organization of textual data. NVivo’s capabilities in coding and word queries were harnessed to expedite qualitative analyses. Beyond word frequencies, the software facilitated transcript coding to extract pertinent concepts and ideas regarding potential enhancements in the framework. The decision to use NVivo underscored the author’s commitment to a comprehensive and theme-driven exploration.

2.3. Improving and Substantiating the Theoretical Framework (Stage 3)

The final stage of the methodology was the implementation in the theoretical framework of supplementary data obtained in two steps:

First, the data extracted from an update of the literature review were used. The update of the literature review started in 2019 (at the time of the interviews). A formalization of a part of this literature review is summarized in [28] through the drawing of a trans-scalar framework (Figure 1, stage 3). The trans-scalar framework was used as a new basis to develop the final framework.

Second, data were extracted from the analysis of the interviews. The contribution from the interviews included results derived from a two-step analysis. Initially, interviewees' comments were categorized into five modification/improvement types for application to the theoretical framework (Figure 1, Stage 3): (1) organization of the framework, (2) collaborative platforms and data exchange, (3) initiating a project with a digital CE approach, (4) stakeholder engagement and team organization, and (5) BIM models. The improvements are visually represented through different boxes in Stage 3 in Figure 1: (A) framework scheme, (B) initiating a project with a CE approach, (C) collaborative platforms (Building and material levels), (D) checking and deliverables, and (E) EOL and recovered materials processes, which are shown in Figures 3–6 in [30]. The development of aspect (E) was undertaken by the author in a separate publication [30].

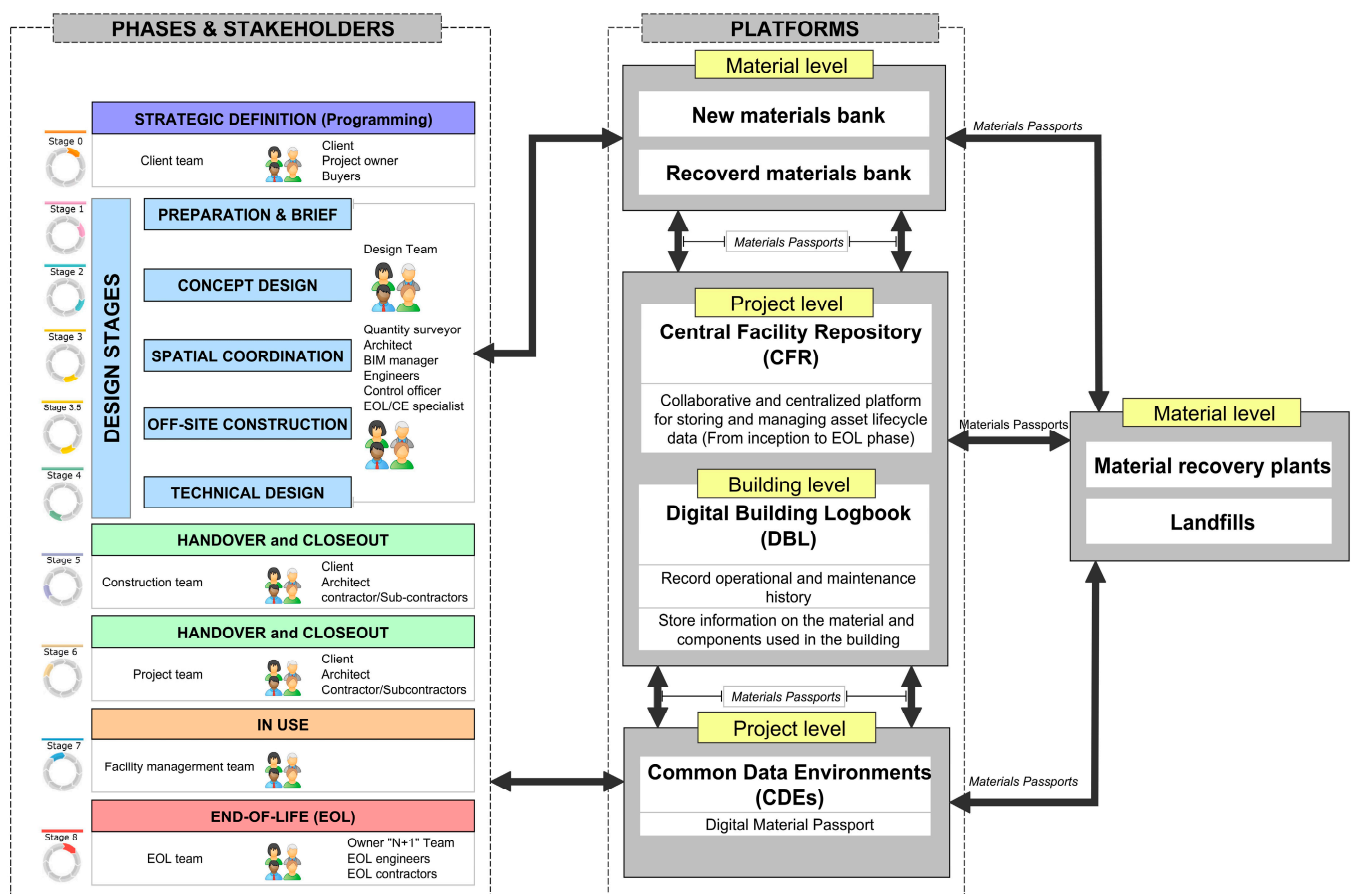


Figure 3. The digital and circular framework scheme.

