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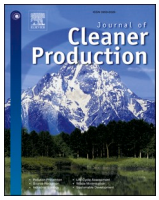

# How to deploy the PSS towards a circular economy in housing? A multiple-case study

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ABSTRACT

Transitioning to a circular housing economy necessitates innovative business models informed by Circular Economy (CE) principles. Yet, a business viewpoint is almost absent from the current circular housing discourse. Of various applicable business approaches, the Product-Service System (PSS) has frequently been put forward due to its resource reduction capacity. Nonetheless, its practical application within the realm of circular housing remains an uncharted territory. To address this knowledge gap, this study employed a multiple-case study, investigating the practices of five frontrunners in the field through interviews and document analysis. The findings informed an empirically grounded framework of 14 guiding principles that provide actionable knowledge for deploying the PSS for a CE in housing across the value proposition, value creation and delivery, and value capture components of the business model concept. Additionally, the findings highlighted the role of intermediary-led collaborative value networks as catalysts for PSS and CE implementation in housing. Beyond these theoretical contributions, the findings and framework presented herein can serve as a dependable point of reference for practitioners in their quest to explore and capture the potential of the PSS towards a CE in housing.

## 1. Introduction

Housing represents a significant and increasing proportion of environmental impacts. Housing accounted for 13.5 billion tonnes of global greenhouse gas (GHG) emissions in 2019, ranking as the second-highest contributing sector with 22.8% of all GHG emissions (Circle Economy, 2022). These considerable emissions pose a significant threat to the planetary boundaries defined as a safe operating space for humanity (Rockström et al., 2009), but also present an opportunity for substantial improvements. The environmental impacts of housing largely stem from the excessive use of multiple resources, including material and energy, during its entire life cycle, spanning pre-use (extraction, manufacturing, transport and construction/assembly), use (operation, maintenance and retrofit) and post-use (deconstruction and disposal) stages (Achterberg et al., 2016). Hence, the overall result of the—so far—incremental improvements focused on one resource or life cycle stage remains marginal. For example, while the use of solar panels has reduced the operational energy impacts of housing, it is estimated that it will generate up to 78 million tonnes of waste by 2050, or more in case of early replacements (Van Opstal and Smeets, 2023). Beyond environmental impacts, housing plays a critical role in shaping the health, comfort, well-being, quality of life and productivity of its inhabitants (Pinto et al., 2019), and thereby it is recognised as a key objective across the Sustainable Development Goals (SDGs) (Cohen, 2021). Yet, both the environmental and social dimensions of housing are often overshadowed by initial costs and affordability considerations. With a projected global population of 9.7 billion people by 2050 (UN, 2022), responding adequately to housing demands while mitigating its environmental impacts has become an even more pressing challenge that requires integrated and systemic solutions beyond mere incremental improvements.

In this context, the concept of a Circular Economy (CE) has gained momentum over the past decade as it introduces a systemic approach to economic development that can address wider environmental and social issues (Kirchherr et al., 2017). A CE is seen as a means to minimise resource input, waste and emission (Geissdoerfer et al., 2020) through four principles of narrowing (using less), slowing (keeping in use for as long as possible and at the highest utility and value), closing (using again) and regenerating (using non-toxic, renewable and biobased) material and energy flows (Bocken et al., 2016; Konietzko et al., 2020).

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Accordingly, a circular building (in this case, house) is defined as "a building that is designed, planned, built, operated, maintained, and deconstructed in a manner consistent with CE principles" (Pomponi and Moncaster, 2017, p. 711). Hence, while the environmental implication of a CE requires careful assessment (Muñoz et al., 2023), its implementation extends beyond incremental improvements and touches upon myriad practices across the life cycle of buildings.

Within the context of housing, several studies have explored how a CE can be applied to build new or retrofit houses (Allam and Jones, 2018; Heisel et al., 2019; Köhler et al., 2022; Oorschot and Asselbergs, 2021). A review of these studies has characterised housing in a CE as housing that is designed to passive standards, built of circular materials, adapted to potential change over time and tailored to its specific context (Ghafoor et al., 2023). In practice, however, the transition to circular housing has been slow to unfold as the logic cannot rely on the same premises as conventional industry practices. The latter rely on the ownership of materials and components for a certain period until they reach the end of their useful life and are disposed of (Guerra and Leite, 2021). Consequently, despite soaring material and energy costs, as well as supply shortages, circular interventions that aim to decouple economic activity from resource consumption are primarily hindered by fragmented value chains, competitive instincts and the short-termism of these practices that favour transactional relationships (Adams et al., 2017; Hart et al., 2019; Hossain et al., 2020). This implies a need for innovating the industry's underpinning business models in driving the housing CE transition (Guerra and Leite, 2021). However, the industry has primarily been approached from a technical point of view, and research from a business perspective remains notably sparse (Das et al., 2023).

Of the various innovative business approaches, the Product-Service System (PSS) stands out as one of the most frequently cited for its CE potential (Bocken et al., 2016; Rosa et al., 2019). The PSS is regarded as a business approach that shifts the business focus from the "sale of products" to the sale of a system of products and services that delivers "value in use" (Baines et al., 2007). Hence, by retaining the ownership of products towards performance delivery, the PSS internalises the cost of waste and introduces incentives to reduce the volume and speed of resource flows (Stahel, 1997). In doing so, the PSS creates a business case for reducing resource consumption towards a CE. For example, when applied in the delivery of housing or its components, the PSS can promote efficiency, longevity and sufficiency in energy, material and space usage levels (Ghafoor et al., 2023). Additionally, the long-term relationships induced by the ongoing delivery of shared performance objectives of the PSS and consequent redistribution of incentives, responsibilities and risks can further facilitate circular interventions that are hampered in conventional practices.

However, the integration of the PSS in housing encompasses major changes in the business practices of the industry (Azcarate Aguerre et al., 2023). This includes product and process innovations such as the adoption of rigorous design standards, industrialised construction methods, smart home devices and remote monitoring systems (Brown et al., 2022). It also involves innovations in the way those products and processes are brought to the market through, for example, collaborative value creation (Lazarevic et al., 2019) and the introduction of renewed roles for and agreements between stakeholders (Galle et al., 2019). In this context, Azcarate-Aguerre et al. (2022) proposed a multi-stakeholder model for the development of façade technologies in the delivery of façade-as-a-service. Fargnoli et al. (2019) demonstrated the benefits of integrating Building Information Modelling (BIM)-based approaches for the management of building equipment maintenance in a PSS context. Andersson and Lessing (2019) and Robinson et al. (2016) emphasised the importance of assessing the company's position within the value chain and consistently coordinating internal and external activities when construction companies shift towards the PSS. Despite these insights on the implementation of the PSS, actionable knowledge for navigating the changes required, particularly in housing, remains limited (Ghafoor et al., 2023). This deficiency is a significant barrier to PSS adoption in housing.

Moreover, it is unclear how a CE can be enabled in housing PSS operations. Although the concept of PSS has emerged out of growing environmental concerns, switching from a product to a system of products and services does not automatically contribute to circularity (Mont, 2002; Tukker, 2015). A performance-oriented PSS may hold greater environmental potential than others (Michelini et al., 2017; Tukker, 2004; Yang et al., 2018). Still, a poorly employed PSS may offset its environmental potential due to, for example, rebound effects resulting from the changes in user behaviour (Kjaer et al., 2019). This highlights the necessity for research that considers the CE aspect of PSS adoption and identifies the key success factors from that perspective (Manninen et al., 2018). Nevertheless, investigations specifically centred on the deployment of the PSS and its CE potential in housing are conspicuously lacking in the current body of scholarly literature.

