Interreg North Sea

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CircleBIM

Conceptualisation of a common and transferable

CircleBIM Framework

to enable innovative use of BIM in circular public planning and procurement processes

CIRCLEBIM

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Conceptualisation of a common and transferable

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Summary

This document presents the development and redesign of the CircleBIM framework, the output of Activity A1.3 within Work Package 1 of the CircleBIM Interreg North Sea project. The aim is to enable the integration of Building Information Modelling (BIM) with Circular Economy principles in public planning and procurement of construction projects. The framework was developed through a combination of literature synthesis, review of standards and guidelines, and iterative engagement with project partners and stakeholders. It is deemed to utilise a common and transferable structure that operationalises circular ambitions across the building lifecycle while remaining adaptable to national and project-specific conditions. The framework connects directly to earlier WP1 activities, including A1.1 (stakeholder survey and mapping of existing practice) and A1.2 (collection of methods and good practices), and frames subsequent work in A1.4 (co-design implementation templates for pilots and LCCPs) and A1.5 (monitoring and evaluation for pilots and Local Circular Construction Partnerships).

The CircleBIM structure organises circular interventions across the lifecycle by describing each phase, identifying relevant stakeholders, and specifying a circular-BIM setting for information exchange and decision-making. The lifecycle framing used in this version reflects the practical needs observed in partner exchanges. It is intended to highlight four principal synergies across phases where circular interventions and information management converge: planning versus delivery, design versus operation, permitting & procurement versus pre-demolition audit, and construction versus deconstruction. For each lifecycle phase, the framework indicates what differs from business-as-usual practice and which BIM-enabled steps and stakeholder roles should be emphasised to achieve circular outcomes. The framework, therefore, aims to make circular ambitions actionable by prescribing ambitions, recommending appropriate measurement methods, and clarifying which parties should be involved at key decision points.

A central tenet of CircleBIM is that BIM operates as the digital backbone for capturing and transferring circularity information. The design embeds information management principles inspired by ISO 19650 to clarify responsibilities, information requirements, delivery planning, and use of a Common Data Environment (CDE). The framework recognises that only relevant, authorised information should be exchanged between phases and that information management must be proportionate to project scale and complexity. Where available, BIM is expected to host reuse inventories, material passports, and links to assessment tools; where BIM is absent, the framework accommodates alternative, phased approaches to digital integration. The first redesign responds to partner feedback by strengthening the BIM and data aspects, clarifying information flows, decision points, required deliverables, and emphasising open, interoperable approaches to support cross-stakeholder exchange.

To make circularity measurable, the framework integrates assessment logic that links established environmental indicators with material-flow-oriented methods. Material Flow Analysis (MFA) is introduced as a supporting measurement method to compile inventories of inflows and outflows, quantify losses and recoveries, and place material reuse within spatial and temporal system boundaries. Sankey-style visualisations are proposed to present MFA outcomes, illustrating primary and secondary inputs, stock accumulation, and waste flows. These visualisations enable the comparison of scenarios (for example, selective deconstruction versus conventional demolition) and help identify circular hotspots. By aligning MFA outputs with BIM-derived object and quantity data, the framework aims to shift evaluation from static indicators to dynamic, scenario-based assessments that better inform design and procurement choices.

The first redesign incorporated partner suggestions received in workshops and the consortium meeting: a pre-demolition audit phase was explicitly added; initiation was expanded to include context

and asset analysis; construction guidance now includes reverse logistics and on-site validation for reused elements; and delivery and operation phases acknowledge circumstances where as-built BIM models may be unavailable. The visual presentation was revised to function as a conceptual template that pilots can customise and potentially develop into decision trees reflecting project-specific entry points and critical interventions.

Next steps focus on operationalisation and evaluation. Activity A1.4 will deliver implementation templates and guiding questions for each phase of the pilot application; Activity A1.5 will provide a monitoring and evaluation framework with multi-method KPIs to assess LCCP innovation processes and pilot technical, regulatory, and user-acceptance outcomes. The framework is not a final product but a living tool to be refined through iterative pilot testing, stakeholder feedback, and alignment with complementary annexes that will document circularity ambitions, measurement methods, and open BIM data practices. Annexes will be developed to complement its application, including an overview of common circularity ambitions (Annex A), assessment methods and metrics (Annex B), and open BIM tools and collaboration platforms (Annex C). Together, these resources will provide both conceptual clarity and technical guidance for project partners.

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1. Introduction

The integration of Building Information Management (BIM) with Circular Economy (CE) principles has emerged as a critical area of research to address construction waste and promote resource management, as well as sustainable practices. This report synthesises key recent publications to assess current frameworks, their technical capabilities, and the persistent challenges in enabling CE through BIM, thereby developing a comprehensive and transferable framework for applying circularity in construction projects.

BIM, as a model-based process, enhances collaboration among stakeholders by providing a shared digital environment. Aguiar, Vonk, and Kamp (2019) reframe BIM as a process for managing building information to support circular design, emphasising the concept of buildings as material banks. Their CE BIM models introduce material passports, defined as digital records of component specifications, embedded in BIM models to facilitate circular design. The study distinguishes between the coordination model (general information), the revision As-built model (detailed information), the lifecycle models (tracking maintenance), and the circular models (optimised for disassembly). It highlights that stakeholder alignment on data requirements determines the effectiveness of CE within the BIM context.

Efforts to align BIM with CE have led to the development of various assessment tools and frameworks. For example, the Material Efficiency BIM Assessment Tool shifts the focus from life-cycle estimates to project-based material flow analysis, providing real-time visualisations of circularity through colour-coded 3D models (Jiang, van den Berg, Voordijk, & Adriaanse, 2022). The authors acknowledge that their tool was developed based on a single large-scale renovation project, which limits its usability to testing and, therefore, provides incomplete materials flows for other projects.

A BIM-based circularity framework that integrates different measurement methodologies represents a significant contribution in automated circularity assessment, specifically targeting the assessment of strategies such as detachability (Jiang, van den Berg, Voordijk, & Adriaanse, 2025). The Building Circularity Index (BCI) framework enables early design phase assessments by quantifying material reuse potential and disassembly metrics through standard BIM tools such as Dynamo scripts linked to BIM models (Van Der Zwaag, Wang, Bakker, Van Nederveen, Schuurman, & Bosma, 2023). This tool identifies "circular hotspots" and supports iterative design optimisation, although its effectiveness is limited in retrofits due to incomplete as-built data. Similarly, the BIM-based Circularity Assessment Tool (B-CAT) dynamically assesses circularity at the material, product, system, and building levels, adapting to different levels of development (Jiang et al., 2025). Existing tools are often tied to specific project phases (e.g., renovation and retrofit) and lack integration with other tools and frameworks, which limits their compatibility and interoperability. Despite these advancements, existing tools are often not designed for scalable and transferable use across diverse public planning and procurement contexts. Proprietary BIM tools are also not yet optimised for end-of-life or circularity-specific functions, and require customisation or advanced skills (e.g., via Dynamo scripts) to be usable for material reuse or inventory integration (Akbarieh, 2024).

Standardising circularity data requirements within BIM workflows remains a challenge. First, a clear vision and requirements for circularity may not have always been set. Second, there's a need to translate these circularity requirements into formats enabling semi-automated compliance checks for material composition, environmental impact, and disassembly protocols (Tomczak, Benghi, van Berlo, & Hjelseth, 2024). While most aspects of circularity can be expressed through Industry Foundation Classes (IFC) standards, significant challenges remain in modelling element connections and disassembly sequences, which often require manual documentation (Tomczak et al., 2024).

Additionally, fragmented standards for material specifications, software interoperability gaps, insufficient information regarding data quality, and availability are identified as key barriers (Tomczak et al., 2024). For the CircleBIM framework, this challenge is directly relevant to the underlying data, which must be structured in a way that allows different stakeholders and digital tools to interpret it without ambiguity. In practice, this means that CircleBIM aims to guide what to formulate for circular ambitions, but also contributes to shaping how circularity-related data can flow across stakeholders and phases, making the framework more operational in real project contexts.

Effective collaboration requires shared objectives, transparent information flows, and clear mechanisms for communication and decision-making. Early engagements are critical for setting circularity ambitions and objectives that all parties agree upon. BIM could support the realisation of these shared ambitions by enabling, for instance, the "buildings as material banks" concept, but this potential is not yet fully realised due to a range of implementation and regulatory constraints. (Charef & Emmitt, 2021). Another example of these constraints includes the limited availability of standardised BIM object libraries for reused or bio-based components. Despite significant progress having been made in research projects and initiatives, fundamental challenges continue to constrain the effectiveness and CE adoption of BIM. Moreover, information interoperability remains a key technical barrier, with inconsistent schemas for circularity-related data limiting integration across platforms and stakeholders (Charef & Emmitt, 2021). Implementation barriers extend beyond technical and organisational limitations to include industry adoption challenges, difficulties in cost-benefit justification, and the complexity of stakeholder collaboration. The authors emphasised the need to develop detailed process mappings for the use of CE in BIM (Charef & Emmitt, 2021).