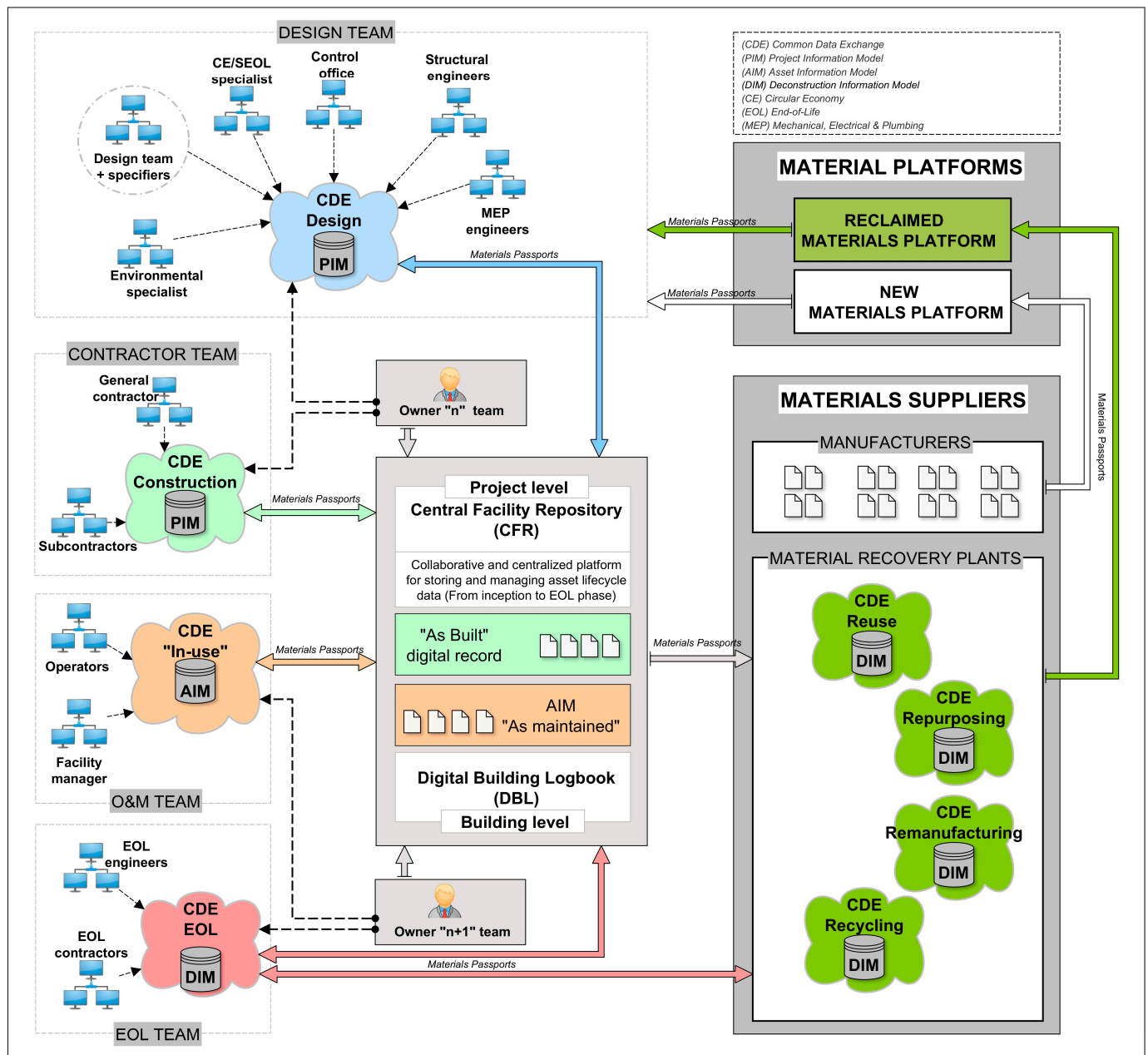
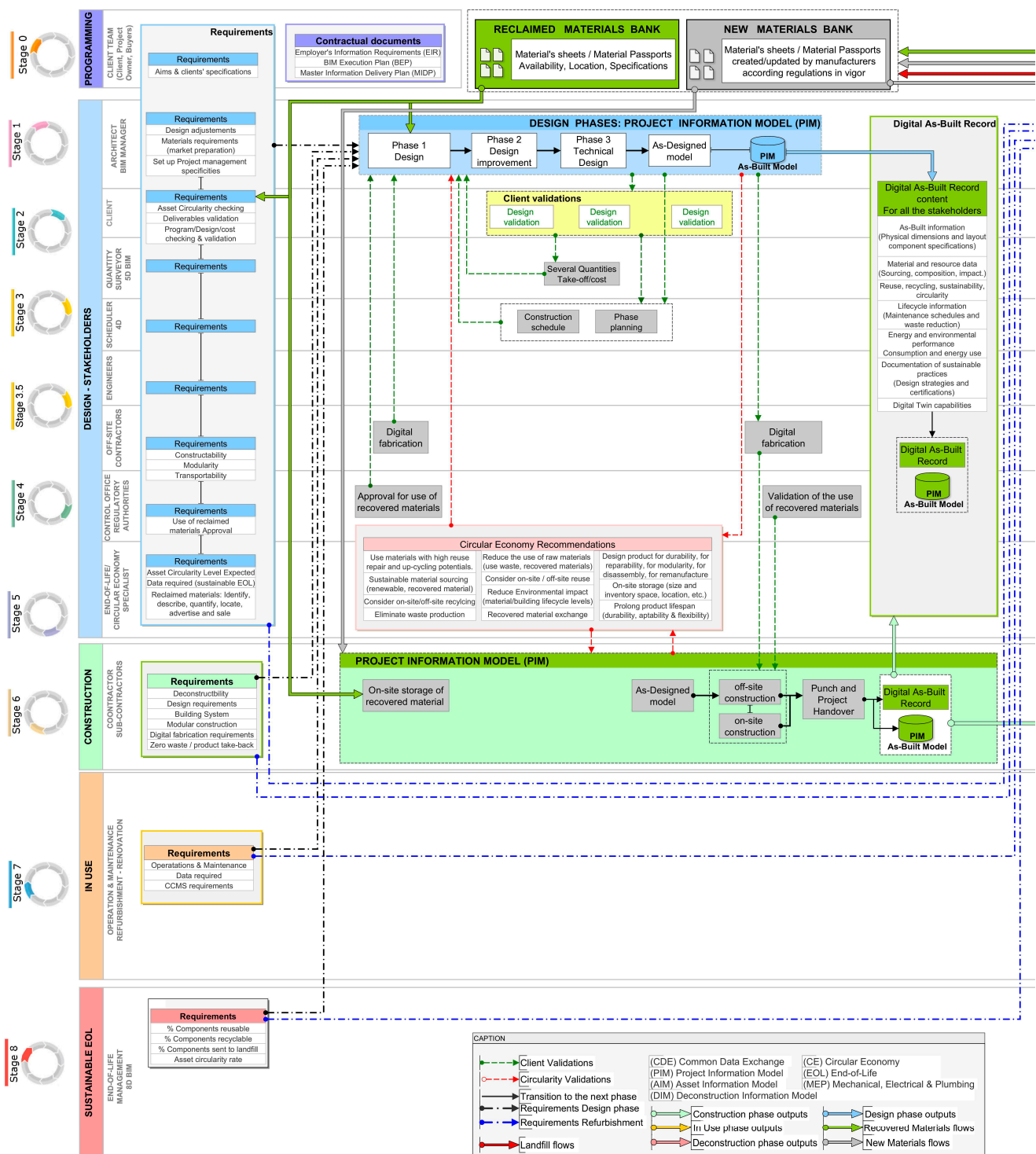
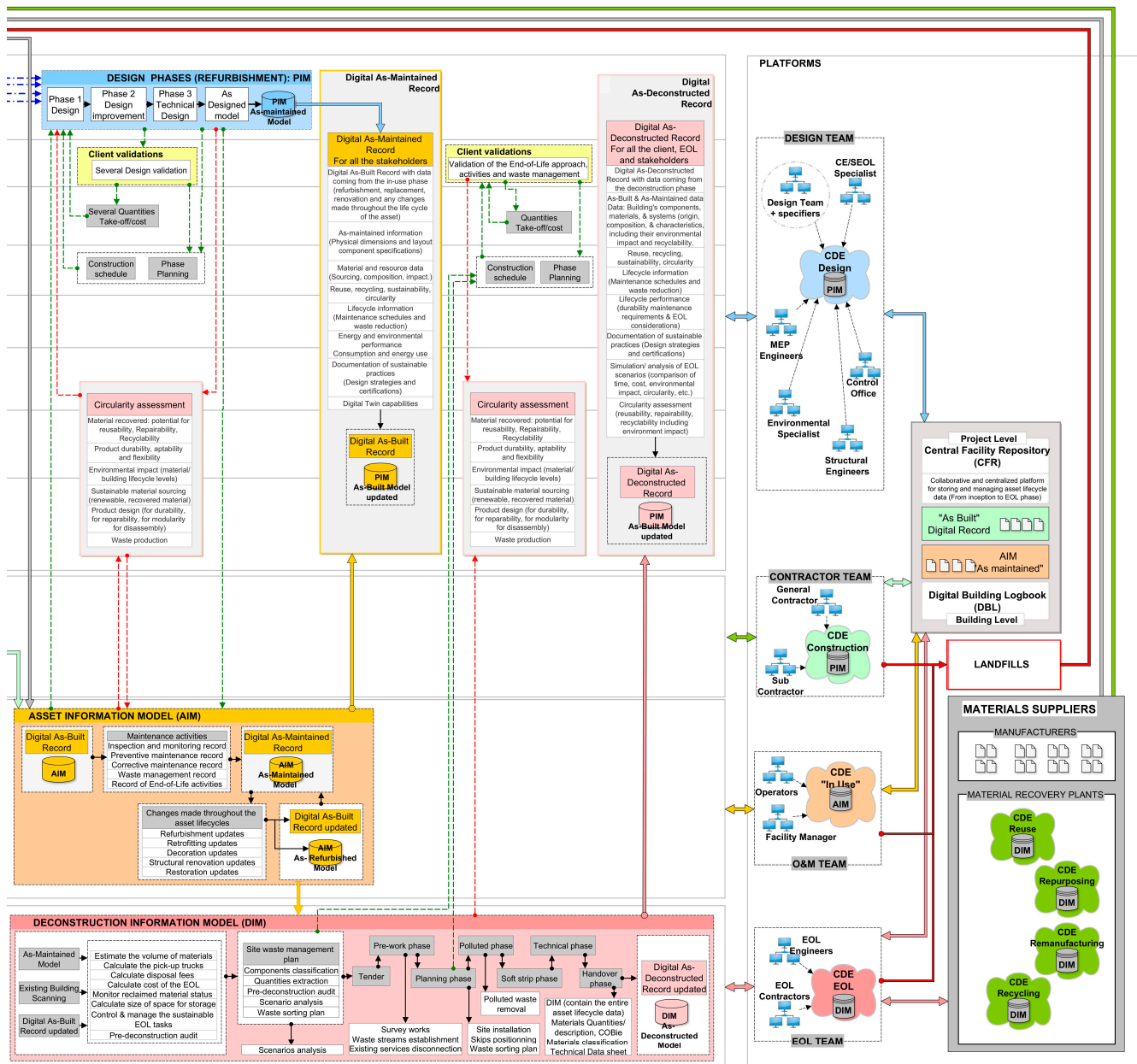


