Initiating and designing an emerging multi-platform ecosystem for the circular economy in the built environment: An empirical case study

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Abstract
Platform ecosystems have proliferated, being useful mediums that connect and enable seemingly geographically dispersed and diverse businesses to exchange products and services. However, initiating and designing a new platform ecosystem for the circular economy in the built environment is challenging. Our case study explores the challenges of initiating and designing an emerging platform ecosystem to recirculate the construction waste materials and industrial production side streams across the built environment. Our study offers insights into how several platform owners initiate and design multi-platform ecosystems by combining their capabilities and resources into one efficient network to support the circular economy growth in the built environment. A specific challenge identified is designing the multi-platform ecosystem, a business model, for equal value creation and capture by the platform owners. This study provides recommendations for the policymakers while contributing to the literature on the platformisation for the circular economy in the built environment.

Keywords: Multi-platform ecosystem, circular economy, circulation of waste materials, built environment

1 Introduction
In recent years, platform ecosystems have gained importance in various markets. Amazon, Google, Facebook, Netflix, and Alibaba are well-known examples of platform ecosystems. These ecosystems enable growth and value creation by the interdependent, complementary actors around technological platform via open-source technologies or shared technical standards to attract customers (Gawer, 2014; Jacobides et al., 2018). The ecosystems include actors from various industries (Moore, 1993) and provide non-generic modular complementarities (Jacobides et al., 2018). Since platform ecosystems gained momentum, the platforms proliferated across many sectors, such as energy (Kiesling, 2016), transportation (Svahn et al., 2017), and banking (De Reuver et al., 2015).

The platform ecosystems for the circular economy in the built environment have also gained importance (European Commission, 2015; Berg and Wilts, 2019; Benachio et al., 2020; Chidepatil et al., 2020; Mosca et al., 2020). The circular economy is an emerging economic system based on business models that support the recycling and recovery of materials in production and consumption processes (Korhonen et al., 2018; Ghaffar et al., 2020). It is based on the three principles: design out waste and pollution, keep products and materials in use and regenerate natural systems (EMF - Ellen MacArthur Foundation, 2020). Circular economy and recycling models have been studied for several decades, but the number of publications is still growing

(Ginga et al., 2020). Construction and demolition waste is the largest waste worldwide, e.g., 36% in the European Union in 2016, and the percentage is growing each year (Ginga et al., 2020). For example, the value of recycling brick and concrete waste was estimated to add 44.7 million USD to the Bangladesh economy (Islam et al., 2019). Industrial side streams, which come as a side product from the production process, can also be considered waste that can be reused. For example, fibre sludge is one side stream of the pulp and paper industry to be recycled (Leppänen et al., 2020). As the circular economy is cross-disciplinary and cross-industry in nature, a platform can be a useful medium to connect and enable seemingly geographically dispersed and diverse businesses into circular and cyclical business models (Lacy et al., 2020). The leading firms that unlocked new value creation models with platforms for the circular economy are Siemens, IKEA, Share Now, Banyan Nation, Adidas and Ecovative (Lacy et al., 2020). The platform ecosystems provide promising means to support the circular economy for the recirculation of the construction waste materials and industrial production side streams across the built environment (Berg and Wilts, 2019).

Initiating and designing a digital platform for the circular economy is, however, not an easy task. For instance, in the early stages of platform ecosystem initiation, the platform leaders are challenged to generate the network effects (Katz and Shapiro, 1994), design and govern ecosystems around platforms (Shapiro and Varian, 1998) and balance the pricing dynamics. They also need to compete for dominance (Eisenmann et al., 2006) and resolve the tensions that manifest in various forms on multiple levels (De Reuver et al., 2017). Overall, the early developmental stages of a platform and the key decisions made during the platform's emergence and evolution are crucial for the platform's survival (Tian et al., 2021).