This report responds to these challenges by conceptualising a common and transferable CircleBIM Framework. It incorporates insights from research and stakeholders to address technical, methodological, and practical gaps in implementing CE principles through BIM. It emphasises collaborative workflows, the use of standardised metrics, and the need for integration of digital tools across construction phases, while defining stakeholder roles and measurement methods.

This report is structured as follows: Chapter 2: Methodology describes the research approach and development of the framework; Chapter 3: Requirements for the CircleBIM Framework identifies the technical, procedural, and practical prerequisites for effective integration of CE and BIM; Chapter 4: Development of the CircleBIM Framework presents the conceptual and practical design of the framework, including its core elements and workflow components; Chapter 5: Verification of the Framework outlines the verification process and initial feedback from stakeholder meetings; Chapter 6: First Redesign and Revision of the Framework discusses iterative improvements based on feedback and lessons learned; and Chapter 7: Discussion and Conclusions outline the results, highlights implications for practice within pilot projects, and suggests directions for future work.

2. Methodology

This chapter provides a brief explanation of the methodology employed in developing the framework as part of WP1 (Common Framework for CircleBIM), which consists of 6 activities. The framework is the outcome of activity A1.3 of WP1. It closely connects to other deliverables, such as activity A1.1, where the initial stakeholder survey was conducted to gather experience and knowledge on circular practices and BIM. It also frames the future work in A.1.4 for an implementation template, and A1.5, a monitoring and evaluation framework will be developed for both the Local Circular Construction Partnerships (LCCPs) and pilot projects.

2.1 Framework Development Approach

The CircleBIM Framework is developed through a systematic, iterative methodology comprising six main phases, the first four of which are targeted in this report:

1. Identification of requirements for the CircleBIM framework (Chapter 3)
2. Initial framework design (Chapter 4)
3. Verification of the framework through stakeholder feedback (Chapter 5)
4. Redesign of the framework based on the verification phase (Chapter 6)
5. Implementation and validation of the framework in the pilot projects (in WP2)
6. Redesign of the framework based on the validation phase (in WP2)

This approach aligns with established BIM protocol development methodologies, which emphasise collaborative validation through expert review cycles to ensure practical applicability and industry relevance. The framework development process was grounded in four fundamental blocks that collectively enable circular economy integration within BIM workflows:

1. **Circularity Ambitions:** Define measurable circular economy objectives for projects. These ambitions serve as the conceptual basis for all subsequent design and decision-making processes (Annex A).

2. **Strategies (e.g., design strategies):** Implement specific circular approaches for each construction phase. These strategies aim to translate circularity ambitions into actionable insights for each phase (described within the framework).

3. **Measurement Methods:** Established and standardised metrics and assessments to evaluate circular performance (Annex B).

4. **BIM (Digital) Tools:** Specific software applications, plugins, and digital platforms that enable automated circularity assessment, material tracking, and stakeholder collaboration across project phases (Annex C).

2.1.1 Verification and Validation Process

The framework verification was conducted following the consortium project meeting held in Molde, Norway. A structured stakeholder meeting, including sets of interactive workshops, was organised involving representatives from project partners. Each element of the framework was presented to stakeholders using a structured review to gather their feedback on the approach, considering technical feasibility, practical applicability, and alignment with existing regulatory frameworks.

2.1.2 Framework Revision and Refinement

Based on stakeholder feedback, the initial framework was systematically revised to fill the identified gaps and improve practical applicability. This feedback was gathered during both the general online meetings and the physical consortium meeting, resulting in several rounds of feedback iterations. After each online meeting, project partners had been asked to share their written feedback, and during the physical meeting, each pilot project partner received a template of the existing framework to reflect on the details of the latest version of the framework.

It should be noted that in this report, only the two most recent versions of the framework are presented. Chapter 4 outlines the version that was already revised following initial feedback gathered from partners during a series of online meetings. This version was subsequently used as the basis for discussion during the physical consortium workshop held in Norway. Then Chapter 6 provides an overview of the first major redesign, reflecting both the feedback received during the workshop and further insights aimed at guiding future development. As such, while the first redesign and its proposed improvements are documented in this report, additional modifications are expected as part of the continued work under task A1.5 (WP1), which includes the ongoing monitoring and evaluation of the framework.

2.2 Lifecycle Phase Integration

The framework integrates circular interventions across nine distinct phases of the construction lifecycle, from initiation through demolition and deconstruction. While there is no single international standard that prescribes these exact phases, they are grounded in established lifecycle perspectives, such as those embedded in EN 15804 and ISO 19650. Building on these references, the phases were further outlined based on the authors' experience to align with both circular economy practices and BIM-enabled information management.

In addition to the initiation and scoping phase, the eight phases are structured to capture four key synergies across the lifecycle: (1) planning vs. delivery, (2) design vs. operation, (3) permitting & procurement vs. pre-demolition audit, and (4) construction vs. deconstruction. These pairs represent distinct junctions where circularity interventions can deviate from business-as-usual practices and require specific BIM-supported workflows. For example, pairing planning with delivery highlights whether early circular ambitions are realised in handover. At the same time, construction vs. deconstruction captures the continuity of material flows across end-of-life and new life cycles.

Each phase incorporates specific circular activities, stakeholder roles, and potential questions to guide the involved stakeholders, which is further elaborated in A1.4 as a complementary work to this initial design of the framework, making it more practical and transferable. The framework includes a row on a description of each phase, and then provides a circular BIM setting that involves specific stakeholders for each lifecycle phase. The phases are described in Chapter 4.

2.3 Stakeholder engagement

Stakeholder engagement is a central component in the initial development and iterative refinement of the CircleBIM Framework. Recognising that circular construction relies on collaboration across diverse actors, the framework is designed to capture both practical needs and conceptual insights from stakeholders at various phases of the construction lifecycle.

In parallel, the framework references insights from A1.4, A1.5, and A1.6, where complementary work is being conducted to define stakeholder roles further and evaluate implementation in pilot settings. These efforts are particularly focused on ensuring that emerging actors are represented and supported within the framework. The stakeholder engagement methodology thus serves not only to validate the framework content but also to align its relevance and usability across the pilots and LCCPs.

As part of the framework development process, two key stakeholder groups were identified: Local Circular Construction Partnerships (LCCPs) and pilot projects. LCCPs provided regional insights, policy context, and cross-sector collaboration, while pilot projects served as real-world demonstrators for applying and validating the framework in practice. (see Figure 1). A detailed analysis of their roles, contributions, and integration into the framework is presented in Chapter 4.

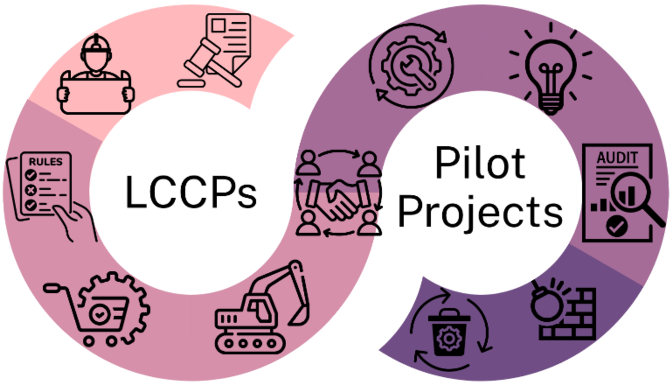

Figure 1: Stakeholder engagement from initiation (top left) to the end of the life cycle(bottom right), involving LCCPs (Municipalities, designers, engineers, contractors, etc.)and the pilot projects as the two main categories of stakeholders within the CircleBIM project.

As shown in Figure 1, a construction project may involve various stakeholders associated with LCCPs and pilot project partners. Each project may have its unique types of stakeholders and partners, depending on the scope of the project system. However, a general collaborative and iterative workflow can be identified between these two main types of stakeholders. The connections between LCCPs and pilot project partners are discussed in the coming chapters.

3. Requirements for the CircleBIM framework

The first step in the development of the CircleBIM framework entails a closer definition of this framework. In the project proposal, Activity 1.3 was described as follows:

> Acknowledging country-specifics of legislation & BIM practices (A1.1), of methods and (good) practices (A1.2), project partners co-develop a common & transferable CircleBIM framework that:
> a. carves out key stakeholder processes & applicable BIM approaches to efficiently steer circular public planning and construction (PPC) projects,
> b. enables national/regional adaptations, and
> c. provides a base for a step-by-step guidance to set-up own innovation platforms (Local Circular Construction Partnerships, LCCPs) that enable innovative use of BIM in circular PPC processes.