The aim of this study is thereby to address these gaps, asking: how to deploy the PSS for a CE in housing? To answer this question, a multiple-case study was conducted with five frontrunners who provide PSSs in housing to enable a CE. Housing comes in various types, including individual dwellings and apartments, and is provided under different tenures, such as owner-occupied, rental and social. This study considers housing in all its types and tenures and reflects on the particularities observed within the case studies. Using the business model concept, this study provides a guiding framework for implementing the PSS in housing. The specific objectives are as follows.

1. Identify guiding principles for deploying the PSS in housing, and
2. Examine the actions that can be taken to align the PSS with a CE.

The remainder of this study is structured as follows. Section 2 sets the scene against the theoretical background. This is followed by an elaboration of the multiple-case study approach and methods in Section 3. Section 4 presents the findings, while Section 5 discusses the findings, their theoretical contributions and practical implications. Section 6 concludes the study by summarising the findings, acknowledging the limitations and highlighting consequent areas for future research.

## 2. Theoretical background

### 2.1. The PSS and housing in a CE

The PSS is known as a marketable set of products and services combined in a system to meet user needs by shifting the business focus from sale to value in use (Baines et al., 2007; Goedkoop et al., 1999; Manzini and Vezzoli, 2003). Accordingly, the PSS is classified into three types as per the ratio of service provided: product-oriented PSSs (sells products with additional services, e.g., maintenance); use-oriented PSSs (offers access to tangible products, e.g., leasing); and performance-oriented PSSs (offers an agreed result without specifying products, e.g., key performance indicators (KPIs)) (Tukker, 2004). In the delivery of housing or its components, the PSS means abandoning business models predicated on energy and materials throughput in exchange for models based on access or performance, for example, heating or even comfort instead of units of energy or material (Ghafoor et al., 2023). Such a shift could radically overhaul how houses are designed, built, used and treated at the end of life.

In conventional housing industry practices, houses are generally designed and constructed without much deliberation on the size and the choice of materials or energy systems. As a result, oversized dwellings (Stephan and Crawford, 2016) despite decreasing household size (Cohen, 2021), poor building envelopes, inefficient energy technologies and reliance on non-renewable energy sources increase material and energy use (Shadram and Mukkavaara, 2019). Further, as the design does not accommodate change, more resources are used during various invasive refurbishments over the life cycle, so that the house or its

components can be maintained or fulfil the changing needs of their users, e.g., change in family composition, lifestyle, work or climate condition (Cambier et al., 2021). Ultimately, many houses are demolished prematurely, long before reaching their full technical service life, despite the availability of technology that allows for their durability (Pomponi and Moncaster, 2017). These demolitions often generate large quantities of non-reusable materials due to, for example, technical constraints such as the lack of design for disassembly or financial limitations such as the absence of a market for secondary materials (Munaro and Tavares, 2023).

Such excessive use of energy and materials over the life cycle has resulted in significant environmental impacts (Circle Economy, 2022). Although many efforts have been focused on mitigating these impacts, creating a CE in housing necessitates more fundamental changes to conventional industry practices, such as the integration of the PSS. This is because, by broadening the focus of the industry from the point of delivery of a house or its components to the entire life cycle, the PSS can promote efficiency, longevity and sufficiency across energy, material and space usage levels towards a CE (Ghafoor et al., 2023). The introduction of the PSS in housing, however, requires major changes in the business practices of the industry. Adopting the business model concept can offer a strategic approach to navigating the changes required for operationalisation (Moro et al., 2022).

### 2.2. The PSS and the business model concept

Business models describe the core logic of how firms do business (Osterwalder and Pigneur, 2010). Researchers typically describe a business model as a set of components that define what value is provided and to whom (value proposition), how value is provided (value creation and delivery), and how revenue and other forms of value are captured (value capture) (Richardson, 2008), Table 1.

This characterisation offers a general framework that has been used in multiple contexts, including PSS-informed business model innovations (Moro et al., 2022). The literature notably emphasises the enlarged value proposition of the PSS in moving the focus from products to systems (Kristensen and Remmen, 2019). This means that reliance on tangible products as the core value component decreases and the user needs are formulated in more intangible terms (Petrulaitiene et al., 2018). So to address user needs with the right value proposition, it is recommended to segment customers (Adrodegari et al., 2017). In this sense, early involvement and increased relationships with customers are highlighted as means to improve the value proposition (Beuren et al., 2013). To create and deliver this value, firms are encouraged to extend their responsibility to products' entire life cycle. This extension entails taking on new tasks (Reim et al., 2015), developing new competencies (Kindström and Ottosson, 2016) and capabilities (Wallin et al., 2015), embracing digital technologies (Ardolino et al., 2018) and collaborating with other firms (Gebauer et al., 2013). Additionally, a focus on designing products that are easy to maintain, upgrade and reuse is noticeable (Adrodegari et al., 2017). As for the value capture, various revenue mechanisms linked to the value proposition are considered (Van Ostaeyen et al., 2013). However, as the payback time increases, the need for capital becomes more pronounced (Barquet et al., 2013). Furthermore, taking more responsibilities, and thereby risks, necessitates structured agreements between involved parties to clearly specify rights and responsibilities and balance mutual interests (Reim et al., 2015). While this extant literature provides a good foundation, actionable knowledge on how to deploy the PSS in housing, particularly for a CE, is currently lacking.

**Table 1**
Business model components based on Osterwalder and Pigneur (2010) and Richardson (2008).

| Component | Corresponding question |
|---|---|
| **Value proposition** (Product/service, customer segment) | What value is provided and to whom? |
| **Value creation and delivery** (key activities, resources, channels, partners, technology) | How is value provided? |
| **Value capture** (cost and revenue streams) | How are revenue and other forms of value captured? |

### 2.3. Business model innovation for a CE in housing

The research on business model innovation for a CE has mainly emerged in response to the need for rethinking business models (Pieroni et al., 2019). Innovating a business model can include reconfiguring the existing business model or designing a new one (Massa and Tucci, 2021). The principles of narrowing, slowing, closing and regenerating material and energy flows inform CE implementation in innovating business models to facilitate absolute reductions in energy and material throughput and create the preconditions for the enhancement of social and environmental well-being (Nuβholz, 2017). It is therefore argued that business model innovation for a CE aims to minimise throughput consumption by prioritising value over volume (Konietzko et al., 2023).

