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A Method for the Development of Business Models for Collaborative Product Service Systems in the Industrial Sector

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Abstract

Purpose: This study aims to introduce a methodology dedicated to developing business models for industrial product service systems (IPSS) in mechanical engineering. It identifies shortcomings in generic methods and emphasizes the importance of a systematic approach.

Design/Methodology/Approach: Grounded in a thorough literature review, a careful selection of eleven scientific papers has been identified and explored in a two-step literature review and analysis process. To develop an adjusted reference methodology, we used a multi-phase development model for structural guidance. The emphasis is on a step-by-step and iteratively validated approach to overcome the particular challenges of IPSS in mechanical engineering.

Findings: The comprehensive review of literature revealed a gap in research concerning IPSS business model development within mechanical engineering, as none of the reviewed studies fully met all predefined requirements. Additionally, the absence of focus on small and medium-sized enterprises (SMEs) in the literature suggests an important area for further investigation. These findings underscore the need for a more systematic methodology to address this deficiency. Despite these limitations, valuable insights were extracted through careful content analysis, organized into distinct phases, resulting in the development of a systematic reference model.

Practical Implications: Project managers and organizations can view this reference model as a strategic roadmap, providing step-by-step guidance for the effective development of IPSS business models in engineering companies.

Originality/Value: We contribute a systematic reference methodology for the development of collaborative IPSS business models in mechanical engineering, addressing industry-specific needs and paving the way for future research on incorporating company-specific factors into the business model development process.

Keywords Business Model, Industrial Product Service Systems, Mechanical Engineering, Collaboration

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1. Introduction

In the rapidly evolving landscape of globalization and digitalization, the industrial sector is undergoing continuous transformation, presenting persistent challenges (Gebauer et al., 2005; Li and Found, 2017). The increasing uniformity of products and services, coupled with the dynamic of rapid innovation cycles and technological advancements, diminishes companies' competitive advantages, making aggressive pricing a short-term market necessity (Lasi et al., 2014; Cedergren et al., 2012). Recognizing this, business model innovation has become pivotal, offering sustainable competitive advantages by navigating the dynamic market landscape as emphasized by Saebi et al. (2017), and aligning with Chesbrough's (2010) argument that organizations must unlock value from new technologies though the adoption of appropriate business models.

This transformative landscape disproportionately affects sectors like mechanical and plant, automotive, and electrical engineering (Kagermann et al., 2013), as affirmed by Piccinini et al. (2015) and Jewapatarakul and Ueasangkomsate (2022). Emphasizing the need to respond to evolving customer demands in the digital transformation era, as advocated by Oztemel and Gursev (2020), our study centers on the mechanical engineering sector. This specific focus stems from a recognition of the sector's unique challenges and opportunities, specifically the rising demand for tailored, service-driven solutions (Mont, 2002). To fully exploit digitalization and adapt to market conditions, mechanical engineering companies must transition from product providers to solution providers, facing obstacles such as evolving business models, stakeholder management, and cultural changes (Baines et al., 2007; Meier et al., 2010a; Mont, 2002).

During this transformation, small and medium-sized enterprises (SMEs) face distinct challenges, concentrating on a single business model, limiting resource access, and fostering uncertainty in new business model development (Müller et al., 2018a, 2018b). Due to their limited size, SMEs will also require support from appropriate partners to meet the challenges presented (Müller, 2019). Given the research bias towards larger companies, tailored solutions addressing SME needs are lacking (Müller et al., 2018a). Our study strategically combines a primary focus on mechanical engineering with supplementary exploration into SME concerns, aiming for a comprehensive understanding of the research landscape.