Figure 4. The platforms.



(a)

Figure 5. Cont.



(b)

Figure 5. (a) Improved digital framework. (b) Improved digital framework.

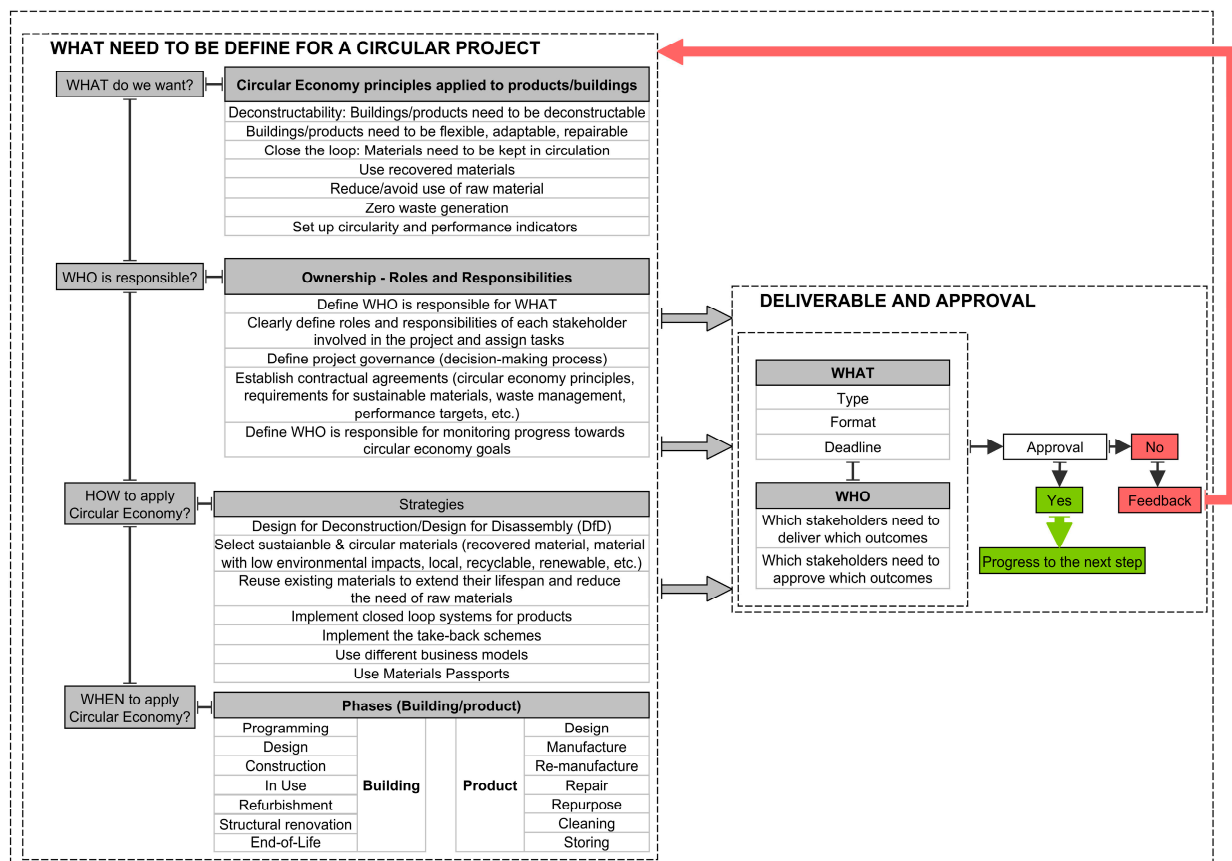


Figure 6. The key aspects of circular projects: What, who, how and when.

3. Trans-Scalar Framework: Areas for Improvement

3.1. Reconsideration of the Asset Lifecycle

The theoretical framework on which the interviewees reflected was based on a literature review ending in 2019 and the project phases defining the asset lifecycle taken from the RIBA plan of work. To accommodate the EOL as a stage in the building's lifecycle, the digital plan of work was amended to introduce the deconstruction stage as phase 8. This modification reconsidered the commonly known asset lifecycle and necessitated adapting the information delivery cycle to incorporate the EOL phase and its related information exchanges. In the revised asset lifecycle concept, three models were utilized throughout the building's lifespan, a concept extensively illustrated and discussed by [28]. In the following sections, the data extracted from the interviews are discussed and analyzed to improve the trans-scalar framework in the context of BIM to obtain the final framework.

3.2. Organization of the Framework

The improvements suggested by the interviewees were organized into five categories, presented in this section, and added to the framework. The main structure of the framework presented to the interviewees was kept. However, an interviewee suggested adding the RIBA stages alongside the phases and using ISO 19650 [34] to help practitioners understand it and use it (International Organization for Standardization (2018)).