As a more concrete operationalisation of the framework, a shared understanding is crucial. The following was proposed and agreed upon in an online monthly (WP1 meeting on 26 February 2025):

'The CircleBIM framework is a practical guideline prescribing step by step what needs to be done at each stage of a construction project -from initiation to demolition/deconstruction. It shows which parties should be involved at each step, and how to use BIM tools to achieve the project's circularity goal(s).

The second step is to identify the requirements for the CircleBIM framework. The following sets of requirements (see Table 1) have been identified based on (i) the proposal, (ii) information about the pilots, and (iii) the results of Activities 1.1 and 1.2. These requirements were discussed and agreed upon in an online monthly WP1 meeting on 25 March 2025.

Table 1: Defined requirements of the framework and their corresponding sources.

#	Requirements	Source
1	Include key stakeholder processes and BIM approaches over the whole lifecycle of a construction project.	Proposal
2	Allow for variety in contract forms (e.g. Design & Build (DB), Engineering & Build (EB), DB(F)M, DBFMO, …)	Pilots (WP2)
3	Allow for variety in definitions of circularity (from A1.1) or project aims with regard to circularity.	A1.1, A1.2 and pilots (WP2)
4	Allow for variety in construction types: (commercial/residential) buildings and infrastructure, both existing and new.	Pilots (WP2)
5	Allow for variety in national/regional rules and regulations.	A1.1
6	BIM software/platform independence.	A1.1 and A1.2

First, the framework must cover the entire lifecycle of a construction project, from early planning to deconstruction. Circularity is not limited to the design phase; it requires interventions at multiple phases. Therefore, the framework must guide BIM-supported actions across all lifecycle phases, showing how stakeholder roles and digital information evolve over the lifetime.

Second, the framework needs to be flexible across different contract forms. Public and private projects operate under varying procurement models (such as DB, DBFM, or Engineering & Build), each with different timelines, responsibilities, and data needs. The framework must not be limited to a single contractual scenario. Instead, it should remain adaptable, enabling circular strategies to be embedded regardless of how the project is procured or delivered.

A third requirement is to support different goals and scopes of circularity. Across partners and pilots, circularity is defined in various ways, given each stakeholder's interest. The framework must reflect this diversity by allowing users to define their own circular targets and select relevant indicators. Rather than enforcing a single definition, it should serve as a flexible tool that can adapt to evolving priorities.

Fourth, the framework must be applied to a diverse range of construction types, including buildings, infrastructure, and both new and existing assets. Renovation and retrofitting are key to circular strategies but come with unique challenges, such as limited digital data and practical barriers. The framework should remain inclusive and relevant to public and private actors working across various asset types and life cycle stages.

The fifth requirement concerns the diversity in national regulations and policy maturity across Europe; the framework also needs to be adaptable to different legal and regional contexts. Some countries have strict circular procurement rules or BIM mandates, while others are in the early stages. The framework must accommodate these differences while still promoting shared principles and workflows.

Lastly, the CircleBIM Framework must be BIM software- and platform-independent. Project partners and stakeholders utilise a variety of tools, and proprietary software constraints may limit their adoption. The framework should focus on open data standards and incorporate workflows that can be implemented across various digital environments. This not only supports broader interoperability but also encourages partners from smaller actors, who often operate outside of major BIM ecosystems.

4. Development of the CircleBIM framework

The CircleBIM framework builds upon stakeholder engagement, insights from project partners, and structured feedback loops, and responds directly to the requirements defined in Chapter 3. Its purpose is to support aligning digital practices with circular goals.

The first design of the framework is organised as a matrix (see Table 2), with nine vertical phases representing the building lifecycle and three horizontal components that define the technical (business as usual vs circular approach) and collaborative layers of circular BIM integration. This structure reflects both a chronological project timeline and a layered approach to implementation. Each cell in the CircleBIM row captures the key circular interventions, while the bottom row refers to stakeholders typically involved. Since the first draft does not include specific methodological aspects, a reflection on existing common circularity ambitions, measurement methods, and digital tools will be provided in the Annexes.

In conventional construction practice, the initiation phase primarily focuses on establishing fundamental project objectives, constraints, and functional requirements, often with limited consideration for circularity or lifecycle impact. Decisions made at this stage typically prioritise feasibility, cost, and time, which can lead to linear outcomes that are challenging to reverse in later stages (Charef & Emmitt, 2021). The CircleBIM approach reframes this early phase as a critical and central phase for applying circular ambitions into the project's foundation. Here, the client should be supported, where necessary, by a sustainability or circularity consultant for defining specific, measurable circularity targets. These may include goals such as increasing the reuse of materials, designing for disassembly, or minimising embodied carbon. Selecting a suitable measurement method to track these ambitions can be operationalised and monitored through the BIM environment. This early integration sets a clear roadmap for project partners to align their decisions with circular performance outcomes.

The traditional planning and procurement phase is primarily concerned with formalising the project plan, selecting design partners, and setting out contract terms based on predefined objectives such as budget, schedule, and technical performance. However, circular ambitions are often not fully integrated into procurement documents, which limits their influence on design outcomes. In contrast, the CircleBIM approach utilises this phase to translate circular ambitions into a measurable and enforceable procurement strategy, with explicit integration into the design tender process. Drawing on the Dutch national guideline "Circular Procurement in 8 Steps" (van Oppen & Bosch, 2020), this involves a systematic process that begins with internal alignment around the project's circular vision and digital strategy, with a strong focus on collaboration, particularly regarding BIM integration (van Oppen & Bosch, 2020). After formulating the circularity ambitions, the client (together with the consultant) is responsible for embedding these ambitions in the tendering procedure and the procurement documents, potentially with input from consultants. Architects can also play a key role in interpreting these requirements and proposing design strategies that meet both functional and circular goals. Lastly, to secure circularity interventions, measuring and assessing them should be an integral part of the process, as explored in A1.5 as part of the monitoring and evaluation framework.

Generally, the design processes focus on technical feasibility, compliance with building codes, and cost efficiency, often within a linear material logic. Once the initial concept is approved, design iterations largely follow a path toward final engineering and detailing, with a limited structured evaluation of how decisions affect resource circularity. By contrast, the CircleBIM approach introduces an assessment loop, ensuring that circularity ambitions (defined in earlier phases) remain integrated and traceable throughout each stage of the design cycle, from preliminary to final engineering. For the BIM aspect, the digital model and data management should be reviewed to verify alignment with the circular targets. The circular design approach is based on the structured application of circular design strategies, as formalised in the Platform CB'23 Circular Design Guide (2023), which outlines seven principles: prevention, design for quality and maintenance, design for adaptability, design for disassembly and reusability, design with reused parts, design with secondary raw materials, and design with renewable resources. In practical terms, this means within the CircleBIM framework, the design team should explore and validate end-of-life strategies such as Design for Disassembly (DfD), Design for Adaptability (DfA), as well as immediate strategies such as Design with Reuse (DwR), and Design with Biobased materials (DwB), all of which need to be modelled and simulated within the BIM environment. In line with the design qualities described by Galle et al. (2019), the design process should also prioritise simplicity, durability, reversibility, and compatibility, qualities that enhance the long-term circular performance of the built asset. Throughout this phase, the architect and engineers lead the process. Among the others, the client, project owners, and potential circular consultants provide feedback to ensure that decisions are verifiable and supported by BIM-based information structures.

The permitting and procurement phase typically focuses on compliance with building regulations, obtaining necessary permits, and tendering for construction services. While these activities are essential for legal and technical approval, they rarely prioritise circularity or collaborative innovation. The CircleBIM approach introduces critical enhancements by aligning circular interventions with legal and regulatory frameworks and embedding them meaningfully into the procurement process. This includes verifying that circular ambitions should not only be technically feasible but also compliant with current codes, which is essential for securing permits and public approvals (van Oppen & Bosch, 2020). More importantly, this phase marks the transition from ambition to execution, and thus calls for a collaborative procurement strategy. Drawing on the Circular Procurement in 8 Steps guideline (van Oppen & Bosch, 2020), the client is encouraged to create space for shared interest-building among contractors, designers, and suppliers by opening channels for market consultation and dialogue. This can be done through pre-tender meetings, Requests for Information, or one-on-one sessions with supply chain actors to explore viable circular solutions and technical possibilities (van Oppen & Bosch, 2020). The tendering procedure itself should correspond to the project's complexity and specificity while also allowing for further innovation and flexibility, such as functionality-based procurement. In public projects, legal tendering principles should be maintained, but the process can still include criteria that stimulate circular performance and digital deliverables through BIM. Clients lead this process, while contractors, suppliers, and designers become active contributors to defining what is possible and co-creating practical pathways for delivering the circular ambitions established earlier in the project.

