Elucidating Potential Contributions of Product-Service Systems towards Improving Built Environment Circularity Performance and Associated Barriers: A Scoping Review

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Abstract

Background:

The construction industry significantly influences economic growth but at the expense of the environment, marked by high resource extraction, energy consumption, waste generation, and greenhouse gas emissions. The prevailing linear economic model in construction which is “extraction, production, disposal” necessitates a shift towards more sustainable practices.

Purpose:

This study explores the potential contributions of Product-Service Systems (PSS) adoption in the built environment towards improving Circular Economy Performance (CEP) alongside probable obstacles to the adoption.

Research Design/Methodology:

Employing a scoping review research design, the study reviews a combination of academic and grey literature (n=25) extracted from key databases, Scopus and Web of Science. The selection criteria were stringent, focusing on quality and relevance of the documents to the nexus between PSS, CEP, and the Built Environment. The data was analyzed thematically relying on a set of pre-determined themes.

Findings:

The study’s findings reveal the significant impact that Product-Service Systems (PSS) can have on Circular Economy Performance (CEP) within the built environment. Moreover, the potential for PSS to improve the built environment's environmental footprint is evident, suggesting a need for certain interventions to facilitate its successful implementation and the attainment of the desired outcomes.

Value:

This research contributes to the academic discourse by clarifying the role of PSS in advancing CEP within the built environment. It calls for cross-disciplinary collaboration and innovative approaches to overcome systemic barriers, paving the way for a more circular and resilient built environment. This study serves as a foundation for further investigation into the long-term impacts of PSS on CEP.

Keywords: Built environment, resource efficiency, servitization, sustainability, waste reduction.

INTRODUCTION

The shift towards a more sustainable and resilient built environment necessitates innovative strategies that reconcile economic development with environmental stewardship and resource conservation. The construction industry, a significant driver of economic growth, also contributes significantly to environmental degradation due to extensive resource extraction, high energy consumption, considerable waste generation, and greenhouse gas emissions during the delivery and management of the built environment (Pomponi and Moncaster, 2017; Joensuu et al., 2020). The traditional linear economic model, which is predicated on extraction, production, and disposal processes, has led to substantial environmental damage and resource depletion (EMF, 2017). This context underscores the pressing need for transformative approaches that can ensure the industry's transition towards sustainability.

The Circular Economy (CE) concept has emerged as a promising framework to address these challenges. CE principles aim to redesign the current linear system into a regenerative loop, focusing on the reduction, reuse, and recycling of materials to extend the lifecycle of products and minimize waste (Geissdoerfer et al., 2017). However, the operationalization of CE within the built environment presents complex challenges, necessitating innovative solutions that can adapt to the sector's unique characteristics (de Pádua Pieroni et al., 2018; Ghafoor, et al., 2023).

CE transitions facilitated by Product-Service Systems (PSS), remain a critical area of research (Tukker, 2015; Joensuu et al., 2020; Munaro et al., 2020; Ghafoor et al., 2023). PSS has been identified as a key CE-oriented business model for achieving resource efficiency and enhanced sustainability performance due to its provenance in integrating products and services in one offering (Tukker, 2015; Michelini et al., 2017). However, the widespread adoption of PSS across various sectors has been hindered by challenges ranging from consumer acceptance to environmental implications (Tukker, 2015).

Product-Service Systems (PSS) constitute a strategic approach to enhancing built environment Circular Economy Performance (CEP) (Pomponi and Moncaster, 2017; Eberhardt et al., 2019; Ghafoor et al., 2023). PSS engenders a shift from focusing on traditional product ownership to the provision of services using these products to potential end-users, promoting the use of durable, maintainable, and recyclable materials (Tukker, 2015). Despite the recognized potential of PSS to drive sustainable practices by emphasizing material efficiency and extending product lifecycles, there is a critical gap in understanding how effectively these systems can be adopted in the built environment to advance CEP (Ghafoor et al., 2023; Henriques et al., 2023).

Consequently, this study endeavors to address this knowledge gap by conducting a comprehensive review of existing literature to clarify the role and impact of PSS in advancing CEP, shedding light on the actual effectiveness and operational challenges in the construction sector. The central issue addressed by this research is the insufficient understanding of the efficacy of Product-Service Systems (PSS) in advancing Circular Economy Performance (CEP) within the context of the built environment. This investigation specifically concentrates on elucidating the potential contributions of PSS adoption towards facilitating improved built environment CE performance and the challenges negating its seamless adoption.