3.2.1. New Phases Added

In Stage 0, a programming phase was added, as requested by three interviewees, Figure 3. In the CE context, this is a crucial phase in which clients express their requirements regarding digitalization and the CE approach. Then, the stakeholders are identified. An interviewee considered the programming phase as the key because it is the moment when the market should be assessed and prepared if necessary (for example, if the project requires

specific circular materials). Manufacturers should adapt their Material Technical Data Sheets to align with the sustainable EOL and CE requirements that need to be expressed in the programming phase and reflected during the design phase. As part of a design for circularity, whether via design for deconstruction or disassembly, the modularization of the design meeting the disassembly/assembly requirements should be considered during Stage 3.5, relating to off-site construction, which was added. The rehabilitation and diagnostic phases were also added, as requested by two interviewees. Several interviewees requested adding the recovered materials' processes to the framework. In addition to the connection between the EOL phase with the recovered materials' processes, they also recommended connecting the construction and "in-use" phases, in which refurbishment or replacement activities could appear. The recovered material flows and the re-prescription flow were added to the framework accordingly (Figure 3).

3.2.2. Adaptations to Existing Phases

The design phase in the framework should encompass more subphases and new actors, such as the CE specialist and the scheduler. The actors involved in the refurbishment and off-site construction phases were thus added. According to nine respondents, the sustainable EOL phase was modified, with particular attention put on the diagnostic stage. The deconstruction stage was explained and discussed by the author in another study (1) [30]. The framework was adjusted accordingly, as shown in Figure 5a,b.

Moreover, using reclaimed materials has an impact on the design phase, which cannot be completed until the design team obtains the information from the reclaimed materials. Therefore, a link was added between the design phase and the reclaimed materials bank. Due to the regular surplus of new materials that end up as recovered materials, although they are new, it was suggested to add a flow in the framework linking the construction phase with the recovered material bank and suppliers. These materials or components that are not used for the construction could either be returned to the supplier if a take-back scheme is in place or be sent to the recovered material bank. In the construction phase, the client should be added as they play a crucial role. They either do or do not validate the decisions taken during construction. The checking process during the execution phase should be mentioned in the framework. Compliance with the design and budget are checked at this moment in time. In Stage 6, when the building is handed over, delivering asset data should be distinct from geometric information using construction operations building information exchange (COBie) and should appear in the framework, as shown in Figure 5a,b.

3.3. Collaborative Platform and Data Exchange

3.3.1. The Central Facility Repository

The databases concerning the lifecycle of construction assets encompass two levels: the project level and the national/regional level, as delineated in Figure 4. At the project level, the Central Facility Repository (CFR) is a collaborative platform used for storing and managing asset lifecycle data, aligning with the proposals of some authors who highlighted the efficacy of BIM partnering in managing client involvement [35]. The CFR serves as a comprehensive repository, encapsulating detailed information about the asset from its inception to its EOL phase.

Concurrently, databases at the national/regional level, namely, the reclaimed materials bank and the new materials bank, are instrumental in managing material availability and environmental impact, considering the critical factor of the distance from which materials originate. The CFR plays a pivotal role by focusing on the storage of diverse project-related information, thereby contributing significantly to the principles of the circular economy. It facilitates transparency and collaboration across the construction lifecycle, promoting resource efficiency and waste reduction through well-informed decision making. Serving as a centralized platform, the CFR enables architects, engineers, and project managers to access crucial data, aligning with circular economy principles [36].

3.3.2. Digital Building Logbook (DBL)

Complementary to the CFR, the Digital Building Logbook concentrates on the recording of operational and maintenance history, thereby enhancing the longevity and performance of building systems [37]. Facility managers, armed with insights from the logbook, can implement proactive maintenance strategies, optimize energy efficiency, and ensure responsible resource utilization. Indeed, in addition to storing the operational and maintenance history, the Digital Building Logbook can also store information on the materials and components used in the construction and renovation of buildings, such as their origin, composition, quality, quantity, and location. This information can facilitate the identification, recovery, and reuse of valuable materials at the end of the building's life cycle or when parts of the building are replaced or upgraded [38].

Authors presented a survey of the existing literature and initiatives related to the Digital Building Logbook and identified the main challenges and opportunities in its development and implementation [39]. They explored the concept and its potential by providing comprehensive and reliable data on the environmental performance of buildings. They considered the Digital Building Logbook as a tool that can facilitate the transition to a circular economy in the building sector.

3.3.3. Material Bank Platforms

The integration of the material bank with the project, as suggested by an interviewee, allows quantities and locations of reclaimed materials to inform design prescriptions, thereby enhancing sustainability practices. Recycling and reuse plants can supply the reclaimed material bank during the EOL phase of the asset. Proposed at the regional or national level, these material banks contribute to a dual-level database framework, addressing the imperative for both localized and broader perspectives in sustainable materials' management throughout the building's lifecycle.

Together, the CFR, the Digital Building Logbook, and the material bank platforms form an integrated system that supports a holistic approach to sustainability in the construction sector, fostering a circular economy through efficient resource management and reduced environmental impact, while extending the life cycles of built assets. Central to this integrated system is the concept of the material passport. A material passport provides an identity to materials, preventing them from becoming waste. It is a critical tool that documents essential information about the materials' composition, origin, and lifecycle, facilitating their reuse, recycling, and efficient management throughout the building's life cycle [40]. By offering a comprehensive profile, material passports enable better decision-making in design, construction, and demolition phases, thereby supporting the circular economy. This documentation bridges the gap between different building phases and integrates seamlessly with platforms like the CFR, Digital Building Logbook, and materials bank, promoting sustainable practices and extending the lifecycle of built assets and their components (Figure 4).

3.3.4. Data Management

The complexities of data management were acknowledged as a significant challenge in asset management by several interviewees. They highlighted the limitations of collaboration platforms and emphasized the importance of clearly defining collaboration parameters at the project's outset. Similarly, authors argued that collaboration limitations could be overcome by the establishment of responsibilities and the improvement in communication among disciplines [28]. Additionally, the development of protocols and sharing via a common model stored centrally or hosted on distributed environments can support overcoming the collaboration limitations [41]. Aligned with this statement, some interviewees suggested the establishment of a collaborative platform, a common data exchange (CDE), designed for the project and fed by each stakeholder. While the consolidation of all data within a CDE is deemed essential, challenges arise in the form of multiple CDEs on a project. Some interviewees proposed focusing on the CFR as the primary vision for centralizing

building data. They suggested framing data exchange and interoperability issues rigorously in the BIM Execution Plan (BEP). The BEP is a document that defines the objectives, standards, and processes for BIM collaboration. This aspect was explained in a recent study proposing a trans-scalar framework to support construction stakeholders. The author illustrated the complexity of the interaction between the multiple stakeholders involved in the various phases of a construction project, in the BIM and circular economy contexts [28].

3.3.5. Potential Benefits of the Use of Collaborative Platforms

Some potential uses of the CFR and the Digital Building Logbook include enabling the reuse and upcycling of recovered materials, reducing the demand for new resources, lowering the environmental impact of material extraction and production, and creating new opportunities for circular business models in the construction sector. Indeed, a study discussed how the circular economy principles can be applied to the building sector and how the Digital Building Logbook can be a useful tool for monitoring and optimizing the material flows and energy efficiency of buildings [9]. The Digital Building Logbook is a key tool for supporting material circularity and resource efficiency in the built environment. The European Commission provides several reports on whether to provide a comprehensive overview of the Digital Building Logbook, its definition, objectives, benefits, and challenges or to explore the potential of the Digital Building Logbook in facilitating the transition to a circular economy in the construction sector [42–44]. Additionally, to set up collaborative platforms at the building and material levels, several key actions need to be adopted, including sustainable design strategies.