Studies focused on the early development phases of platform ecosystems exist (e.g., Tiwana et al., 2010; Tian et al., 2021). However, insights on the early development phases of a platform ecosystem for the circular economy where several platform owners initiate and design platform ecosystems are scarce. Indeed, the platform ecosystem literature has emphasised singular firms' role in leading the platform ecosystem, e.g., 'keystone' or a 'hub firm' (Iansiti and Levien, 2004). This study addresses this research gap by empirically exploring how several platform owners from distinct industries combine their capabilities and resources into one efficient network to enable circular economy growth in the built environment. Thus, the study poses the following research questions: *How do several platform owners from distinct industries initiate and design an emerging platform ecosystem for the circular economy in the built environment? What are the challenges that they experience?*

We contribute to the literature on the initiation and design of the circular economy's emerging platform ecosystems in the built environment (e.g., Tiwana et al., 2010; Tian et al., 2021). Specifically, we explore the roles of a consultancy firm and three platform owners that aimed to merge their complementary platforms to combine the capabilities and resources needed for the circular economy in the built environment (Iansiti and Levien, 2004). While illuminating its emergence processes, we also highlight the challenges and opportunities that the platform owners experienced when they attempted to co-configure their businesses into one efficient network to support the circular economy growth in the built environment. Thus, we offer novel insights into the design of a multi-platform ecosystem for the recirculation of waste and materials.

2 Existing theories & previous work

In this section, we present earlier research on platform ecosystems.

2.1 Platform ecosystems

With the rise of the digital economy, platforms have gained an important role in enabling value creation and capture in information-intensive industries (Cusumano and Gawer, 2002; Iansiti and Levien, 2004). The platforms are also gaining a vital agenda in the circular economy (c.f., Berg and Wilts, 2019; Chidepatil et al., 2020; Ghaffar et al., 2020). Indeed, platforms are viewed as important mediums that facilitate and coordinate value-adding activities by the users and complementors (Nambisan and Sawhney, 2011) and drive industry diversity. With diversity, platforms can enable ecosystem growth depending on the platform's threats, rules, and

governance mechanisms (Autio et al., 2018; Jacobides et al., 2018). Often, the platforms generate value by reducing transaction costs (Gawer, 2021).

Despite that the theory of platform ecosystems is still evolving (Jacobides et al., 2018), there is an emerging understanding that platforms exist in various types. For example, Cusumano et al. (2019) and Gawer (2021) list three platform types based on their purpose: transaction platforms, innovation platforms and hybrid platforms. Transaction platforms are multi-sided markets that facilitate exchanges and transactions across both sides, the demand and supply (McIntyre and Srinivasan, 2017). Uber, Airbnb and Google Play provide examples of transaction platforms. On the other hand, innovation platforms are technological architectures that enable creation and innovation in complementary products and services by the users and complementors. Examples of innovation platforms are Nintendo, WeChat and Google Android. Finally, the hybrid platforms combine features from the transactions and innovation platforms (Gawer, 2021). Typically, successful platforms evolve into hybrid platforms over time (Gawer, 2021). Examples of these are Amazon, Facebook and Alphabet Google.

We adopt a unified definition of digital platform ecosystems provided by Gawer (2014). She states that platform ecosystems are evolving organisations that coordinate actors that can both innovate and compete; they create value by developing economies of scope in supply and/or in demand; and they build on a technological architecture, which is modular and includes a core and a periphery (Gawer, 2014).

2.2 Design of platform ecosystems

The distinctions between platform types are directly related to the design and governance mechanisms that platform owners take (Gawer, 2014; Jacobides et al., 2018). The role of the platform owners has been documented critical to the success of platform businesses (Iansiti and Levien, 2004) as they are responsible for the functioning of their platforms, imposing and coordinating the rules, constraints, and shaping behaviours in their ecosystems (Boudreau and Hagiu, 2009; Tiwana et al., 2010). They also design appropriate incentive structures, control mechanisms and regulations to enable the growth and prosperity of its complementors and users (Tiwana, 2013). In sum, platform leaders' role is to design, coordinate and establish mechanisms for value creation and capture by the ecosystem participants. The platforms act as regulators to ensure the actors' participation by setting control and incentive mechanisms, such as algorithms with recommendations, regulation of free riding or sustaining the balance between demand and supply (Evans et al., 2006).

One of the challenging tasks for platform leaders is designing the incentive structures for the network effects (Cennamo and Santalo, 2013). The platform's value is contingent on the direct and indirect network effects. The direct network effects are created when the users value a platform with a larger number of other users (Eisenmann et al., 2011), and indirect network effects are generated via the availability of the complementors that provide value to the users. The network effects are considered critical aspects of emerging platform design responsible for the platform dominance (McIntyre and Srinivasan, 2017) and are subject to positive feedback loops (Katz and Shapiro, 1985). The greater the number of users, the greater the incentives for the complementors to offer complementary products and services and vice versa (Cusumano and Gawer, 2002). Thus, the platform leaders must attract both sides of the platform, the complementors and the users, to generate the network effects and facilitate transactions between them (Eisenmann et al., 2006).