Traditionally, value has been associated with the realisation of economic value. The term "cost" instead of "value" has taken precedence in the construction industry with buildings designed to a budget and contracted to the lowest tender (Brady et al., 2005), with limited performance guarantees. However, within the realm of circularity and sustainability, the notion of value takes a more systemic approach and includes social and environmental goals (Boons and Lüdeke-Freund, 2013). For example, these may include the quality of a house and its effects on the health and well-being of occupants or energy use. Additionally, value has been predominantly defined based on the benefits acquired by organisations and exchanged with customers. This perspective is further enforced in the project-based context of the construction industry, which suffers from extreme fragmentation across vertical (separated into different stages of the life cycle), horizontal (separated into trades/disciplines) and longitudinal (separated into distinct projects) dimensions (Fergusson and Teicholz, 1996). However, an emerging body of literature argues that the notion of value extends beyond customers and organisations alone to encompass all stakeholders within the value network (Zott and Amit, 2010), including the environment and society (Evans et al., 2017; Stubbs and Cocklin, 2008). This is because, particularly within the context of circular and sustainable business models, associated value chains have become more complex with the participation of a wider range of stakeholders in the value system (Yang et al., 2017). Hence, circular business models need to be designed in housing to ensure value for all stakeholders in more than one sustainability dimension.

## 3. Research methods

To understand the practicalities of how the PSS can be deployed for a CE in housing, this study performed a qualitative multiple-case study. The case study method is particularly useful for exploration and theorising when little is known about a complex and contemporary phenomenon under investigation, such as the one investigated here (Eisenhardt and Graebner, 2007). Additionally, since implementation efforts largely stem from practitioners' subjective assumptions, experiences and interpretations, a case study was deemed appropriate to allow for in-depth and holistic perspectives from real-world practices (Yin, 2014). In so doing, a multiple-case design was used to strengthen the evidence base through within and cross-case analysis and hence allow for more robust claims (Eisenhardt and Graebner, 2007). The research process is illustrated in Fig. 1.

### 3.1. Selection and description of cases

Consistent with theoretical sampling (Yin, 2014), two selection criteria were applied to identify suitable cases. First, the cases employ

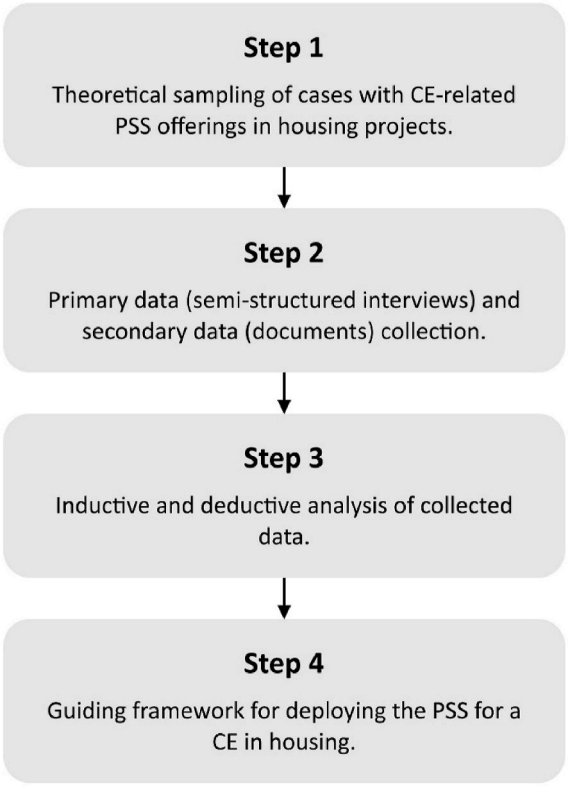


**Fig. 1.** Overview of the research process. Source: authors.

the PSS for material and/or energy services in housing projects, following the categorisation offered by Ghafoor et al. (2023). Such cases were found by searching publicly accessible databases, reports from consultancy firms and company websites, looking for terms such as "product-service system", "servitisation", "as-a-service" or "integrated solution". Second, the cases consider CE a key focus when describing PSS business activities on their company website. Based on these selection criteria, an initial list was compiled. The cases were subsequently approached to participate in the study with the intention to purposefully sample for diversity in PSS type and application, so as to increase the external validity and generalisability of findings (Yin, 2014). Consequently, five cases were accepted to participate in the study. Table 2 outlines the key features of the selected cases.

### 3.2. Data collection

Data was collected from multiple sources. The primary data source was semi-structured interviews to reveal rich and context-specific information (Eisenhardt and Graebner, 2007). The interviews were designed to be semi-structured to allow for probing and further elaborations as required. This flexibility ensured that a comprehensive understanding of the studied phenomenon could be achieved and that all relevant aspects were explored. The interview data were supplemented and triangulated with secondary data such as company websites, documents, reports, news articles, media interviews and research reports to ensure internal validity and reliability (Yin, 2014).

As the study concerned the business and operation aspects, the selection of key informants was directed towards senior managers and value chain stakeholders holding key positions such as director, market development manager, sales manager, sustainability manager, commercial advisor and business development specialist. In total, nine interviews were conducted, for which ethics approval was obtained from Deakin University's Human Research Ethics Committee. Interviews were based on an interview protocol, as shown in Table 4. The interview protocol was devised based on the study's objectives and refined through feedback from the research team (Castillo-Montoya, 2016). Accordingly, it was structured in three parts, which were evaluated and honed after each interview (Yin, 2014). The first part covered the role and background of informants. The second part explored how the cases approached business model components—namely, value proposition, value creation and delivery, and value capture—in deploying the PSS in housing. The third part focused on the cases' vision and specific actions towards CE, their motivations and challenges, as well as topics that emerged from the interview or review of secondary data. Questions were open-ended to gain rich and detailed descriptions. Due to the geographical dispersion of interviewees, the interviews were conducted online to allow for participation from different locations. On average, each interview lasted 53 min. All interviews were recorded, transcribed and anonymised to maintain confidentiality.

**Table 2**
Key features of the selected cases. Source: authors.

| Case | Specialisation | Location | Size | Year founded | PSS description | PSS type | Initial motivation |
|---|---|---|---|---|---|---|---|
| A | Carpet and resilient flooring manufacturer | Australia | Large | 1973 | Design, installation and take-back of carpet tiles for fixed monthly fees over a 10-year contract. | Use-oriented | Complementing circular products |
| B | Elevator manufacturer | The Netherlands | Large | 1951 | Design, installation, maintenance, repair and take-back of elevators for a variable initial fee and fixed annual fees over a 20-year contract with a performance guarantee for malfunctions and downtimes. | Performance-oriented | Commercial growth |
| C | Housing retrofit solutions provider | France | Small | 2016 | Coordination of design and delivery of housing retrofits with offsite manufactured insulated envelopes integrated with low-carbon energy systems and controls (e.g., solar, heat pump) for fixed monthly fees over a 30-year contract with a performance guarantee for internal temperature and a set allowance of hot water and electricity consumption. | Performance-oriented | Sustainability mission |
| D | Housing solutions provider | The Netherlands | Small | 2015 | Coordination of design and delivery of housing solutions including insulated envelopes, heat pumps, mechanical ventilation, shower heat recovery units, integrated sun protection and solar panels for sale with a performance guarantee for net zero annual energy consumption. | Product-oriented | Sustainability mission |
| E | Housing energy solutions provider | The Netherlands | Medium | 2017 | Design, installation, maintenance, repair and take-back of housing energy solutions including heat pumps, solar panels, batteries and electric vehicle charging stations for fixed monthly fees or variable usage fees over a 15-year contract. | Use-oriented | Sustainability mission |

### 3.3. Data analysis

A structured data analysis approach was employed that iterated between first-order codes, second-order themes and emergent theory (Eisenhardt and Graebner, 2007). In the first step, first-order codes were developed by open coding primary and secondary data for each case to identify the cases' major activities in deploying PSS business models and realising CE. Subsequently, connections between the first-order codes were identified to derive second-order themes. This step was guided by the cross-case replication logic, aiming to identify and confirm generalised themes across the cases (Eisenhardt and Graebner, 2007). This inductive approach to data analysis was complemented with deductive reasoning to compare the emergent theory with the literature and identify relevant theoretical concepts embedded in the data (Eisenhardt and Graebner, 2007). Lastly, the refined themes were grouped within the three components of the business model concept according to whether they support value proposition, value creation and delivery, or value capture. Fig. 2 illustrates the coding process. This iterative process led to the development of a guiding framework for deploying the PSS towards a CE in housing. NVivo 14 was used to assist with the coding process.