3.4. Initiating a Digital Circular Project

3.4.1. Strategies for a Circular Design Approach

Circular design principles need to be discussed during the programming phase and integrated from the project's inception, as suggested by some respondents. As highlighted, for projects following the “design for circularity” approach, the focus on holistic asset lifecycle management requires a strategic investment perspective, allocating budgets with long-term implications to avoid higher costs in the future. A vital consideration is the incorporation of design for deconstruction, disassembly, or dismantling, which is a concept advocated by multiple studies [45].

According to an interviewee who is an architect, unique approaches, such as minimizing finishing works and utilizing earth-based materials, contribute to waste reduction and minimize the environmental impact at the EOL of buildings. This strategy involves deliberate design choices to expose structural elements and HVAC systems, thereby reducing construction waste. This interviewee stated that they often integrate this approach with the use of earth-based materials for structural components, such as rammed earth or compressed earth blocks. Notably, several respondents addressed sustainability requirements by employing excavated raw earth as a construction material, usually landfilled as waste. This serves a triple purpose: waste reduction, a localized and therefore quantifiable CO₂ impact, and minimized EOL environmental impact, provided that cement-stabilized earth is not used.

Modular construction, as highlighted by one respondent, offers flexible utilization and recovery for future projects, aligning with the global pursuit of sustainable construction practices [46]. Drawing inspiration from practices in other industries, such as the automobile and consumer product sectors, the integration of prefabrication and design for manufacture and assembly (DfMA) has emerged as a promising avenue for enhancing demountability and reducing construction costs [47]. Circularity needs to be incorporated during the design phase and considered during the in-use and refurbishment phases. Some authors incorporated circularity by identifying 10 design and operation determinants that can facilitate building resilience, asset value creation, and waste elimination [48]. Indeed, recognizing adaptability as a critical design consideration contributes to the longevity and sustainable use of buildings, aligning with the evolving needs of occupants, according to

several respondents. Design decisions made early in the project lifecycle significantly influence the ease of disassembly and materials' recovery during the EOL phase. Embracing design for deconstruction principles, modular construction techniques facilitate material recovery and reuse during the EOL phase and reduce waste generation, contributing to the achievement of the circular economy's objectives.

The management of the asset lifecycle should be supported by digital tools, as evidenced in some studies [25,47]. This statement was unanimously acknowledged by respondents, who confirmed the necessity of having a digital framework to support practitioners in the understanding and implementation of the CE in the digital context. Some of them confirmed the usefulness of BIM in simplifying day-to-day practices and offering valuable insights into deconstruction. For existing buildings without BIM, data for sustainable EOL management are gathered through 3D scans, 2D documents, and on-site surveys. The pivotal role of BIM technology in effective EOL management was further emphasized, with accumulated data throughout the asset lifecycle serving as crucial resources for optimizing EOL decision making [28,30]. Leveraging BIM for materials' recovery, particularly reuse, is a growing area of interest, with frameworks developed to select EOL scenarios with minimal environmental impacts based on comprehensive lifecycle data [49]. The use of materials passports further enhances the effectiveness of BIM technology by providing detailed information about each material's composition, origin, and lifecycle. This integration ensures that materials are tracked and managed efficiently throughout their multiple lifecycles, facilitating their recirculation and reuse within a closed loop.

3.4.2. Procedures and Data Requirements

As stressed in 2011, for BIM projects, an effective multidisciplinary collaboration necessitates new contractual relationships and process reorganization [50]. In BIM projects, adherence to the ISO 19650 series, as outlined by [28,30], is crucial for defining project requirements. The original figure in PAS 1192-2:2013 (now part of ISO 19650) lacked consideration of the asset's EOL phase, which was deeply explained and addressed by the author in a previous study [28]. The incorporation of the sustainable EOL phase into the asset lifecycle shakes the current practices and raises contractual concerns. Indeed, tendering and procurement methods require adjustments, as stressed by several respondents. Thus, standard contract forms and the BIM protocol must evolve to encompass the contractual terms related to the CE and its stipulated requirements.

Respondents unanimously emphasized the significance of obtaining a clear understanding of client requirements, particularly regarding the management of the asset's EOL, at the programming stage. A respondent further elucidated the need for various documents (EIR, MIDP, AIR, AIM, etc.) and contractual agreements at the project's inception. In a CE approach, clients express expectations related to EOL management, EOL simulations, and asset circularity objectives. The BEP plays a pivotal role in regulating the working processes among project stakeholders. AIM requirements, crucial for project commencement and ongoing development, were underscored. Furthermore, data classification requirements must be outlined in the BEP [51]. Several interviewees advocated for clearly defining the type of data needed, their timing, parties responsible for provision, storage locations, verification, and updating responsibilities.

3.4.3. Definition of Deliverables

The identification and definition of deliverables, along with associated responsibilities and formats like IFC, native format, and COBie, are crucial in construction projects. Early agreement and inclusion of these deliverables in the BEP are imperative, as are essential supplementary deliverables like EOL simulations. Integration of specific deliverables and models aids in efficient planning, with COBie development typically occurring at RIBA Stage 6. The involvement of stakeholders from inception, including facility managers, is necessary to determine the AIM and digital as-built content. Architects need to be on site during construction to control material substitution and maintain design specifications.

3.4.4. Verification throughout the Asset Lifecycle

Multiple verification stages must be established throughout the project lifecycle. During the design phase, clients assisted by the “Assistant to the Contracting Authority” should ensure CE compliance. One respondent suggests incorporating a verification stage during permit approval to align with CE principles and EOL management. Sustainable EOL management verification necessitates specific contractual clauses for facility managers. Authors proposed a new framework for construction projects, including indicators, action plans, and quantitative tools for assessing circularity [52]. Data integrity throughout the asset lifecycle is crucial, with Chen (2015) emphasizing the need for well-controlled management policies [53]. Figure 6 provides a schematic representation of the verification process, highlighting the essential steps and stakeholders involved in ensuring compliance with circular economy principles throughout the building lifecycle. Another aspect highlighted by the interviewees was the early involvement of some actors, a specific organization of teams organization and the fact that the roles and responsibilities of stakeholders must be clearly defined.

3.5. Stakeholder Engagement and Team Organization

3.5.1. Stakeholder Involvement

In the traditional procurement method, contractors are involved after the technical design stage once designs and detailed specifications are finalized. As indicated by several interviewees, it is imperative to engage the contractor earlier in the design phase to facilitate collaboration with the design team when selecting strategies and material specifications. This early involvement of contractors in the design stage aligns with the findings reported by [54] and by some authors who considered that it brings significant cost savings and value to projects [55]. The requirement for a collaborative culture and clear objectives necessitate the use of appropriate regulations and tools to ensure successful Early Contractor Involvement (ECI) [56]. According to some authors, to facilitate ECI, the best method would be the utilization of the Integrated Project Delivery (IPD) method, coupled with a collaborative BIM environment [57].

