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RESEARCH ARTICLE

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Contextualizing a process information approach in material passports: a case on modelling circular façade product requirements

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ABSTRACT

Information gaps are a key challenge in transitioning to a circular economy, particularly beyond the first use of building products. Material passports could bridge these information gaps by acting as shared information repositories across actors and product stages. However, current material passport research primarily defines product-centric information requirements addressing the here and now, while process-related information to enable future reuse remains less examined. This research developed a stepwise method to identify contextual process information requirements. The method combined a canvas linking process, organizational and information dimensions from the end of use to next use with process modelling. The canvas was tested in a workshop that produced a window maintenance contract case, which was translated into a BPMN process model to derive its information requirements. Their analysis confirmed that across literature and regulations, process information is largely overlooked, a gap that widens towards next use. Overlooked requirements concern capabilities, sequencing dependencies, actors' roles and agreements. The results suggest material passports should shift from accumulating perishable product descriptions towards sustaining circular models. The maintenance contract case illustrates how service agreements could initiate this shift and keep material passports updated, while the method offers practitioners a way to design circular model adoption.

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Closed-loop information management; circular building products; digital material passport; process information requirements

Introduction

Achieving a circular transition in the built environment through closed-loop pathways, whether reuse, remanufacturing or recycling, depends on reliable information that flows across organizational boundaries and persists beyond a product's first use (Bellini et al., 2024). Responsibility for this information is divided among architects, producers, suppliers, contractors, facility managers and demolition companies, who tend to operate within specific stages and rarely engage across the full product cycle (Adams et al., 2017; Çetin et al., 2023). This fragmentation disrupts the flow of critical information, particularly beyond first use (Moscati et al., 2023). As a result, products reach their end of use poorly documented, creating inefficiencies and diverting potentially reusable products into waste streams (Hosseini et al., 2015; Wijewickrama et al., 2021). Closed loops are further complicated by uncertainties regarding timing, reclaimed product quantities, disassembly depth, reprocessing sequences and secondary market demand (Guide, 2000; Priyono et al., 2016).

To address this fragmentation and uncertainty, Material Passports (MPs), the term used in construction for Digital Product Passports (Çetin et al., 2023), have emerged as digital repositories in which information can be held and retrieved beyond first use (Honic et al., 2024). MPs depend on clearly defined, structured inputs (Heinrich & Lang, 2019), referred to as information requirements, which vary across materiality scales (Çetin et al., 2021).

At the product scale, existing studies have primarily focused on identifying the essential 'ingredients' of MPs, such as product types, composition, characteristics, performance metrics and reuse potential, together with 'instructions' like maintenance, safety and disassembly guidelines (Byers et al., 2024; Guerriero et al., 2024; Munaro & Tavares, 2021; van Capelleveen et al., 2023). In parallel, practice-based initiatives such as Buildings as Material Banks (BAMB, 2015), Platform CB'23 (2018) and Circular Construction in Regenerative Cities (CIRCuIT, 2023) have conceptualized and disseminated MP requirements through standards and protocols for

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construction industry applications. Moreover, in European Union (EU) policy, regulatory instruments for MPs are being developed under the Ecodesign for Sustainable Products Regulation (ESPR) (Regulation (EU) 2024/1781) and the Construction Products Regulation (CPR) (Regulation (EU) 2024/3110). These instruments will define MP requirements to increase closed-loop uptake, transparency, and compliance, and are expected to enter into force before 2030.

These contributions across research, practice and policy have advanced the conceptualization of MPs and their information requirements. However, they still offer limited depth on process-related information, particularly beyond first use (Mao & Cao, 2025). We argue that MP requirements, in their current form, resemble a recipe that lists ingredients and instructions while saying little about the processes needed to execute them: by whom, with whom, in what sequence, where, and under which constraints. This contextual process information concerns how a circular transition is to be implemented, which has received limited attention in construction literature (Kocaturk & Hosseini, 2023).

To address this gap, this study developed a method aimed at deriving contextual information requirements beyond first use, specifically in the transition between the end of use and the next use. The method, which involved three steps, drew on three analytical dimensions established in the background: process, organizational and information. First, a canvas structured around these dimensions was developed to facilitate dialogue among relevant actors and collect inputs around a specific 'to be' circular business model (hereafter circular model) and product type, as emphasized in ISO 59040:2025. Second, the information from the canvas was translated into a process model, which captured the sequence of activities and related information (as in Koppelaar et al., 2023; Schamne et al., 2024). Third, the information requirements were derived from the process model and formalized in a table specifying the process each belongs to and the responsible actor. The full method was tested on a façade product case, specifically aluminium windows, organized around a maintenance contract in the Dutch context. Façade products were selected because they hold high potential for reprocessing (Yang et al., 2022), and windows are among the first product groups expected to comply with the CPR. Accordingly, the guiding research question of this study was:

> What process information is required in MPs to facilitate closed loops for façade products?

Background: process, organizational and information dimensions in closed loops

Literature on closed loops suggests that process information requirements cannot be understood in isolation; they emerge from the interplay between how products are physically processed, how actors are organized, what roles they play, and how information is managed. These context-dependent relationships have been examined in manufacturing and construction literature.

In manufacturing literature, Thierry et al. (1995) demonstrate that information on product composition and condition, volumes, timing, or reprocessing capacity only becomes relevant when tied to strategically chosen closed-loop processes and specific allocation of actors' roles. Bras and McIntosh (1999) similarly frame closed loops through product, processes and organizational design, arguing that arranging processes that connect the end of use with next use depends on bi-directional information flows across actors. Priyono et al. (2016) further develop this lens by identifying process choices and organizational characteristics as core issues in closed loops, focusing on how processes are organized and sequenced, and how relationships, roles and network structures shape their performance. Information is not named as a distinct dimension, but it is present throughout, both within the discussion of process and organizational characteristics and in the extensive treatment of closed-loop uncertainties, which they largely attribute to missing or incomplete information.

A similar logic is expressed in construction literature. Wijewickrama et al. (2021) conceptualize closed loops through coupled material, information and financial flows, arguing that information is the critical coordinating mechanism for managing the other two, thereby reinforcing information as a distinct third dimension linking product processes and organizational relationships. Through the concepts of channel creation and network integration, Ding et al. (2023) describe how products flow back into their next use through closed-loop processes, facilitated by collaborative arrangements and cross-actor governance. They also acknowledge that both channel creation and network integration depend on the availability, structure and governance of information. Illankoon and Vithanage (2023) likewise show that closing product loops depends jointly on circular product and process strategies, organizational shifts (including new circular models, actor coordination), and digital information infrastructure. Together, these contributions motivate studying closed-loop process information requirements across three dimensions: process, organizational and information. Drawing on these

dimensions from existing literature, we developed the Process Information Requirements Framework presented in Figure 1. The following sub-headings explain each dimension in greater detail.

Process

Closed loops involve a sequence of physical processes to reclaim a product, partially or fully disassemble it, and reassemble it into a new one. These processes can be grouped into five recurring operations: i. end of use, ii. collection and transport, iii. inspection and storage, iv. treatment or reprocessing, and v. preparation for next use (Ijomah, 2002; Jayasinghe et al., 2019; Lambert, 2003). These closed-loop operations are interdependent, and a lack of coordination or inefficiencies at any stage can negatively affect the remaining operations (Gerding et al., 2021).

Audits conducted before the end of use may precede this sequence of operations to improve efficiency and coordination. They collect information on condition, use history and product attributes through archival resources, previous knowledge from auditors, or digital tools such as Building Information Modelling (BIM) (Byers et al., 2024; Honic et al., 2021; Koutamanis et al., 2018). These audits first assess whether a product's use phase can be extended; when this is not feasible, the audits can help classify, plan and pre-allocate products for their next use, and may identify new owners or applications before disassembly or deconstruction begins (Wijewickrama et al., 2021; Yu et al., 2024). For example, Sanchez et al. (2024) show how a BIM-enriched model can be used to derive disassembly sequences and plan deconstruction processes. By contrast, van den Berg et al. (2020) show that when information on as-is conditions, disassembly potential and market demand remains partial, actors lack a shared basis for aligning their next-use decisions, and products already disassembled for reuse can ultimately be disposed of.

Before next use, reclaimed products typically undergo quality certification processes that range from visual and instrumental inspection to material and performance testing (Rota et al., 2023). Because these processes provide evidence of performance, safety and regulatory compliance, they support issuing warranties and formal certifications, which facilitate acceptance by new owners (Ghaffar et al., 2020). These quality certification processes also serve as critical decision points at which products' condition, composition and design are re-evaluated to determine their optimal next use (Nwonu et al., 2025).

Organizational

Closing product loops depends on a transformation of roles, in which actors evolve from isolated, stage-specific involvement to collaborative and interconnected roles (Havinga et al., 2023; van Vooren & Galle, 2024). Actors such as architects, (demolition) contractors and manufacturers typically operate with minimal role overlap, handing over responsibilities and information sequentially. This creates discrete handovers. For example, architects produce BIM models that contractors later adapt without shared updates, which weakens knowledge transfer and process feedback needed to transition into circular models (Jiang et al., 2025).

van Capelleveen et al. (2023) formalize the actors involved in a circular built environment, and several studies have documented how new actors emerge and conventional construction actors reorganize their roles to create closed loops (Eshun et al., 2025; Salvioni & Almici, 2020; van Uden et al., 2025b). This

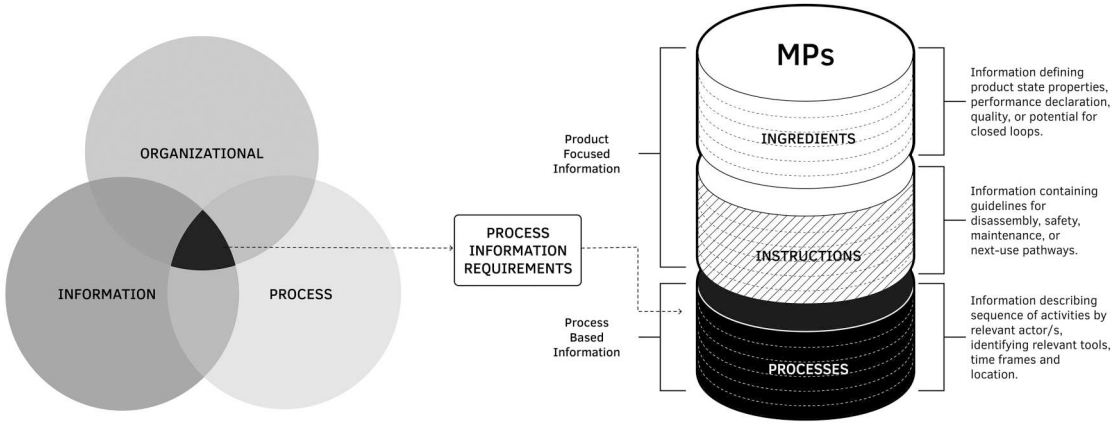


Figure 1. Process information requirements framework, developed by the authors.

involves new and overlapping roles, extended actor involvement, and smoother 'baton passing', enabling better feedback loops, information continuity and alignment of activities across the product stages. For example, Gerding et al. (2021) describe a case study in which actors lacked the knowledge to implement a product-as-a-service model, where ownership stays with the supplier rather than transferring to the client. A circular expert (new role) was brought in to resolve the coordination challenges among actors. In a second case, a contractor became the owner and assumed operational responsibility for the building and its information, which reduced discontinuity typically created at handover. Together, these two examples illustrate how role reconfiguration is often tied to adopting new forms of contracts and circular models, sharing information and risks, and aligning long-term circular goals (European Commission, 2020; van Uden et al., 2025a; van Vooren & Galle, 2024).

Regulatory developments also challenge traditional models. The ESPR, for example, empowers the European Commission to set requirements for product durability and reparability, undermining traditional models based on rapid turnover. Simultaneously, technological advances and economic shifts can make reclaimed products more competitive against primary materials (OECD, 2019). Manufacturers, therefore, have a growing incentive to expand their roles and retain ownership across multiple cycles. Circular models, such as product-as-a-service, enable this shift but require higher upfront investment from the manufacturer, often beyond what they can finance (Azcarate-Aguerre, Conci, et al., 2022; Azcarate-Aguerre, Klein, et al., 2022). Moreover, if a building changes hands, it is unclear who becomes responsible for the products and their associated information. These developments suggest that future closed loops will likely require new circular models and forms of governance to manage both products and their information.

Information

MPs, as information repositories, have been addressed along two lines of work. The first addresses the static limitation of MPs and proposes dynamic technology-based solutions (e.g. Abruzzini & Abrishami, 2022; Markou et al., 2025; Wang et al., 2020). The second, in which this study is positioned, addresses the conceptualization of MPs and the information they should contain (e.g. van Capelleveen et al., 2023; Veliz Reyes et al., 2025).

The dynamic technology-based line of work, for example, makes MP information machine-readable and interoperable through Information Delivery Specification (Tomczak et al., 2024), Industry Foundation Classes (IFC) (Schamne et al., 2024), or linked data (Kebede et al., 2024). Other studies examine the wider infrastructure, combining Scan-to-BIM technologies with IFC to assess circular scenarios (Guerriero et al., 2024), plan deconstruction processes (Sanchez et al., 2024), or coordinate closed loops through dedicated platforms (Charef, 2024; Yu et al., 2023). While these studies focus on technology development, some also address process information requirements, both conceptually and methodologically. For example, Kebede et al. (2024) propose a circular ontology linking product-level information with actors' roles, processes, exchanges, time, trajectories and spatiotemporal dimensions; Sanchez et al. (2024) identify detailed process information for deconstruction planning; and Charef (2024) presents a process model, namely a BIM-based 'trans-scalar framework', which identifies relevant requirements, information exchanges and actors for each product stage. The framework was developed through a literature review and unstructured interviews to improve the architecture of a circular digital platform.

In the conceptualization line of work, BAMB, through its project output MPs-Best Practice (Heinrich & Lang, 2019), was among the first to organize information requirements conceptually and distinguish process-related categories. Stella et al. (2023), as part of the CIRCuIT project, provide a comprehensive list of requirements structured by product levels and relevant functions ('synergies'). Platform CB'23 (2018) contributes primarily by setting preconditions for MPs, such as defining roles, responsibilities, access to information and ownership. Scientific outputs, such as KC et al. (2025), Mao and Cao (2025) and Senarathne et al. (2025), integrate these aspects into their information requirements, presenting them by stage, product level, process and main responsible actor, from extraction to end of use. Alongside research, the Product Circularity Data Sheet (ISO 59040:2025) was the first attempt to standardize requirements through a list of true/false statements and guide manufacturers in creating their own MPs. In the EU, where the case is situated, the ESPR sets the horizontal framework for product sustainability and introduces the Digital Product Passport (DPP) across industries, while the CPR is the industry-specific instrument for construction products. Both are in force, but the delegated acts specifying MP requirements for each product type are still being developed. Figure 2 presents the analysed practice, research and policy landscape and outlines in grey their relevant contributions to this research.