## 4. From cases to findings

This section collates the findings from the five cases to derive empirically grounded principles that underpinned the deployment of the PSS in the cases within the three business model components. Table 3 provides a summary of the cases' findings that guided the analysis, including their primary value propositions and the mechanisms for value creation and delivery, as well as value capture.

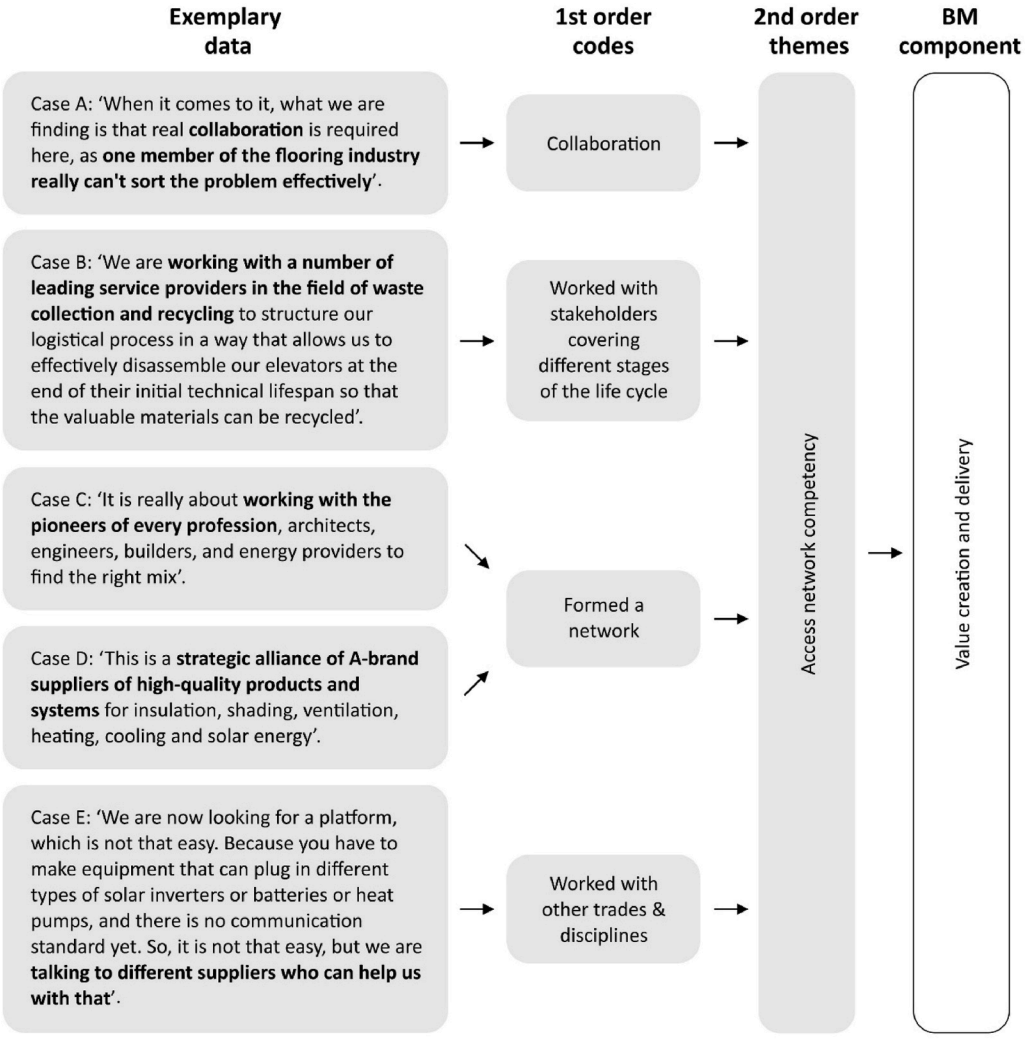


**Fig. 2.** An example of the coding process. Source: authors.

**Table 3**
Summary of key findings of the cases. Source: authors.

| Case | Value proposition | Value creation and delivery | Value capture |
|---|---|---|---|
| A | • Durable carpet tiles with a warranty<br>• Narrow, slow and close resource flows<br>• Social housing and build-to-rent apartments | • Use of local, bio-based and secondary materials (e.g., recycled nylon, discarded fishing nets) and renewable energy in production.<br>• Modular design with random patterns.<br>• Dismantlable installation.<br>• Take-back service and reuse/recycle of used carpet tiles.<br>• Digital data set for tracking reclaimed carpet tiles.<br>• Multi-disciplinary team.<br>• Collaboration with local retailers and seeking partnerships with other fit-out suppliers. | • Fixed monthly fees over a 10-year contract with the option to extend the contract as required. |
| B | • Accessible quality vertical transport with malfunction and downtime guarantees<br>• Narrow, slow and close resource flows<br>• Apartments | • Use of materials appropriate for reuse/recycling (with cradle-to-cradle certificate).<br>• Design for disassembly.<br>• Real-time monitoring and material passport.<br>• Predictive maintenance (aligning maintenance with actual usage).<br>• Optimal design of elements by tailoring to usage requirements.<br>• Training employees.<br>• Collaboration with waste collection and recycling as well as digital technology providers. | • A variable initial fee, fixed annual fees, and usage allowance over a 20-year contract with the option to renew the contract for another 20 years with lower annual costs. |
| C | • Affordable net zero energy home with a healthy and comfortable indoor climate and an internal temperature guarantee<br>• Narrow and regenerate resource flows<br>• Social housing apartments | • Use of local and bio-based materials.<br>• Modular, dismantlable and mass-customised design.<br>• Offsite manufacturing.<br>• Standardised administration processes.<br>• Real-time monitoring, 3D laser scanning and BIM.<br>• Specifying low-carbon energy technologies.<br>• Forming networks and intermediation of interests. | • Fixed monthly fees and hot water and electricity consumption allowance over a 30-year contract. |
| D | • Net zero energy home with annual net zero energy consumption guarantee<br>• Narrow and regenerate resource flows<br>• Individual dwellings and apartments | • Use of bio-based, recyclable and durable materials.<br>• Pre-engineering components and processes.<br>• Modular, dismantlable and mass-customised design.<br>• Offsite manufacturing.<br>• Real-time monitoring and BIM.<br>• Preventive maintenance.<br>• Specifying low-carbon energy technologies.<br>• Forming a coalition and assuming the role of intermediary. | • Direct sale. |
| E | • Carefree electric energy factory home with a warranty<br>• Narrow and regenerate resource flows<br>• Individual dwellings and apartments | • Specifying low-carbon energy technologies.<br>• Preventive maintenance.<br>• Exploring the use of real-time monitoring.<br>• Collaboration with suppliers and local trading partners and seeking partnerships with digital technology providers. | • Fixed monthly fees or variable usage fees over a 15-year contract. |

### *4.1. Value proposition*

#### *4.1.1. Focus on improving living quality*

The core value proposition of the cases revolved around improving living quality for users. As one interviewee in case C reflected,

*'This is an opportunity for rethinking how people live'.*

This improved living quality was mainly devised by rethinking the purpose of housing components and aligning them with actual user needs. In so doing, a new understanding of user needs was presented, though the level of abstraction differed based on the PSS type. For example, instead of an elevator, a quality vertical transport (case B); instead of envelope and energy technologies, a net zero energy home (case D) with a healthy and comfortable indoor climate (cases C); and instead of individual energy technologies, an electric energy factory home (case E) were proposed. An exception was found in case A, where the carpet remained unchanged, though efforts were made to reframe the proposition by collaborating with other fit-out suppliers.