Manufacturers are also actors who need to be involved in the programming phase to see if they are ready for the requirements expressed by the client. If not, they have the duration of the design process to prepare themselves. Manufacturers must know very early on what the client’s objectives are to be able to make the material data available during the tender phase through documents such as the Environmental ProductDeclarations (EPDs), the Environmental and Health Declaration Sheets (FDESs), or theDeclaration of Performance (DoP) documents that are usually requested. These documents provide transparent and standardized information to help stakeholders make informed decisions about material selection, construction practices, and sustainability goals. Therefore, for circular projects, the tendering phase should be adapted.

Although it seemed unlikely for some interviewees, practitioners who had already been involved in circular projects asked to add the involvement of the EOL actors and facility managers to the framework. The early involvement of these actors allows early consideration of EOL implications. Indeed, by integrating their expertise and insights into the decision-making process, the project team can identify opportunities to design buildings to be easily disassembled and to optimize the recovery of materials without damaging them. This may include specifying modular construction techniques, designing for easy access to building components, and selecting materials that are recyclable or biodegradable. By considering these factors during the design phase, stakeholders can maximize the potential for resource recovery and minimize waste generation during the EOL phase.

3.5.2. Clear Roles and Responsibilities

Stakeholder identification and role definition are crucial for ensuring effective collaboration and accountability throughout a project’s lifecycle. The clear delineation of responsibilities minimizes ambiguities and enhances communication among project par-

ticipants. According to RIBA 2012, in addition to the identification of key players, their roles and responsibilities must be precisely defined, and contractual boundaries must be established from the start of a BIM project [50,58]. Similarly, the adoption of a CE approach necessitates the same level of clarity and contractual commitment [59]. In the area of technology adoption, Lindblad (2018) suggested that for tools like BIM, the most effective acceptance strategy is a contractual imposition, making it a non-negotiable aspect [60]. In the CE context, similar ideas have been expressed by various authors, collectively highlighting the need for contractual agreements delineating the roles and responsibilities of construction stakeholders. Furthermore, they have emphasized the importance of a unified strategy, understanding interdependencies and promoting a cooperative approach [61,62]. Adopting collaborative methodologies such as Integrated Project Delivery (IPD) and BIM increases interdisciplinary coordination and nurtures a culture of shared responsibility among project participants. The early engagement of stakeholders, including contractors and facility managers, fosters a shared understanding of project objectives and requirements, facilitating the seamless integration of circular economy principles into project delivery processes. The contractual integration of stakeholder roles and responsibilities ensures alignment with project objectives and facilitates effective implementation of circular economy principles throughout the project's lifecycle. Some interviewees argued that proper stakeholder identification, an effective project team organization, and a clear definition of roles and responsibilities are crucial. Manufacturers are also key players in circular economy approaches, and standardizing their responsibilities and obligations for the content of their products is vital for addressing transparency and recoverability concerns. While some products are initially 100% recyclable, their recyclability can be compromised by additional materials, as seen with plaster walls covered with paint or wallpaper. Similarly, the stabilization of earthen materials with cement hinders the natural recyclability of the material and sharply increase its embodied energy. The early involvement of the facility manager is essential, particularly in BIM-managed buildings using reclaimed components or equipment instead of new materials. In the context of on-site materials' reuse or recycling, the assistant to the contracting authority plays a key role. Mainly, all the interviewees agreed that client engagement is fundamental in the circular economy approach and the adoption of BIM, necessitating the presence of dedicated individuals [63].

4. Conclusions and Future Research

This study presented a comprehensive framework for implementing the circular economy (CE) principles in the construction sector, informed by expert opinions and insights. By addressing key areas for improvement and incorporating feedback from professionals, the revised framework aims to enhance practical utility and promote sustainable practices throughout an asset's lifecycle. This study underscores the importance of integrating circular economy principles at different stages of construction projects, emphasizing the need for holistic and systemic approaches to resource efficiency and waste reduction.

This study makes several practical contributions to improving the digital framework to include circular economy concerns. Firstly, it highlights the importance of incorporating circular economy data into all lifecycle stages of construction projects from design and procurement to operation and end of life. This integration can enhance the ability of digital tools like Building Information Modeling (BIM) to support sustainable decision making. Furthermore, this study provides insights into the technical aspects of integrating circular economy principles with digital technologies by addressing the complexities of digital frameworks and emphasizing the need for stakeholder coordination.

The framework developed in this study has several practical applications in the construction sector. It can be utilized by project managers and sustainability officers to design and implement projects that prioritize resource efficiency and waste reduction. Additionally, policymakers can use the framework to develop regulations and guidelines that encourage the adoption of circular economy practices across the industry. Educational institutions

can also incorporate the framework into their curriculum to train future professionals in sustainable construction practices.

Despite the potential benefits, there are several barriers to the adoption of circular economy principles in the construction sector. One of the primary challenges is the resistance to the changes in mindset and practices, which can be time-consuming and costly. Additionally, the integration of circular economy principles into existing digital frameworks presents technical challenges. These include ensuring interoperability between different systems, managing the complexity of data integration, and coordinating various project stakeholders.

Future research in this area could focus on the practical implementation and validation of the revised framework in real construction projects. Longitudinal studies could track the impact of adopting circular economy practices on the resource consumption, waste generation, and overall sustainability performance in the construction sector. Additionally, exploring the role of digital technologies, such as BIM, in facilitating circular economy practices could provide valuable insights for industry stakeholders. In the construction sector, the issue is often not the availability of new technology or processes but their adoption into existing systems, which requires significant time, cost, and stakeholder involvement. It is also important to discuss the technicalities of circular economy integration with digital technologies, particularly BIM and digital twins. Additionally, it is recommended to specify the technical points that are currently missing on the integration of circular economy data in the lifecycle stages. Further research could also investigate the scalability and replicability of the framework in different construction contexts and for different project scales, as well as the potential policy implications for promoting circular economy principles in the built environment. By continuing to advance the knowledge and practices in implementing circular economy in construction, researchers and practitioners can contribute to a more sustainable and resource-efficient built environment.

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References

1. Geissdoerfer, M.; Savaget, P.; Bocken, N.M.P.; Hultink, E.J. The Circular Economy—A new sustainability paradigm? *J. Clean. Prod.* **2017**, *143*, 757–768. [CrossRef]
2. Eberhardt, L.C.M.; van Stijn, A.; Stranddorf, L.; Birkved, M.; Birgisdóttir, H. Environmental design guidelines for circular building components: The case of the circular building structure. *Sustainability* **2021**, *13*, 5621. [CrossRef]
3. Foundation, E.M. Reimagining Our Buildings and Spaces for a Circular Economy. Available online: <https://www.ellenmacarthurfoundation.org/topics/built-environment/overview> (accessed on 2 July 2024).
4. Robles, D.R. Ceramic and Mixed Construction and Demolition Wastes (CDW): A Technically Viable and Environmentally Friendly Source of Coarse Aggregates for the Concrete Manufacture. Ph.D. Dissertation, Ghent University, Ghent, Belgium, 2016.
5. Eurostat. Eurostat—Data Explorer. Available online: <http://appsso.eurostat.ec.europa.eu/nui/submitViewTableAction.do> (accessed on 30 April 2019).
6. CEN/TC 350/SC 1; Circular Economy in the Construction Sector: Framework, Principles, Guidelines, and Requirements. European Committee for Standardization (CEN): Brussels, Belgium, 2021.
7. Su, B.; Heshmati, A.; Geng, Y.; Yu, X. A review of the circular economy in China: Moving from rhetoric to implementation. *J. Clean. Prod.* **2013**, *42*, 215–227. [CrossRef]
8. Ghisellini, P.; Cialani, C.; Ulgiati, S. A review on circular economy: The expected transition to a balanced interplay of environmental and economic systems. *J. Clean. Prod.* **2016**, *114*, 11–32. [CrossRef]
9. Pomponi, F.; Moncaster, A. Circular economy for the built environment: A research framework. *J. Clean. Prod.* **2017**, *143*, 710–718. [CrossRef]