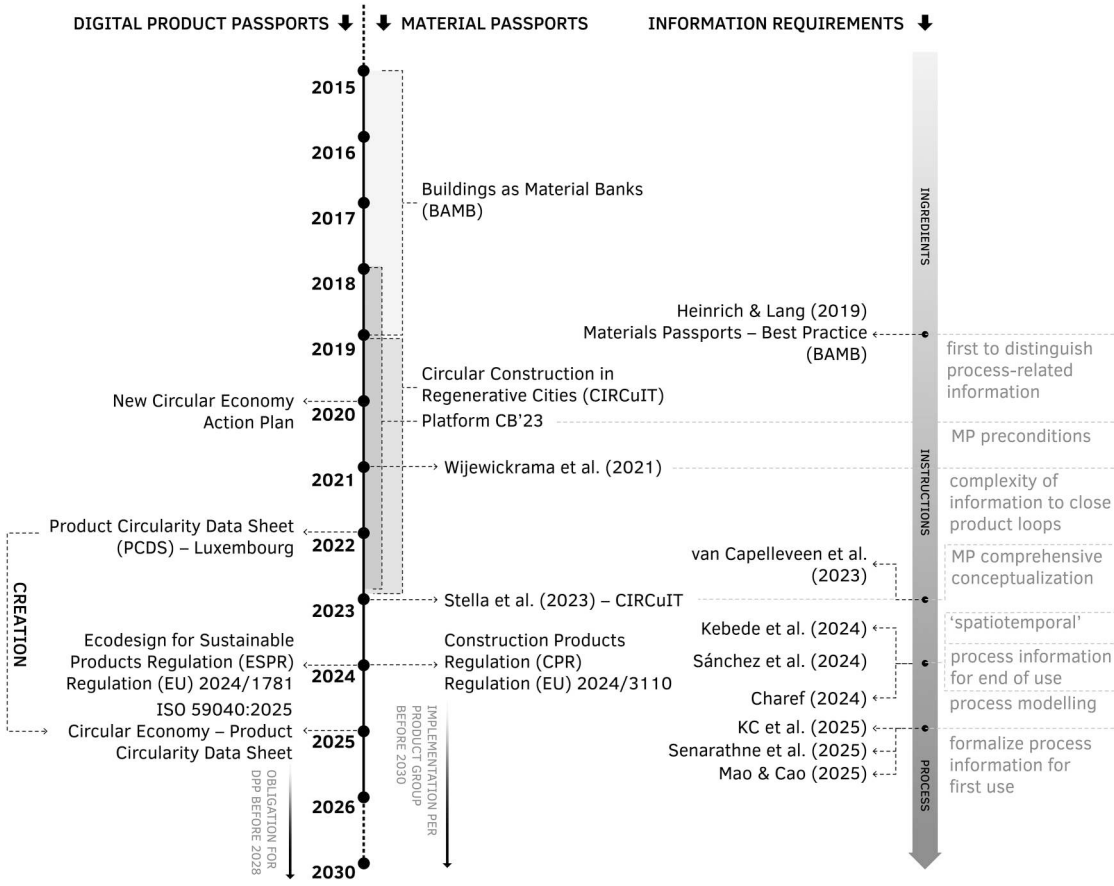


Figure 2. Evolution of material passports and information requirements.

Across this landscape, the process information required for closed loops remains implicit, because existing contributions formalize only the first product cycle. Yet, research on closed loops suggests that information requirements set for the first use might not translate directly into the information needed to link products to their next use. At the end of use, when decisions about next use are made, reducing uncertainty depends on how well information aligns with decision needs (van den Berg et al., 2020), and Wijewickrama et al. (2021) show that both closed-loop processes and the information they require are complex. These requirements cover the product, the process and the conditions under which they can occur (Mulhall et al., 2022), all of which might vary with the circular model implemented and the roles actors perform within it (Zhang & Seuring, 2024). Current contributions offer little methodological guidance on how to account for this contextual complexity when defining information requirements. This study therefore developed a stepwise method to extract contextual process requirements beyond the first use, accounting for product type, closed-loop pathway and circular model, including actors, their roles and relationships.

Method

Canvases and other tools developed for circular models are effective at reducing complexity, structuring the design of 'to-be' circular business, and building a shared understanding among actors involved (e.g. Bocken et al., 2019; Lewandowski, 2016; Nußholz, 2018). Process models add activity-level detail and have been used to model information requirements (Charef, 2024; Koppelaar et al., 2023). This study combines the two in three steps: (i) the canvas to define the context, (ii) the process model to formalise it, and (iii) the information requirements are derived and analysed. A fourth step was added to validate the results and evaluate the designed method.

Step 1. Canvas for circular model design

This step aimed to define the context, that is, the 'to be' circular model and the selected product. A canvas was created for this purpose, structured as shown in Figure 3. Its columns represent the operations between the end of use and the next use, and its rows represent the dimensions from the process information requirements

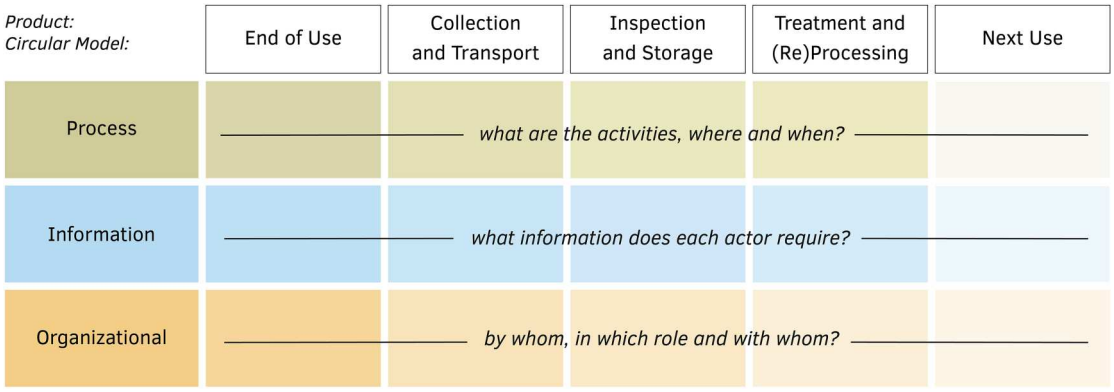


Figure 3. Process information requirements framework canvas.

framework. For each operation, the process row captures the physical activities to close the product loops, the organizational row specifies the actors involved and the roles they perform, and the information row captures the information actors require.

The canvas provided the structure for an 'expert' workshop in which participants collaboratively designed circular models for different product types. Studies drawing on expert knowledge have traditionally involved experts in established practices and have treated their accounts as authoritative descriptions of what already exists. The premise of this workshop was different. Closed loops and the circular models that enable them are not yet established in practice (Akbarieh & Teferle, 2026; Bocken et al., 2015; Yang et al., 2022). Participants' inputs were therefore intended to envision circular models that do not formally exist, and no single participant could hold complete knowledge of the solution under exploration (Bocken et al., 2015). Thus, participant selection combined partial and complementary perspectives drawn from domain-specific knowledge.

A diverse group of 30 'experts' was selected to participate in an in-person workshop. Figure 3 shows the group's composition by professional affiliation, role and workshop category. The 'experts' comprised 12 academics and researchers, 13 practitioners and 5 government and policy representatives. This composition was intended to reflect the plurality of actors in closed-loop processes and bring regulatory, strategic and operational perspectives to the discussion of a circular 'to-be' case (Blomberg et al., 2023; Dorrego-Viera et al., 2026). All 'experts' were affiliated with organizations based in the Netherlands, a country recognized for its leadership in the circular economy (Circle Economy, 2022; Marino & Pariso, 2020). 'Experts' were recruited through two channels: direct outreach to ensure domain knowledge, and an open call to broaden perspectives, mitigate selection bias, and support diversity of professional backgrounds.

Participants were organized into four mixed groups to support active engagement. Each group consisted of 7–8 participants, comprising 2–3 researchers, 2–3 practitioners and 1–2 government representatives. Each group was assigned a moderator and a product in a different building layer (Brand, 1994) or materiality. Moderators guided the group in selecting a product and a circular model in which at least one participant had direct experience. This grounded the exercise in practical knowledge and meaningfully stress-tested the canvas. The workshop was divided into three rounds, corresponding to the three dimensions of the process information requirements framework. The workshop procedure was as follows:

- *Introduction* (10 min). Each round began with a brief presentation to introduce the dimension.
- *Guided Discussion* (20 min). Questions were prepared to trigger the discussion and adapted as it progressed. Participants recorded inputs by placing sticky notes on the canvas. This allowed inputs to be iterated.
- *Reflection* (5 min). At the end of each round, each subgroup shared a summary of the information collected with the rest of the participants. The objective of the reflection round was to facilitate knowledge exchange across groups and collective reflection, enriching and refining the depth and relevance of the inputs collected in subsequent rounds. In the final round, the reflection captured overall impressions, informal insights, and participants' perceptions of the cases and the workshop.

The workshop produced four cases, which can be seen in Appendix 1, Figure A1: reuse and recycling of steel frames (structure); reuse of interior wall frames and

furniture (Space Plan + Stuff); recycling concrete beams and columns (structure); and maintenance contracts for window reuse, remanufacturing and recycling (skin-façades). Modelling all four would have exceeded the scope of an article. Therefore, the subsequent steps focused on the aluminium window case, selected for its next-use potential, regulatory relevance and the originality of the proposed model. Façade products hold high potential for reprocessing (Yang et al., 2022), windows are among the first product groups expected to comply with the CPR, and the maintenance contracts are rarely studied in circular models. This decision limited cross-case comparison, but allowed an in-depth analysis of the selected case.

Step 2. Case description via process model

The second step formalized the maintenance contract case into a process model. Process models represent how work is carried out by describing the events that occur, the activities performed, the logic connecting them, the actors responsible, and the information each activity requires (Russell et al., 2016). BPMN core components, in particular, create models that are easy to understand and communicate between actors with diverse backgrounds (Ismail et al., 2017). Moreover, as Figure 4 illustrates, its core components align with the dimensions and inputs the canvas captures (Chinosi & Trombetta, 2012). The main operations between end-of-use and next-use are represented as pools, and the actors performing them as lanes, which carry the organizational dimension of the canvas. The sticky notes within the process dimension become connected activities. The information dimension is represented by MPs that become data objects and data stores. Points where the loop branches, such as decisions on whether a product will be reclaimed, are represented as gateways, with further contextual detail as artefacts. The relationships between actors can be inferred from how activities and information flow from one actor to another. BPMN sequence flow conventionally reads from left to right. In the maintenance case process model, the flow direction was adapted to fit the article's format, so flow should be read through the connectors rather than by their arrangement on the page.

The BPMN was developed at a high level of abstraction aligned with the scope of the case inputs collected. This means that the model focused on the overall process flow, actor responsibilities, and key information exchanges (Xu et al., 2009). This approach provided a strategic overview useful for coordinating actors and understanding information dependencies, rather than the detailed technical subprocesses of each actor involved. This level of detail could be reached through interviews with practitioners, including suppliers, producers and (façade/demolition) contractors (Charef, 2024).

The researcher who moderated the case took notes during the workshop and modelled the BPMN. This was deemed necessary because the canvas alone did not capture enough qualitative detail to reconstruct the inputs from the discussion. The researcher therefore read each sticky note alongside the notes to create the BPMN model. Figure 5 illustrates this translation from the sticky note highlighted in yellow, through the notes that become activities in the BPMN. The complete

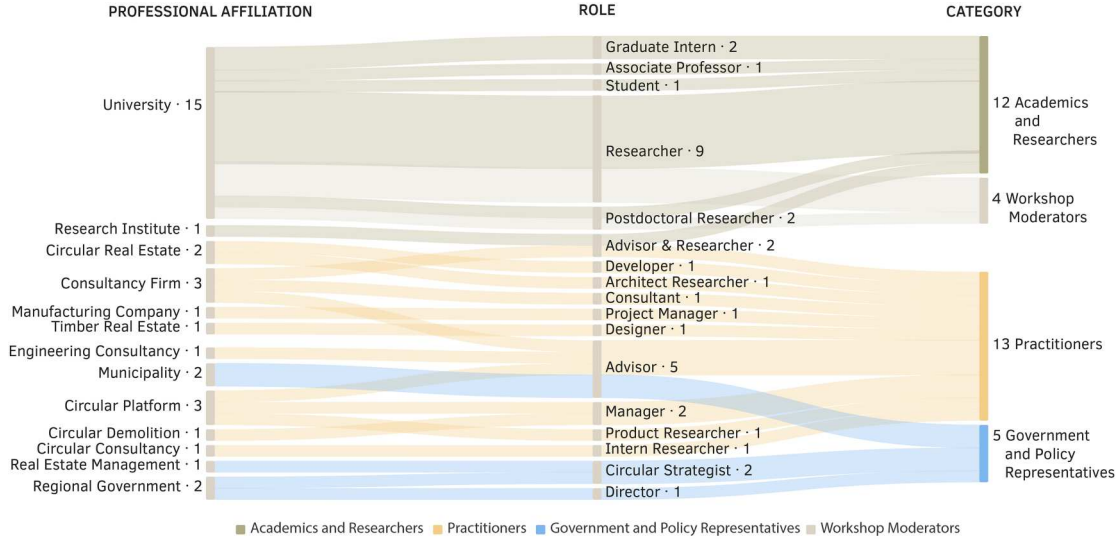


Figure 4. 'Expert' workshop participants and moderators by professional affiliation, role and category. Domain-specific knowledge of each of the participants is presented in Appendix 1; Table A1.

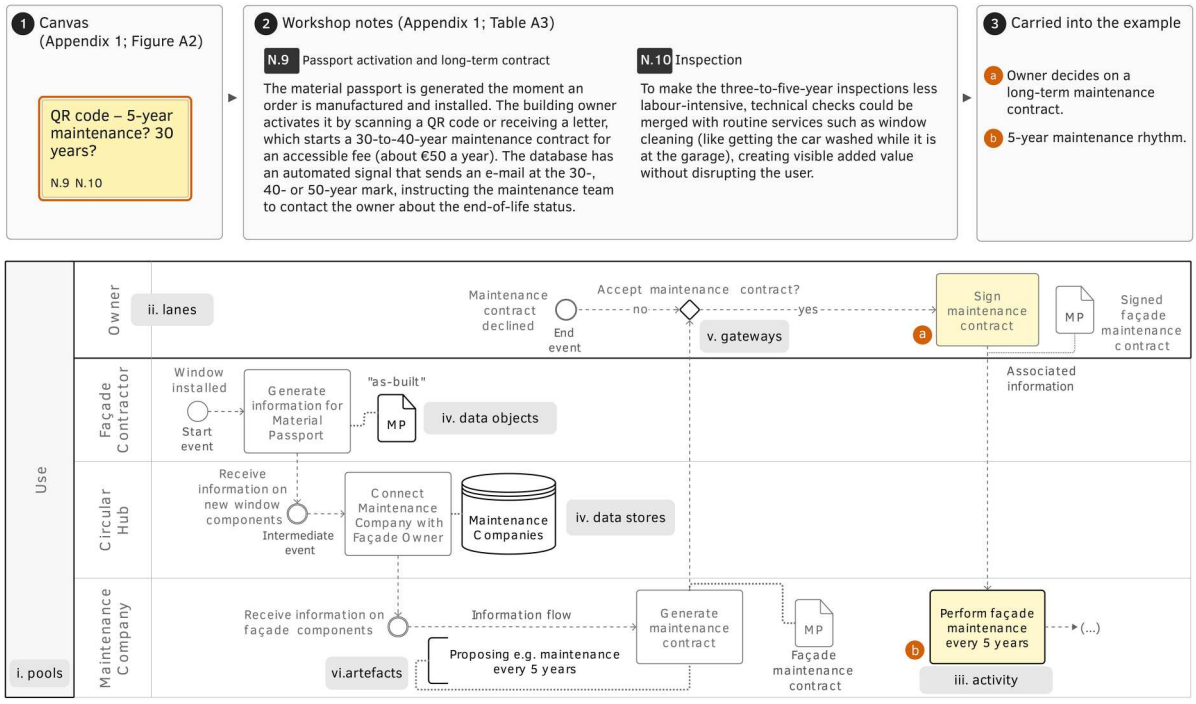


Figure 5. Sample of the maintenance contracts process model (Figure 7).

window canvas and the notes are in Appendix 1, Figure A2 and Table A3, respectively.

Step 3. Information requirements and analysis

The third step derived information requirements for the maintenance contract case and assessed them against current bodies of knowledge. Although the study focuses on process information, the case also revealed product information, which was included. This made it possible to assess whether existing sources account for both types of requirements beyond first use to different extents. The requirements were derived from a single façade product, the aluminium windows covered by the maintenance contract. Derived requirements are indicative rather than an exhaustive list of the category.

Requirements were listed using the structure proposed by KC et al. (2025), which identifies the stage, process, related information and responsible actor. Each identified requirement was classified as product or process and labelled with the notation used in the process model. Responsibilities were further specified using the Responsible, Accountable, Consulted and Informed (RACI) framework to distinguish actors who perform the process from those who are consulted or informed. No standard or existing classification scheme was used to describe the requirements; standards only entered the assessment step described below.