LITERATURE REVIEW

Improving the Circularity Performance of the Built Environment

Circular Economy (CE) represents a paradigm shift in how societies view and manage resources, aiming to transition from traditional linear economic models of "take, use, dispose" towards more sustainable models characterized by the principles of reducing, reusing, and recycling materials (Ramakrishna et al., 2020). This approach seeks not only to minimize waste but also to extend products and resources lifecycle, thus creating a regenerative loop that maintains the value of materials as long as possible (Zvirgzdins et al., 2019). Geissdoerfer et al. (2017) emphasize the importance of designing out waste, keeping products and materials in use, and regenerating natural systems. The adoption of CE principles is pertinent in sectors with high environmental footprints, such as the built environment and the construction industry, both of which have been flagged as major consumers of natural resources and significant contributors to waste generation.

However, applying CE principles within the built environment poses distinct challenges. One of the primary issues is the sector's substantial use of materials and waste generation. The built environment is responsible for a significant proportion of global resource extraction, consuming around 40% of raw materials and generating about 33% of waste (Eberhardt et al., 2021). This intensive utilization of resources is compounded by the sector's traditional reliance on linear practices, where buildings and infrastructure are demolished and disposed of at the end of their useful life, without sufficient consideration for the reuse or recycling of materials (Benachio et al., 2020). Furthermore, the heterogeneity of materials used in construction and the complexity of dismantling and sorting processes make recycling and reuse challenging. Additionally, current economic and regulatory frameworks often do not support or incentivize circular practices, which further impedes CE transitions within the built environment (Durdyev et al., 2023).

To overcome these challenges, innovative approaches and systemic changes are required. This includes the development of new construction materials and methods that facilitate disassembly and reuse, the implementation of policies that encourage circular practices, and fostering of a culture shift among stakeholders towards prioritizing resource efficiency. The successful integration of CE principles in the built environment requires collaboration across disciplines, including architects, engineers, policymakers, and other construction industry stakeholders, to reimagine and reshape how buildings and infrastructure are designed, constructed, and decommissioned (Muñoz-Villamizar et al., 2015).

Product-Service Systems (PSS) as a veritable strategy

Product-Service Systems (PSS) have emerged as a transformative CE business model (Vence and Pereira, 2019). PSS has been defined as a system of products, services, supporting networks, and infrastructure that is designed to be competitive, satisfy customers' needs, and have a lower environmental impact than traditional business models (Tukker, 2015). This innovative approach encourages companies to look beyond the mere transaction of selling a product, towards exploring how they can deliver value to their customers through services derived from these products. PSS can be categorized into three main types: product-oriented, use-oriented, and result-oriented (Wallin et al., 2013; Beuren et al., 2016).

- *Product-oriented PSS* involves offering a product with added services, such as maintenance or take-back services at the end of the product's life. In the built environment context, this could manifest as selling building materials with the promise of reclaiming them for recycling or reuse.
- *Use-oriented PSS* allows customers to use a product through lease or sharing arrangements without owning it. An example in the built environment could be shared construction equipment or facilities management services for commercial buildings, reducing the need for individual ownership.
- *Result-oriented PSS* focuses on delivering a desired result or outcome rather than a specific product or service. In the built environment space, this might involve offering a service contract for maintaining indoor climate conditions at optimal levels, irrespective of the specific heating or cooling systems used.

The benefits of implementing PSS in the built environment are multifaceted. Firstly, PSS models promote enhanced resource efficiency by extending the life of products through maintenance, reuse, and recycling, thus reducing the demand for raw materials (Corvellec et al., 2017; Vogiantzi and Tserpes, 2023). For instance, by providing maintenance services for building components, their lifespan can be significantly increased, and the materials can eventually be reused or recycled, thereby minimizing waste (Aguerre et al., 2017). Secondly, PSS can lead to a reduced environmental impact. The shift towards the use and result-oriented models decreases the overall material consumption and energy use, contributing to lower greenhouse gas emissions and a smaller environmental footprint. This is particularly relevant in the construction sector, where resource use optimization and product lifespan maximization can significantly mitigate environmental impacts (Bocken, et al., 2014). Lastly, PSS opens new business opportunities by fostering innovation in service offerings and customer engagement. Companies can differentiate themselves in the market by providing unique value propositions that go beyond traditional product sales, building stronger relationships with customers and creating new revenue streams. For construction companies, this could mean developing innovative solutions for sustainable building maintenance, retrofitting services, or offering performance-based contracts for energy efficiency (Henriques et al., 2023).