10. Jemal, K.M.; Kabzhassarova, M.; Shaimkhanov, R.; Dikhanbayeva, D.; Turkyilmaz, A.; Durdyev, S.; Karaca, F. Facilitating Circular Economy Strategies Using Digital Construction Tools: Framework Development. *Sustainability* **2023**, *15*, 877. [\[CrossRef\]](#)
11. Afzal, M.; Li, R.Y.M.; Ayyub, M.F.; Shoaib, M.; Bilal, M. Towards BIM-Based Sustainable Structural Design Optimization: A Systematic Review and Industry Perspective. *Sustainability* **2023**, *15*, 15117. [\[CrossRef\]](#)
12. Charef, R.; Morel, J.C.; Rakhshan, K. Barriers to implementing the circular economy in the construction sector: A critical review. *Sustainability* **2021**, *13*, 12989. [\[CrossRef\]](#)
13. Charef, R.; Ganjian, E.; Emmitt, S. Socio-economic and environmental barriers for a holistic asset lifecycle approach to achieve circular economy: A pattern-matching method. *Technol. Forecast. Soc. Chang.* **2021**, *170*, 120798. [\[CrossRef\]](#)
14. Oluleye, B.I.; Chan, D.W.M.; Saka, A.B.; Olawumi, T.O. Circular economy research on building construction and demolition waste: A review of current trends and future research directions. *J. Clean. Prod.* **2022**, *357*, 131927. [\[CrossRef\]](#)
15. Kirchherr, J.; Reike, D.; Hekkert, M. Conceptualizing the circular economy: An analysis of 114 definitions. *Resour. Conserv. Recycl.* **2017**, *127*, 221–232. [\[CrossRef\]](#)
16. Kirchherr, J.; Yang, N.H.N.; Schulze-Spüntrup, F.; Heerink, M.J.; Hartley, K. Conceptualizing the Circular Economy (Revisited): An Analysis of 221 Definitions. *Resour. Conserv. Recycl.* **2023**, *194*, 107001. [\[CrossRef\]](#)
17. Vermeulen, W.; Reike, D.; Witjes, S. Solving confusion around new conceptions of circularity by synthesising and re-organising the 3R's concept into a 10R hierarchy. *Renew. Matter* **2019**, *27*, 12–15. Available online: http://www.renewablematter.eu/en/art/1141/Circular_Economy_3_0 (accessed on 2 July 2024).
18. Uvarova, I.; Atstaja, D.; Volkova, T.; Grasis, J.; Ozolina-Ozola, I. The typology of 60R circular economy principles and strategic orientation of their application in business. *J. Clean. Prod.* **2023**, *409*, 137189. [\[CrossRef\]](#)
19. Gennari, F. The transition towards a circular economy. A framework for SMEs. *J. Manag. Gov.* **2023**, *27*, 1423–1457. [\[CrossRef\]](#)
20. Davari, S.; Jaber, M.; Yousfi, A.; Poirier, E. A Traceability Framework to Enable Circularity in the Built Environment. *Sustainability* **2023**, *15*, 8278. [\[CrossRef\]](#)
21. Rahla, K.M.; Mateus, R.; Bragança, L. Implementing circular economy strategies in buildings—From theory to practice. *Appl. Syst. Innov.* **2021**, *4*, 26. [\[CrossRef\]](#)
22. Kebede, R.; Moscati, A.; Tan, H.; Johansson, P. Circular Economy in the Built Environment: A Framework for Implementing Digital Product Passports With Knowledge Graphs. In Proceedings of the 2023 European Conference on Computing in Construction and the 40th International CIB W78 Conference, Heraklion, Greece, 10–12 July 2023. [\[CrossRef\]](#)
23. Chauhan, C.; Parida, V.; Dhir, A. Linking circular economy and digitalisation technologies: A systematic literature review of past achievements and future promises. *Technol. Forecast. Soc. Chang.* **2022**, *177*, 121508. [\[CrossRef\]](#)
24. Sparrevik, M.; de Boer, L.; Michelsen, O.; Skaar, C.; Knudsen, H.; Fet, A.M. Circular economy in the construction sector: Advancing environmental performance through systemic and holistic thinking. *Environ. Syst. Decis.* **2021**, *41*, 392–400. [\[CrossRef\]](#)
25. Charef, R.; Emmitt, S. Uses of building information modelling for overcoming barriers to a circular economy. *J. Clean. Prod.* **2021**, *285*, 124854. [\[CrossRef\]](#)
26. Charef, R. Is Circular Economy for the Built Environment a Myth or a Real Opportunity? *Sustainability* **2022**, *14*, 16690. [\[CrossRef\]](#)
27. Cramer, J. How circular economy and digital technologies can support the building sector to cope with its worldwide environmental challenge? *NPJ Urban Sustain.* **2023**, *28*, 1–3. [\[CrossRef\]](#)
28. Charef, R. Supporting construction stakeholders with the circular economy: A trans-scalar framework to understand the holistic approach. *Clean. Eng. Technol.* **2022**, *8*, 100454. [\[CrossRef\]](#)
29. Charef, R.; Alaka, H.; Ganjian, E. A BIM-based theoretical framework for the integration of the asset End-of-Life phase. *IOP Conf. Series: Earth Environ. Sci.* **2019**, *225*, 012067. [\[CrossRef\]](#)
30. Charef, R. The use of Building Information Modelling in the circular economy context: Several models and a new dimension of BIM (8D). *Clean. Eng. Technol.* **2022**, *7*, 100414. [\[CrossRef\]](#)
31. Segal, D.L. Structured versus Semistructured versus Unstructured Interviews. In *The Encyclopedia of Clinical Psychology*; John Wiley & Sons Inc.: Hoboken, NJ, USA, 2015.
32. Fellows, R.; Liu, A.M. *Research Methods for Construction*, 4th ed.; John Wiley & Sons. Ltd.: Hoboken, NJ, USA, 2015.
33. Boyce, C.; Neale, P. *Conducting In-Depth Interviews: A Guide for Designing and Conducting In-Depth Interviews for Evaluation Input*; Pathfinder International Tool Series; Watertown, MA, USA, 2006.
34. International Organization for Standardization. *ISO 19650-2:2018: Organization and digitization of information about buildings and civil engineering works, including building information modelling (BIM) — Information management using building information modelling — Part 2: Delivery phase of the assets*. 2018.
35. Porwal, A.; Hewage, K.N. Building Information Modeling (BIM) partnering framework for public construction projects. *Autom. Constr.* **2013**, *31*, 204–214. [\[CrossRef\]](#)
36. Charef, R.; Lu, W. Factor dynamics to facilitate circular economy adoption in construction. *J. Clean. Prod.* **2021**, *319*, 128639. [\[CrossRef\]](#)
37. Méda, P.; Hjelseth, E.; Calvetti, D.; De Sousa, H. Data Templates and Digital Building Logbooks boosting Digital Twin in Construction. In Proceedings of the Conference CIB W78 2021, Luxembourg, 11–15 October 2021; pp. 683–692.
38. Puček, M.M.; Khoja, A.; Bazzan, E.; Gyuris, P. A Data Structure for Digital Building Logbooks: Achieving Energy Efficiency, Sustainability, and Smartness in Buildings across the EU. *Buildings* **2023**, *13*, 1082. [\[CrossRef\]](#)