Information requirements were then assessed on a three-point alignment scale against scientific literature, practice guidelines and policy relevant to the Dutch context, in which the case is set. The CPR delegated act for windows has not yet been published. Therefore, the policy documents included in the analysis are the CPR, ESPR and ISO 59040. The results section explains this procedure through a worked example that also defines the alignment scale.

Step 4. Validation and method evaluation

The final step validated the research outputs and evaluated the method's robustness. Unlike the workshop, this step aimed to scrutinize the method and its results rather than develop them. The validation and evaluation panel was therefore broadened to include senior academics, whose experience supported a critical appraisal of the method's robustness. It consisted of seven academics and researchers, field 'experts', with expertise in façades (four), digitalization (three) and circular construction (two); some covered more than one field (see Appendix 1; Table A2).

The validation was structured in two parts. Participants first assessed the preliminary BPMN model and information requirements for logical coherence and clarity, checking that the process flow was easy to interpret and that the derived requirements were consistent. The second part focused on a critical reflection of the research method itself. Participants were asked to identify the strengths and limitations, and to provide suggestions for refining the overall method.

The validation session influenced the final model by improving its clarity and structure and refining how the information requirements were articulated. A practice-based co-author with over 30 years of expertise in façades, now specialized in façade digitalization and circularity, reviewed the refined requirements internally. The feedback was used to improve the requirements specification or to inform the discussion of this article.

Appendix 3 provides all inputs gathered during validation and evaluation: Table A5 covers the BPMN, Table A6 the Information requirements, and Table A7 the method evaluation. The feasibility of the maintenance contract case itself was not validated, as this would require the involvement of the actors who would design and implement it.

Results

Case description: a baton passing 'to-be' maintenance contract

The expert workshop informed a 'to-be' circular model case centred on reclaiming aluminium frames, glass panes and windows through maintenance contracts. Figure 6 gives an overview of the 'to-be' model. It traces a window from its first use to next use and, at each stage, contrasts current 'as-is' practice with the proposed 'to-be' arrangement. The two differ in the number of actors and the stages each spans, the activities performed at each stage and the continuity of information between stages.

In the current 'as-is' practice, three actors are involved: the owner, the demolition/deconstruction contractor and the waste processor, each confined to a single stage. The owner or an ad hoc external party may carry out repairs during use. As a result, maintenance responsibility is diffuse, and no single actor maintains a continuous record, severing the digital thread from first use. At the end of use, the demolition contractor relies on waste/demolition audits, and next-use pathways depend on the capabilities of whichever waste processor receives the product, typically ending in downcycling.

The 'to-be' maintenance contract replaces this fragmented handover and reactive next-use decisions. At first use, the façade contractor passes the 'as-built' information to a circular hub, which identifies a suitable maintenance contractor and connects it with the owner to agree on a scheduled maintenance procedure. From this point, the maintenance contractor and an aluminium window supplier (hereafter, window supplier) sustain the information record and, unlike the 'as-is', remain involved across several stages, passing the windows and their MPs like a baton. They proactively

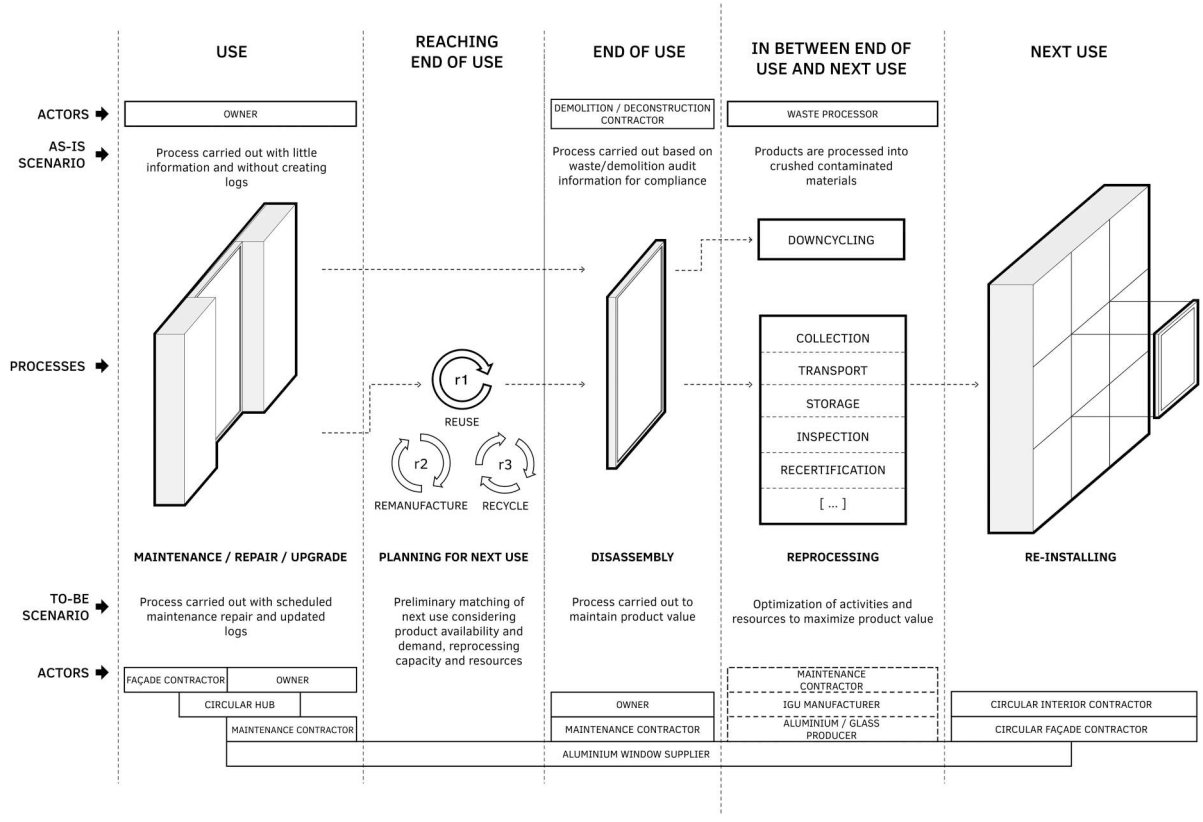


Figure 6. Contrasting 'as-is' and 'to-be' maintenance contracts case overview.

link the end of use with the next use and coordinate the relevant activities, information and actors, whether manufacturers, producers or circular contractors depending on the selected pathway. This arrangement, together with the maintenance logs, inspection results and recertification records included in the MP, sustains the digital thread. The organization of activities changes accordingly. Maintenance becomes scheduled and logged, and reuse (r1), remanufacturing (r2), or recycling (r3) pathways are matched before deconstruction begins. Actors further down the loop are selected for their ability to deliver the desired next use, rather than the next use being a consequence of the waste processor's capabilities.

The 'to-be' case is further elaborated in the following sub-headings across its process, organizational and information dimensions, and presented as a BPMN process model in Figure 7. Figure 7 traces the window across use, end of use, collection and transport, inspection and storage, treatment and processing, and next use, with lanes assigning each activity to its responsible actor. It also captures the associated information exchange, showing where MPs are generated and updated and where decision points route products towards reuse, remanufacturing and recycling. In-text codes [P.1–P.4; O.1–O.3; I.1–I.18] link the narrative to labelled regions and notations in Figure 7.

Process: from reactive to proactive maintenance and next use

The process begins once a façade is installed or refurbished, when the maintenance contractor schedules periodic inspections rather than waiting for failure. During use, components that wear out sooner are replaced or upgraded, which reinforces the principles of designing for easy access and maintenance [P.1]. As the façade approaches an anticipated tipping point, typically after 30–40 years depending on its condition [P.2], it may become advantageous to reclaim the windows. If so, the maintenance contractor deconstructs, collects and delivers the units to the window supplier's warehouse for inspection and reprocessing. Inspection includes a visual assessment for minor defects, while a representative sample is tested (e.g. for corrosion) to support recertification [P.3]. Reprocessing activities are ordered by preference, from those requiring the least intervention to those requiring the most. Windows that meet intended façade performance and regulatory requirements are directly reused; otherwise, they may be reused for interior partitions. Where direct reuse is not feasible, indirect reuse separates, refurbishes and reassembles the frames and insulated glass units into a window. Failing that, remanufacturing reworks the profiles and insulated glass units, requiring further disassembly and transport. When remanufacturing is not feasible, the glass panes and aluminium profiles are sent to the respective producers as cullet and aluminium scrap for recycling [P.4].

Organizational: redefining ownership and responsibilities

The processes outlined above depend on a change in information ownership and responsibilities. In 'as-is' practice, information and responsibilities are fragmented across actors with misaligned incentives, so no party is positioned to plan next use in advance. In the 'to-be' model, the window supplier acquires or partners with the maintenance contractor, gaining continuous access to the window's information during use and the means to regain material ownership at the end of use [O.1]. From this position, the window supplier can transfer information, material ownership, and responsibilities to the appropriate actors once a next-use pathway is chosen [O.2]. It also removes two common barriers to reuse: because the window supplier oversees inspection and testing, it can recertify reclaimed units and carry their warranty, which prevents disputes that arise when responsibility is split across actors further in the chain [O.3], and can manage windows irrespective of the original manufacturer, offering a more comprehensive take-back service. Moreover, because it has access through the MPs to the information on how the windows were made, it can offer a window take-back service regardless of who made the windows.

Information: creating actionable information for next use

The 'to-be' model transforms MPs from static birth certificates into dynamic logs that support closed loops (blue information objects in Figure 7). 'As-built' information is generated when the window is installed [I.1], then stored in a digital platform provided by the circular hub, which also creates the data template and secures the record. Through this digital platform, the maintenance contractor and the window owner are connected [I.2]. If the owner accepts the maintenance service offered by the maintenance contractor [I.3], the contractor carries out periodic inspections, replacements or upgrades, and logs them in the MP (e.g. photos, records of any repairs) [I.4]. At the end of use, this 'as-maintained' MP gives the window supplier the rich use-history information needed to assess next-use options by weighing the product's state against external factors such as market demand, site conditions, and reprocessing capacity [I.5]. In the 'as-is' practice, the equivalent decision rests on a one-off demolition audit performed at the end of use, with no record of how

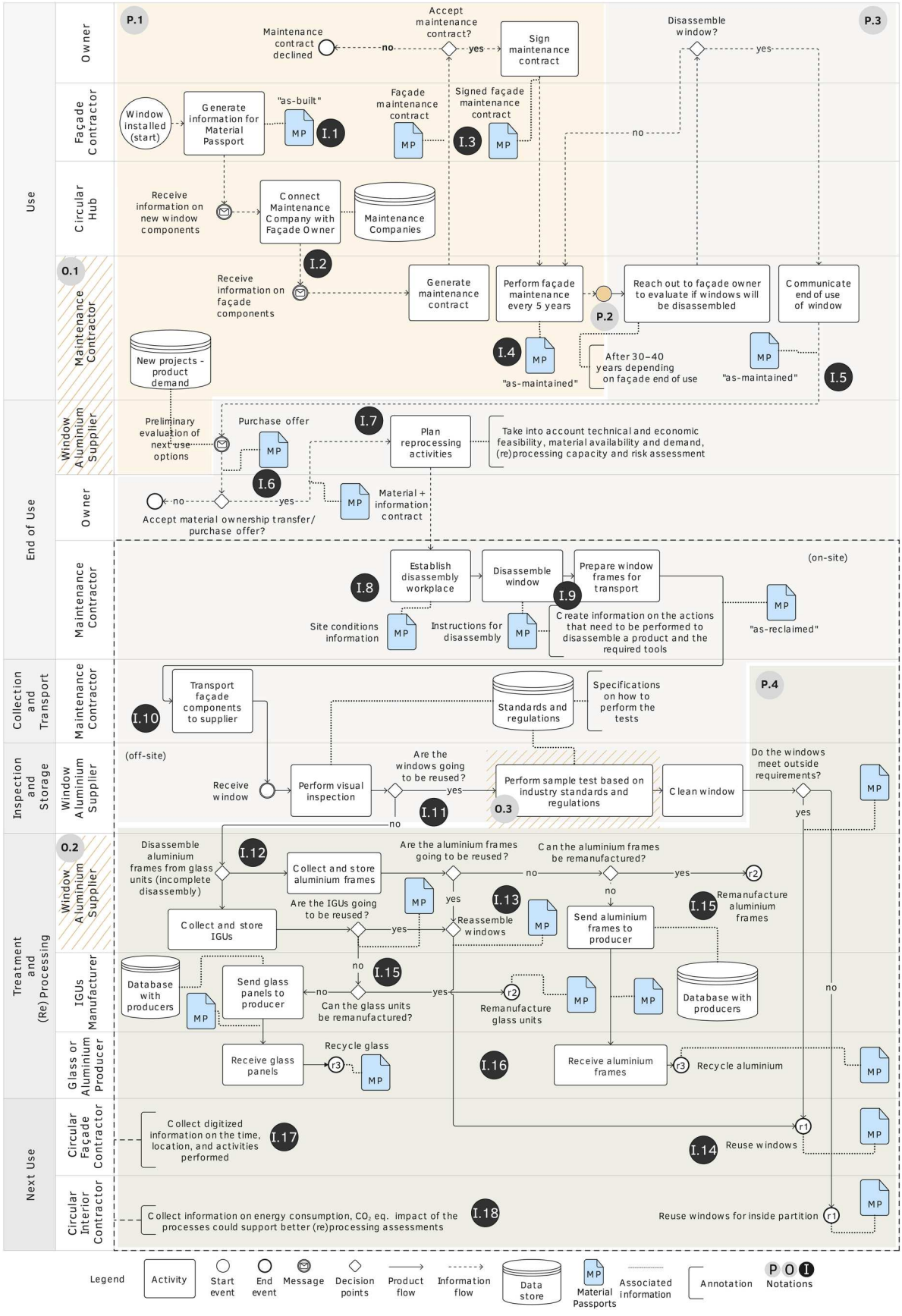


Figure 7. Maintenance contracts – process model.

the window performed in service, so the decision is made with greater uncertainty and less time to properly coordinate higher next-use pathways. Once agreements over transferring product and information ownership are made [I.6], the window supplier issues the maintenance contractor with deconstruction instructions and a timeline [I.7]. After the maintenance contractor carries out the work, the 'as-reclaimed' state of the window is recorded [I.8–I.10]. When the reclaimed product arrives at the warehouse (off-site), another inspection ensures no damage has occurred during reclamation and transportation, and further testing for recertification is carried out [I.11]. Each subsequent pathway carries its own information exchange. At the decision gateways, the MP records whether the full window or its components are routed to reuse (r1), remanufacturing (r2), or recycling (r3). Product and information ownership is updated as products pass to manufacturers, producers and contractors [I.12–I.16]. Finally, each activity is logged, including its energy consumption and CO_2 emissions, to create a baseline for improving future next-use assessment and planning [I.17, I.18].

Information requirements for façade products closed loops

Table 1 presents a sample of the information requirements, with the actors responsible for them, and an assessment of how far each requirement is already specified in existing bodies of knowledge (see full description in Appendix 2, Table A4). The first column identifies each process by the corresponding information notation in Figure 7. The second column classifies each requirement as product or process type, and the third describes it. Next, a column assigns actor roles using the Responsible, Accountable, Consulted and Informed (RACI) framework. The final three columns report alignment assessment of each requirement with three bodies of knowledge: peer-reviewed literature as *research* (R); regulations and standards as *policy* (P); and research project frameworks as *practice guidelines* (G).

For example, process information requirement 5 presented in Table 1 was created by combining the following information in Figure 7, the 'as Maintained MP', with the information on 'new project/product demand' to conduct a preliminary evaluation of next-use options. The derived process that explains this sequence of activities is 'Matching availability and demand'. The window supplier is responsible and accountable for conducting this process. It obtains availability information from the maintenance contractor and consults actors further down the loop, such as the glass supplier or façade contractor, about potential demand.