Several other value elements contributed to this proposition. The first common value element was convenience. This was to reduce *'hassle'* for clients by integrating complementary components and activities. So, instead of dealing with various counterparts for design, installation, operation, maintenance, repair and take-back of one or multiple components, clients benefited from '*a single point of contact'* that relieved them of those responsibilities.

The second value element was the technical quality of components. As the focus shifted from production costs to the life cycle, cases leveraged their expertise to provide quality offerings by enhancing durability (e.g., by reducing premature breakdowns) and reliability (e.g., by reducing the number and length of breakdowns) of components. As one interviewee in case B described,

*'The business as usual is to sell and install an elevator … and then earn money by replacement and maintenance as much as possible. It [our business model] is not optimised cost by replacements, but optimised cost by no replacements'.*

The last value element was the provision of performance and product guarantees, as well as insurance services that moved technical risks away from clients. This was partly driven in response to a lack of trust. As reflected by an interviewee in case C,

*'The biggest barrier is trust in this market … a warranty really helps in building trust … for the system to move forward'.*

Thus, the PSS should focus on improving living quality that encompasses actual user needs and provides convenience, technical quality and performance guarantee.

#### 4.1.2. Make the improved quality accessible

The accessibility of the improved living quality was considered significant in all cases, as one interviewee in case D highlighted,

> *'This transition is also price-driven'.*

Accessibility was largely driven by novel revenue mechanisms that reduced, or, in some cases, eliminated initial investment for clients. For example, refurbishments in case C were paid back through clients' savings in energy bills and maintenance and repair costs over 30 years, allowing clients to have the same monthly expenses on energy bills while enjoying the benefits of refurbishments. As explained by an interviewee in case C,

> *'It is going net zero that pays for itself by blending real estate and energy economics'.*

From this perspective, the product-oriented PSS in case D exhibited the least potential for accessibility. Cost efficiency and the consequent reduced total cost of ownership were also attained as the life cycle of components was considered. Other economic values for the client included financial certainty around life cycle costs and a potential increase in property value because of improved living qualities. Hence, accessibility is an important principle.

#### 4.1.3. Consider life cycle environmental implications

The value proposition of the cases went beyond clients to include environmental implications. Case A, which realised the average turnaround of their carpets ranged from nine to 11 years, despite having a warranty of 20 years, employed PSS to enable the take-back of carpets for direct reuse or recycling into new carpets, effectively narrowing, slowing and closing material flows. Case B employed the PSS to provide competitive pricing for quality elevators. Over time, and in response to environmental concerns, the PSS has grown to incorporate CE principles. While the efficient use of elevators narrowed material and energy flows, case B is working on design and reverse logistics to enable the reuse and recycling of elevator components to slow and close material flows. Cases C, D and E employed PSS to facilitate the adoption and efficient use of low-carbon energy technologies, thereby narrowing material and regenerating energy flows. They are also exploring ways to reuse and recycle components at the end of service life. Thereby, while the initial motivation for PSS may vary, a CE objective should be formed that considers life cycle environmental implications to narrow, slow, close and regenerate material and energy flows effectively.

#### 4.1.4. Differentiate according to housing type and tenure

The cases cover a range of client bases from different housing types (individual dwellings and apartments) and tenures (rental, owner-occupied and social). Build-to-rent and new-build apartments were generally the most preferred, because of centralised management and uniform stock that facilitated scalability. However, dealing with diverse individuals in existing owner-occupied apartments posed challenges, as explained by an interviewee in case E,

> *'In the existing apartment blocks … if you have to convince a group of people … it is almost impossible … because you have to talk to sometimes 60 or 100 people … this is very difficult'.*

In social housing apartments, split incentives between housing providers and tenants also impeded progress. As the interviewee in case E further explained,

> *'The housing provider has to make the investment, but the upside goes to the tenant. And then the housing provider has to find some ways to get that money back, [while] they are not allowed to raise the rent because it is social housing. So, it is a very difficult context'.*

It was therefore argued that the government, as a key stakeholder in social housing, can influence adoption significantly, as exercised in case C. Another concern associated with social housing was the user behaviour of tenants, as elaborated by an interviewee in case A,

> *'The problem he [the housing provider] saw with it was the transient nature of some of the people that are in social housing'.*

In contrast, individual dwellings provided a simpler client interface, yet the lack of scale and scalability remained a challenge. The service needs of users across these types and tenures were also recognised to be different. That is, cases D and E tailored their offering for individual dwellings and apartments in response to their distinct characteristics. Hence, while build-to-rent, new-build and government-supported social housing apartments show significant potential for market entry, the PSS requires differentiation and customisation to account for varying opportunities, challenges and user needs across different housing types and tenures.

### 4.2. Value creation and delivery

#### 4.2.1. Re/co-design components and processes

In all cases, the components and their production and management processes were (re)designed in alignment with several CE principles. Depending on the position of the case, manufacturer or provider, various activities were undertaken. In the pre-use stage, a shift in the choice of materials towards reused/recycled, durable, bio-based, non-toxic and local materials, as well as in the production processes towards local, industrialised and offsite manufacturing with renewable energy was observed. The design of the components also showed a shift towards modular, dismantlable and mass-customised design. In the use and post-use stages, activities included the incorporation of material passports, real-time monitoring, predictive maintenance and reverse logistics. The cases also demonstrated redesign in the way in which components and processes were integrated. For example, case D reported a pre-engineering step in which components and processes were optimally matched to each other to ensure better design and build quality, necessitating their co-design beyond the boundaries of individual stakeholders. Thus, the PSS entails a deliberate and integral re/co-design of components and processes in alignment with CE principles.

#### 4.2.2. Standardise components and processes

The cases demonstrated a shift towards standardised components and their production and administration processes. This standardisation was in part to minimise cost and time through economies of scale and learning rates. As one interviewee in case C asserted,

> *'Do the same way many times in order for it to become affordable'.*

Nevertheless, a degree of flexibility was maintained to accommodate user needs. As the interviewee further explained,

> *'So, it is really jumping from we do everything very differently to let's do it in a very standard way with simple deviations … because growing organic Kiwi is not the same as growing organic banana'.*

Standardisation also enabled a more efficient life cycle management and circularity of components by facilitating their repair and future reuse or recycling. For example, the modular carpet tiles in case A reduced installation waste and permitted localised repair without having to replace the entire area. Similarly, the offsite manufacturing of wall and roof panels in cases C and D allowed for their assembly/disassembly for remanufacturing, reuse or recycling by creating *'a simple system to plug and unplug'*. Standardised administration processes also provided a transparent framework for collaboration and circularity through a code of conduct adopted by all stakeholders. Thereby, the PSS

requires standardisation of components and processes to enable cost and time efficiencies and facilitate CE implementation.