From the foregoing, the potential usefulness of PSS in contributing to the advancement of CE within the built environment can be discerned. By promoting the use of products as services and focusing on delivering desired outcomes, PSS can enhance resource efficiency, reduce environmental impacts, and create new opportunities for businesses involved with the delivery and operationalization of the built environment. As the sector continues to evolve towards sustainability, PSS offers a pathway for companies to innovate and thrive in a circular economy (Romero and Rossi, 2017; Henriques et al., 2023). However, literature detailing PSS implementation within the built environment for the purposes of improving the CE performance, remains limited. This lack of relevant literature is more pronounced in the developing country context. This has culminated in the low uptake of this business model by major built environment stakeholders in these contexts as a panacea for curbing the debilitating impact of the plethora of anthropogenic activities associated with the built environment on society's sustainability aspirations. Accordingly, this study seeks to contribute towards addressing this gap by enunciating the potential contribution of the PSS to improved built environment circularity performance and the barriers negating its uptake among critical stakeholders as detailed in extant literature using a scoping review. It is expected that the findings of the study, albeit preliminary, will provide a foundation for further studies seeking to articulate veritable frameworks for deepening the adoption of PSS for CE performance improvement purposes within the built environment context, with particular emphasis on developing countries.

RESEARCH METHODOLOGY

This study employed a scoping review research design to explore the current state of knowledge concerning the impact of Product-Service Systems (PSS) on Circular Economy Performance (CEP) within the built environment. The choice of a scoping review was motivated by the need to understand the breadth and depth of the literature on this emergent topic, where evidence is still developing, and there is considerable ambiguity around specific investigative approaches (Munn et al., 2018). Scoping reviews are particularly suited for such exploratory investigations as they allow for the inclusion of a wide range of literature types, including grey literature, providing a comprehensive overview of the subject matter (Munn et al., 2018; Mak and Thomas, 2022).

Search Strategy

The literature search strategy was designed to capture relevant studies that discuss the integration and impact of PSS on CEP within the construction sector. A search string comprising of a combination of the following keywords "Product-Service System," OR "Servitization," AND "Circular Economy," AND "Construction Industry," OR "Built Environment" was used to elicit relevant documents from the following academic databases Scopus, Web of Science, and Google Scholar. These terms were searched in various configurations to ensure the capture of all pertinent studies. The search was conducted with literature for a decade (between 2014 -2024), covering publications up to the current year to ensure the most recent evidence was included. Grey literature, such as industry reports and policy documents, was also considered to ensure a comprehensive collection of evidence.

Inclusion and Exclusion Criteria

Studies were selected based on predetermined criteria, focusing on those that explicitly examined the role of PSS in enhancing CEP within the construction industry and/or the built environment.

The inclusion criteria were as follows:

- Peer-reviewed articles and grey literature in English.
- Studies that specifically addressed PSS, servitization, and their impact on CEP in the construction sector and/or the built environment.

Exclusion criteria included:

- Non-English language publications.
- Studies not directly related to the construction industry and/or built environment or not explicitly addressing PSS and CEP.

Data Extraction and Synthesis

Following the literature search, 198 papers were identified. After applying the inclusion and exclusion criteria, 25 papers were deemed relevant for detailed review for this study (Table 1 and Figure 1). The data extraction process was systematically conducted, with information related to the research objectives, methodology, and key findings being documented for each study.

Table 1: Proportion of documents used classified by type.

Type of Document	Number
Journal Article	13
Conference Papers	6
Book Chapter	3
Book	1
Government Policy/standards	2
Total	**25**