A potential solution to the challenges mentioned is highlighted by Aurich et al. (2016) in the form of industrial product service systems (IPSS). This paper adopts the definition by Meier et al. (2010a) as its foundational understanding: "An Industrial Product Service System is characterized by the integrated and mutually determined planning, development, provision and use of product and service shares including its immanent software components in Business-to-Business applications and represents a knowledge-intensive socio-technical system." (p.608)

Building upon this foundation, Mittag (2019) identifies several methodological approaches for the development of service and data-oriented business models already present in the literature. However, Dommermuth's (2021) insights reveal that these approaches are often generic in structure, necessitating a high degree of contextualization before they can be effectively applied to the unique landscape of

mechanical engineering, thereby compounding the difficulties encountered by engineers as they navigate the task of determining appropriate measures and solutions within their domain. Mont's (2002) perspective suggests that overcoming these challenges requires the establishment of collaborative value networks. However, Kölsch and Aurich (2019) highlight challenges associated with collaborative approaches, underscoring the complexities involved. While the development of service-based business presents opportunities, it also poses substantial challenges, particularly in the domain of bi- or multi-lateral collaboration during the development and implementation of new business models. This emphasizes the need to address challenges in collaborative strategies within the dynamic landscape of business transformations.

Transitioning from an examination of challenges to proposing practical solutions, this paper aims to develop a systematic methodology for the creation of collaborative business models conducive to IPSS in mechanical engineering. Focused on simplifying and supporting the development process, with a specific target on project managers and teams engaged in designing such business models, our research is driven by the following primary question:

"How can collaborative business models for industrial product service systems be developed for mechanical engineering companies and particularly for SMEs?"

To address this primary question, we explore two key sub-research inquiries.

Firstly, we investigate: "What are the specific requirements and challenges faced by small and medium-sized enterprises in mechanical engineering companies when developing collaborative business models for industrial product service systems?"

Secondly, we focus on: "How can an original methodology be formulated to create collaborative business models that effectively address the unmet requirements and challenges in the implementation of industrial product service systems for these companies?"

Crafting explicit research questions initiates our methodology for conceptualizing collaborative business models, with a focus on IPSS. Key terminologies and specific requirements, derived from the unique challenges and opportunities of IPSS, guide our exploration throughout the subsequent steps of our research process. Through a systematic literature review, including a two-step comparison of papers, we document and categorize insights, shaping our reference methodology. Utilizing a multi-phase development model, we structure our approach to address the unique challenges and opportunities in IPSS within mechanical engineering.

2. Theoretical Background

We begin by establishing a theoretical foundation for exploring collaborative business model design methodologies in IPSS within mechanical engineering. Towards this end, we highlight five key terminologies essential to our methodological approach in the literature review, serving a central role in creating a terminology matrix and shaping search strings, which has been derived from our research question, that form the basis of our study. These terms are fundamental to providing a common context and understanding, guiding our exploration of collaborative business model design in the

subsequent systematic literature review. As our investigation progresses, these terminologies will serve as critical criteria for comparing and evaluating methodologies derived from the literature, ensuring a comprehensive analysis grounded in a solid theoretical foundation.

Accordingly, the five key requirements for a collaborative business model design methodology for IPSS in mechanical engineering are the following:

The first is the *mechanical engineering* sector which is a part of the capital goods industry (Liu, 2021). This industry has less dynamic business models and follows a traditional logic with a focus on innovating products and processes, maintaining high quality standards, strongly identifying with physical products, and prioritizing customer satisfaction through high levels of personalization (Gerl, 2020). Services primarily serve as after-sales offerings (Stich et al., 2022). According to Gerl (2020), mechanical engineering is product oriented. This study focuses on the types of companies involved in mechanical engineering which produce multi-part products with a complicated technological structure and offer a range of services, from custom one-time production to standardized series production (Ebi, 2021).