#### 4.2.3. Take advantage of digital technologies

The cases were found to rely on various digital technologies to manage the life cycle and circularity of components. The first common trend observed in most cases was the use of sensors and intelligent software that monitored various components and usage variables in real time. For example, case B used real-time monitoring to track factors such as usage, condition, noise and comfort levels. The employees were thought to apply this data to improve the timing and nature of their maintenance activities, thereby minimising downtime while improving the cost-efficiency, use-efficiency and lifespan of components. As described by an interviewee in case B,

> *'In the past, we had a certain kind of document and some lines that we had to take care of … now we have implemented more intelligence that tells us what to do and when … we have implemented this in not only central technology but also ICT environment to enable it in a very deep way in our organisation and behaviour of the maintenance people'.*

The data on the condition of components were also expected to facilitate their reuse based on their technical lifespans. Similarly, case D employed real-time monitoring to provide insight into the operation of the home and a logbook for preventive maintenance. The interviewee compared it to *'the dashboard of a car'* that provides all the information required for optimum and durable functioning. The ability to visualize the information on components and users was also seen as essential for raising awareness and acceptance, as well as benchmarking and future projection. Case E was also exploring a range of digital technologies for real-time monitoring to influence user behaviour. As an interviewee in case E explained,

> *'What we try to offer is to monitor the equipment and then give some tips on how they can save energy by, for example, using lower temperatures'.*

Secondly, digital datasets were used for tracking purposes. For example, case A used a digital data set for reclaimed carpets that tracked their movement within reverse logistics processes and provided feedback. Similarly, case B created material passports to facilitate the reuse of elevators at the end of the contract.

Thirdly, 3D laser scanning was employed in case C to create a detailed outer skin image model of the house. This model was then used to design and prefabricate wall and roof panels that are snapped to the exterior of the house to improve its thermal efficiency. This along with offsite manufacturing technologies helped to reduce the retrofit cost and time to less than 10 days. Lastly, BIM was employed in both cases C and D for communication and coordination of the design process. The PSS thus necessitates digital transformation for efficient life cycle management and circularity of components.

#### 4.2.4. Develop internal and access network competency

The cases highlighted the necessity of diverse competencies for operationalising PSS, covering such areas as digital technologies, as well as financial, relational and legal aspects. Several activities were undertaken to address the competence need. Firstly, the cases developed internal competency by forming multidisciplinary teams and establishing processes such as training and innovative workshops. Secondly, the cases extended their value network to access complementary competencies, given the complexity and cost of internally acquiring all necessary competencies. As an interviewee in case A reflected,

> *'It is very difficult to justify developing a model for one business alone. What we are probably looking at, at the end of the day, is collaborations'.*

The cases extended their networks both vertically, with stakeholders covering different stages of components' life cycle, and horizontally, with other trades/disciplines. For example, case A collaborated with local retailers to resell carpets and sought partnerships with other fit-out suppliers for a more comprehensive offering. Case B worked with waste collection and recycling providers to structure reverse logistics and partnered with digital technology providers to optimise the design and reuse of their elevators. Case E collaborated with local installers and sought partnerships with digital technology providers to optimise the use of their energy systems. Cases C and D took a step further and formed a network of competencies contributing to the PSS. As an interviewee in case C explained,

> *'It is really about working with the pioneers of every profession, architects, engineers, builders and energy providers to find the right mix'.*

Therefore, diverse competencies are essential for PSS implementation, and cultivating internal competency and establishing collaborative value networks for accessing complementary competencies are key principles.

#### 4.2.5. Align interests towards shared goals

With the participation of a wider range of stakeholders in the value system, the cases underscored the importance of aligning interests towards shared goals. This was particularly exemplified in case D, where a coalition of suppliers was formed to establish (de)centralised management based on suppliers' core competencies. However, conflicts largely arose from misalignment between individual interests. This may have been in part because of a lack of shared goals. As an interviewee in case D explained,

> *'What I see with the coalitions is that it is possible if you have the same focus, the same goals and the same interests'.*

Defining shared goals and aligning interests towards those goals is therefore vital. Navigating the new roles and responsibilities that forming such a coalition brought may have added to the complexities experienced, especially with established stakeholders. So, partners need to be clear about their roles and responsibilities in relation to shared goals to avoid misplaced expectations. As the interviewee further reflected,

> *'When working together, especially with large manufacturers, they should be aware that they are part of the solution, not the solution'.*

This realisation led case D to assume the role of an intermediary that governs PSS activities. Similarly, case C, assumed an intermediary role, but from the outset, which enabled them to define shared goals and govern stakeholders' involvement towards those goals. As the interviewee in case C described,

> *'The idea is to let liberty to solution provider's guide, be smart to play in it and find the best strategy and the best mix of solutions to fit'.*

Hence, the PSS necessitates the alignment of stakeholders' interests toward shared goals. In this regard, a gradual reorganisation of roles, with an intermediary governing stakeholders' involvement in pursuit of those goals, may prove more practical.

#### 4.2.6. Experiment and advocate for change

The cases described the implementation process of the PSS as akin to a *'journey'* marked by continuous improvements. As one interviewee in case D described it metaphorically,

> *'I don't speak about revolution, but evolution … revolution is quick … but this is a long way with small steps'.*

This could be attributed, in part, to the nature of gaining proficiency in adapting to new roles, which unfolds gradually rather than in a sudden event. As reflected by another interviewee in case B,

> *'You cannot take care of everything when you start this journey … [When] we started in 2017, we had some issues and we had improvements to make. So, every day we are learning, every day, we are improving'.*

Additionally, as the PSS often challenged established legal and financial systems, such as property law or financial risk models, its implementation required a corresponding adaptation of those systems. Thereby, the cases' efforts extended beyond their immediate operations and sought to modify regulatory landscapes and industry practices, which proved to be time intensive. As one interviewee stated,

*'It may take sometimes between five to seven years to change a [financial] risk model'.*

Hence, the PSS is not yet the core focus of the cases; this is so that they can survive commercially, while also experimenting with the PSS and driving change in established systems for its widespread adoption. Thus, the PSS demands a gradual implementation process that allows for experimentation and adaptation to new roles while concurrently fostering change in established ways of working.

### 4.3. Value capture

#### 4.3.1. Innovate revenue mechanisms

The cases developed innovative revenue mechanisms that improved accessibility for clients while addressing environmental concerns. In cases A and E, availability-based fixed periodic fees were used, though case E also used usage-based fees for clients in apartments. In cases B and C, availability-based fixed periodic fees were used with the key difference of connecting those fees with variable charges/compensations for over usage (of vertical transport in case B, and hot water and electricity in case C) or unmet KPIs. In case D, as a counterexample, revenue was through sales, yet net zero is guaranteed. The periodic fees linked to availability, usage level or performance of components removed the burden of initial investment and drove cost-efficiency through resource efficiency and longevity, aligning economic and environmental considerations. As highlighted by an interviewee in case B,

*'We can enlarge our margin by improving the quality and extending the lifespan of components'.*

Therefore, PSS requires innovativeness in the revenue mechanisms that align economic and environmental considerations.