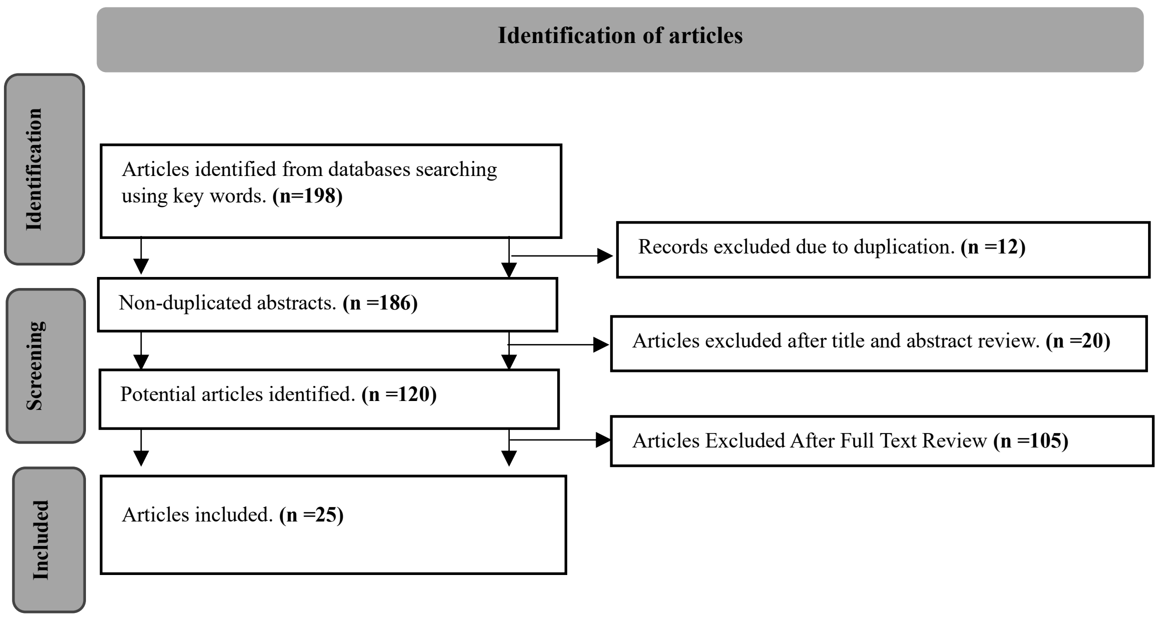

Figure 1: Scoping review process

The thematic analysis which was predicated on pre-set themes was used to analyze the data. This approach facilitated an understanding of the collective insights on PSS and CEP within the built environment context whilst highlighting areas that required further investigation.

FINDINGS AND DISCUSSION

The key findings from the scoping review are discussed under relevant themes in this section. These themes reveal insights into the potential benefits, challenges to implementation, and the pivotal role of policy and other interventions in facilitating the increased adoption of Product-Service Systems (PSS) in the built environment context as a vehicle for improving its circularity performance.

Theme 1: Potential of PSS in enhancing CEP

The integration of Product-Service Systems (PSS) into the construction industry demonstrates notable potentials for enhancing Circular Economy Performance (CEP), primarily through initiatives that extend the lifecycle of materials and reduce waste (Romero and Rossi, 2017). This focus on service provision over product ownership aligns with the circular economy's goals of reducing resource consumption, reusing materials, and recycling products at the end of their lifecycle. Tukker (2015) highlights that PSS offers a paradigm shift in consumption and production patterns, promoting the use of products as services, which inherently encourages sustainable resource management.

Accordingly, the integration of Product-Service Systems (PSS) within the built environment reveals a significant, yet largely untapped, potential for these systems to mitigate the sector's environmental footprint. This potential stems from the inherent characteristics of PSS, which prioritize the efficiency of resource use, the extension of product lifecycles, and the maximization of material reuse and recycling (Han et al., 2020). Such a shift from traditional, ownership-based consumption models towards service-oriented models can fundamentally alter the environmental impact of the construction industry, promoting a more sustainable approach to development and building management (Koukopoulou, 2020).

PSS offers the built environment a pathway to sustainability that aligns with CE principles. By focusing on the provision of services rather than the sale of products, PSS encourages the optimization of material use and the implementation of strategies that extend the durability and utility of construction materials and components. For example, PSS models that include maintenance, refurbishment, and recycling services can significantly reduce the demand for new materials, thereby decreasing the industry's reliance on resource extraction and its associated environmental impacts (Tukker, 2004; Han et al., 2020).

Moreover, the adoption of PSS in the built environment has the potential to foster innovation in sustainable building practices. Through the development of new business models that emphasize service provision, companies can explore alternative ways of meeting client needs while minimizing environmental harm. This could include, for instance, designing buildings for disassembly and reuse, thus facilitating material recovery and recycling at the end of a building's life cycle (Bocken et al., 2014; Sassanelli et al., 2019).