Alignment was reported using a three-stage indicator: ● fully addressed, where it specified all the requirements; ◐ partially addressed, where some requirements were specified, or when requirements were specified for a different context; and □ not addressed, where no source addressed any requirements. The three examples below illustrate the approach for each indicator presented in Table 1. ● Research: *fully addressed* > Mao and Cao (2025) discuss future demand forecasting and product availability in the design stage and potential interested parties in deconstruction and reprocessing. Charef (2024) discusses managing product availability, including product locations and making the relevant information available during the tender phase, which could be understood as a pool signal. Wijewickrama et al. (2021) frame demand requirements from demanders as the trigger, along with salvaged-waste availability and a web-based waste exchange for matching. KC et al. (2025), availability time. Yu et al. (2024) and Yu et al. (2023) include time and space dimensions and matching of supply and demand. □ Policy: *not addressed* > None addresses the demand 'pull' information. ◐ Practice Guidelines: *partially addressed* > Heinrich and Lang (2019) identify the supply-and-demand disconnect and propose a material stock analysis, but does not specify matching information at the product level. Platform CB'23 (2018) propose 'push-pull' systems and digital databases to optimise supply and demand. Therefore, they acknowledge information conceptually but do not specify it.

Figure 8 extends the assessment to the full list of 32 information requirements identified (16 product and

Table 1. Sample information requirements.

	Process	Information type	Information description	Actors (RACI)	R	P	G
	End of use (planning for disassembly and next use)						
I.5	Matching availability and demand of windows	Process	Requirements specifications (including timeline and location) from new projects that act as the 'pull' signal for potential reclaimed inventory. Requirements specifications (including availability, timeline and location) for reclaimed products.	R: Window Supplier A: Window Supplier C: Potential Clients (e.g. Glass Producer, Façade Contractors, Design Team) and Maintenance Contractor	●	□	◐

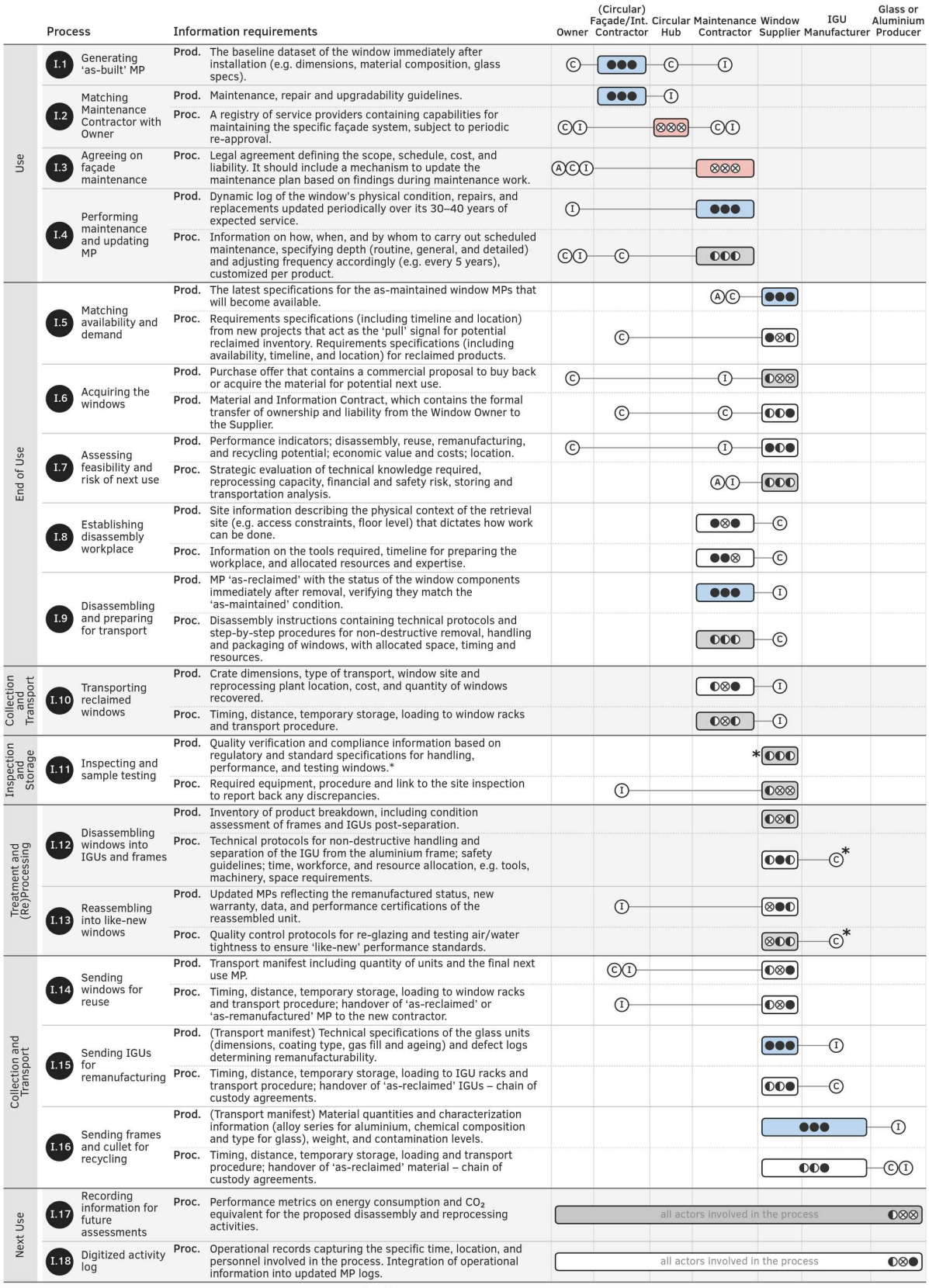


Figure 8. Maintenance contracts – information requirements for window.

16 process) across [I.1] to [I.18]. Each information requirement alignment indicator appears inside a box in the responsible actor column. Circled connected letters mark the accountable (A), consulted (C) and informed (I) actors per process. The coloured boxes highlight consistency in alignment results across the three bodies of knowledge: blue for fully addressed; grey when none fully address it; and red when none address it. Read by row, the figure shows how information flows between actors, and read by column, actors' responsibilities.

Only seven requirements are fully addressed across all three bodies of knowledge, and all are product requirements describing the window or its components (blue boxes). Coverage weakens once the reclaimed window enters the in-between stage, for example, in quality verification [I.11–I.13]. None of the three bodies of knowledge fully addresses 12 requirements (grey + red): nine are process requirements, and two relate to specific requirements of the maintenance contract (red). Practice guidelines have the highest rate of full coverage (16/32), followed by research (11) and policy (10) and each fully addresses only a few process requirements (4, 2, 2/16, respectively). After first use, most responsibility falls on the Window Supplier and the Maintenance Contractor, in line with the designed model.

Discussion

In the following sub-headings, the research results are discussed using the dimensions identified in the process information requirements framework, reflecting on the research question in the information dimension. This is followed by advantages and limitations of the proposed method and a reflection of the study's implications for research, policy and practice.

From first use to next use through information-rich processes

The process dimension background positioned audits immediately before the end of use to gather relevant product attributes such as condition and use history (Byers et al., 2024; Honic et al., 2021; Koutamanis et al., 2018). The 'to-be' maintenance contract case revealed that the use-stage, absent from the initial canvas, could be an earlier and essential source to collect and update these product attributes [I.4 Prod.]. Maintenance activities could record modifications or damage that, in turn, evidence history and condition and additionally indicate future product availability. This became relevant when products' potential next use was assessed before deconstruction even began to improve coordination of closed-loop processes [I.5 Prod.] (Wijewickrama et al., 2021). Standards such as BS 8210:2020 (British Standards Institution, 2020), ASTM E22270-14 (ASTM International, 2019) and the Guidelines on Periodic Façade Inspection (Building and Construction Authority, 2026) offer building owners, maintenance contractors and facility managers guidance on these maintenance procedures and their frequencies [I.4].

Emerging digital tools and digitalized workflows offer promising opportunities to capture and process use and maintenance information (Balogun et al., 2024; Çetin et al., 2022; Giovanardi et al., 2023). For example, routine-level information could be collected using street-view or drone imagery, and reduce the need for individual inspections. The digitalized façade pipeline developed by Liang et al. (2024) offers a way to capture early signs of degradation through imagery or applications supported by AI and integrated into the MPs or specific maintenance digital platforms, such as SFG20 (SFG Platform, 2025).

Beyond updated records, each closed-loop pathway required its own set of information and processes. For direct reuse of windows, sample testing against industry standards and regulations was proposed to facilitate acceptance of the reclaimed windows (Ghaffar et al., 2020). Relevant parameters to be checked included air permeability, watertightness and thermal transmittance, e.g., EN 14351-1:2006+A2:2016 (European Committee for Standardization, 2016), AS 2047-2014 (Standards Australia, 2014), CSA A440.4:19 (Canadian Standards Association, 2019). In recycling, material characterization information (alloys, glass composition and type, weight, etc.) accompanied the as-reclaimed MPs [I.16 Prod.]. Once the material, carefully treated to avoid contamination, is mixed into the new material, it could qualify as recycled content under established recycled-content schemes. Further development of the BPMN model is needed to establish specific criteria and protocols for indirect window reuse and remanufacturing of IGUs, glass panes and aluminium frames, although experimental methods for these processes have been researched (Nwonu et al., 2025; Rota et al., 2023).

The design journey fell outside the scope of the study, yet design and assembly conditions could challenge the proposed circular model (Hartwell et al., 2021). Therefore, future research should also consider feedback loops to inform designers and engineers.

Shifting roles and new responsibilities in circular models

Moving from the 'as-is' to the 'to-be' maintenance contract shifted roles and reallocated responsibilities in

product upkeep, information tracking, and decision-making. First, it positioned the circular hub and maintenance contractor as information intermediaries, while reclaimed products flowed directly from the owner to the window supplier. This aligns with the anticipated model from van Uden et al. (2025b) and addresses the concerns about information upkeep acknowledged in Platform CB'23 (2018). Second, the window supplier acted as a closed-loop coordinator for the actors further along the loop: the IGUs' manufacturer, which became a remanufacturer; the glass and aluminium producers, which became material reprocessors; and the (circular) contractors. Overall, coordination and information responsibilities concentrated in defined roles, which reduced discontinuity of information that conventional sequential handovers create (Jiang et al., 2025). This aligns with the need for actors to move from isolated, stage-specific involvement towards more collaborative and interconnected roles (Havinga et al., 2023; van Vooren & Galle, 2024). To prevent conflicts and address acceptance of reclaimed products, the window supplier was assigned the responsibility for product recertifications across reuse, remanufacturing and recycling (Ghaffar et al., 2020). Yet, the agreements that such a model would require sit in tension with current practices, and its feasibility remains uncertain.

Product-as-a-service models typically demand higher upfront investment from the supply side (Azcarate-Aguerre, Conci, et al., 2022; Azcarate-Aguerre, Klein, et al., 2022) and can still face information continuity challenges (Gerding et al., 2021). The maintenance case offered an alternative arrangement in which the investment of the window supplier shifted from an immobilized asset, the window product, to the acquisition of a maintenance contractor. The maintenance contractor was responsible for extending the product's use cycle and updating the MP. Thus, product ownership was separated from product and information responsibility. This maintenance service model was identified to be well-suited for large asset owners (e.g. public buildings, hospitals), but could be adapted for smaller owners by bundling additional services. The continuity of the maintenance contracts across changes in building and ownership remains uncertain, since the new owner would still have to accept them.

Beyond these internal governance questions, the maintenance contracts case aligns with the ESPR by extending the window-use stage and maintaining up-to-date information. The window supplier, whose product turnover such a shift might reduce, integrated the maintenance contractor into its circular model and established a more future-proof position, since reclaimed products might become more competitive in the future (OECD, 2019). While the ESPR provided the relevant framework for the European context of the study, similar policy directions with varying regulatory implications are emerging internationally, including China's Circular Economy Promotion Law (Standing Committee of the National People's Congress, 2018), Japan's Sound Material-Cycle Society (Government of Japan, 2000), and Australia's Circular Economy Framework (Department of Climate Change, 2024). Transferring the model to these settings requires a deeper understanding of their value chains, in particular, the arrangement of actors and intermediaries, the maturity of closed-loop infrastructure, and the availability and compatibility of end-of-use information (Ding et al., 2023).

Reframing material passport requirements beyond first use

This study asked what process information MPs should carry to facilitate closed loops for façade products. Behind that question lay a simple premise: MPs should evolve from a static list of 'ingredients' (product information) into executable 'recipes' (process information). The requirements reported in the study were derived from a single façade product, windows and are therefore indicative rather than exhaustive. Figure 8 shows that product information is consistently well covered at the defined states from first-use to end-of-use ('as-built' [I.1], 'as-maintained' [I.4], 'as-reclaimed' [I.9]), but its coverage weakens as the window and its components are reprocessed. Process information, by contrast, is partially covered or absent, and unevenly distributed from the outset. Assessing both types of requirements together, however, revealed a more nuanced picture, with implications beyond what a simple product-process divide would suggest.

The two requirements that no source addresses are a registry of qualified maintenance providers [I.2 Proc.] and a contractual agreement defining scope, liability and conditions for updating the maintenance plan [I.3 Prod.]. Although both are specific to the defined case, they are precisely the mechanisms through which the 'as-maintained' MP is produced. Research, policy and practice guidelines thus specify what information should exist, but fall short in defining the mechanisms to produce it. This gap also appears in the information that determines whether a reclaimed window can re-enter the market. For example, under the CPR (Article 26), a remanufactured window must be declared as new, yet the supporting inspection and quality control protocols remain largely unaddressed [I.11, I.13]. Similarly,

operational records [I.17, I.18 Proc.] typically rely on generic values and assumptions rather than data captured from actual processes, so CO_2 assessments of closed-loop pathways remain approximations.

The three bodies of knowledge identify the actors responsible for producing MP information, but the exchanges and the actors who depend on that information are rarely translated into requirements, even though their importance is highlighted (Kebede et al., 2024; Platform CB'23, 2018). Specifying these exchanges, for example, through the RACI model, would clarify who provides the information, who is accountable for it, and who receives it. Knowing who needs the information, and how, would in turn help determine the required level of detail and format, so that the effort of generating it remains proportionate to its use.

Finally, the three bodies of knowledge cover information requirements in distinct ways. Research demonstrates broad awareness but shallow specification. Requirements such as timing, sequencing and costing surface in disassembly research (Sanchez et al., 2024), but remain conceptual rather than operational [e.g. I.9, I.15 Proc.]. Regulatory instruments are strong on product declarations and conformity, their core domain and reach process information mainly where it can be declared as a safety protocol [I.8, I.12]; information related to transport, commercial transactions or provider registries falls outside their scope by design. Practice guidelines come closest to the executable recipe, since they are written for implementation, yet consistently omit scheduling and resource allocation [e.g. I.8, I.10, I.12 Proc.]. The gap is therefore not a uniform blind spot, but reflects what each body of knowledge is built to do.

Read together, these findings show that information requirements beyond first use cannot be left implicit: the link between the end of use and the next use, where current coverage weakens, and loop re-entry is decided, needs explicit requirements contextualized within a specific product type and management model.

Advantages and limitations of the proposed method

The canvas helped to set the scope of the information requirements by identifying the product and its closed-loop activities, debating actor-specific roles and responsibilities, and initiating discussions on new circular models and their implications [Appendix 3; Table A7; V.1–V.4]. To retain qualitative detail and nuances of the workshop discussions, such as motivations and timing, the BPMN modeller should be directly involved, as in this study, or the session recorded [V.6-V.10]. A few refinements would also clarify the canvas. To distinguish 'as-is' activities from those of the circular 'to-be' model, different coloured sticky notes could be used [V.5] and the sequence of activities could be represented by drawing connecting lines between the sticky notes [V.11]. The RACI framework coding could also be included to define responsibilities more firmly from the outset [V.14], and the organizational dimension row could be split into two to reflect the potential divide between information and product ownership. The use stage could also be included as a new column in the canvas, with the next-use column reserved for the activities that connect the reprocessed product with the new owner [V.26].