The construction phase is defined by executing the building works according to the approved design and specifications, with primary concerns focused on timelines, cost control, and technical performance. Waste minimisation and circular resource use are often treated as secondary goals or compliance tasks rather than core aspects of site management. The CircleBIM approach considers this phase as a key opportunity to implement and monitor circularity strategies on-site actively. According to guidelines such as Level(s) Indicator 2.2 on Construction and Demolition Waste (Donatello et al., 2021), the focus shifts toward reducing construction waste at the source, maximising the reuse of materials, and maintaining tight control over material flows. This includes reducing material loss, using just-in-time to minimise onsite storage damage, and training contractors and subcontractors in site-specific circular waste practices. Contractors and suppliers play an essential role during this phase, not only executing tasks but also contributing to circular outcomes through informed decision-making, waste monitoring, and material handling practices, often guided by site-specific Waste Management Plans (WMPs).

The delivery phase typically is about formal handover of the completed construction, including physical inspection and regulatory approvals. The CircleBIM approach reframes delivery as a critical convergence point between physical and digital assets, where the handover includes not only an accurate as-built model, but also data representing circularity indicators. This should reflect all deviations from the original engineering design, including material substitutions and construction adaptations, thereby aiming for a digital twin that represents the as-built model. Moreover, the delivery phase involves a formal evaluation of the project's circularity ambitions, utilising the indicators and objectives established during earlier phases. As highlighted by Soman et al. (2024), emerging digital tools can influence how delivery is conceptualised, enabling handovers that bridge physical completion with ongoing digital use, and enriching BIM supplements. Key stakeholders in this phase include the client, who receives and owns the digital twin; the contractor, responsible for compiling accurate as-built data; and the suppliers, who contribute to final material and data validation

The operation and maintenance phase is often treated reactively, adapting to user needs, with little integration of data or long-term circularity objectives. The CircleBIM approach defines this phase as a core opportunity to prolong the functional life of the building through proactive, digitally supported decision-making. Hence, if BIM is connected to sensor data and updated throughout previous phases, it enables facility managers and owners to plan and manage maintenance, replacements, and renovations based on actual performance rather than assumptions; i.e. the building model functions as a real-time digital twin. As such, BIM provides a platform for retrieving and managing data within a digital 3D environment, supporting tasks such as maintenance and energy monitoring (Gao & Pishdad-Bozorgi, 2019). The CircleBIM framework emphasises not only the registration of all physical modifications in the BIM model but also the integration of energy efficiency goals, including the use of sustainable or on-site renewable energy sources. Advanced digital technologies are also emerging as valuable tools during this phase, enhancing users' ability to visualise systems and intervene efficiently, particularly in complex maintenance scenarios (Casini, 2022). This provides facility managers with a smart and digital environment (e.g., a dashboard) that supports decision-making on maintenance or renewal of building elements. Residents, building owners and facility managers are the primary stakeholders during this phase, responsible for interpreting BIM data and using it to inform ongoing operations. The CircleBIM framework and its use should be tailored to the competence level of these core stakeholders, who often lack extensive BIM knowledge.

The pre-demolition audit phase is often not present in conventional practices, typically viewed only when a regulatory or cost-estimating audit is required before demolition. However, in the CircleBIM approach, this phase needs to be elevated as a strategic point for maximising value retention through the systematic identification and recovery of high-quality and high-value materials and components. This means that the circularity ambitions of the project should be made available in the BIM model in terms of material lifespan, recycling or reuse potential. As described in the guidance from the Level(s) Indicator 2.2 framework (Donatello et al., 2021), a pre-demolition audit is used to prepare a comprehensive inventory of the construction elements present in the structure (from the most available as-built BIM model), and supplemented with field surveys when necessary to account for deviations or undocumented changes. The audit should identify materials, including any hazardous substances, and prioritise recovery strategies based on their condition, technical quality, and local end-use markets. High-value elements can be planned accordingly, along with the logistics of material handling, temporary storage, and potential future reuse. Stakeholders include the client, who commissions the audit; the contractor, who integrates audit results into deconstruction planning; and waste management or material recovery partners, who advise on feasible sorting, processing, and market pathways.

In the CircleBIM framework, the deconstruction phase is not seen as a final, isolated stage, but rather as a critical stage that aims to close the materials loop and initiate new cycles of reuse, recycling, and value retention. While the current framework establishes foundational principles, this phase is highlighted for future development and refinement through applied testing across pilot projects. These explorations will examine BIM-supported approaches that incorporate performance indicators to simulate and compare deconstruction options based on project specifications, reflecting both technical feasibility and the potential for value retention for circularity documentation, particularly linked to local or national material recovery standards. The technical prerequisites for high-value deconstruction through BIM can incorporate a comprehensive database of materials and components, ultimately with detailed instructions for their removal, reuse, or recycling (Roxas et al., 2023).

Table 2: The primary CircleBIM framework, designed to engage different stakeholders with their respective potential roles

Phase	Description	CircleBIM	Stakeholders
Initiation	**Define project objectives & constraints**	Define the circularity **ambitions** for the project. Make sure these ambitions are **measurable**. Select an appropriate measurement/evaluation **method**.	Client (Consultant)
Planning & procurement of design	**Development of project plan & procurement of design**	Include the measurable circularity ambitions + evaluation method in the **tender**. Redefine project objectives	Client (Consultant) Architect(s)
Design (preliminary - concept - final - engineering)	**Design of the construction object(s)**	After each step in the design cycle, **verify** whether circularity ambitions are still met. Possible **design strategies** to be considered: ▪ Design for Disassembly (DfD) ▪ Design for adaptability (DfA) ▪ Design with Reuse (DwR) ▪ Design with Bio-based (DwB)	Architect(s) Civil engineer(s) Building physics Consultant(s)
Permitting & procurement of construction	**Regulatory compliance, tendering, and procurement**	Ensure that **circular interventions** align with regulations and codes to facilitate the **awarding of contracts**. Creating a **collaborative procurement** process by making shared interests among different stakeholders, including client and **market parties**. Choose a tendering procedure that matches the project's objectives and allows **scope for innovation**.	Client Contractor Suppliers Designer(s)
Construction	**On-site activities related to construction and installation**	Reduce on-site **construction waste** and control material usage. Employing advanced construction techniques and adhering to defined circular objectives. In the case of the existing structure, maximize the utilization of **retaining materials** from construction sites. Keep track of **changes** with respect to the Engineering Design.	Contractor Suppliers
Delivery	**Construction is marked completed and transferred to the client**	The delivery must include an updated, **as-built Building Information Model**, which the client can use in further operation/exploitation of the construction. Assess whether (or to what extent) **circularity ambitions are met**. Draw lessons for future projects accordingly.	Client Contractor Suppliers
Operation, management, maintenance	**Use phase over the life cycle of the structure**	Consider maintenance, repairs, replacements, refurbishments, and renovations to **extend the lifetime** of the structure. **Reduce operational energy** use and aim to **utilize sustainable energy generated** during the operation. **Register any modifications** to the construction in the Building Information Model.	Resident(s) Building owner(s)
Pre-demolition audit	**Outline the planning for demolition work**	Prepare **inventory** and quantity & quality estimations using the most recent **Building Information Model**, supplemented with field surveys and inspections, if needed. Striping of **high-value** materials and components. Examine the **logistics** of retaining materials and components.	Client Contractor Waste management partner(s)
Demolition/ deconstruction	**End of Life management, including demolition waste handling**	**Selective** deconstruction and facilitate **systematic deconstruction** methods. Explore scenarios such as energy and material **recovery, recycling**, and ultimately, **reuse** opportunities.	Client Contractor Waste management partner(s)

5. Verification of the CircleBIM framework

The development of the CircleBIM framework has been a collaborative process, involving a series of verifications with project partners, pilot stakeholders, and technical experts through multiple interactions within consortium meetings. This chapter outlines the sequence of activities through which the initial version of the framework was tested, refined, and verified while also highlighting key feedback that informs future development and operationalising the CircleBIM framework.

The first version of the framework was shared during the WP1 meeting on 25 March 2025, where the core nine lifecycle phases were presented for review. This discussion initiated partner feedback, including the suggestion to add a dedicated pre-demolition audit phase, reflecting its increasing relevance in circular construction workflows. The revised framework was further presented on 2 April 2025, focusing on the initiation, planning/procurement, and design phases. Feedback collected by the end of April informed the next iteration, which was discussed during a WP1 meeting on 7 May 2025.

An important step toward operationalising the framework involved developing accompanying implementation templates (linked to A1.4), which were presented alongside the framework on 26 May 2025 in preparation for the in-person consortium meeting in Molde, Norway. The framework and templates were then tested during an extensive workshop session on 3 June 2025, where participants engaged in five interactive rounds to apply the framework to each pilot project, test its usability, and explore scenario-based implementation strategies.