Next, it is relevant to note *that small and medium sized companies (SMEs)* typically refer to companies that satisfy specific size criteria based on the number of employees and turnover. Characterized in the EU recommendation 2003/361, SMEs encompass enterprises: “which employ fewer than 250 persons and which have an annual turnover not exceeding EUR 50 million, and/or an annual balance sheet total not exceeding EUR 43 million” (European Commission, 2003). Acknowledged as vital players in the economy, they are commonly recognized for driving innovation, employment, and regional prosperity. Research findings from the European Commission in 2023 further support that SMEs have the potential to significantly contribute to job creation and overall economic development. (European Commission, 2023). When exploring the challenges faced by SMEs, as highlighted by Åkesson et al. (2022), it becomes evident that these enterprises are being confronted with various complexities in designing Product Service Systems (PSS). Factors such as time constraints, financial limitations, organizational structure, and their position in the value chain present interconnected challenges that can make it challenging for SMEs to prioritize and address them individually. Recognizing these challenges is crucial in understanding the broader landscape in which SME operate, emphasizing the importance of context-specific considerations in addressing PSS design challenges within the SME sector.

Another pivotal aspect to consider is the *business model* construct, which has risen in importance in recent decades; however, a uniform definition is lacking in the literature (Liu, 2021). Due to its utilization in diverse academic disciplines with varying focuses, different variations of the term have emerged over the years (Ebi, 2021). Business models are conceptual tools, according to Weiner et al. (2010), designed to represent the links between objects to illustrate the value creation process and cash flows. Teece (2010) states that a business model creates value for customers through the architecture of revenues, costs, and profits. The current interpretation of the term "business model" in this paper is based on the broader understanding of Kavvadia (2022), who describes business models: “the way organizations create and deliver value necessary for their existence and development” (Kavvadia, 2022, p.96). Jensen (2013) contributes a significant insight to this discussion, suggesting that rather than settling on a single

definition, there is a need for multiple definitions that build upon a shared understanding of business models. In line with this approach, we propose adopting an additional definition offered by Fielt (2013), which provides a more detailed perspective on the business model construct. According to Fielt: “We conclude that a business model describes the value logic of an organization in terms of how it creates and captures customer value and can be concisely represented by an interrelated set of elements that address the customer, value proposition, organizational architecture and economics dimensions” (Fielt, 2013, p.99). Fielt's definition complements Kavvadia's more generic interpretation, providing a deeper understanding of the intricacies involved in business model development and implementation.

Transitioning to the fourth requirement, it is relevant to emphasize that *collaboration* is an approach to achieving common goals through closely coordinated iterative interactions between distinct parties. The literature emphasizes the many advantages of collaboration, which include increased efficiency, risk sharing, and improved innovation capabilities due to access to different perspectives and expertise (Inkpen & Tsang, 2005). It is important to differentiate between the terms "collaboration" and "cooperation", as delineated by Brechtel et al. (2024), building on the distinctions made by Mattessich and Johnson (2018). In comparison to cooperation, collaboration implies that resources and skills are used jointly and, in a value-adding manner through continuous coordination. This distinction emphasizes a deeper form of collaboration that focuses not only on occasional exchange, but on a continuous and coordinated use of resources. In our context, we thus refer to a specific type of collaboration that goes beyond mere cooperative action and creates sustainable added value. A related business concept is coopetition, a term coined by Brandenburger and Nalebuff (1996), which merges cooperation and competition. In this strategic partnership, companies cooperate in certain areas while simultaneously competing in others, enabling the exploitation of synergies while preserving individual competitive advantages.

Concluding the list of requirements, it is essential to highlight that *product service systems (PSS)* are bundles of services that include a technical product offered alongside various services throughout its lifespan. A critical aspect of PSS is the strong emphasis on customer benefits, with the goal of enhancing customer satisfaction and loyalty (Aurich et al., 2016). PSS extend to both consumer and capital goods markets. Given the focus on mechanical engineering, only *industrial product service systems (IPSS)* that operate within the B2B sector are in focus here (Meier et al., 2011). Key characteristics of IPSS include its socio-technical nature, with interpersonal interactions occurring not only during implementation, but throughout the entire IPSS life cycle (Gorldt et al., 2017). This human-centered approach enables the creation of tailored solutions that fully meet customer needs (Boßlau, 2014). Additionally, involving value-added partners in the development process is essential for the success of an IPSS as they can compensate for any missing skills or capacities and expand the range of solution ideas (Farhadi, 2019). In contrast to traditional business models based on classic transactions, where customer contact usually ends after the product has been put into operation, the relationship between provider and customer in IPSS is characterized by its long-term nature (Herzog et al., 2017). This is due to services having their value created in the interaction between the customer and provider, making cooperation beyond the transaction essential (Boßlau et al., 2017). The components of an IPSS can undergo modifications during its