While most of the research has taken the leading firms' perspective, some research has documented several platform owners initiate new platform ecosystems by combining their capabilities and resources necessary for the new value creation models to function (Ianisiti, 2004; Müller-Seitz, 2012). Studies often focus on singular firms and their roles implicating the ecosystem dynamics. Nevertheless, the strategic shaping of the emerging platform ecosystems when several platform owners are involved in the decision-making processes is underexplored. This study's empirical part explores how several platform owners design and initiate a multi-platform ecosystem to enable value creation and capture by its supply and demand.

3 Methods

We adopt an inductive qualitative case study research (Yin, 2009) to articulate and analyse the challenges of the early developmental stages and models of value creation and capture in a multi-platform ecosystem. A case study is proper when the research phenomenon is not very well explored and requires a qualitative investigation of the observed phenomenon (Langley and Abdallah, 2011).

3.1 Case study

Our case study is an emerging circular economy multi-platform ecosystem that is based on three digital platforms operating in the built environment. The ecosystem actors are secondary raw material suppliers (secondary material producers, building and infrastructure owners) and secondary material customers (such as construction companies, process industry and small companies). The platform owners aim to enable business model innovation by the users and complementors and provide the circular economy marketplaces, both for reusing and recycling construction waste materials and industrial production side streams. This is an appropriate research setting for several reasons. It is an emerging platform ecosystem with distinct components: (a) It seeks to enable new value creation models for the circular economy in the built environment; (b) three platform owners lead the initiative, which is a unique setting to study platform design; (c) the emerging platform illuminates challenges related to a circular economy that implicate policymaking.

3.2 Interview data and analysis method

The interview data comprises of ten in-depth interviews conducted with key actors involved in developing the multi-platform ecosystem. We used qualitative procedures based on the semi-structured interview analysis. The following topics and questions were explored:

(a) *Platform ecosystem initiation*: How was the multi-platform ecosystem initiated?

(b) *Platform ecosystem design:* How was the multi-platform ecosystem designed?

(c) *Platform ecosystem for the circular economy challenges and opportunities:* What are the challenges of designing a multi-platform ecosystem for the circular economy, and how to overcome those challenges?

Interview transcripts were used as primary data, while archival sources were used to refine our interpretations of the phenomenon, thereby guiding the results' integration. We began our analysis by synthesising data into an overview of the multi-platform evolution. The focus was on the challenges and opportunities the informants experienced while initiating and designing the ecosystem.

One author collected and analysed data while the other authors read through data analysis and encouraged further data collection when needed. Through continuous discussions, the authors were able to revisit data and synthesise the findings into emergent patterns surrounding the initiatives by the platform owners. This iterative data analysis process allowed the authors to create a common understanding of the findings eventually. While analysing the data, the authors identified the linkages between different challenges and opportunities and induced categories, forming a storyline. Though it sounds streamlined, the authors had to cycle between the literature and data for several rounds to reach an understanding of the platform design process and its associated challenges (Jick Todd D., 1979). The findings are next described under three themes, following the research questions.

4 Findings and discussion

The findings illuminate three essential themes of our study: (1) initiating an emerging platform; (2) designing the emerging multi-platform ecosystem; and (3) overcoming challenges in designing a platform ecosystem for the circular economy in the built environment.

4.1 Initiating multi-platform ecosystem for the circular economy

The multi-platform ecosystem development started in early 2020 when a management consultancy firm initiated a meeting with three platform owners interested in developing a data-

driven approach for the circular economy. They are **SideStream, Waste** and **DataIntegration**. Their names are acronyms. **SideStream** is developing a digital platform for reusing industrial side streams with the funding provided by several large firms in the manufacturing industry. **Waste** is developing a transaction platform with several other construction industry firms to recirculate construction waste materials. **DataIntegration** owns a platform and provides data integration services for Business-to-Business (B2B) customers. Each platform owner had already an emerging platform in their respective industries. The consultancy firm and some R&D partners had identified an opportunity to combine these platforms and leverage existing networks for new business models to recirculate construction waste materials and industrial side streams. In autumn 2020, the platform owners got funding from a public innovation organisation to support their joint initiative.