Partner feedback revealed both alignment with and necessary extensions to the initial proposed structure. Across the nine phases, the feedback focused on four interconnected dimensions: circularity ambitions, design strategies, measurement methods, and BIM tools (see Table 3). A sample of this structure was used during the workshop in the form of feedback tables, helping participants link theoretical ambitions to practical design and digital workflows.

*Table 3: Example of the template shared with partners to conceptualise and navigate the feedback from circularity ambitions to the BIM utilisation (*further explanation for the used terms can be found in Annexes)*

Circularity ambition (not exhaustive)	Design strategy (not exhaustive)	Measurement methods (not exhaustive)	BIM (digital) tools (not exhaustive)
Remountable facades	Design for disassembly (deconstruction)	Disassembly/detachability index (LI)* https://www.dgbc.nl/whitepapers/circular-buildings-een-meetmethodiek-voor-losmaakbaarheid-v2-0/	
30 (mass)% biobased materials	Design with renewable (biobased)	BCI, MCI, CB'23*	CircleTool 2.0*
Transforming an existing (old) office building into a residential complex	Design for adaptability (renovation)	Level(s) 2.3*	

5.1 Feedback Themes and Incorporation

The feedback confirmed the relevance of the lifecycle-based structure and the inclusion of stakeholders and roles for each phase, but also highlighted several areas where the framework could be further detailed, clarified, or made more adaptable. In particular, partners highlighted the need to enhance the early phases, improve usability, integrate BIM tools and data requirements more explicitly, and strengthen the framework's role as both a guideline and a driver of circular ambition. Key recurring insights are summarised below, incorporating both early feedback and new suggestions from the Molde meeting:

- **Circularity Ambitions**: Partners consistently emphasised the importance of early-phase circularity planning, recommending that the framework allow for even pre-initiation activities such as context and site analysis, and inventorying of existing assets (e.g., buildings, materials, infrastructure, and available data). This was seen as critical in projects that begin with renovation or demolition rather than new design. Suggestions included defining Early Information Requirements (EIR) specific to circularity, as well as assessing the reusability and residual value of existing components. There was also a call for the framework to act more decisively as a driver of circular ambition, encouraging clients to go beyond compliance and aim for higher-value retention and reuse targets.
- **Design Strategies**: Several partners referenced tools such as the Circular Built Tool, Circular Actions scenario planning, and design principles from the CB'23 guideline. These were used to support an iterative, multi-scenario design process enabling flexibility, reversibility, and reuse. Beyond the previously mentioned Design for Disassembly (DfD), Design with Reused Materials (DwR), and Design with Biobased Materials (DwB), participants highlighted the need for inspiring examples and more explicit guidance. The framework should not only recommend strategies but also help users select, combine, and apply them according to their project context.
- **Measurement Methods**: The need for clear and measurable performance indicators was raised and discussed, particularly those aligned with existing regional and national tools (e.g., GRO tool and Circular Built metrics in Belgium, Level(s) European framework). New feedback also recommended establishing a circularity scoring or Key Performance Indicators (KPIs) structure for each lifecycle phase, potentially allowing users to track progress through project implementation. Furthermore, participants suggested integrating these measurement methods with the decision-making process, providing feedback loops at critical project milestones.
- **BIM Integration**: BIM was repeatedly mentioned as the core digital tool application for implementing the framework. Therefore, there was a call to make the BIM aspects more explicit and operational, not only in principle but also in terms of tools, data structures, and use cases. Recommendations included:
    - Including specific BIM tools (e.g., model checkers, scan-to-BIM technologies, and software tools) relevant to each phase.
    - Connecting BIM to external tools such as Life Cycle Assessment (LCA) platforms and material passport platforms, and compatibility with BuildingSMART Data Dictionaries.
    - Tracking condition and modification over time for asset management and maintenance with a focus on clear guidelines in data workflows and data exchanges.
    - Incorporating object identification and scanning techniques to support the creation of digital twins and as-built models, especially for existing buildings.

- Highlighting that BIM models may not be available at the start of renovation or reuse projects, requiring manual workflows to support model creation from surveys or scan data, as well as using simple tools to allow the data structuring.

5.2 Incorporated improvements

This thematic synthesis informed a set of concrete improvements and additions to the framework, described in this section (5.2). The feedback also confirms that while the CircleBIM framework provides a foundation, its strength should lie in its adaptability, the clarity of its lifecycle structure, and its ability to evolve alongside pilot needs. Future development will continue to prioritise the dual goals of guidance and measurability, ensuring the framework takes into account the ambition for enabling technical precision and applying digital tools in practice. Several feedback were already implemented into the updated version of the framework presented in Chapter 4:

- A dedicated pre-demolition audit phase was added, with emphasis on inventorying and assessing reusable elements or recovery potentials, acknowledging that not all projects begin at the design phase.

- The initiation phase was expanded to include scoping and other types of analysis or assessment of the existing structure, and testing of the building elements for retaining the existing structure.

- The construction phase included proposals for on-site quality control of materials and planning for logistics to be observed as a critical phase in which BIM models would be adjusted for as-built information and possibly digital twins.

- The operation phase should acknowledge real-world conditions, including cases where BIM models do not yet exist, highlighting the linkage of BIM with maintenance and monitoring processes.

6. First redesign & revision of the CircleBIM framework

Following initial development, the framework was reviewed by project partners and stakeholders, resulting in feedback that highlighted both conceptual and practical areas for improvement. Suggestions included introducing a pre-initiation phase to capture existing assets and data, reconsidering the framework's linear structure in favour of a more iterative, circular format, and incorporating both inspiration and technical guidance to enhance the practicality and usability of the framework in real-world projects.

A strong emphasis was remarked from the partner meeting held on June 4, 2025, in Molde, Norway, on the need to expand the depth and clarity of the framework, particularly in how it integrates circularity assessment and BIM-driven data processes. Several partners noted that while the initial visual structure was conceptually a good starting point, its implementation required a more refined clarification on data flows, stakeholder interactions, and measurable outcomes. These insights informed a first redesign and revision of the CircleBIM framework, aimed at improving its clarity, functionality, and alignment with pilot projects.

This chapter is structured around three interrelated aspects of the framework: 1) Visualisation and graphical, 2) BIM and data, and 3) Circularity and assessment aspects as follows.

6.1 Visualisation and graphical aspects

This section presents the updated graphical representation of the framework, which has been improved from the initial matrix structure. It focuses on improvements that enable circular flows and iterations, rather than binding it to a linear, sequential structure, and yet aligns conceptually with the real project cycles. Also, attention is given to how the lifecycle phases correspond one-to-one, and adjustments are made, such as centralising the initiation phase (see Figure 2).

The redesigned figure includes eight main lifecycle phases (excluding initiation, which connects all phases), with a greater emphasis on the flexibility to move between phases that are most relevant to each pilot project. For example, renovation-focused pilots may begin with a pre-demolition audit or even the operation phase, rather than the design phase, making it necessary to visually and conceptually support non-linear entry points.

To accommodate this diversity, the revised visualisation is not a static diagram but a conceptual template. It is intended to be customised by each pilot project, functioning as a support tool that can potentially be transformed into a decision tree, which helps identify the critical lifecycle phases and where key decisions and interventions must occur. Such a decision tree cannot be predefined at this stage, as the relevance of phases, decision points, and information flows varies across pilot projects. Therefore, it can be developed iteratively through the pilot implementations (A1.4) and in the evaluation and monitoring framework (A1.5). The aim is to capture critical lifecycle phases where decisions on circularity must be made for each pilot, link them to specific information requirements and data exchanges, and provide conditional pathways depending on project context (e.g., new build, renovation, or demolition-first). Then, the decision tree will complement the framework and step-by-step implementation as a practical roadmap.

In future iterations, the CircleBIM framework's visualisation could also be linked to interactive digital tools, such as tools for circular scenario explorations (dynamic pathways), digital twins with real-time feedback, LCA tools integrated into the BIM environment, or dashboards (like Power BI) to monitor circular goals and KPI's over time. Such tools enable stakeholders to explore pathways, stimulate decisions, and track the progress of circular goals, while also being linked to or integrated into the BIM environment.