operational phase, rendering it a dynamic construct. The need to accommodate the demands of new customers can be a catalyst for change in the solution space, prompting the provider to initiate alterations (Kölsch, 2022).

The identified terminologies will guide the construction of search strings in Figure 1 for our terminology matrix and inform the comparison of papers in Table 1.1. within our concept matrix, enabling a comprehensive analysis based on these key criteria.

Having concluded the explanation of the five key terminologies essential to our methodological approach, including the concept of IPSS, we now turn our attention to refining our understanding of collaborative business model design methodologies within mechanical engineering. In this section, we recognize the need to deepen our exploration of the IPSS framework and its potential implications for addressing the challenges identified earlier. Considering this, we have derived an additional set of five specific requirements directly from the IPSS context. These supplementary prerequisites, emerging from a thorough analysis of both the previously highlighted challenges and the specific nuances of IPSS, form a more targeted foundation for our methodology. Guided by these refined parameters, we will proceed to evaluate the results of our systematic literature review and structure our analysis accordingly.

- *Alignment with the value proposition:* Instead of focusing on the product, the methodology should focus on innovating the value proposition during development.
- *Integration of the customer:* For full capture and treatment of the customer's needs and problems, it is necessary to integrate the customer into the development process.
- *Iterative Process:* To respond to changing markets, customer needs, and new information, the methodology should follow an iterative approach. This entails fostering collaboration and partnering in customer-focused innovation, ensuring a dynamic process that can swiftly adapt to emerging challenges.
- *Life Cycle Orientation:* Due to the long-term supplier-customer relationship of an IPSS business model, the extended time horizon should be considered in the development.
- *Support for Creative Thinking:* To counteract the dominant industry logic and promote a service-oriented mindset, the methodology should encourage creative ideation beyond incremental innovations.

These specific requirements derived from the concept of IPSS will serve as crucial criteria during our two-step literature review. In Table 1.2, these requirements will be employed to compare and evaluate the papers, ensuring a comprehensive analysis of their relevance to IPSS business model development in mechanical engineering.

With the identification of overall ten requirements derived from our exploration of collaborative business model design methodologies in the context of IPSS within mechanical engineering, we have established a solid foundation for our methodological approach. These requirements will serve as crucial reference points beyond this section. In subsequent segments of the paper, they will guide our analysis as we assess and

compare various approaches discussed in the upcoming systematic literature review. This strategic application ensures that the groundwork laid in this chapter becomes instrumental in providing a structured framework for evaluating methodologies explored in the broader context of IPSS business model development. By systematically evaluating and comparing methodologies against these requirements, we aim to derive insights that contribute to the advancement of collaborative business model design practices in the mechanical engineering domain.