Each company had their already existing businesses in their industries. Each of them had specific challenges that they identified and could be resolved by combining their platform capabilities and resources. The platforms were not yet financially viable because each respective industry's reuse and recycling practices were not yet enough developed, although some practices were already operative. Each platform owner's critical challenge was a mismatch between the supply and demand necessary for the circular economy. **SideStream** had already identified several industrial side streams that were not efficiently reused because the potential buyers did not know the availability of side streams, their location and reuse potential. Those customers who identified the potential were concerned about the fluctuating availability and inconsistent quality of side streams. **Waste** identified that construction waste materials were not efficiently reused. Currently, waste material is mainly incinerated for energy use or landfilled. For example, some materials, e.g., uncontaminated soil, blast stone and concrete, were only partially recycled as potential customers did not know their existence, location, application potential or price. By combining the capabilities and existing networks, the platform owners envisioned matching the potential suppliers with buyers to enable growth as a starting point. To connect the potential suppliers with buyers, they proposed that data-driven matchmaking could solve this mismatch. Potentially, data could offer visibility to the existing supply of materials and demand for those materials and connect demand to supply. As a result of a joint effort in articulating the value proposition for an emerging multi-platform ecosystem, the platform owners envisioned that a new platform ecosystem would matchmake the supply with demand across industries. This potential of the platform could be expanded into an innovation platform ecosystem in the future. So, the potential complementors, the designers, consultants and logistics firms, could create platform-dependent service applications and data-driven business models with service-oriented logic.

As a result of a joint effort in articulating the value proposition for an emerging multi-platform ecosystem, the platform owners envisioned that a new platform ecosystem would connect supply with demand across industries. Finally, it can offer integrated solutions for the circular economy in the built environment. Figure 1 illustrates the business processes included in the circular economy.

4.2 Designing a multi-platform ecosystem for the circular economy

To realise the data-driven matchmaking vision, the platform owners had to decide on the design of the new multi-platform ecosystem. However, designing a business model when three platform owners are involved was not without its challenges. At first, SideStream and Waste considered integrating their platforms. However, the integration process turned out to be a complex issue,

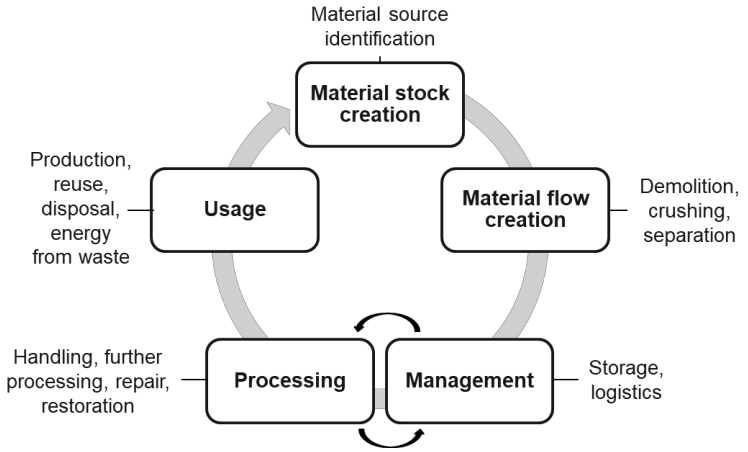

Figure 1. The multi-platform ecosystem supports the business processes of the circular economy

both financially and technically. The platform owners recognised that the integration would require a multidisciplinary approach and expertise from several domains. *Financially,* the new platform required considerable investment and development as well as maintenance. Financial experts are needed to advise on the monetisation models for creating and capturing value from the transactions. Platforms often require long-term investments before they become profitable. The efforts to match the demand with supply can take years. *Legal experts* are also required to negotiate intellectual property rights (IPR) between the platform owners and the participating actors. *Technically,* Waste's platform for material recycling currently relies on the manual input of data into the platform. *Technical experts* are needed to develop processes for automation. Data from several existing systems, e.g., Enterprise Resource Planning (EPR) systems, needed to be integrated. *Circular economy content experts* are needed to specify what data should be shared and with whom through the platform to enable reuse and recycling practices.

While the firms expressed interests in data-driven matchmaking by integrating the platforms, a firm's investment in the development was not entirely feasible. After considering the challenges related to the design, the platform owners decided first to develop their platforms separately and later on to use DataIntegration platform to integrate data from Waste and SideStream platforms and, thus, connect existing supply and demand actors from both platforms to each other. The data-driven end result would offer a marketplace where suppliers and buyers could transact. The transaction requires efficient data integration systems that were not in place in any of the platforms they owned, nor data was standardised across B2B customers and suppliers. DataIntegration would offer integration by enabling data standardisation and transactions between the existing supply and demand from Waste and SideStream.