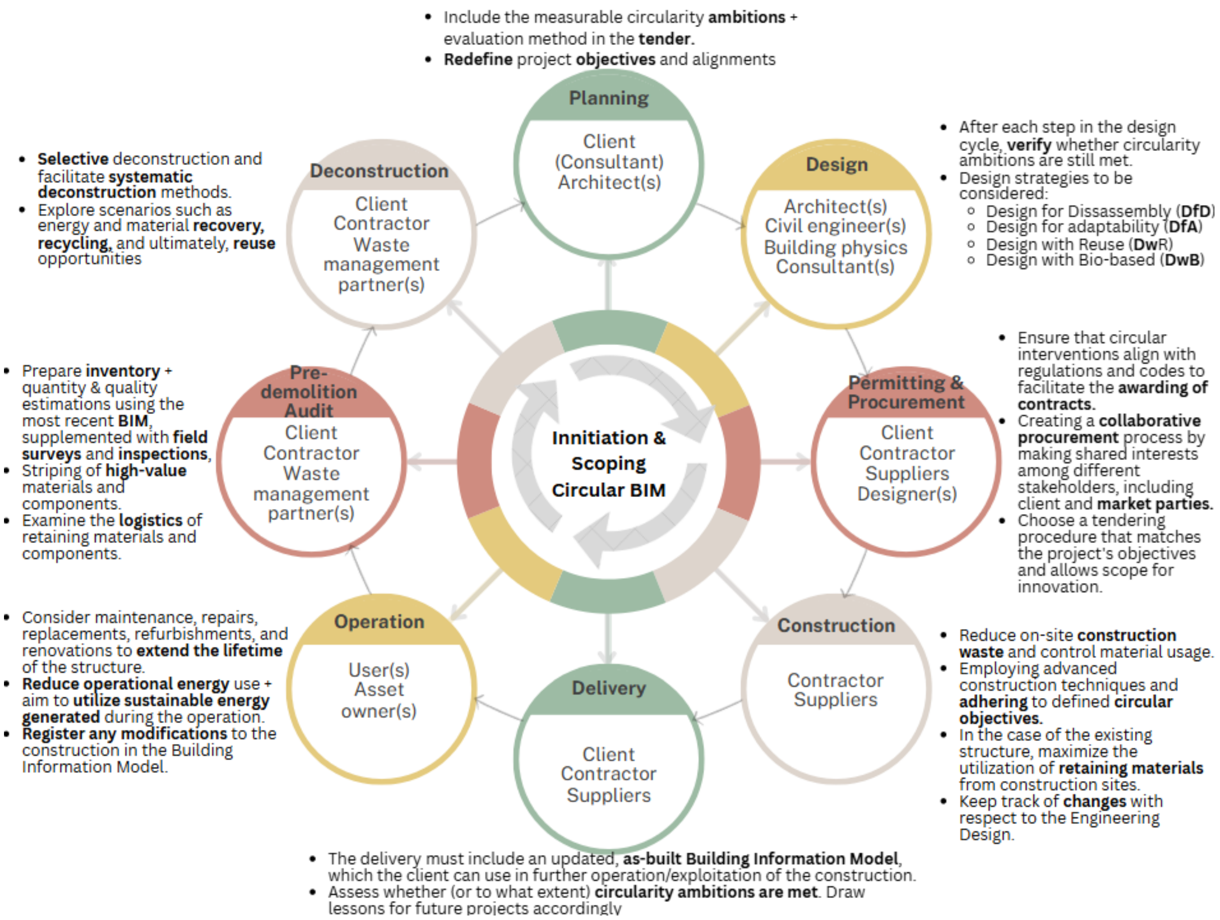

Figure 2: The first redesign of the Circle BIM framework, based on the feedback received from project partners in terms of enhancement in visualisations.

6.2 BIM and data aspects

This section addresses the feedback related to the depth and technical integration of BIM within the CircleBIM framework. It elaborates on how BIM serves as the digital support for material tracking, reuse, recycle or recover documentation, and circular performance monitoring. It also outlines necessary data flows, collaboration needs, and potential integration points with external platforms such as LCA tools or material passports. Ultimately, the aim is to deliver a BIM model that feeds circular approaches, i.e. design for maintenance, design for reuse, design for adaptability or design for disassembly.

Figure 3 summarises key information from the ISO 19650 series regarding the role of information management throughout the building lifecycle (ISO 19650-1:2019). Information management is distinct from, yet closely connected to, information production and delivery, and it should be applied consistently across both the delivery and operational phases. The process begins with each new appointment (formal or informal), involving the definition of information requirements, planning of delivery strategies, and validation of deliverables. Responsibilities for information management are assigned to relevant project participants or stakeholders (e.g., the appointing party, typically the client, or the lead appointed party, which is usually the main contractor) without necessitating the creation of new organisational roles. Importantly, only pertinent and authorised information should be exchanged between phases, and the process must remain proportionate to the project's complexity and scale. The use of a Common Data Environment (CDE) supports collaboration and facilitates the structured exchange of information, including federated models that reflect the needs of all stakeholders. Figure 3 illustrates this BIM workflow by showing the subdivisions of the building lifecycle, decision points, and information exchange moments in alignment with ISO 19650's guidance (ISO 19650-1:2019).

The ISO template can help CircleBIM pilots define data workflows. It can outline where and when information is produced and exchanged in a structured manner, and responsibilities should be clearly defined. It can also reflect information flows and deliverables, stakeholder decision points, and information exchanges throughout the life cycle phases.

If we translate the principles from ISO19650 to the CircleBIM framework, it is important to consider the following aspects:

- Specify Exchange Information Requirements (EIR) that explicitly include circularity-related data needs.
- Make use of a Common Data Environment (CDE) to facilitate structured storage and version-control of (circularity) data and boost collaboration between involved project partners
- Specify an Information Delivery Planning (IDP) that includes circular milestones, i.e., when material passports are delivered, when reuse or future use scenarios will be evaluated.
- Define the Level of Information Need (LoIN), considering file formats, level of detail, and appropriate circularity metadata (lifespan, material origin, reuse history, recyclability, etc.)
- Assign roles for circularity-related information management, i.e. who is responsible for delivering, checking or maintaining what kind of data.

Table 4 shows an example elaboration for the CircleBIM framework in a tabular approach, tailored to setting circular ambitions during project initiation (Planning phase).

Table 4. Example for circular attributes to be considered by the lead appointing party (client) when setting circular ambitions during the planning phase.

Project phase	Description	Responsible	Circularity attributes to consider	IFC mapping examples
Planning	Specify Exchange Information Requirements (EIR) related to circularity ambitions	Client, consultants, BIM specialists	• Material passport • Lifecycle data • Reuse potential • Disassembly instructions • Biobased share of material • Operational energy use sources • Circular KPI's • …	IfcMaterial IfcPropertySet.LifecycleAssessment IfcPropertySet.ReusePotential …