The BPMN model helped visualize the overall process flow and identify process and organizational challenges, as well as information needs. It was most valuable for role allocation, enabling shifts from company-based roles to function-based responsibilities, e.g. window supplier to closed-loop coordinator [V.15, V.16]. It also raised questions about why the processes were sequenced in a certain way and why an actor took a specific responsibility [V.17, V.20]. In an iterative process, these are the questions to raise and resolve before the circular model is settled. Whether the model prompts them depends on how easily it can be read and what it was asked to show. The level of detail should always align with the model's purpose (Xu et al., 2009), the direction of flow should follow a left-to-right sequence, as standardized BPMN notation recommends (Russell et al., 2016), and information should be prioritized where possible [V.22–V.28, V.30]. Information exchanges could be clearer in a dedicated lane, as Sanchez et al. (2024) propose [V.14].

Drawing information requirements from the BPMN model context helped specify not only what information is needed but also when it becomes relevant, who produces it, and who uses it [V.32, V.33, V.36, V.37]. This broadened current MP discussions to also include process information [V.34, V.35], and it still yielded new insights into product requirements, such as the specific contracts governing information and material ownership transfer [Figure 8; I.6]. However, these new requirements insights did not align with any standard [V.38]. Actors drawn from different domains, such as construction and manufacturing, may describe the same concepts in different terms [V.39]. Future applications should therefore clarify definitions, roles, and terminology, for instance by agreeing on existing frameworks before discussions begin [V.9, V.40, V.41]. Relevant ISO standards (ISO 12006-2:2020; ISO

59040:2025) or project-based initiatives on MPs (Heinrich & Lang, 2019; Stella et al., 2023) can both align conversations and provide a more extensive template for extracting and reflecting on information requirements until the product-specific requirements under the CPR become available.

Implications for researchers, practitioners and policy bodies

Specifying the information a circular model requires to close product loops is only a first step: whether a circular model is implemented depends on who initiates it, who maintains the MPs across stages, and under what conditions the circular model is adopted. These governance and adoption questions apply broadly to circular models rather than to any single construction product, and no single actor can resolve them alone (Bocken et al., 2015). Mapping them onto a concrete case can give actors a shared tangible basis for deciding how such models could be set up. The circular model based on maintenance contracts serves that purpose, suggesting plausible scenarios for each question while engaging research, policy and practice to different degrees.

Initiating circular models could follow a regulatory or value-driven route. The regulatory route is a matter for policy: the ESPR and CPR already stipulate that DPPs must remain accurate, complete and up to date. Once the DPP obligations apply, this will require 'as-built' and 'as-maintained' MP and thus set a precondition for circular models from the top down. The value-driven route is a matter for practice, taken by an actor for whom a reclaimed product holds clear residual value. This route is already noted in MP research (van Capelleveen et al., 2023) and in the BAMB project, which also observes that actors tend to prioritize near-term returns over residual value that arrives only decades later (Debacker & Manshoven, 2016). In the case studied, this actor is a window supplier operating a take-back arrangement alongside a maintenance contractor. They capture value during the use stage by offering a maintenance service while retaining the option to acquire the windows at the end of use.

Sustaining the MPs across a use stage that may span decades, during which owners and contractors are likely to change, is primarily a question for practitioners and researchers. The option studied considers a service provider, the maintenance contractor, with recurring custody of the window information. Under the maintenance contracts, each intervention (e.g. inspections, repairs and upgrades) gives the maintenance contractor both access and a reason to update the MP record. Wan and Jiang (2025) examine smart contracts that carry terms of use between parties; extending this to product-ownership and information-upkeep agreements would also fill the maintenance-contract gap identified [Figure 8; I.3 Prod.]. An alternative way to sustain the MP would be a more neutral intermediary whose continuity is independent of ownership and potentially of commercial value: a circular hub that holds the record as the product changes hands, consistent with the ownership-transfer provisions that practice frameworks already describe (Heinrich & Lang, 2019; Platform CB'23, 2018). In the case study, the circular hub was a digital marketplace created by demolition and construction companies, but public bodies that already approve construction projects could also be a candidate, since they hold comparable information and don't need a value model to sustain their role. Policy could support the design and implementation of this custodial role or assign formal responsibility for the DPP upkeep, which current instruments leave open.

Beyond deriving contextual requirements, the method developed in this study offers an approach to explore and design 'to-be' circular models supported by MPs. The three-step method shows whether the actor responsible for the product, the actor sustaining the MP or both will benefit after the product's first use. Adoption is likely to depend on market conditions, value-chain configuration and a common threshold: the residual value of a reclaimed product must exceed the cost of sustaining the product and its record over time and product cycles. Whether residual value alone is sufficient to initiate the shift and maintain the MP, or whether regulatory preconditions such as DPP mandates and neutral intermediaries are also required, remains an open empirical question, best addressed through pilot projects across regulatory frameworks and market conditions.

Conclusion

The façade process information required to close product loops is context-dependent, and it reframes how MPs should be approached. It cannot be specified as a set of attributes alone; which information matters depends on the product, circular model in place, the selected pathway, and the actors involved, and this context needs to be designed and modelled. In the aluminium window maintenance contract case, this yielded requirements related to information upkeep, spatiotemporal activity sequencing, capabilities, actor roles and relationships, and the agreements governing information and material ownership.

To derive these contextual requirements, a stepwise method was developed consisting of a canvas to define

the context, a BPMN process model to formalize it, and the derivation of the information requirements. The full method was applied to one product under one circular model, so the requirements reported in the study and the coverage gaps identified against existing literature and regulations are specific to the case. The method itself rests on a different basis. Its first step, the canvas, was applied across products with different time-cycles, residual value, performance requirements and next-use pathways. This indicates the canvas and subsequent dependent steps are not specific to the window, so the method could plausibly accommodate other products.

Policy can formalize information requirements for compliance, but only to the level of a minimum set of attributes extending beyond first use. That minimum should nonetheless be specified in awareness of the processes it has to serve. The process information itself follows from the circular model and the actors involved, and those actors should define it through formal arrangements within each product loop. The canvas developed in this study offers an accessible basis for that discussion.

Future research could build on this study by deepening the level of analysis within the current maintenance contract case. This could include modelling the specific subprocesses involved in reuse, remanufacturing and recycling within the present case to evaluate which information becomes relevant and which proves unnecessary. It would also clarify the timing, responsibilities, sequencing, and spatial distribution of the next use activities, strengthening the practical relevance of the proposed circular model. Another avenue of research could test the full method on products with different ownership structures, time-cycles and next-use pathways to assess how far some requirements beyond first use are specific to the product, specific to the model or generalisable across both.

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Author contributions

CRediT: **Anna Batallé Garcia:** Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Project administration, Visualization, Writing – original draft, Writing – review & editing; **Tong Wang:** Conceptualization, Methodology, Supervision, Writing – review & editing; **Ulrich Knaack:** Conceptualization, Supervision; **Edward Forwood:** Validation, Writing – review & editing; **Paul Chan:** Conceptualization, Supervision, Writing – review & editing.

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Data availability statement

The authors confirm that all data supporting the findings of this study are available within the article and its appendices, published under an open CC BY licence. These materials, together with earlier versions of the BPMN model, are also available in the 4TU.ResearchData repository under the collection 'Information Requirements for Circular Façade Products - Process Approach', DOI: 10.4121/a76acf2a-6307-4822-a9c1-9dd1154854f8

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Appendices

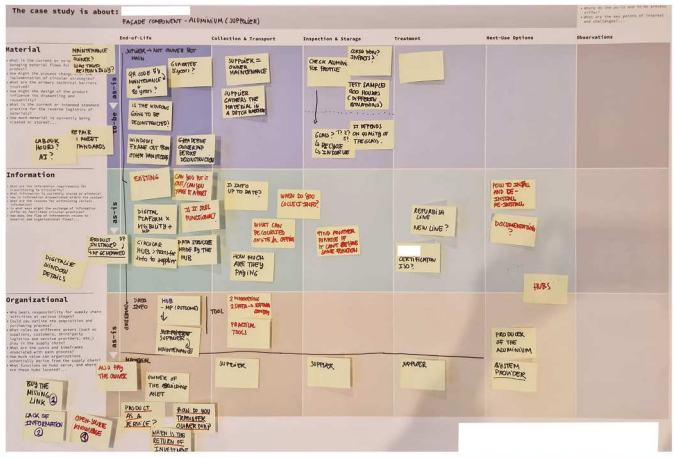
Appendix 1. Participants and workshop outputs

Table A1. Workshop participants profile.

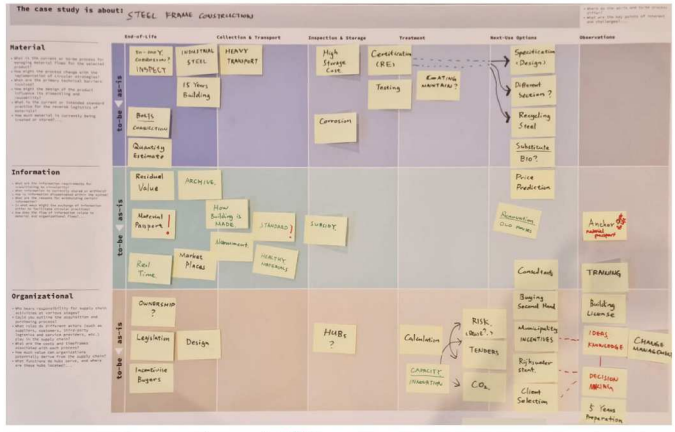
#	Role	Professional Affiliation	Expertise
		Academic and researchers (r)	
r.1	Researcher	University	Circular Models, Circular Design
r.2	Post Doctoral Researcher	University	Conceptual and Material Dynamics
r.3	Researcher	University	Circular Collaboration
r.4	Graduate Intern	University	Circular Innovation
r.5	Graduate Intern	University	BIM Management
r.6	Researcher	University	Circular Urban Data Science
r.7	Researcher	University	Human-AI deliberation
r.8	Advisor and Researcher	(Innovation and) Research Institution	Sustainability in the Built Environment
r.9	Researcher	University	Circular Indicators
r.10	Associate Professor	University	Sustainable Building Engineering
r.11	Researcher	University	Circular Procurement
r.12	Student	University	Change Management
		Practitioners (p)	
p.1	Developer	Circular Real Estate Company	Modular Design and Construction
p.2	Architect Researcher	Circular Real Estate Company	Circular Building Systems
p.3	Project Manager	Manufacturing Company	Biomaterials
p.4	Consultant	Consultancy Firm	Urban Strategists
p.5	Designer	Timber (Construction) Real Estate (Company)	Prefabricated timber construction
p.6	Advisor	Circular Platform (Company)	Industry Circular Innovation
p.7	Advisor	Engineering Consultancy (Firm)	Sustainability and Circular Economy
p.8	Advisor and Researcher	Consultancy Firm	Circular Economy Transitions
p.9	Manager	Circular Platform (Company)	Circular Development
p.10	Manager	Circular Demolition (Company)	Concrete Circularity
p.11	Product Researcher	Circular Platform (Company)	Circular Products
p.12	Advisor	Consultancy Firm	Circular Transition Management
p.13	Intern Researcher	Circular Consultancy (Firm)	Circular Supply Chain Analytics
		Government body and policy representatives (g)	
g.1	Circular Strategist	Regional Government	Circular Transition Management
g.2	Advisor	Municipality	Sustainable Buildings
g.3	Circular Strategist	Real Estate Management (Company)	Circular Value-Chain Coordination
g.4	Advisor	Municipality	Circular Project Developments
g.5	Director	Regional Government	Circular Policy, Public/Private Partnerships
		Workshop moderators (m)	
m.1	Postdoctoral Research	University – Space Plan + Stuff	Circular Information Modelling (end-of-use)
m.2	Researcher	University – Structure	Circular Supply Chains Logistics
m.3	Researcher	University – Structure	Circular Practices
m.4	Researcher	University – Skin (facades)	Circular Processes Management

Table A2. Validation field 'experts' profile.

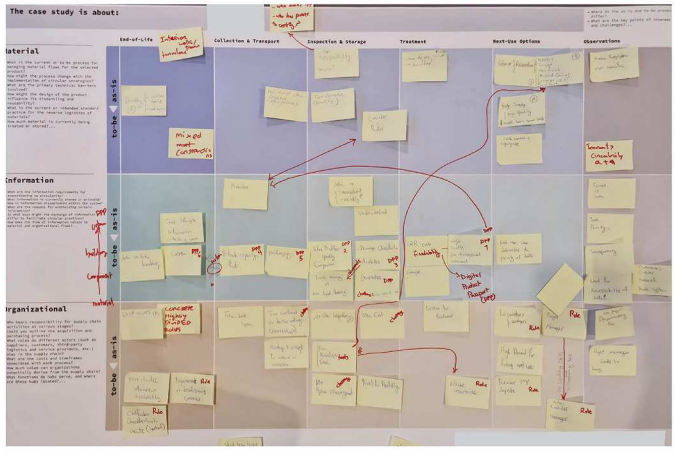
#	Role	Category	Expertise
1	Researcher	Façades + Digitalization	Digital Technologies for Building and Façade Performance
2	Researcher	Circularity	Reuse, Remanufacturing and Recycling of Façades
3	Research Assistant	Circularity	Circular Products
4	Associate Professor	Façades	Green Buildings and Façades Engineering
5	Associate Professor	Façades + Digitalization	Intelligence and Resource Efficiency Façades
6	Researcher	Digitalization	Digital Building Logbooks
7	Researcher	Façades	Façade Performance



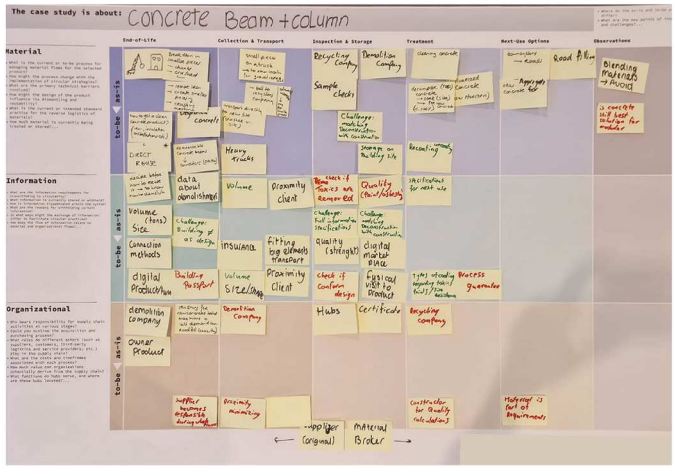
Maintenance contracts for window reuse, remanufacturing and recycling (skin-façades)



Reuse and recycling of steel frames (structure)



Reuse of interior wall frames (partitions) and furniture (Space Plan + Stuff)



Recycling concrete beams and columns (structure)

Figure A1. Workshop canvas cases.

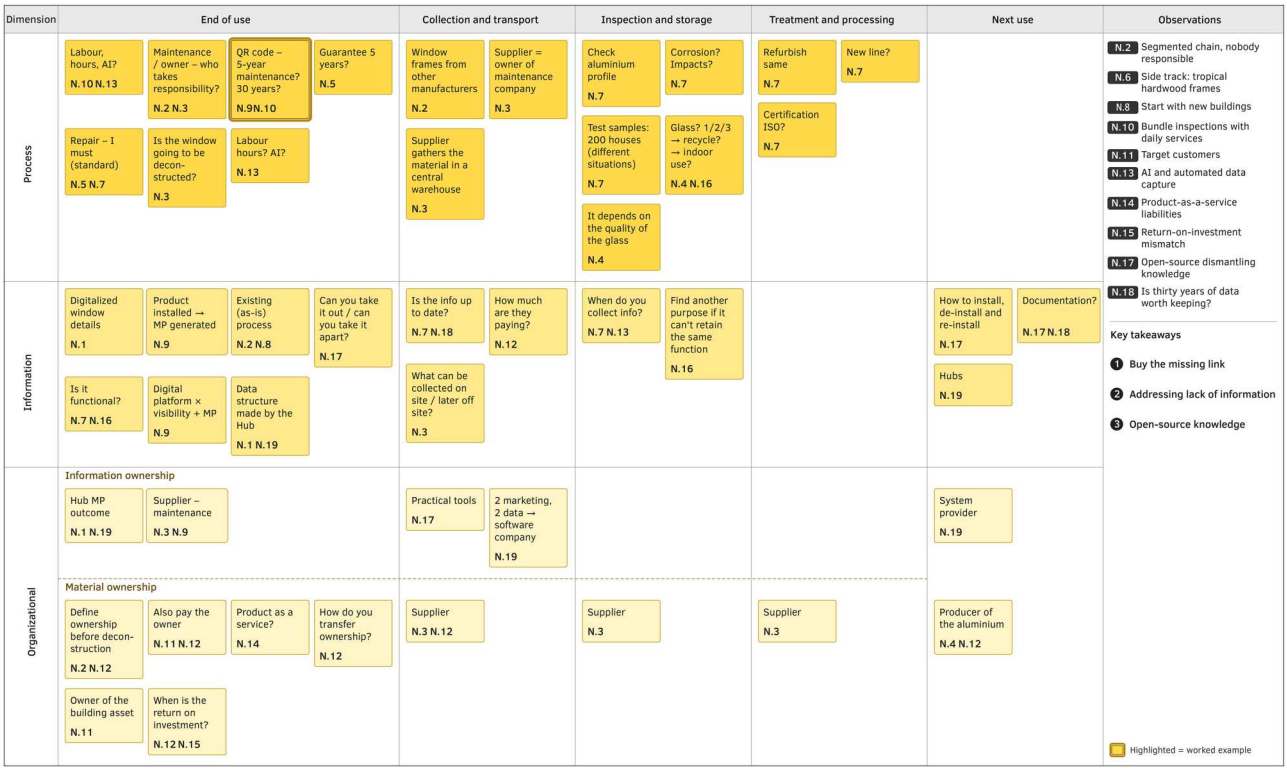


Figure A2. Window maintenance contracts case.