Interestingly, the boundaries between the supply and demand in our case are blurred as supply and demand, the B2B customers and suppliers, can act on both sides of the platform. Figure 2 illustrates the overall design of the multi-platform ecosystem, the circular economy marketplace in the built environment. An important assumption of platform design is that platform owners increase their platforms' value with the network effects (McIntyre and Srinivasan, 2017). The platform's value is contingent on the number of active customers and suppliers on both sides of the platform (Cennamo and Santalo, 2013). Thus, the platform owners' important role is to create an incentive structure to build an ecosystem around their platforms. The case study's platform owners were challenged because several platform owners are involved and have access to data. Transparency of the processes was a key issue in trust-building. Some potential ecosystem actors were reluctant to share data because they were unsure how value is created and captured. A lesson learnt was that an emerging platform ecosystem necessitates a neutral platform leader, possibly a company that can organise the platform's technical aspects and support the creation of data-based services, starting from viable use-case descriptions that lead to potential value-capturing opportunities for the ecosystem actors.

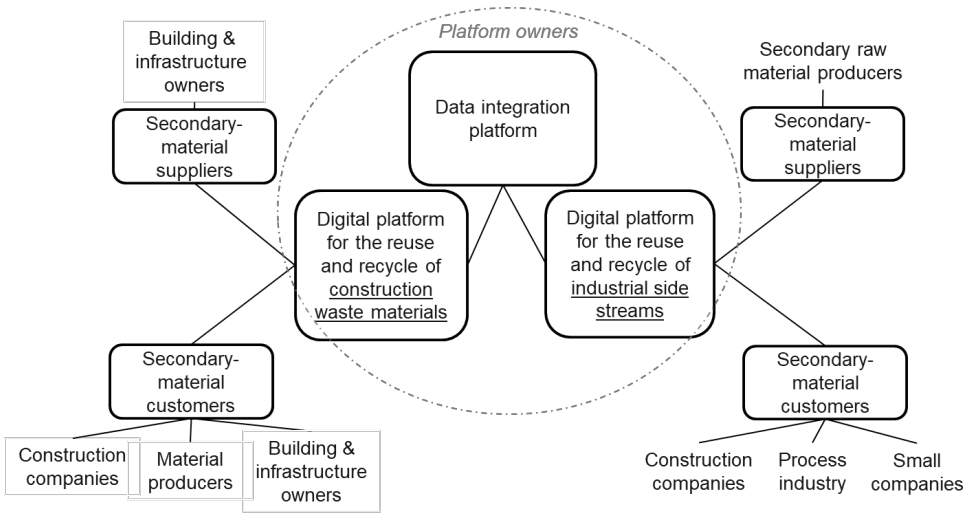

Figure 2. The three digital platforms forming a multi-platform ecosystem for the circular economy

For example, a secondary-material consumer may need to locate available industrial side streams for its production processes. In this case, the value-capture potential for the B2B customer is to have an overview of available secondary raw material. Table 1 presents the value creation and capture potential of the multi-platform ecosystem for the suppliers and customers. The ideas for value creation and capture potential are mainly provided by one interviewee who envisioned the further development of the ecosystem in spring 2021, as the idea for the multi-platform ecosystem had matured over time in their mind.

Table 1. The value creation and capture potential of the multi-platform ecosystem for the actors

Ecosystem actors	Value creation potential	Value capture potential
Suppliers: building and infrastructure owners, secondary raw material producers, logistics firms	Access to a larger database of potential customers, matchmaking for new recycling opportunities.	Increased revenues, reputation, the level of recycling, and visibility on the market, reduced waste, and attraction of new investors.
Customers: construction firms, material producers, building & infrastructure owners, manufacturing firms	Access to up-to-date data about available materials, secondary raw material and equipment, matchmaking for new recycling opportunities.	Cost reduction, improved efficiency, increased level of recycling, and waste reduction, reputation, and attraction of new investors.
Platform owners	Enablement of the circular economy across distinct industries, increased visibility to customers and their needs, matchmaking suppliers to customers.	Growth of individual market share, increased membership base.