Although empirical studies specifically quantifying the impact of PSS on CEP in the construction sector are limited, existing evidence from case studies provides valuable insights. For instance, Mont (2002) and Bocken et al. (2016) presented case studies where PSS models, like building leasing and performance-based contracts, led to measurable improvements in resource efficiency and waste management. These models have been instrumental in ensuring that materials are not only used more efficiently but also that they are reused and recycled, reducing the demand for new resource extraction (Chávez et al., 2019).

Also, PSS has shown potential environmental benefits in the built environment by promoting the maintenance and repair of building components. This approach significantly lowers the environmental impact associated with the construction and demolition processes. Lieder and Rashid (2016) discuss how effective implementation of PSS can diminish the need for new materials, consequently decreasing energy consumption and greenhouse gas emissions from material production.

The existing impacts of PSS underscore its viability as a strategy to achieve CE objectives in the construction industry, particularly the built environment. Despite the challenges negating broader adoption and the need for more detailed quantitative studies, preliminary evidence suggests that PSS can play a crucial role in reducing the environmental footprint of construction activities. Therefore, advancing the understanding of PSS's impacts and developing a metrics for their assessment are essential steps toward realizing the full potential of circular economy practices in the built environment (Sassanelli et al., 2019).

Theme 2: Existing barriers in implementing PSS to enhance CEP

However, this transition towards improved built environment circularity performance leveraging PSS is not without its challenges. Some of the challenges identified in the reviewed literature include cultural resistance, regulatory hurdles, and financial challenges.

a. *Cultural Resistance*

One of the primary barriers to the implementation of PSS is cultural resistance from both organizations and consumers. Traditional business models in the construction industry are deeply ingrained, focusing on the sale of products rather than services (Tokarz et al., 2020). This mindset poses a significant challenge to adopting PSS, as it requires a fundamental shift in how value is perceived and delivered. Consumers and stakeholders may also be hesitant to embrace new models due to unfamiliarity and concerns over quality and reliability (Tukker, 2015; Kirchherr et al., 2018).

b. *Regulatory Difficulties*

An examination of Product-Service Systems (PSS) within the built environment highlights a critical need for substantial policy interventions to catalyze their adoption and effectiveness in enhancing Circular Economy Performance (CEP). However, the prevailing regulatory environment can significantly impact the feasibility and attractiveness of PSS models therein. Existing regulations may not accommodate or incentivize the adoption of product-service oriented business models, particularly in sectors as heavily regulated as construction. For example, building codes and standards that do not recognize or support the reuse of materials can hinder the implementation of PSS strategies aimed at extending the lifecycle of products (Bocken et al., 2014). This misalignment suggests that for PSS to reach its full potential in driving sustainability within the construction sector, a reevaluation and restructuring of policy frameworks remain imperative (Repo et al., 2018).

c. Financial Challenges

Implementing PSS models often requires upfront investment in redesigning products, developing new service offerings, and establishing supporting infrastructure. Such investments can be substantial, and the return on investment may be uncertain or long-term, making it difficult to secure financing. Moreover, the cost structures of PSS models are different from traditional sales models, which can pose additional financial planning and management challenges (Mont, 2002).

Theme 3: Interventions for Improved PSS adoption in the Built Environment

a. Policy and Legislative interventions

The development of a legislative environment that actively encourages sustainable business practices is essential for the successful integration of PSS into the construction industry. Such an environment should include the provision of tax incentives for companies that adopt PSS models, thereby reducing the financial risk associated with transitioning to service-based offerings (Van Loon et al., 2021). Additionally, subsidies and financial support for green innovations can further stimulate the development and adoption of PSS by lowering the initial investment barrier, making it a more attractive proposition for businesses (Rothenberg et al., 2001; Van Loon et al., 2021).

Furthermore, regulations specifically designed to favor circular economy practices can create a more conducive environment for PSS. For instance, policies that mandate the recycling and reuse of materials in construction projects can drive demand for PSS solutions that are inherently designed to facilitate such practices. Implementing regulations that recognize and reward the environmental benefits of PSS, such as reduced material waste and lower carbon emissions, can also serve as a powerful incentive for businesses to adopt these models (Bocken et al., 2014; Lieder and Rashid, 2016).