39. Alonso, R.; Olivadese, R.; Ibba, A.; Recupero, D.R. Towards the definition of a European Digital Building Logbook: A survey. *Heliyon* **2023**, *9*, e19285. [CrossRef]
40. Costa, A.R.; Hoolahan, R. *Materials Passports: Accelerating Material Reuse in Construction*; Orms Designers and Architects, Ltd.: London, UK, 2024. Available online: [https://www.lancaster.ac.uk/media/lancaster-university/content-assets/images/lica/MaterialPassportsPolicyPaper\(1\).pdf](https://www.lancaster.ac.uk/media/lancaster-university/content-assets/images/lica/MaterialPassportsPolicyPaper(1).pdf) (accessed on 5 July 2024).
41. Alreshidi, E.; Mourshed, M.; Rezgui, Y. Requirements for cloud-based BIM governance solutions to facilitate team collaboration in construction projects. *Requir. Eng.* **2018**, *23*, 1–31. [CrossRef]
42. Volt, J.; Toth, Z.; De Regel, S.; Carbonari, G.; Dourlens-Quaranta, S.; De Groote, M.; Glicker, J.; Borragán, G. *Definition of the Digital Building Logbook: Report 1 of the Study on the Development of a European Union Framework for Buildings' Digital Logbook*; Publications Office of the European Union: Luxembourg, 2020; Available online: <https://data.europa.eu/doi/10.2826/480977> (accessed on 2 July 2024).
43. Dourlens-Quaranta, S.; Carbonari, G.; De Groote, M.; Borragán, G.; De Regel, S.; Toth, Z.; Volt, J.; Glicker, J.; Lodigiani, A.; Calderoni, M.; et al. *Study on the Development of a European Union Framework for Digital Building Logbooks—Executive Summary*; Publications Office: Luxembourg, 2020. [CrossRef]
44. Carbonari, G.; Ricci, M.; Dourlens-Quaranta, S.; Calderoni, M.; Loureiro, T.; Sterling, R.; Glicker, J.; Toth, Z.; Volt, J.; De Groote, M. *Building Logbook State of Play: Report 2 of the Study on the Development of a European Union Framework for Buildings' Digital Logbook*, Publications Office of the European Union. 2020. Available online: <https://op.europa.eu/en/publication-detail/-/publication/58580f81-06b7-11eb-a511-01aa75ed71a1> (accessed on 2 July 2024).
45. Rios, F.C.; Chong, W.K.; Grau, D. Design for Disassembly and Deconstruction—Challenges and Opportunities. *Procedia Eng.* **2015**, *118*, 1296–1304. [CrossRef]
46. Zhang, J.; Long, Y.; Lv, S.; Xiang, Y. BIM-enabled Modular and Industrialized Construction in China. *Procedia Eng.* **2016**, *145*, 1456–1461. [CrossRef]
47. Gbadamosi, A.-Q.; Mahamadu, A.-M.; Oyedele, L.O.; Akinade, O.O.; Manu, P.; Mahdjoubi, L.; Aigbavboa, C. Offsite construction: Developing a BIM-Based optimizer for assembly. *J. Clean. Prod.* **2019**, *215*, 1180–1190. [CrossRef]
48. Hamida, M.B.; Jylhä, T.; Remøy, H.; Gruis, V. Circular building adaptability and its determinants—A literature review. *Int. J. Build. Pathol. Adapt.* **2022**, *41*, 47–69. [CrossRef]
49. Ge, X.; Livesey, P.; Wang, J.; Huang, S.; He, X.; Zhang, C. Deconstruction waste management through 3D reconstruction and BIM: A case study. *Vis. Eng.* **2017**, *5*, 13. [CrossRef]
50. Sebastian, R. Changing roles of the clients, architects and contractors through BIM. *Eng. Constr. Archit. Manag.* **2011**, *18*, 176–187. [CrossRef]
51. *BIM Project Execution Planning Guide—Version 2.1*; The Pennsylvania State University: Pennsylvania, PA, USA, 2011. [CrossRef]
52. Medina, E.M.; Fu, F. A new circular economy framework for construction projects. *Proc. Inst. Civ. Eng. Eng. Sustain.* **2021**, *174*, 304–315. [CrossRef]
53. Chen, K. A strategic decision making framework for organisational BIM implementation. 2015. Doctoral Thesis, Cardiff School of Engineering, Cardiff, UK, September 2015. Available online: <https://www.semanticscholar.org/paper/A-strategic-decision-making-framework-for-BIM-Chen/41d07ef9fde441932049ca669e8a3ff8f92c97d6> (accessed on 2 July 2024).
54. Liu, Z.; Osmani, M.; Demian, P.; Baldwin, A. A BIM-aided construction waste minimisation framework. *Autom. Constr.* **2015**, *59*, 1–23. [CrossRef]
55. Laryea, S.; Watermeyer, R. Early contractor involvement in framework contracts. *Proc. Inst. Civ. Eng. Manag. Procure. Law* **2016**, *169*, 4–16. [CrossRef]
56. Plebankiewicz, E. The role of public procurement in implementing the circular economy in construction. *Inżynieria Bezpieczeństwa Obiektów Antropog.* **2022**, *4*, 69–78. [CrossRef]
57. Jayi, S.O.; Oyedele, L.O.; Akinade, O.O.; Bilal, M.; Owolabi, H.A.; Alaka, H.A.; Kadiri, K.O. Reducing waste to landfill: A need for cultural change in the UK construction industry. *J. Build. Eng.* **2016**, *5*, 185–193.
58. RIBA. *BIM Overlay to the RIBA Outline Plan of Work*; RIBA: London, UK, 2012.
59. Bouwens, G.; Mooij, F.; Lafta, M.; Lafta, R.; Van Uiter, J. Towards circular economy in Architecture. *Res. Archit. Urban. II* **2016**.
60. Lindblad, H. Construction Management and Economics Black boxing BIM: The public client's strategy in BIM implementation Black boxing BIM: The public client's strategy in BIM implementation. *Constr. Manag. Econ.* **2018**, *37*, 1–12. [CrossRef]
61. Lingegård, S.; Havenvik, M.I.; Eriksson, P.E. Circular public procurement through integrated contracts in the infrastructure sector. *Sustainability* **2021**, *13*, 11983. [CrossRef]
62. Almeida, F.; Vieira, C.S.; Carneiro, J.R.; de Lurdes Lopes, M. Drawing a Path towards Circular Construction: An Approach to Engage Stakeholders. *Sustainability* **2022**, *14*, 5314. [CrossRef]
63. Adams, K.T.; Osmani, M.; Thorpe, T.; Hobbs, G. The role of the client to enable circular economy in the building sector. In *Proceedings of the International HISER Conference on Advances in Recycling and Management of Construction and Demolition Waste*, Delft, The Netherlands, 21–23 June 2017.

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