#### 4.3.2. Tap into residual/soft values

The shift towards long-term revenue mechanisms presented an opportunity to tap into the residual value of components, though it was not yet fully realised in most cases. As an interviewee in case B explained,

*'We are not there yet, but we are studying how to improve the residual value, how to bring these components back and enlarge the value on them'.*

Nevertheless, the length of contracts that spanned from 10 years in case A to 30 years in case C hold promise. As an interview in case E stated,

*'We don't know, yet, but we have 10 years to figure that out'.*

Further, this shift in revenue mechanism generated other benefits. Notably, it changed the client relationship from a mere transactional one to a more long-term and dynamic one, thus serving as a competitive advantage.

#### 4.3.3. Balance lock-in and flexibility

The locking-in effect of such long-term contracts resulted in stability and predictability in cash flow. As described by an interviewee in case B,

*'Although the margin is slightly less than before, we no longer have after-sales difficulties. We have the benefit of knowing for sure that this cash flow will follow us for the upcoming years'.*

But to avoid mistrust, the contracts catered to clients' flexibility requirements. One common feature was the provision for terminating or extending the contract as per the client's requirements. Another feature was performance guarantees. Lastly, there was tailoring the fees to client needs, such as variable initial fees in case B and different fee structures for individual dwellings and apartments in case E.

#### 4.3.4. Find suitable financing mechanisms

As components are not generally sold, the negative cash flow at the outset created a new financing need. Access to finance therefore became a key factor. The cases referred to financing stakeholders that offered alternative ways of securing finance for closing the negative gap, predominantly banks or investment funds. Several interviewees, however, reported that many financing stakeholders were either unfamiliar with the PSS or considered it too risky under their current risk models. This hesitance was rooted in several factors, including the long payback period of building components, the low solvency ratio of extended balance sheets, the immovability, un-traceability or low residual value of components and the nature of clients. As one interviewee reflected,

*'It is hard to fit it into the system because the system is linear'.*

Despite these challenges, sustainability-oriented institutions showed a growing interest in investing in the PSS for its CE potential. However, the lack of historical data and regulatory context made the change a time-intensive process. As one interviewee explained,

*'It is not that we are not working on that, but it takes a lot of time to work the linear model and with the regulator'.*

The prospect of government subsidies also provided an avenue to secure funding, as seen in case C. Several other interviewees emphasised the role of government in bridging the funding gap.

## 5. Discussion

This study took a business viewpoint to explore the implementation of the PSS for creating a circular housing economy. By conducting a multiple-case study of five frontrunners, this study contributed empirical evidence from those real-life practices to identify guiding principles that inform actionable knowledge for deploying the PSS towards a CE in housing. Fig. 3 synthesises these principles within the three components of the business model concept, namely, value proposition, value creation and delivery, and value capture, and highlights its link to the value network.

The findings from the cases suggest that in deploying the PSS the value proposition should evolve from mere physical aspects. It should rethink the purpose of housing and its components, aligning them to the core functionality that fulfils actual user needs, thereby improving overall living quality. This insight lends support to earlier conceptual research suggesting that the PSS promotes a more systematic view of value, which includes other forms of value usually overlooked in transactional relationships of conventional housing models (Ghafoor et al., 2023). However, it was found that this value proposition is more likely to be achieved through use/performance-oriented models that integrate multiple complementary components and their associated life cycle activities in a system, emphasising convenience, technical quality and guaranteed instead of estimated performance. Yet, the viability of such a value proposition hinges on its accessibility, which can be realised through innovative revenue mechanisms that reduce or eliminate the burden of initial investment for clients. This finding once more underscores the undeniable role of financial justification as a prerequisite to adopting circularity-related innovations, similar to findings by Chileshe et al. (2018). Such innovations should however drive cost efficiency through resource efficiency and longevity, aligning economic and environmental concerns. Additionally, a CE objective should be formalised that considers life cycle (pre-use, use and post-use) environmental implications to narrow, slow, close and regenerate material and energy flows effectively. In accordance with the suggestion of Adrodegari et al. (2017) for segmenting customers, the distinct opportunities, challenges and needs of users within different housing types and tenures

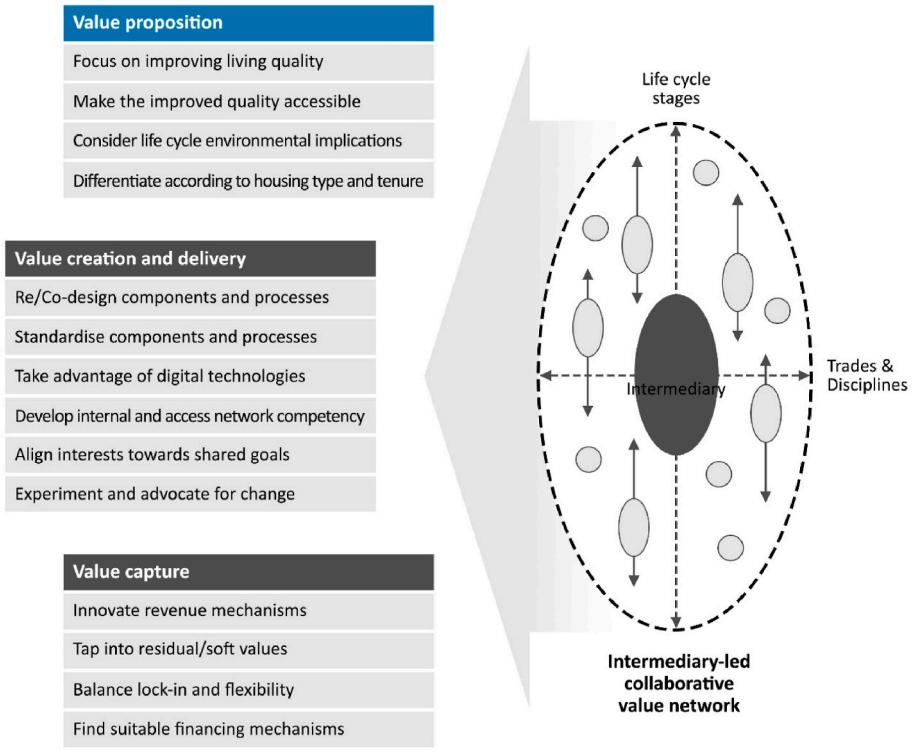


**Fig. 3.** A guiding framework for deploying the PSS for a CE in housing. Source: authors.

require prioritisation and differentiation. Nevertheless, build-to-rent and new-build apartments show prominence due to their centralised management and scalability, while government-supported social housing apartments also hold significant potential for market entry.