Regarding the supply side, some companies were reluctant to share data related to the materials' pricing and quantity because this was their competitive advantage; revealing too much data could potentially damage their businesses. They also felt the platform's disruptive power to their businesses as, traditionally, they relied on long-term agreements with their customers. The platform owners realised that only specific information could be shared with the customers. This was necessary for trust-building with their customers and suppliers. The information that could be shared is the following: seller information, price, material quantities, materials' technical and quality information, and '*the material recipes*'. The material recipe would facilitate the reuse of materials and waste by informing the customers and suppliers about how the materials and waste can be recycled into raw materials or materials for specific uses. The platform owners have a

crucial role in coordinating the mechanisms for value creation and capture between their customers and suppliers by building trust between all parties.

4.3 Overcoming challenges in designing a multi-platform ecosystem for the circular economy in the built environment

While initiating and designing a multi-platform ecosystem for the circular economy in the built environment, the platform owners experienced three specific challenges to the context of implementation. The interviewees also provided solutions for resolving those challenges.

First, *lack of availability and access to reliable, structured and harmonised data* about building materials and industrial side streams has serious implications for connecting demand to supply and enabling new data-driven business models by the complementors. For example, an owner of a demolished building has limited data on the building materials. The government has already generated a pre-demolition audit guideline to address this issue: the materials must be reported in a formalised manner (Wahlström et al., 2019). However, the manual Excel-based reporting on the demolished materials is time-consuming and laborious. Thus, a forthcoming policy will require the builders to report a planned new property's assets in a digital, structured format before receiving the building permit. A digital as-built model will also need to include information about used materials to facilitate maintenance, renovation, and demolition of built assets to reuse materials to the maximum. This would necessitate creating a material passport that includes information about the used material in a standardised way. The passport aims to keep the material's value and identify what can be reused and recycled.

Second, *the lack of procedures for certifications and classification* of what is interpreted as a product and a waste implicates the liabilities of suppliers and demand. This disincentivises actors from reusing the materials. For example, an opened cement sack at a construction site cannot be used on another site since the cement manufacturers cannot guarantee an opened sack's quality. Another example is the reuse of concrete. Some concrete elements can be reused depending on the quality, whereas others have to be processed for recycling. Standardised procedures are needed to help decide, case by case, who is responsible for determining when waste is a material that can be recycled.

Third, *the fluctuating availability and inconsistent quality of material and side streams* complicate matching the supply with demand. This finding has been earlier reported also by Leppänen et al. (2020). Industrial-scale production requires uniform, pure and steady volumes of side streams as raw material. However, companies cannot rely on receiving side streams continuously, complicating investments into expensive industrial processing machinery. Also, the volume of recyclable waste materials varies and depends on the available demolished built assets. The future platform ecosystem should offer forecasts on the potential availability of waste materials and side streams.

These challenges require new policies to support emerging platform ecosystems for the circular economy in the built environment. One of the recent policies was launched by the European Commission (EC) that offered a new waste framework directive for managing and disposing waste (European Commisssion, 2018).

5 Conclusion

This study contributes to the literature on the initiation and design of emerging multi-platform ecosystems for the circular economy in the built environment (Tiwana et al., 2010). It offers insights into the specific challenges that the multi-platform ecosystems face when several platforms are combined for the reuse and recycle of construction waste materials and industrial production side streams to support the growth of the circular economy.

The study identified specific challenges. The challenges are availability and access to data, liability and procedures, manual reporting of information, and fluctuation of supply and demand. This study shows that several platform owners may combine their capabilities and resources in one efficient network. Still, they can also struggle to articulate new business models for equal value creation and capture and take investment risks. To overcome some of those challenges, policymakers are advised to demand harmonised procedures and processes in the businesses of

the platform's users. For example, construction waste material and industrial side stream data should be collected and stored in a digital, structured way to enable their usage to benefit the circular economy. The platform ecosystem actors can invest in developing capabilities to forecast material availability by utilizing machine learning algorithms with the platforms' data to enable service-dominant logic. Overall, this study presents the value creation and capture potential of the emerging multi-platform ecosystem for circular economy in the built environment. Our core contribution is an empirical exploration of the multi-platform ecosystem for circular economy growth in the built environment, as previous studies have emphasised single firms in leading their platform ecosystems, e.g., 'keystone' or a 'hub-firm' (c.f., Iansiti and Levien, 2004).

A limitation of our study is that the results are derived from a limited number of interviews. However, our ten deep-dive interviews with the platform owners have alleviated this limitation as the platform's initiation and design processes were discussed in-depth. Future research can follow the emergence processes of multi-platform ecosystems in other sectors and across several case studies to aid our findings and development of the circular economy and widen the research from platform owners' perspectives to external platform participants.

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