Appendix 2. Information requirements

The following Table A4 presents the full list of information requirements, along with the assessment against scientific research (R), policy documents (including regulations and standards) and (P) Practice Guidelines (G).

Table A3. Workshop notes. Each note is referenced on the canvas (Figure A2) by its N.# notation.

Note	Key point	Comments	Status
N.1	Data structure organized upfront	Manufacturers build custom frames to municipal specifications (e.g. a city-wide colour-harmonization code). The Circular Hub provides the data structures that let project managers inventory public areas up to 18 months ahead and plan the logistics.	P
N.2	Segmented chain, nobody responsible	The window supplier produces semi-finished profiles; a manufacturer adds the glass and a third-party installer fits the window. Because the chain is so segmented, nobody takes long-term responsibility for the final product, which leads to lengthy legal disputes over installation mistakes.	P
N.3	The window supplier integrates a maintenance company	The window supplier acquires a specialized maintenance company to act as the bridge to the owner. When a building is scheduled for demolition, a four-month notice triggers frame extraction and return to the window supplier's central warehouse for inspection and refurbishment. With a take-back guarantee, the supplier becomes the single point of contact, which relieves client anxiety.	M
N.4	Glass is handled separately	The window supplier focuses only on the aluminium profiles. The maintenance company handles the glass: single panes are sent to be recycled into float glass or are sold for indoor use or IGU remanufacturing.	M
N.5	Take-back guarantee and standard repair	A full-service programme in which the supplier guarantees take-back and repairs frames to a defined standard replaces the current situation, where repair is a one-off obligation when the product breaks.	M
N.6	Side track: tropical hardwood frames	Older buildings contain enormous volumes of tropical hardwood. Reusing the frames is hard because modern glazing does not fit the old regulations and the old paint is toxic; instead, the wood is recycled, laminated and glued and sold on to window makers.	O
N.7	Continuous documentation replaces individual testing	Every recovered 40-year-old profile does not need testing, because the maintenance company inspects the frames every three to five years and digitally logs the exact status (coastal salt corrosion, scratches, graffiti) per row and floor. Thanks to this unbroken chain of data, a 15% sample (e.g. a corner house and a middle house) verifies a batch of about 200 houses. Frames are repaired to current industry standards and sold through a refurbished line.	M
N.8	Start with new buildings	The system must begin with newly constructed buildings, because it will take a generation to build up the historical data the model depends on.	O
N.9	Passport activation and long-term contract (Worked Example)	The material passport is generated the moment an order is manufactured and installed. The building owner activates it by scanning a QR code or receiving a letter, which starts a 30–40-year maintenance contract for an accessible fee (about €50 a year). The database has an automated signal that sends an e-mail at the 30, 40 year mark, instructing the maintenance team to contact the owner about the end-of-life status.	M
N.10	Inspections (Worked Example)	To make the three-to-five-year inspections less labour-intensive, technical checks could be merged with routine services such as window cleaning (like getting the car washed while it is at the garage) creating visible added value without disrupting the user.	P
N.11	Target customers	Following the 80/20 rule the model targets utilities, hospitals and large factories: owners willing to pay for quality and a ten-year life extension.	O
N.12	Financial incentive to return materials	A symbolic refund (about €100) at the end of the lifecycle secures the return of the frames. This is strategic for the manufacturer because the price of raw aluminium is expected to double over the next thirty years.	M
N.13	AI and automated data capture	Manual inspection will inevitably be complemented by drones, street-mapping vehicles or cars driving at 80 km/h that generate 3D point clouds of façades.	O
N.14	Product-as-a-service challenges	A large lighting manufacturer's light-as-a-service initiative struggled financially: holding physical assets on the balance sheet for decades is very difficult in weak international markets.	O
N.15	Return-on-investment mismatch	The linear economy relies on short lifecycles for immediate profit: a 400-year-old lamp still burns, yet business models demand lamps that fail after 1000 hours. Asking a manufacturer to wait 30 years for a return instead of one to three years is a major hurdle.	O
N.16	Functional downgrading	Seventy-five-year-old single-glass metal frames salvaged from a large hospital were too thick for modern exterior glazing rules. Instead of remanufacturing them at €30,000–40,000, they were refurbished and installed as decorative meeting-room walls inside an office building. (indirect reuse)	M
N.17	Open-source dismantling and reprocessing knowledge	Like software documentation, manuals on how to disassemble products should be widely available. This threatens the supplier's business model, however, because it would let competitors take over the work – much as electric vehicles disrupted traditional mechanics.	P
N.18	Is 30 years of data worth keeping?	Technological shifts may make today's storage methods obsolete; in three decades AI cameras might identify materials instantly, or prefab housing may no longer exist. Consensus: the future is unknown, but the systems must be built to prepare for change.	O
N.19	Role of the hub	The Circular Hub acts as a neutral provider of data structures and connections between actors.	M

Modelling status: M = modelled in the BPMN diagram; P = Partly modelled; O = O bservation only.

Table A4. Product and process information requirements.

	Process	Information type	Information description	Actors (RACI)	R	P	G	Justification assessment
			Use (operation and maintenance)					
I.1	Generating MP 'as-built' (should be done before handover)	Product (a)	The baseline dataset of the window immediately after installation (e.g. dimensions, material composition, glass specs).	R: Façade Contractor A: Façade Contractor C: Circular Hub, Building Owner I: Maintenance Contractor	●	●	●	R. As-built content specified across the passport reviews, except Sanchez et al. (2024). Not specified for façades. P. CPR full as-built record via declaration of performance and identification (Annex V point 1 essential characteristics and performance in Annex V point 9; environmental Annex II and Article 15). ESPR (Article 7, Annex I composition and substances) and ISO 59040 (Product composition 3.1, Product identification 2.1) reinforce composition but not the full performance baseline; the three align. Façade: a window harmonized standard under CPR and an ESPR delegated act would define the specific essential characteristics. G. As-built content specified by Waterman and BAMB. Platform CB'23 covers the recording process
I.2	Matching Maintenance Company with Façade Owner	Product (a)	Maintenance, Repair and Upgradability Guidelines	R: Façade Contractor A: Façade Contractor I: Circular Hub	●	●	●	R. Maintenance is acknowledged across reviews and repair is mentioned more thinly; both are specified most directly by Wan and Jiang (2025) for the use stage, including updates by third-party repairers. Wan and Jiang (2025) also specify upgradability as renewability, but the other references overlook it. P.ESPR possibility of maintenance, reparability and upgradability, as Annex I parameters (Article 7). CPR adds operational detail, operation and maintenance instructions, and repair recommendations (Annex IV points 2.1(c), 2.3, 2.7(a)), spare parts (Article 22(8)), and upgradability (Annex III 3.1(h)). ISO adds the Maintenance and repair module (5.2 UID) and upgradability (5.3 UID). G. Maintenance and Repair are addressed, but the upgradability of the products is not.
		Process	A registry of service providers containing capabilities for maintaining the specific façade system, subject to periodic re-approval.	R: Circular Hub A: Circular Hub C: Maintenance Contractor , Owner I: Maintenance Contractor, Owner	□	□	□	R. No capability registry. P. None addresses a registry of maintenance providers. This is outside the product information regulation. However, the ISO does mention that the MP should provide information on the manufacturer and producer's repair services. G. No capability registry
I.3	Agreeing on façade maintenance	Process	Legal agreement defining the scope, schedule, cost and liability. It should include a mechanism to update the maintenance plan based on findings during maintenance work.	R: Maintenance Contractor A: Owner C: Owner I: Owner	□	□	□	R. No reference specifies the maintenance service agreement, but a contractual dimension is acknowledged. Charef (2024) discusses new contractual agreements, and Wan and Jiang (2025) describe smart contracts that carry access policies and terms of use between contracting parties. Both are related to different contexts, procurement and data access. This dimension is also acknowledged in product-based requirements (see e.g. Invoices, Contractual Agreements (ownership) by van Capelleveen et al. (2023). In Wijewickrama et al. (2021), demolition procurement via tender/specification defines scope and cost (context-shifted to demolition, not maintenance); liability and plan-update mechanism absent. P. None specifies a maintenance service agreement; it is a commercial and contractual transaction outside product information scope. G. Platform CB'23 acknowledges in '6.9.3 Ownership' that specific ownership agreements within a circular can be made.
I.4	Performing maintenance of windows and updating MP 'As-Maintained'	Product (a)	Dynamic log of the window's physical condition, repairs and replacements updated periodically over its 30–40 years of expected service.	R: Maintenance Contractor A: Maintenance Contractor I: Owner	●	●	●	R. Wan and Jiang (2025) specify a dynamic use stage updated by third-party providers; Senarathne et al. (2025) and Kebede et al. (2024) cover the as-maintained record. van Capelleveen et al. (2023) name condition (C.1), servicing/repairs (C.20), replacements via the component tree (C.19), expected lifespan (C.2) and dynamic life-cycle registration (defining feature) at the object level. In Wijewickrama et al. (2021), maintenance records are recognized as an end-of-use source of condition/repair history (building level), but W specifies no maintained dynamic product log over service life.

(*Continued*)

Table A4. Continued.

	Process	Information type	Information description	Actors (RACI)	R	P	G	Justification assessment
								P. ESPR and CPR > DPPs information must be kept accurate, complete and up to date throughout the life cycle. ISO's PCDS is versioned through its PCDS change process (7.4). It can be inferred from maintenance specifications and keeping information updated G. Platform CB'23 directly specifies recording maintenance modifications during use and acknowledging responsibilities. BAMB and Waterman support an as-maintained record.
		Process	Information on how, when and by whom to carry out scheduled maintenance, specifying depth (routine, general and detailed) and adjusting frequency accordingly (e.g. every 5 years), customized per product.	R: Maintenance Contractor A: Maintenance Contractor C: Owner, Façade Contractor I: Owner	◐	◐	◐	R. Maintenance information is acknowledged across references, but the depth and frequency scheduled per product are not. P. CPR is closest, with adjustments; maintenance and inspection operations specify frequency (Annex IV 2.3(a)(b)); ESPR covers ease of repair and maintenance (Annex I (b)); ISO has Maintenance and repair (5.2). They also mention adding labour skill specifications, spare parts availability and cost. Façade Examples: BS 8210:2020 or ASTM E22270-14. Platform CB'23 directly specifies recording maintenance modifications during use and acknowledging responsibilities. BAMB and Waterman support an as-maintained record.
			End of use (planning for disassembly and next use)					
I.5	Matching availability and demand of windows	Product (a)	The latest specifications for the 'as-maintained' window MPs that will become available.	R: Window Supplier A: Maintenance Contractor C: Maintenance Contractor	●	●	●	R. The latest specifications of products are well covered P. Same justification as [4.a]: ESPR and CPR > DPPs information must be kept accurate, complete and up to date throughout the life cycle. ISO's PCDS is versioned through its PCDS change process (7.4). It can be inferred from maintenance specifications and keeping information updated G. Not directly mentioned, but implicit in BAMB and Platform CB'23. Waterman calls it Used Element Passports
		Process (b)	Requirements specifications (including timeline and location) from new projects that act as the 'pull' signal for potential reclaimed inventory. Requirements specifications (including availability, timeline, and location) for reclaimed products.	R:Window Supplier A:Window Supplier C: Potential Clients (e.g. Glass Producer, Façade Contractors, Design Team) and Maintenance Co	●	□	◐	R. Mao and Cao (2025) discuss future demand forecasting and product availability in the design stage, as well as potential interested parties in deconstruction and reprocessing. Charef (2024) discusses managing product availability, including product locations and making the relevant information available during the tender phase, which could be understood as a pool signal. Wijewickrama et al. (2021) frame demand requirements from demanders as the trigger, along with salvaged-waste availability and a web-based waste exchange for matching. KC et al. (2025), availability time. Yu et al. (2024) and Yu et al. (2023) include time and space dimensions and matching of supply and demand. P. None addresses the demand 'pull' information G. BAMB identifies supply and demand disconnect, and proposes material stocks analysis, but does not specify matching information at the product level. 'push-pull' systems proposed by Platform CB'23 and digital databases to optimize supply and demand. Presented conceptually but not specified
I.6	Acquiring the windows	Product (a)	Purchase offer that contains a commercial proposal to buy back or acquire the material for potential next use.	R: Window Supplier A: Window Supplier C: Owner I: Maintenance Co	◐	□	□	R. Same justification as 3a > while the specifics of such contracts are not stated. The need to include contractual information is acknowledged; for example, van Capelleveen et al. (2023) mention take-back options by manufacturers (C.51) and valuation (C.3), and Wijewickrama et al. (2021) acknowledge secondary-market pricing/commercial dimension (marketing-stage needs). P. None addresses commercial transactions, although they mentioned green procurement in CPR (Article 83) and ESPR (Article 65) G. Not addressed
		Product (a)	Material and Information Contract, which contains the formal transfer of ownership and liability from the Window Owner to the Supplier.	R: Window Supplier A: Window Supplier	◐	◐	●	R. Same justification as 3a > while the specifics of such contracts are not stated. The need to include contractual information is acknowledged. Moreover,

(*Continued*)

