



Systematic Framework for Early-Stage Sustainable Product-Service System (PSS) Design in Capital Goods Manufacturing Companies

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As a key driver of the circular economy, product-service systems (PSS) have regained attention in sustainable design research after a period of decline (Koide et al., 2022). The unique characteristics of PSS challenge the conventional belief that economic growth and resource consumption are inseparable, providing an opportunity to reconcile this contradiction (Kjaer et al., 2019). Manufacturing companies play a crucial role in the implementation of PSS but face numerous barriers such as a limited understanding of the sustainability implications of PSS and the lack of suitable approaches for PSS design. To overcome these obstacles and achieve the sustainability benefits of PSS, a systematic framework is necessary to guide the design process and aid decision-making (Vasantha et al., 2015). Currently, such support is lacking in academic literature and industry practices (Sakao & Neramballi, 2020). To fill this gap, three cycles of the design research methodology (DRM) (Blessing & Chakrabarti, 2009) were employed to develop a systematic framework for early-stage sustainable PSS design. The methodology involved a combination of methods such as systematic literature review (SLR), action research, and case studies, intending to provide comprehensive and effective support for capital goods manufacturing companies.

The systematic framework is focused on the early-stage PSS design in capital goods manufacturing companies (Figure 1). The focus was placed on the early stages of design due to its most significant potential for the performance and success of PSS offerings in all three dimensions of sustainability (Sousa-Zomer & Miguel, 2017). The support is targeted towards the capital goods manufacturing companies due to the industrial pull (Saranic et al., 2021) and the opportunity to mitigate the major contribution manufacturers have to climate change (Zhang et al., 2018).

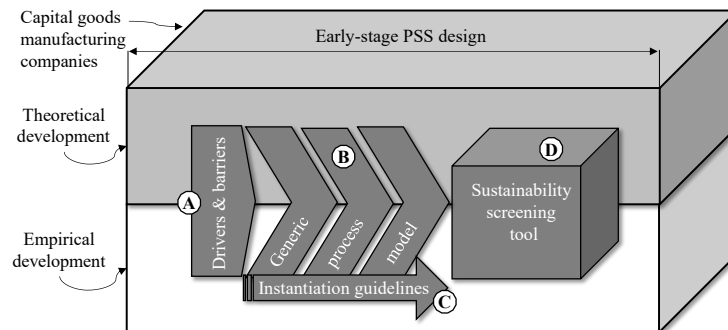


Figure 1. A systematic framework for early-stage sustainable PSS design in capital goods manufacturing companies.

The framework, which has been developed theoretically and empirically, consists of four elements that contribute to an all-encompassing and systematic approach to early-stage sustainable PSS design. As demarked in Figure 1, element A regarding drivers and barriers (Saranic et al., 2021), element B describing a generic PSS process model (Saranic, Pigosso, Pezzotta, et al., 2023), element C regarding instantiation guidelines (Saranic, Pigosso, & McAloone, 2023, forthcoming), and element D presenting a PSS sustainability screening tool (Saranic et al., 2022), respectively form the framework.

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Manufacturers may have different motives to pursue PSS, hence different challenges accompany the development of such offerings. It is crucial to determine the motivation in early-stage design to strategically steer such projects, as elaborated in the contribution related to element A.

Regardless of the motivation, PSS offering design necessitates a structured process which is pivotal to designing new offerings quickly and repeatedly. One such generic process model (GPM) based on an SLR was proposed in the contribution tied to element B. The comprehensive model prescribes a stage-gate process with temporal (three phases) and content dimensions (seven clusters of entities to consider), as well as necessary sustainability considerations connected to each of them. To increase the chances of successful industrial adoption and the impact of the GPM contribution related to element C thoroughly evaluates the model and proposes comprehensive instantiation guidelines to support the creation of company-specific process models. Finally, to align PSS concepts conceived by the manufacturing companies using the GPM with the triple-bottom-line (TBL) corporate strategies, which is the most common framework to implement sustainability in businesses, a concept screening tool has been proposed in the contribution tied to the element D. The four-dimensional Business, Environmental, and Social Screening Tool (BESST) enables PSS concept dissection with respect to the TBL, life cycle stages, the main elements of PSS (product, service, network, and infrastructure), and the concept's value. Thereby, key contributions are made to both the academic and industrial practice of PSS design, including the potential to mitigate uncertainties related to the sustainable performance of PSS.

Keywords: product-service system; sustainability; manufacturing; circular economy; early-stage design

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