The essential role of policy interventions in enabling the transition to PSS in the construction industry highlights the need for a collaborative effort between government bodies, industry stakeholders, and researchers. Policymakers must engage with industry experts to understand the specific challenges and opportunities presented by PSS, ensuring that new regulations are both practical and effective in promoting sustainability. Moreover, the development of policies that are flexible and adaptable is crucial to accommodate the evolving nature of PSS and the construction industry's dynamic requirements (Tukker and Tischner, 2006).

b. Increased cross-disciplinary collaboration

Cross-disciplinary collaboration involves the cooperation of professionals from various fields such as architecture, engineering, business, and environmental science, to address complex challenges. This approach is essential in the construction industry for developing effective product-service systems (PSS) that enhance circular economy performance (CEP), as it combines diverse expertise to create holistic and sustainable solutions.

To practitioners in the construction industry looking to integrate PSS into their operations, several recommendations can be made. First, embracing policy changes that incentivize sustainability and circular economy practices is crucial. Engaging with policymakers to advocate for supportive regulations and incentives can create a more conducive environment for PSS adoption (Repo et al., 2018). Second, fostering collaboration across the value chain, from suppliers to clients, can facilitate the development of comprehensive PSS offerings that meet the diverse needs of stakeholders. Finally, investing in innovation and continuous improvement is key to developing PSS solutions that are not only environmentally beneficial but also economically viable (Bocken et al., 2014).

The realization of the full potential of PSS in advancing CEP within the construction industry necessitates cross-disciplinary collaboration. Architects, engineers, business scholars, and environmental scientists bring diverse perspectives and expertise that are essential for designing and implementing effective PSS solutions. Architects and engineers can innovate in sustainable building design and construction methods, business scholars can develop viable business models for PSS, and environmental scientists can assess the environmental impacts and benefits. Such collaboration can lead to holistic solutions that address the economic, environmental, and social dimensions of sustainability, driving the construction industry towards a more circular economy (Vezzoli et al., 2015; Lieder and Rashid, 2016).

Research Gaps and Future Directions

This review of the literature on Product-Service Systems (PSS) in the built environment and their impact on built environment circularity performance (BECP) reveals notable gaps that need addressing to advance the field. A significant Drawback is the lack of empirical studies quantifying the benefits of PSS for CEP in the built environment. While theoretical discussions and case studies suggest potential advantages, robust empirical evidence is sparse. This gap hinders the ability to understand the full impact of PSS on resource efficiency, waste reduction, and overall sustainability within the construction sector. Such data are crucial for convincing industry stakeholders of the value of PSS and for informing policy decisions that support sustainable practices (Tukker, 2015).

CONCLUSION

The exploration of Product-Service Systems (PSS) within the built environment, to enhance Circular Economy Performance (CEP), has unveiled significant insights into the potential benefits, existing challenges, and the pivotal role of policy interventions in fostering sustainable practices. Through a systematic review of the literature, this study has identified key gaps in current research, particularly the need for empirical evidence quantifying the impacts of PSS on CEP. It has also highlighted the untapped potential of PSS in reducing the environmental footprint of the construction sector and underscored the importance of cross-disciplinary collaboration in realizing this potential.

The findings from this study emphasize the alignment of PSS with the principles of the circular economy—reduce, reuse, and recycle—underscoring their capability to extend product lifecycles and minimize waste. Despite the promising theoretical and case study evidence supporting the benefits of PSS in the construction industry, the scarcity of quantitative research limits the ability to fully comprehend and communicate these benefits to industry stakeholders and policymakers. This gap signifies a critical area for future research endeavors, aiming to provide robust data that can inform decision-making and encourage the adoption of PSS.

Moreover, the study advocates for substantial policy interventions to create a regulatory environment conducive to PSS implementation. The current lack of supportive policies and incentives poses a barrier to the widespread adoption of service-oriented business models within the construction industry. Developing legislative frameworks that encourage sustainable business practices, including tax incentives and subsidies for green innovations, is paramount for facilitating the transition towards a more circular economy.

Furthermore, the potential for cross-disciplinary collaboration in advancing PSS and CEP within the construction industry cannot be overstated. Architects, engineers, business scholars, and environmental scientists each hold a piece of the puzzle in designing, implementing, and evaluating PSS solutions that meet economic, environmental, and societal goals. Fostering such collaboration will be essential in overcoming the complexities associated with integrating PSS into the construction sector and achieving sustainability targets.

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