				C: Owner I: Maintenance Co				Kebede et al. (2024) and KC et al. (2025) mentioned transfer through 'provenance' and when components and information become dispersed at the end of use. P. Only information is addressed: The record transfer is supported by CPR (data carrier and permalink, Article 76) used product information Article 21(3)), ESPR (DPP transferability, Articles 9 to 12) and ISO (PCDS issuance and revision 2.4, 2.5). Liability and ownership are less specified in this context. G. Platform CB'23 directly specifies the transfer of ownership documentation. BAMB supports this through actor information exchange and product ownership and responsibilities, but it does not fully address liabilities; Platform CB'23 transfers liability from manufacturers to the owner, but not vice versa.
I.7	Assessing feasibility and risk for reprocessing and next use	Product (a)	Performance indicators; disassembly, reuse, remanufacturing, and recycling potential; economic value and costs; location.	R: Maintenance Co A: Maintenance Co I: Window Supplier	●	◐	●	R. The potential for circularity across different strategies is acknowledged in reviews. Location is acknowledged as 'origin', and value and cost are assessed through financial assessment. P. ESPR and ISO are the most comprehensive. ESPR names reusability, possibility of remanufacturing, possibility of recovery, and recycled content (Annex I); ISO provides next-use indicators through the availability of the product for disassembly, reuse, remanufacturing, and recycling (Table A.1, 6.7; 6.8). CPR provides reuse, remanufacturing and recycling recommendations (Annex IV 2.7(c)(d)(e). Location is addressed: CPR records the date and place of deinstallation for used products (Annex V point 1(h)); ESPR records a location or building identifier and general geographical information where performance is relevant; ISO records a Global Location Number (2.21.02) and product location through its persistent identifier. Economic value has no dedicated field; it is only mentioned when referring to spare parts. G. BAMB clearly specifies the need to know the location in order to match next use.
		Process	Strategic evaluation of technical knowledge required, reprocessing capacity, financial and safety risk, storing and transportation analysis.	R: Window Supplier A: Maintenance Co I: Maintenance Co	◐	◐	◐	R. Strategic evaluations are addressed partially: financial, safety and transport distances are addressed in Mao and Cao (2025), while knowledge and reprocessing capacity information are less specified. P. They all contribute as predefined parameters, but none address the strategic evaluation, the reprocessing capacity or the financial risk, which are the model's contribution. A façade-specific method would need to combine these inputs into a decision rule for window reprocessing, with capacity, financial, and safety risk thresholds that the instruments do not provide. G. BAMB includes processes, methods, specialized knowledge, costs, required tools, transportation modes, storage requirements and labour for reuse and recycling, residual values as information within the passports, but not included within the proposed evaluations.
			End of use (execution)					
I.8	Establishing disassembly workplace	Product (a)	Site information describing the physical context of the retrieval site (e.g. access constraints, floor level) that dictates *how* work can be done.	R: Maintenance Co A: Maintenance Co C: Window Supplier	●	□	●	R. Sanchez et al. (2024) is the most comprehensive approach and partially addresses this information through accessibility, physical constraints, etc., and Wijewickrama et al. (2021) provide the broader building context (site conditions, on-site investigation and a demolition site-survey report) P. Site defined; access not. CPR records the place of deinstallation for used products (Annex V point 1(h)) and ESPR as 'unique building identifier', so the retrieval site can be identified; none specifies the access, floor level or handling route, which is building-level information. G. Waterman 0. facilitating works (13 appendices)
		Process	Information on the tools required, timeline for preparing the workplace, and allocated resources and expertise.	R: Maintenance Co A: Maintenance Co C: Window Supplier	●	●	□	R. Sanchez et al. (2024) address the specifics of disassembly but not the activities and related information of workplace preparation. Wijewickrama et al. (2021) name resource-allocation plan, staffing/machine deployment and work-plan timing as dismantling needs/sources P. ISO's Disassembly module (clause 6.7.6.3) enables stating the tools, knowledge, number of disassembly steps and the disassembly time (referencing ISO 8887-1 and EN 45556); ESPR's information requirements

(*Continued*)

Table A4. Continued.

	Process	Information type	Information description	Actors (RACI)	R	P	G	Justification assessment
								cover whether specialized tools are needed and the complexity of the process. CPR Annex IV point 2.1, including necessary training G. Not addressed
I.9	Disassembling and preparing windows for transport	Product (a)	MP 'as-reclaimed' with the status of the window components immediately after removal, verifying they match the 'as-maintained' condition.	R: Maintenance Company A: Maintenance Company I: Window Supplier	●	●	●	R. van Capelleveen et al. (2023) > condition (C.1), end-of-life report (C.32) and the dynamic current-state registration (the passport acts as an end-of-use inventory). Charef (2024) > as deconstructed Senarathne et al. (2025) > end-of-use information. Several authors acknowledge recovered product quality. P. ESPR and CPR > DPPs information must be kept accurate, complete and up to date throughout the life cycle and CPR deinstallation date and quantities(Article 21(3); Annex III point 3.1(h). ISO circularity at end of use (6). Verification/Comparison of 'as maintained' vs. 'as reclaimed' is not stated. G. Waterman: Used Product Passport and implicit through condition and quality assessment in BAMB and through recording characteristics in Platform CB'23.
		Process (b)	Disassembly instructions containing technical protocols and step-by-step procedures for non-destructive removal, handling and packaging of windows, with allocated space, timing and resources.	R: Maintenance Contractor A: Maintenance Contractor C: Window Supplier	◐	◐	◐	R. Most of the points are touched on in several reviews, but overall we understand there is no comprehensive view of this stage. Sanchez et al. (2024) mainly address disassembly planning; Charef (2024) includes storage space planning; Kebede et al. (2024) include packaging; and KC et al. (2025) include logistics information P. ISO dedicated Disassembly (5.5), Demounting (5.4) and Dismantling (6.2) modules, which include time, steps, skills, and tools. CPR adds deinstallation recommendations (Annex IV 2.1; 2.7(b)), and ESPR adds a disassembly-oriented parameter (Annex I). Allocated steps and transport preparation are not addressed. G. Waterman and Platform CB'23 mentioned only the need for standardized disassembly manuals and plans (contractor), not the content. BAMB's definition is comprehensive; the only missing information is the scheduling of activities (time dimension) and specific transportation requirements.
Collection and transport								
I.10	Transporting reclaimed windows	Product (a)	Crate dimensions, type of transport, window site and reprocessing plant location, cost, and quantity of windows recovered.	R: Maintenance Contractor A: Maintenance Contractor I: Window Supplier	◐	□	●	R. Transport distances and modes, transport and handling cost, and quantity are specified as passport attributes, including at the end of life; the collection-specific information and packaging are partial. P. CPR and ESPR > transport should be handled to preserve the product's quality, compliance, and safety. CPR sets packaging environmental impact (Article 15(2)) and minimizing the packaging-to-product ratio; ESPR carries minimizing packaging and packaging waste and ease of reuse (Annex I), deferring packaging as a final product to the Packaging Regulation; ISO treats packaging as a separate product with its own data sheet. No one specifies the protective crate, transport cost, or quantity. G. Acknowledge in BAMB: transport and logistics 2.7 and fig 13. Platform CB'23: transportation possibilities, but it is really generic. In Waterman, it is only acknowledged as a life cycle stage.
		Process (b)	Timing, distance, temporary storage, loading to window racks and transport procedure.	R: Maintenance Contractor A: Maintenance Contractor I: Window Supplier	◐	□	◐	R. Transport information is specified across reviews, but the procedure itself, acknowledging time, equipment required, etc., is not. P. CPR and ESPR both require that storage and transport conditions under the responsible operator do not adversely affect conformity; ISO does not address it. Neither specifies transport timing, distance, loading, or routing. G. BAMB's comprehensive definition; only information missing is the scheduling of the activities (time dimension) and specific requirements for transportation and distances

(*Continued*)

Inspection and storage								
I.11	Inspecting and sample testing windows	Product (a)	Quality verification and compliance information based on regulatory and standard specifications for handling, performance, and testing windows.	R: Previous manufacturer and Regulatory Bodies A: Window Supplier I: Window Supplier	◐	◐	◐	R. Quality protocols and tests in product manufacturing are acknowledged upon first use. How to perform these procedures on subsequent uses is not fully addressed. P. CPR covers first-use compliance in full, the declaration of performance, conformity, assessment and verification and factory production control (Annex V points 9 to 11, Article 15(1); Article 3(33), Annex IX), and through Article 26 it reaches used products, but the reach is graded: a unit transformed beyond checking, cleaning or repairing is treated as if new, while a window reclaimed and reused as is carries only the supplier and deinstaller information obligations (Article 21(3)). ESPR adds conformity assessment (Article 4) and reliability (Annex IVI), ISO a verifiable PCDS. From the previous information, it can be inferred that none provides a conformity re-verification route for a directly reused window. G. Waterman Second Use platforms specify that such information is not required. BAMB acknowledges it through quality assurance and warranties.
		Process (b)	Required equipment, procedure and link to the site inspection to report back any discrepancies.	R: Window Supplier A: Window Supplier I: Future next use actor	◐	□	□	R. Inspection frequency, condition survey information (Senarathne et al., 2025; van Capelleveen et al., 2023; Wijewickrama et al., 2021) before building disassembly, and test methods (Mao and Cao, 2025) are partially addressed; however, equipment and procedure are not specified. P. Only CPR inspection requirements under maintenance (Annex IV 2.3(b)) touch on inspection; ESPR and ISO are silent on equipment and procedure. The reclaimed quality inspection method is not specified. G. The procedural aspects are not specified, but Platform CB'23 acknowledges that this would depend on the specific pathway selected, with trial loading and laboratory tests for building structures.
Treatment and reprocessing								
I.12	Disassembly of windows into IGUs and aluminium frames	Product (a)	Inventory of product breakdown, including condition assessment of frames and IGUs post-separation.	R: Window Supplier A: Window Supplier	◐	□	◐	R. Kebede et al. (2024) mentioned dispersed MPs. van Capelleveen et al. (2023) component-tree feature and links to sub-component passports (C.19) plus condition (C.1) support a product-breakdown inventory. However, most studies address the initial disassembly of the building. Follow-up disassembly levels (on-site and off-site) and inventories of the generated sub-assemblies (for more complex products such as windows) are largely unexplored in the construction literature. P. Read as the record of the parts recovered from dismantling and disassembling, with their condition and quantity captured at separation. This would be a post-collection obligation, and none of the three instruments (as far as we understood) imposes it. CPR provides only a container: it identifies the key parts of the product (Annex V point 1(e)) and permits a data carrier or passport per key part (Articles 16, 76), but key part identification is a conformity device, not a record of a recovered unit, and Annex IV point 2.7 supplies recovery recommendations (reuse, remanufacturing, recycling) rather than a record of the parts once reclaimed. ESPR and ISO offer only ex ante design information: ESPR composition and recyclability parameters (Annex I) and ISO disassembly outputs and material fractions (clause 6.7.6.3) describe disassembly potential, not the actual parts recovered. G. Specified implicitly in BAMB and Platform CB'23 and explicitly within Used Material Passport
		Process (b)	Technical protocols for non-destructive handling and separation of IGU from aluminium frame; safety guidelines; time, workforce, and resource allocation, e.g. tools, machinery, space requirements.	R: Window Supplier A: Window Supplier C: IGU Manufacturer and Previous supplier (if other)	◐	●	◐	R. Literature acknowledges the need for testing within manufacturing, and Mao specifies testing at the end of use. However, how these tests are addressed in the second use is less understood. For IGU, there is literature specifying protocols (Rota et al., 2023) and disassembly schemas Hartwell and Overend (2024). P. ISO is comprehensive with Disassembly (5.5); CPR adds deinstallation recommendations (Annex IV 2 and 2.7(b)) and ESPR a disassembly parameter (Annex I (b). Information is generic, not specific to windows.

(*Continued*)

Table A4. Continued.

	Process	Information type	Information description	Actors (RACI)	R	P	G	Justification assessment
								G. BAMB acknowledges instructions, tools, labour. The scheduling of tasks within a constrained space is largely overlooked.
I.13	Reassembling IGUs and aluminium frames into like-new condition windows	Product (a)	Updated MPs reflecting the remanufactured status, new warranty, data, and performance certifications of the reassembled unit.	R: Window Supplier A: Window Supplier I: Future Owner	☐	●	◐	R. Same as before; moreover, Mao and Cao (2025) briefly acknowledge the second use in Fig. 2, but the updated MP after the first use cycle and how this is combined is largely not specified. P. CPR under Article 26: a used product transformed beyond checking, cleaning or repairing, which a remanufactured window is, is treated as if it were new and requires a full new declaration of performance and conformity, supported by the remanufacturing recommendations (Annex IV 2.7(d)) and the used product information regime (Article 21(3)). ISO carries 3.3 verifiable PCDS.ESPR adds conformity assessment (Article 4) and reliability (Annex IVI); G. Remanufactured specific MPs are only made explicit in Waterman, but warranties are not required.
		Process (b)	Quality control protocols for re-glazing and testing air/water tightness to ensure 'like-new' performance standards.	R: Window Supplier A: Window Supplier C: Previous supplier (if other) or Regulatory Bodies	☐	◐	◐	R. Literature acknowledges the need for tests within manufacturing; however, remanufacturing protocols are not addressed - see practice guidelines that distinguish it. P. Because Article 26 treats a transformed recovered unit as if new, the full factory production control regime applies to the re-glazed window (Article 3(33), Annex IX), which is the only operative quality control obligation any instrument imposes. ISO declares remanufacturability and repairability as potential only (UID 6.3). ESPR reaches the requirement only through the possibility of remanufacturing parameter (Annex I), which is not operative until a future product-specific delegated act, so it does not address it. The missing element is the specific quality control protocol (method for verifying a reglazed insulating unit), which could potentially fit within the general factory production control. G. Platform CB'23 acknowledges that this would depend on the selected pathway. Waterman acknowledges re-certification, but it states that such information is not required for second-use products, and BAMB could fit in through quality assurance for reuse and recycling (currently only acknowledged as a barrier).
Collection and transport								
I.14	Sending Windows to a new location for direct and indirect reuse	Product (a)	Transport manifest including quantity of units and the final next use MP.	R: Window Supplier A: Window Supplier C: Façade/Interior Contractor I: Façade/Interior Contractor	◐	☐	●	R. Research models the logistics data a manifest would carry, not the manifest itself. Mao and Cao (2025) include logistics, transportation and supply chain as data template categories. Kebede et al. (2024) go further, modelling material movement through a Trajectory class and a SpatiotemporalExtent pattern, for example, aluminium from supplier to manufacturer. KC et al. (2025) treat it only as a need: logistics for demolition and recovery planning. Charef, Senarathne, Sanchez, Wan and Jiang do not address it. The next use of MP is the passport itself, credited in the passport rows. P. The transport manifest as a consignment document is not supported by any of the three instruments, since logistics documentation falls outside the product information scope. The instruments reach transport only as a conformity duty: CPR requires that storage or transport conditions under the responsible operator do not jeopardize the product's declared performance (Article 25(5)), which guards the unit against damage in transit but does not constitute a manifest, and this is already credited at Item 10. The Materials Passport for the next use is likewise not absent here; it is assessed earlier in the chain as the remanufactured material passport at Item 13a. What remains genuinely missing is the consignment document itself, the manifest of contents, quantity and route accompanying the transported unit. G. Fully addressed in BAMB: transport and logistics 2.7 and fig 13. Platform CB'23: transportation possibilities, but it is really generic. In Waterman,

(*Continued*)

								only acknowledged as a life cycle stage. The final next use MP is the passport specified and credited in row 12a.
		Process (b)	Timing, distance, temporary storage, loading to window racks and transport procedure; handover of 'as-reclaimed' or 'as-remanufactured' MP to the new contractor.	R: Window Supplier A: Window Supplier I: Façade/Interior Contractor	◐	□	●	R. The MP handover is supported; the transport procedure is not. Wan and Jiang (2025) and van Capelleveen et al. (2023) specify the transfer of a dynamically updated passport to the next holder; Kebede et al. (2024) specify the supply chain activity and trajectory model behind it; KC et al. (2025) specify the information flow between stakeholders, and Mao and Cao (2025) carry packaging, transportation (cost, tool) traceability, supply chain and ownership as data template categories. Timing, distance, temporary storage and loading are absent from all. P. Partial, information handover only. CPR (data carrier and permalink, Article 16, 18(2)(g)), ESPR (DPP transfer) and ISO (PCDS issuance and revision) support passing the record to the next actor as justified in item 6b; physical transport is not addressed. G. BAMB actor information exchange (+Deliverable D.1) and transport and storage. Platform CB'23 specifies mandatory data exchange agreements for the handover, and Waterman provides data carriers and interoperable exchange schemas, which together cover passing the As Reclaimed or As Remanufactured MP to the next contractor.
I.15	Sending IGUs to IGUs remanufacturing plant	Product (a)	(Transport manifest) Technical specifications of the glass units (dimensions, coating type, gas fill and ageing) and defect logs determining remanufacturability.	R: Window Supplier A: Window Supplier I: IGU Manufacturer	●	●	●	R. The sources present the technical specifications as generic passport fields, not as IGU-specific parameters such as coating type, gas fill, or edge seal aging (outside the scope of the research articles). KC et al. (2025) and van Capelleveen et al. (2023) list dimensions and physical properties as a passport category. Kebede et al. (2024) model them at the data structure level as a ProductSpecification class, and argue that quality variation from unrecorded exposure should be captured and updated for reuse, the closest any source comes to the defect log determining remanufacturability. Mao and Cao (2025) treat it in the data template as dimensions and product properties, noting appearance attributes for reusable items such as windows. Senarathne et al. (2025) treat it conceptually, validated on concrete. P. (Transport manifest missing as stated in Item 14a)Characteristics could be drawn from the as-disassembled MP Item 9a. G. (Transport same as Item 14a) Technical specifications as generic passport fields, not IGU-specific parameters. Waterman records material properties and a composition overview at the material passport level; BAMB highlights the need for standardized composition information; and CB'23 carries composition items through its NEN 2660-2 decomposition longlist. None explicitly specifies the coating type, gas fill, or edge-seal aging (window characteristics), and none defines an operational defect log to determine remanufacturability.
		Process (b)	Timing, distance, temporary storage, loading to IGU racks and transport procedure; handover of 'as-reclaimed' IGUs – chain of custody agreements	R: Window Supplier A: Window Supplier C: IGU Manufacturer	◐	◐	●	R. Same justification as Item 14b P. Partial, custody information only. Chain of custody can rest on CPR data carriers and permalinks (Article 16, Article 3(40)(41)), ESPR DPP and ISO PCDS issuance; physical transport is not addressed. However, an important point in the chain of custody is what happens with requirements that haven't been fully reverified, just disassembled. G. Same justification as Item 14b
I.16	Sending aluminium frames and glass cullet to aluminium and glass producers for recycling	Product (a)	(Transport manifest) Material quantities and characterization information (alloy series for aluminium, chemical composition and type for glass), weight, and contamination levels.	R: Aluminium/IGU Manufacturer A: Aluminium/IGU Manufacturer I: Aluminium/Glass Producer	●	●	●	R. Material characterization is reached generically, but the alloy series, contamination and reclaimed quantity elements are not operationalized. KC et al. (2025), Kebede et al. (2024), van Capelleveen et al. (2023) and Mao and Cao (2025) carry chemical and material composition as passport fields, and Senarathne et al. (2025) name contamination and toxicity as attributes. P. Transport manifest missing as stated in Item 14a; characteristics could be drawn from the as-disassembled MP Item 9a. G. (Transport same as Item 14a)Material characterization, as specified by the Waterman material-level passport and BAMB composition, could be better addressed, particularly regarding reclaimed quantities and contamination.