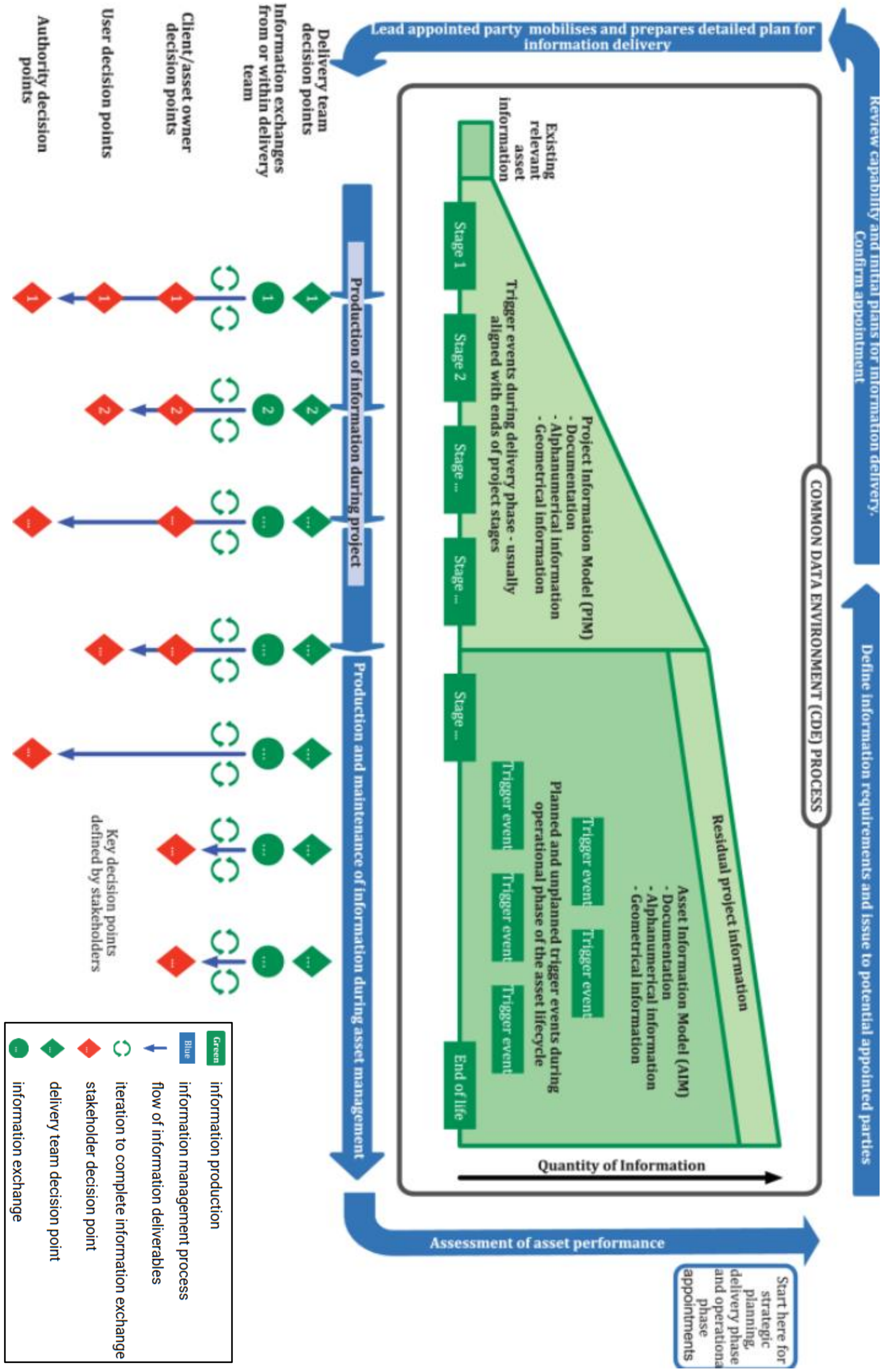

*Figure 3: Information management process during the building life cycle for data exchange among different stakeholders (source: ISO 19650-1:2019)_*

Adapted from the ISO figure, Figure 4 Illustrates how the information management process can be aligned with the CircleBIM framework. It highlights the structured sequences of defining, producing, and exchanging information between stakeholders. At the core of this process is the Common Data Environment (CDE), which provides a shared space for sorting and assessing data constantly across all lifecycle phases.

At the top of the diagram, four key steps define the logic of information management: Strategic Planning, Operational Appointment, Capability Review & Initial Delivery Planning, and Appointment Confirmation & Mobilisation. Circularity-related information requirements (CIRs) need to be clearly defined at the outset, allocated to stakeholders, and supported by concrete delivery plans. This approach outlines responsibilities for data flows aligned with project ambitions in a transparent process.

The diagram illustrates that information management does not end at a single stage, but rather flows continuously across phases, connecting decision points, actions (e.g., information production), and information exchanges. These flows are iterative, requiring validation and refinement to complete the loops of information exchange. Therefore, critical decisions, such as material reuse strategies or procurement choices, should always be supported by authorised data.

The lower part of the figure zooms into the interaction between stakeholders. Each stakeholder contributes specific data, which must be linked to circular information requirements. This ensures that, for example, a supplier's material passport, a designer's disassembly plan, or a contractor's logistics report can all be integrated into the BIM environment.

For CircleBIM pilots, this visual can serve as a template for defining project-specific workflows. Pilots can adapt the figure by identifying relevant lifecycle phases, clarifying involved stakeholder roles, and specifying what information is required and when it should be exchanged. This allows the CircleBIM framework to go beyond conceptual guidance, supporting project-specific information management planning.

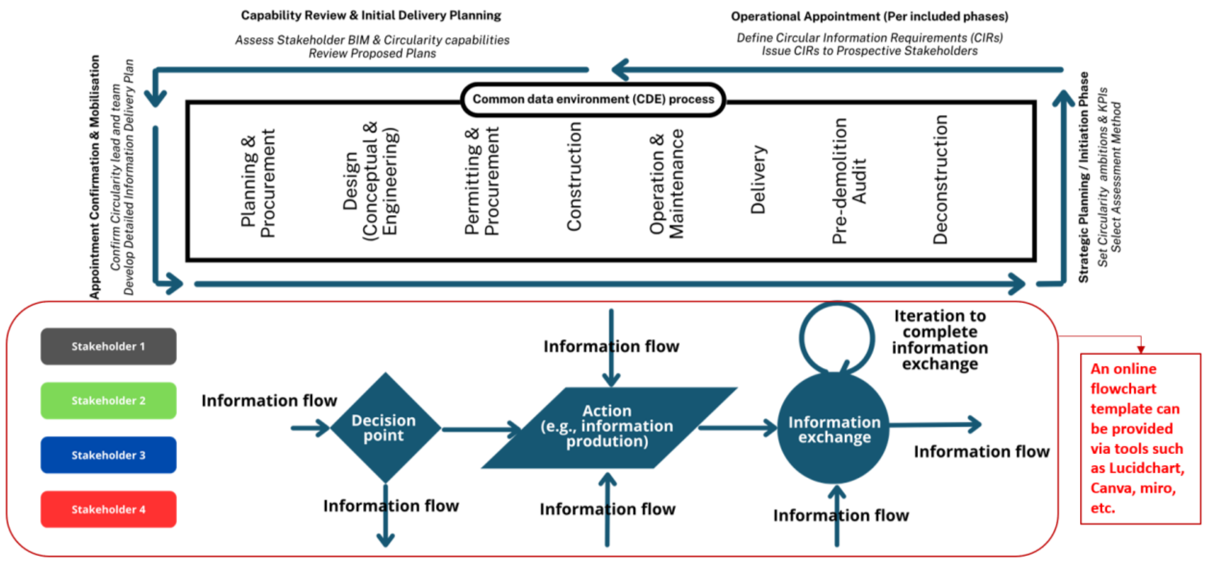

Figure 4: Revised template for the common data environment and information flows within the CircleBIM framework

6.3 Circularity and assessment aspects

Here, the focus shifts to the assessment logic behind the framework, detailing how circularity ambitions can be made measurable, verifiable, and actionable. It expands on indicators, measuring systems, and monitoring of pilot-specific scenario planning in circularity strategies such as selective deconstruction and reuse. This section will be extended by aligning the framework with European guidelines, such as Level(s), and integrating Material Flow Analysis (MFA) as a supporting method in the upcoming annexes.

As part of the first redesign of the CircleBIM framework, Material Flow Analysis (MFA) has been introduced as a supporting measurement method to enhance circularity assessments within the framework. MFA involves compiling a complete inventory of all resource flows into and out of a construction system. This may include not only materials, but also energy, water, and emissions. The approach helps quantify resource inflows and outflows, as well as associated losses and returning flows. This supports evaluating circular performance at different levels as the BIM model evolves.

MFA is particularly relevant for CircleBIM because it provides a bridge between digital object data (from BIM) and systemic material flow monitoring. By linking BIM element data (e.g., quantity, material type, service life) with MFA inventories, the framework can translate design decisions into measurable flow consequences and verify progress toward reuse and recycling ambitions. MFA builds on the mass balance principle but can be extended further by emphasising the recovery and reuse potential of materials after their initial use. To ensure meaningful results, MFA must be applied within clearly defined spatial and temporal boundaries. In construction projects, this poses specific challenges, as life cycle integration must account for long time spans and the often complex task of predicting end-of-use or end-of-life scenarios. Despite these difficulties, incorporating MFA supports a more complete understanding of circularity in the CircleBIM framework, where material value is lost or retained throughout the lifecycle.

To strengthen the framework's ability to assess circularity in a measurable and systemic way, the first redesign suggests the conceptual integration of Sankey-based material flow insights (Delahaye, Bogaart, Couzy, & Schoenaker, 2020). As illustrated in Figure 5, and Figure 6, sankey diagrams can offer valuable visual and quantitative insights into material flows within the BIM context, distinguishing between secondary and primary material inputs, stock accumulation, and waste outputs. Diagrams can directly link BIM-extracted data (e.g., material quantities, recovery potential. Such a type of analysis provides a more detailed understanding of circularity by not only showing the volume of materials being reused or recycled (e.g., reuse rates) but also how they flow into or out of long-term stock. Within CircleBIM, Sankey-based MFA can also support scenario comparison. For example, contrasts conventional demolition with selective deconstruction to quantify the avoided demand for virgin materials. This links assessment directly with decision-making at critical lifecycle phases. Importantly, the Sankey may reveal potential mismatches between material inputs and outputs, highlighting the need for strategies such as refurbishment and high-end reuse to reduce demand for virgin resources (Delahaye et al., 2020).

By incorporating such a material flow system into the CircleBIM framework, it can shift from static indicators to support dynamic assessments that can reflect the benefits of BIM in construction. To complement the CircleBIM framework, MFA checkpoints can be aligned with lifecycle phases where material flows are most relevant: (i) Planning and Design for projected inflows, (ii) Construction for monitoring actual inflows, (iii) Operation for stock accumulation, (iv) Pre-demolition for inventory of recoverable materials, and (v) Deconstruction for mapping outflows and recovery streams. This can be defined more specifically for each project according to the focus and ambitions already defined.