The value creation and delivery require a focus on integral re/co-design of components and processes in line with CE principles. Standardisation on those fronts can cut costs, shorten timelines and facilitate repair and future reuse or recycling. As with the extant literature (Ardolino et al., 2018) and recent work by Azcarate-Aguerre et al. (2022), the findings from the cases highlight the imperative role of digital technologies and the necessity of digital transformation for efficient life cycle management and circularity of components. Moreover, diverse competencies are required for PSS implementation. These competencies can be developed internally and accessed via establishing collaborative value networks, both vertically, with stakeholders covering different stages of components' life cycles, and horizontally, with other trades/disciplines. These findings resonate with assertions from previous studies, highlighting the critical role of seamless information flow and enhanced collaboration among stakeholders in construction supply chains as facilitators for CE business models (Mhatre et al., 2021). With the participation of a wider range of stakeholders in the value system, interests and roles should be aligned towards shared goals. The formation of an intermediary that governs stakeholders' involvement in the pursuit of those goals may help to form and sustain the network, reinforcing the suggestion of Galle et al. (2021) and Lazarevic et al. (2019). Lastly, the value creation and delivery should follow a gradual process that allows for experimentation and adaptation to new roles, while concurrently advocating for changing established systems.

As noted earlier, the findings from the cases suggest that the value capture demands innovativeness to align economic and environmental concerns. This is more likely to be achieved through recurrent revenue streams tied to availability, usage level or performance of components, as this link drives cost-efficiency through resource efficiency and longevity. Furthermore, the locking-in effect of the periodic revenue provides stability and predictability in cash flow while reinforcing ongoing innovation in maintaining the value proposition. Yet, to avoid mistrust, long-term contracts should cater to clients' flexibility requirements. Additionally, the initial negative cash flow creates a financing need (Barquet et al., 2013). Financial institutions with a commitment to sustainability and government subsidies can provide avenues to secure funding. The PSS should also consider the residual value of components as a potential revenue stream and as a means of future resource security. Beyond these, other aspects such as reputation and dynamic client relationships could provide a competitive advantage and hence require attention (Adrodegari et al., 2017).

### 5.1. Theoretical contributions

This study contributes to the emerging research field at the intersection of the PSS, a CE and housing in two ways. First, this study developed a guiding framework of actionable knowledge for deploying the PSS for a CE in housing. While recent studies (such as the work by Azcarate Aguerre et al. (2023) and Galle et al. (2021)) acknowledge the major changes required in the business practices of the industry for the integration of the PSS, actionable knowledge for navigating these changes, particularly for a CE, remains limited. This novel framework that is grounded in empirical evidence provides 14 principles within three components of the business model concept (i.e., value proposition, value creation and delivery, and value capture) for navigating these changes. This is achieved through the extension of existing theories pertaining to the PSS and the business model concept into the domain of housing while subjecting these theories to empirical scrutiny. In this process, the study not only forges new theories but also adapts them based on empirical data derived from the housing context. Such an endeavour notably bolsters the transferability and applicability of established theories from disparate disciplines to the specific housing setting, thereby underscoring the originality of this work. Furthermore, the act of extending and subsequently modifying existing theories, originally derived from diverse disciplines, in response to empirical findings, represents a pioneering effort in the realm of knowledge

creation (Handfield and Melnyk, 1998).

Second, this study identified intermediary-led collaborative value networks as the catalyst of PSS and CE implementation in housing. While collaboration is frequently underscored as the cornerstone of progressing a CE (Leising et al., 2018), its implementation has proven to be challenging, particularly in the construction industry where fragmentation has increased competition and mistrust (Hart et al., 2019). The study's findings highlight the necessity of deliberate efforts to overcome the collaboration challenges prevalent in the industry. Particularly, it identifies the need to establish intermediary roles to navigate fragmentations across horizontal (trades/disciplines) and vertical (different stages of the life cycle) dimensions.

### 5.2. Implication for practice

This study provides practical insights for practitioners seeking to explore and capture the potential of the PSS for a CE in housing. Central to the PSS is the conceptualisation of value into the core functionalities that fulfil actual user needs, are accessible and embed a CE in the life cycle. However, practitioners should be mindful of the opportunities and challenges of different housing types and tenures. Delivering this value requires re/co-design and standardisation of components and processes, incorporation of digital technologies, developing competency and advocating change in established legal and financing systems. However, these activities cannot be done by an actor alone. Collaborative value networks need to be formed in order to deliver this value. Diverse revenue streams can be captured that are linked to efficiency, longevity and residual value of components. Yet practitioners should be mindful of the financing needs at the outset. Practitioners planning to leverage the PSS for a CE in housing must thereby recognise that it is an iterative process that cannot be done instantly or alone.

## 6. Conclusion

CE efforts in housing have been slow to unfold because of a lack of business perspective. PSS-informed business model innovations are increasingly brought to the fore for their CE potential. Actionable knowledge, however, on how to deploy the PSS for a CE in housing has so far been lacking. This study conducted a qualitative multiple-case study of five frontrunners actively employing a CE-related PSS to contribute empirical evidence from those real-life practices. Through interviews and document analysis, this study synthesised guiding principles within the business model components of value proposition, value creation and delivery, and value capture. Additionally, collaborative value networks governed by intermediaries are identified as catalysts of PSS implementation in housing.

This study thereby contributes to the emerging research field at the intersection of the PSS, a CE and housing in two ways: (1) by identifying guiding principles for implementing CE-related PSS in housing; and (2) by highlighting the role of intermediary-led collaborative value networks as the catalyst of PSS and CE implementation in housing. In addition to its theoretical contributions, this study offers a valuable guide for practitioners interested in implementing the PSS in the housing sector, with the dual objectives of achieving profitability and advancing towards a CE.

This study is subject to some limitations that suggest avenues for future research. Firstly, while the theoretical sampling based on diversity aimed to increase external validity, reliance on purposefully selected cases may limit its generalisability. Moreover, although data triangulation through primary and secondary sources ensured internal validity, the qualitative nature of the study remains susceptible to researcher bias. Quantitative research is therefore suggested to further validate and refine the findings of this study in various contexts and settings to enhance its generalisability. Additionally, as the focus was primarily on the housing industry practices, future research should incorporate user perspectives. Lastly, it is imperative to emphasise the significance of empirical research in identifying barriers to implementation and providing insights that possess the potential for broader application in shaping policy implications for the housing industry and refinement of strategic planning processes.

## CRediT authorship contribution statement

**Soheila Ghafoor:** Writing – original draft, Visualization, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Tuba Kocaturk:** Writing – review & editing, Validation, Supervision, Methodology, Conceptualization. **M. Reza Hosseini:** Writing – review & editing, Validation, Supervision, Methodology, Conceptualization. **Matthias Weiss:** Writing – review & editing, Supervision. **Matthew Barnett:** Writing – review & editing, Supervision.

## Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

## Data availability

Data will be made available on request.

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## Appendix A

**Table 4**
Interview protocol

| Category | Guiding questions |
|---|---|
| **General** | Could you please introduce yourself? What does your organisation do? What is your role in the organisation? |
| **Business model** | Could you please describe the PSS offering of your organisation? How does it differ from business as usual? |
| Value proposition | What value is delivered through the PSS and to whom? Which housing segment is the PSS primarily targeting? |
| Value creation and delivery | How is value created and delivered through the PSS? What are the key processes and activities involved? What resources are required? Are there any collaborations or partnerships? How well do these collaborations work? What have you learned from them? |
| Value capture | What are the revenues and costs associated with the PSS? How is the PSS financed? |
| **CE vision, motivation and challenges** | How does your organisation define CE? How is CE incorporated into the PSS offering? What motivated your organisation to adopt the PSS? What challenges or trade-offs have been faced? |

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