(*Continued*)

Table A4. Continued.

	Process	Information type	Information description	Actors (RACI)	R	P	G	Justification assessment
		Process (b)	Timing, distance, temporary storage, loading and transport procedure; handover of 'as-reclaimed' material – chain of custody agreements.	R: Aluminium/IGU Manufacturer A: Aluminium/IGU Manufacturer C: Aluminium/Glass Producer I: Aluminium/Glass Producer	◐	◐	●	R. Same justification as Item 14b P. Same issue as raised in 15b. G. Same justification as Item 14b
End of Use And Next Use								
I.17	Recording of Information to improve future assessments	Process (b)	Performance metrics on energy consumption and CO_2 equivalent for the proposed disassembly and reprocessing activities.	R. All actors involved in the process	◐	□	□	R. The sources carry energy and carbon only as declared lifecycle or building-level passport attributes: van Capelleveen et al. (2023) energy attributes exist but are declared product-level footprints; Kebede et al. (2024) list energy consumption and operational carbon; Senarathne et al. (2025) GWP and energy consumption; KC et al. (2025) an energy consumption field, and Mao and Cao (2025) building-level energy. All are declarations, not an operational record of the reprocessing activity. In the IoT literature, which initially fell outside the scope of this research, this is acknowledged (Giovanardi et al., 2023) but overlooked for the processes addressed in this research. P. CPR climate change effects (Annex II, Article 15(3)), ESPR carbon footprint (Annex I) and ISO Environmental benefits (7.1) metrics have to be stated, but how the information is obtained is not specified, including no energy and CO_2 of the reprocessing activity itself. G. None of the three records the actual energy or CO_2 of the reprocessing activities. Waterman carries declared carbon performance at the material and element level, and CB'23 carries product CO_2 as a linked data attribute; both are ex ante declarations rather than operational records, while BAMB carries material flows and composition but no energy or CO_2 content.
I.18	Digitized Activity Log	Process (b)	Operational records capturing the specific time, location, and personnel involved in the process. Integration of operational information into updated MP logs.	R. All actors involved in the process	◐	□	●	R. Integration of operational information into the passport is supported; the specific record content is partly open. Wijewickrama et al. (2021) operational reports, resource/personnel/timing records and the IS/ICT integration framework are a strong process-level match. van Capelleveen et al. (2023) integrate servicing history (C.20 - contractor/personnel + dates) and the dynamic-update feature into the MP. Wan and Jiang (2025) specify an event log with authorized-personnel control, capturing time and personnel categories, and integration into the updated passport. Kebede et al. (2024), Senarathne et al. (2025) and KC et al. (2025) support dynamic updating as a passport function. P. All three support a digital record kept current, CPR DPP and data carrier (Article 16, 76), ESPR DPP up to date (Article 10) and ISO PCDS revision (2.5), but the specific operational activity log content is not specified. G. Platform CB'23 specifies 'non-product' related data such as product processing, management, maintenance and end of use; BAMB actor exchange supports the activity log.

Appendix 3. Validation and method evaluation

This appendix presents the comments from the validation session (01.05.2025). The full table on how the authors have addressed each of the comments is provided in the supplementary material file under: Validation Session Feedback_AuthorsReply

Table A5. BPMN model.

Comments	Response
The start of the process is not clear.	The start event has been enlarged and labelled 'start' so that the entry point to the process is explicit.
A legend could be helpful to read the process model for people who are not familiar with BPMN.	A legend has been added at the foot of the BPMN model, as suggested.
Legend: actions, output, database, decision points … (please indicate what each of the symbols mean)	
Process overview versus detailed information: not everyone will care about the overall model, and some actors might be more interested in diving into specific parts.	Agreed. The level of detail in the representation depends on the scope and objective of the model. The scope is stated in the article.
It reflects well each of the actors' steps, but the timeline could be clearer.	The timeline has been clarified. The flow normally runs in a single direction, but some adjustments were required to accommodate the article layout. This has been acknowledged in the methods and discussion.
What are the key moments? Prioritization of information.	Information in the BPMN model has been prioritized in the article (not following BPMN standards)
How and why are we using the model? Make it clear in the explanation	The purpose of the model and its intended use are explained in the article.
The model could help understand roles within a closed-loop model. Who is doing what?	This point has been added to the advantages of the method.
It is valuable, but it is not a complete picture.	Agreed. A complete picture would require models at the sub-process level. This has been acknowledged as a limitation.
Roles can be exchanged rather than 'companies or actors.'	This observation has been incorporated into the article.
Missing title and subtitle	A title and subtitle for the model have been added in the article.
In which format are the MPs generated?	MP structure and technological development are outside the scope of this paper.
How do I store the information on MPs?	Information storage is likewise outside the scope of this research. That the question arose during the session nonetheless indicates that the model supports reflection on digitalization challenges beyond the requirements it was built to capture.
Based on what criteria is the maintenance contract accepted or declined?	Acceptance depends on whether the proposed service and its associated costs are attractive to the window owners. The workshop discussion indicated that the model is best suited to public buildings such as hospitals and offices, where maintenance budgets are already allocated. For smaller owners, additional services such as façade cleaning could increase its appeal.
Is the second life starting in the next use or when the material is being reclaimed and reprocessed?	For visualization in this research, next use begins when the window is reused. Where the targeted pathway is remanufacturing, next use may begin earlier. The boundary therefore depends on the pathway applied, and this dependence is noted in the article.
Move numbers to overall reprocessing at the beginning	A frame has been added to indicate I.17 and I.18 belong to the process since disassembly.
Who/What is the circular hub party?	A description of the circular hub and of its role in the case has been added to the article.
The generation of the MPs should probably start with the manufacturer for compliance.	The article now explains that the for the MP originates before the façade contractor, beginning with the manufacturer for compliance purposes (discussion)
Better reflect who is generating the information.	Owing to layout constraints, information objects could not always be positioned within the lane of the actor generating them. The connecting lines have been redrawn to the lane in which the information is generated, which makes provenance clearer and specified in the information requirements.
Why is maintenance generated every 5 years? It probably depends on the product's needs.	Agreed; the interval depends on the product and the contracted services. The article states that, after installation, the maintenance company performs scheduled work, for example, every five years.
Step 'Reach out to the window owner to evaluate if the window will be disassembled'> If low-quality EoL	The model explains the conditions evaluated for next use.
From the information communicated, it would be good to highlight MPs	MPs are highlighted in blue
Is location important? Maybe Highlight Strategies (r2, r5, r7 …) and it needs a legend.	Location is important to plan product collection and transport. R# notations are explained in the article
Consistency in the direction of the text can help the readability of the document	Pools and lane text direction in BPMN are expressed in vertical direction.
Yes/no moments can be bolded, to indicate that these are decision moments	Information has been prioritized; yes/no text has been resized.
Be consistent with the way actions are expressed	Action terminology is now consistent throughout the model.
Provide a short description of how to read the model information Requirements	A description of how to read the model is given in the methods section and before the model is presented in the results section
Who is the owner of the MPs?	It changes hands. Ownership is explained in the MP requirements

Table A6. Information requirements.

Comments first round			
The first round of comments raised three points. First, it was suggested to indicate which information is useful now and which will be useful in the future; each requirement now specifies the stage at which information becomes relevant. Second, it was asked how the requirements could be incorporated into the material requirements, which falls outside the scope of this study. Third, the material requirements were noted to be expressed inconsistently; they have now been harmonised.			
Comments internal validation			
* The observations from the internal validation were used to improve clarity or refine the articulation > Modelled (M) or Partly Modelled (P). Observations (O). Not included requirements don't have comments.			
I.1	Prod.	This activity should have been completed at handover, before the Use phase. I suggest this be termed Keeping as-built documentation current and up to date. You might add an assumption that a robust handover model has been established and followed before the Use phase. Consult the building owner as well.	M
I.2	Proc.	Review that they remain an appropriate organization to continue to be engaged	M
I.3	Prod.	This should be dynamic based upon the findings of planned maintenance activities. I suggest that the building owner should be accountable and the maintenance company responsible. The façade company may be informed, and in a circular model, it would be rather good to inform the original designers so that they know how their design evolves. Moreover, based on RACI management theory, only one party should be accountable.	M + O
I.4	Prod.	Of course, the circular economy would work better if the original designer were informed of the statistics on what actually happens, so they can assess whether their expectations or assumptions about a product's performance are sound or not …	O
	Proc.	There may be benefit in reporting information about the method of access and any issues associated with the method of access - I reckon that the access method might be rather critical to how often maintenance actually happens - I've seen projects where the access strategy ends up failing, and then the façade does not get maintained.	PM
I.5	Prod. (a)	Good, so there is both a donor requirement to specify the expected performance of existing façade stock and a donor requirement to define the required performance of a done project.	M
	Prod. (b)	If the aluminium supplier is accountable for this item, they effectively become a broker. If the original aluminium supplier has a futures contract arrangement, this could work well. These futures contracts could become something that gets traded— a bit like other resources on the London Metal Exchange. The Maintenance company becomes accountable, perhaps if the aluminium supplier does not have a futures contract for the aluminium.	O
	Proc.	Might there also be a QA process at the point of transfer — an incoming materials type check	O
I.7	Proc.	Would this not happen before item 6 ? Or should item 6 be 'Provisional offer for the windows'? If so, perhaps there is a confirmation of commercial terms after item 7 or even 8	O
I.8	Prod.	Is this not a planning item to be completed prior to agreeing terms? How to disassemble and pack assets is a big and detailed activity (r. the model defines when information will be used)	O
I.9	Proc.	Removal, handling and packing	M
	Prod.	As above, a feedback loop to the original designers would be beneficial	O
I.11	Prod.	Ideally, this would link to the on-site inspection, and any discrepancies would be reported back to the team that carried out the site inspection	O
I.12	Prod.	Do you need a glass party involved here? (r. knowledge of the glass party)	O
	Proc.	You have assumed that the glass and aluminium are dismantled as a single item, so your transport distances are greater than if you separate the glass from the frame on site … double handling perhaps …	O
I.15	Prod.	I think you need to add something about glass ageing characteristics … as glass ages, it accumulates more and more damage (e.g. scratches), which may reduce its statistically predicted strength; PVBs may become more brittle; coatings may become oxidized, with performance implications.	M
	Proc.	If a party is consulted, I think that they need not be included as 'informed' as well— they will be by default	M
I.16	Prod.	For the glass, you would want to know if there are any known blockers to recovery, such as frit; you would want to know the name of the original supplier	PM
I.17	Proc.	Façade asset is assigned a circular economy metric value, and its 'maturity' status is updated so there is a periodically revised estimation of when particular stock items in the urban vault may become available based on preferential terms to the original contractor through a materials futures arrangement or to the open market …	PM

Table A7. Method evaluation.

Collection of Information on a specific case through a canvas					
Strengths and advantages		Limitations		Suggestions	
V.1	It is easier to start the conversation by taking a participatory approach, and the Canvas supports the discussion (it makes it something tangible).	V.5	From as-is to to-be, it is difficult to visualize it in the canvas model.	V.9	Define actors and activities to understand the new roles and to make it easier to grasp.
V.2	It supports reflecting on different closed-loop scenarios, the required activities, and the actors involved.	V.6	Qualitative aspects are difficult to grasp only from the canvas and hidden information.	V.10	The person responsible for drawing the BPMN models needs to be involved in the discussion stage to grasp all the qualitative aspects.
V.3	It allows for debates about responsibilities for who would perform each required action, thereby defining new roles.	V.7	The activities are not always happening in an organized/perfect flow. For example, Transport happens many times.	V.11	Adding connection and sequence of activities already in the Canvas.
V.4	It supports reflecting on the specific circular model, the actors involved, and product-specific requirements	V. 8	To proceed to the next step of the proposed method, the Canvas does not provide sufficient information. It is missing the discussion context.	V.12	The use stage is missing, and transport could be represented as an in-between phase.
				V.13	Reflecting ownership of the material vs. information
				V.14	Information provider. This should be stated during the reflections (one might be collecting or generating the data).
BPMN model describing the case					
Strengths and Advantages	Limitations	Suggestions			
V.15	The model could be helpful to better understand roles within a closed-loop model 'who is doing what'.	V.22	Inconsistency in the direction of the text.	V.27	Consistency of the direction of the text can help the readability of the document.
V.16	Roles can be exchanged rather than 'companies or actors'	V.23	There is a lot of noise in the model. Information needs to be prioritized.	V.28	Reducing the model's noise to better visualize the agreed responsibilities per actor.
V.17	It supports starting discussions around digitalization efforts and responsibilities.	V.24	It reflects each of the actors' steps well, but the timeline could be clearer.	V.29	Using colours or greyscale to prioritize information.
V.18	Process overview versus detailed information: it can help identify challenging aspects that can be explored in more depth. Identification of points to focus on and develop in more detail.	V.25	It is challenging to prioritize information within the model.	V.30	Clarification of the scope of the model— what are we trying to achieve - title informative/ before discussion.
V.19	Process overview versus detailed information: not everyone will care about the overall model, and some actors might be more interested in diving into specific parts.	V.26	It is difficult to understand when next use starts.	V.31	Being consistent in the decision points.
V.20	It can help visualize accountability and responsibility for who will do the digitalization effort.				
V.21	It is valuable, but it is not the complete picture; it helps set up a scope for the discussion.				
Identification of Information Requirements					
Strengths and Advantages	Limitations	Suggestions			
V.32	It helps visualize when specific information becomes relevant.	V.38	It does not help to collect information using a specific standard.	V.40	It could be useful to establish a common language for communication between different actors.
V.33	Responsibilities of who is generating the information and who needs to use it.	V.39	Terminology definitions may differ across actors.	V.41	Use a more widely used standard list as a basis to extract information requirements.
V.34	It supports reflection on information needs beyond the 'product' perspective: quantity and quality of the material.				
V.35	It helps identify the databases that are important to generate, as well as other documents that might not be directly linked to the MPs but are essential to creating closed loops.				
V.36	Relate information requirements with the digitalization effort and the responsible actor.				
V.37	It can help visualize different information sources.				