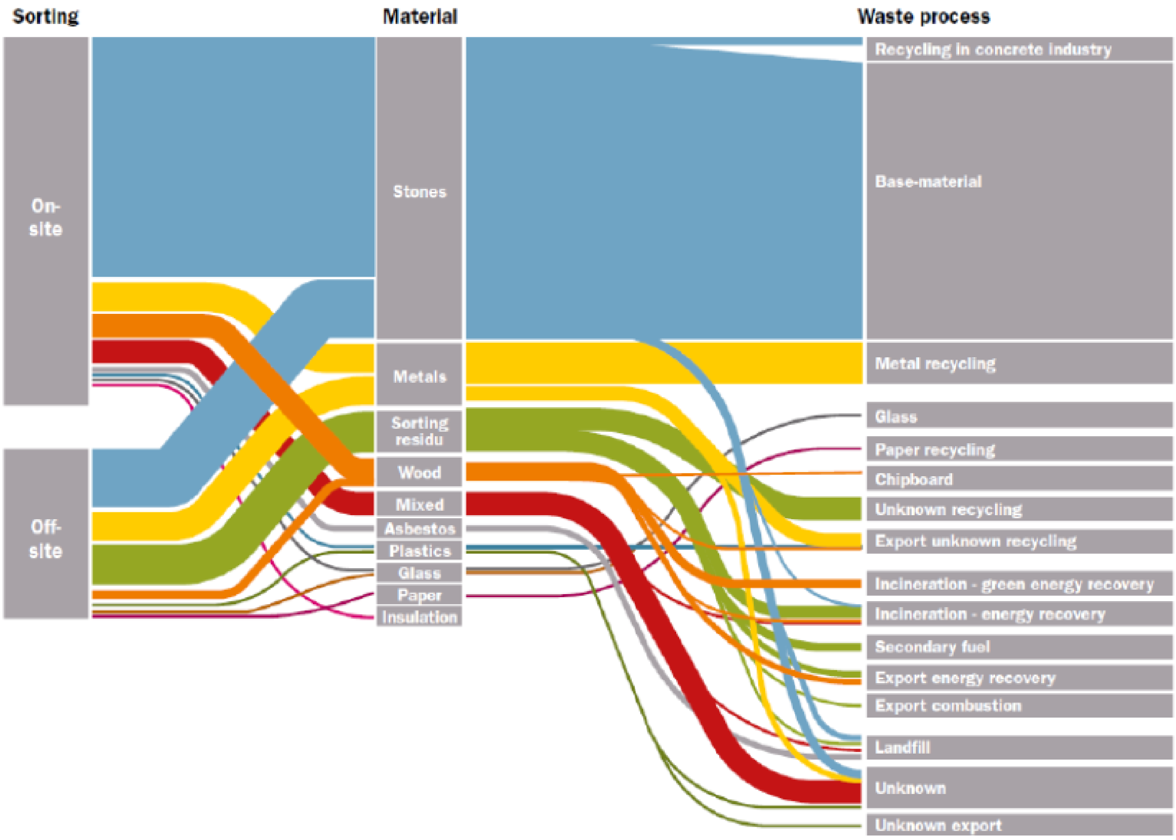

Figure 5: An indication of mapping inflows and outflows of building demolition with a Sankey diagram (source: Ritzen et al., 2019) for the application of MFA in BIM.

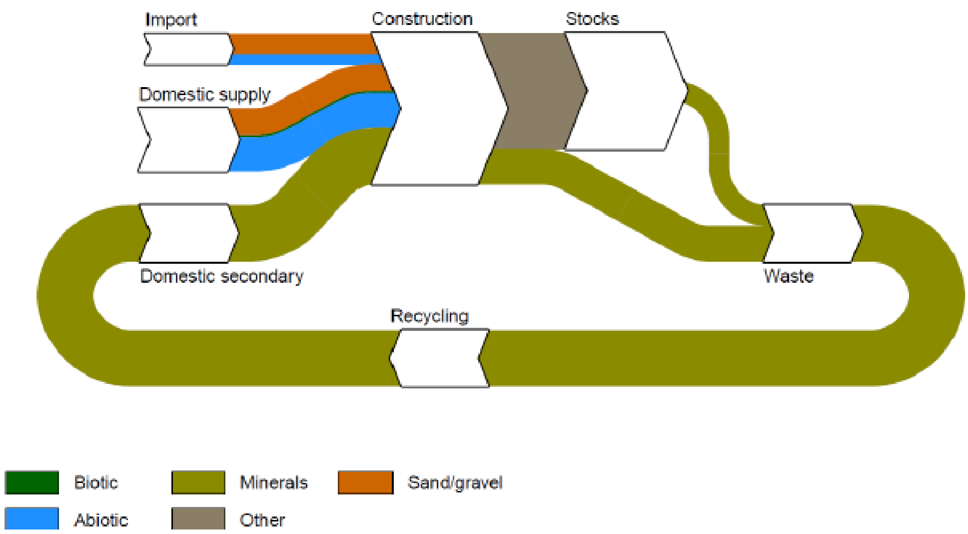

Figure 6: An indication of mapping inflows and outflows and returning flows and stocks for constructions, adapted from Delahaye et al., 2020, for the application of MFA within CE

7. Conclusion and next steps

This report has presented the development, verification, and first redesign of the CircleBIM framework for a common and transferable structure designed to integrate BIM with circular economy principles in public construction projects. Building on insights from literature, EU guidelines, ISO standards, and stakeholder workshops, the framework outlines how circularity can be systematically integrated into all phases of the building lifecycle, from project initiation through to deconstruction. Its ambition is to enable project teams to make circularity measurable, traceable, and actionable, while remaining adaptable to diverse national contexts, regulatory settings, and project types.

The iterative development process has demonstrated that while there is broad consensus on the relevance of circular principles, their operationalisation within real-world BIM processes remains a complex and context-specific challenge. Key contributions of the CircleBIM framework include (1) the alignment of circular ambitions with defining targets across lifecycle phases; (2) the integration of BIM as both a technical and collaborative enabler of circular practices; and (3) a visual and procedural structure that can be adjusted to different project contexts and pilot goals involving various stakeholders. The partner feedback collected during workshops and consortium meetings has confirmed the framework's conceptual robustness, while also identifying areas that require further specification and depth, especially regarding information flows, collaborations, planning, and circularity assessment methods.

To address these needs, the first redesign has introduced three focused improvements: a more flexible visual structure that allows for project-specific adaptations; expanded guidance on BIM and information management across phases and stakeholders; and the introduction of additional assessment tools, such as MFA, to improve circularity measurement.

Looking ahead, the next steps for the CircleBIM framework will focus on pilot testing and further operationalisation. Each pilot project will be supported in adapting the framework to its own context, using implementation templates and possibly decision trees that reflect specific lifecycle phases, circular ambitions, available data workflows, and utilisation of digital tools. Building on the latest feedback from project partners, the next iteration will incorporate guidance in three complementary dimensions:

1. Visualisation and graphical aspects will evolve from a static matrix into possibly a decision tree or flexible roadmap-style diagram, highlighting phase-specific pathways and providing a foundation for developing scenarios. This will allow pilots to visually map their own entry points and circular strategies from their own starting point and to explore alternative workflows via scenarios and planning.

2. BIM and data aspects will be detailed further with tool recommendations (e.g., available software) and data workflow templates. These will clarify the data identification and data formats, digital deliverables and processes, and data protocols between different stakeholders and partners in each phase.

3. Circularity and assessment aspects will be supported by a usability feedback template and a standardised KPI, enabling pilot teams to evaluate their performance (e.g., percentage of reused content, waste diversion rates, and embodied carbon savings) and provide structured measuring aspects on the framework's practicality.

The framework will be further refined in parallel to A1.4 and A1.5, which will monitor the implementation across LCCPs and pilots, collect data on practical application barriers, and facilitate a collaborative BIM environment. This ongoing evaluation will support the development of a more consolidated and scalable version of the CircleBIM framework, with the long-term goal of informing policy and procurement practices, as well as incorporating existing digital standards. As such, the framework is not presented as a final product, but rather as a tool that evolves and will be documented in future annexes. a series of annexes will complement the next iteration of the framework, providing additional references for project partners:

- Annex A: Overview of common circularity ambitions
- Annex B: Overview of (Circularity) assessment methods
- Annex C: Overview of common relevant BIM (digital) tools

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Annex A: Overview of common circularity ambitions

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Annex B: Overview of (Circularity) Assessment Methods

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Annex C: Overview of common relevant BIM (Digital) Tools

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