3. Methodological Approach

3.1 Overview of Research Approach

We begin by providing an overview, highlighting each step and its significance in the research approach. We address the challenges identified in the introduction by formulating research questions to guide our analysis. These questions are derived from the challenges outlined and serve as the central points for our research. From our primary research question, we derive five key requirements essential for evaluating collaborative business models for IPSS in mechanical engineering. These requirements are later incorporated into a terminology matrix utilized during the systematic literature review process. Enhancing this approach, our secondary research question focuses on identifying specific requirements to assess the quality and landscape of research in IPSS business development. These requirements are derived and integrated into a separate concept matrix for comparison during the literature review. Having established our research questions and requirements, we construct a terminology matrix based on our five key requirements and select appropriate databases for our literature search. Following a comprehensive literature review process, we analyze and select papers for in-depth analysis. During the analysis phase, we utilized two concept matrices to comprehensively evaluate the selected papers. The first concept matrix focuses on comparing the papers based on key requirements essential for evaluating collaborative business models for SMEs in mechanical engineering creating, delivering, and capturing value from IPSS. This matrix allows us to examine the papers' coverage of overarching topics and their alignment with our primary research objectives. We utilize a second concept matrix to delve deeper into the analyzed papers, specifically assessing their focus on the specific requirements of IPSS. This detailed analysis enables us to identify relevant complexities within the papers, providing insights into how they address particularly IPSS business model development. To synthesize these insights, we dissect and group the content of each paper, identifying commonalities and patterns. Notably, we observe similarities with the stages outlined in Cooper's model, upon which our methodology is based. Consequently, our methodology concludes with the integration of these insights into distinct phases, mirroring the stages of Cooper's model. This structured approach ensures coherence and clarity in our analysis and contributes to the development of a systematic reference methodology for IPSS business model development within the mechanical engineering domain.

3.2 Utilizing Systematic Literature Review for Research Analysis

Starting our Methodological Approach, we diverge from conventional paths to engage in a systematic literature review, a methodological choice guided by the unique contours of

our research inquiry. While systematic literature reviews traditionally serve to illuminate the current research landscape, our approach is informed by a distinct vision. Central to our methodology is our overarching research question and its five key terminologies, thoughtfully derived from our theoretical foundation. Our focus is not merely on surveying the terrain of existing knowledge but on a pursuit for specificity amongst a plethora of generic models. We acknowledge the abundance of generic approaches and aim to uncover thematically specific methodologies tailored to the intricacies of our inquiry. This intentional deviation from tradition underscores our dedication to a research journey characterized by precision, relevance, and the pursuit of targeted insights. So, strategically supported by its integral role in modern scientific research (Linnenluecke et al., 2020), we have selected a systematic literature review as basis to source data and information for answering our research questions on business model development for IPSS in mechanical engineering. This approach, endorsed by Booth et al. (2022) offers a methodological framework for synthesizing existing knowledge on our topic, ensuring unbiased evaluation, and enhancing result credibility (Pettricrew and Roberts, 2006; Wilson, 2009, Greenhalgh, 1997).

3.3 Database Selection

We opted for Lens.org and Google Scholar as databases for our literature review, considering their distinct merits and suitability. Lens.org, with comprehensive coverage, is the primary source for peer-reviewed articles, allowing a thorough exploration of diverse research (Jefferson et al., 2019; Haddaway et al., 2022). Google Scholar, known for its vast collection and search accuracy (Falagas et al., 2008; Beel et al., 2010), complements the approach. This dual database strategy enhances the overall comprehensiveness of our literature review (Jefferson et al., 2018; Gusenbauer, 2019).

3.4 Terminology Matrix Development

For this systematic literature review, we developed a terminology matrix (Figure 1) derived from the components outlined in our research question and expounded upon in our theoretical background. The five components and its related terms, namely "Business Model", "Mechanical Engineering", "Industrial Product Service System", "SME" and "Collaboration" guided our search strategy. Initially, a simultaneous search for all components proved insufficient, prompting a stepwise approach. As a result, the initial focus will be on Component 1 *“Business Model”*. The aim of this block is the identification of generic tools or frameworks for business model innovation. Next, the terminology used in Components 2-5 (*“Mechanical Engineering”; “Industrial Product Service System”; “SME”; “Collaboration”)* is contextualized, whereby we can identify any approach that is wholly or partially specialized in the research development of this paper. Consequently, the study followed the subsequent structure utilizing the terms from components 1 and 2, 1 and 3, 1 and 4, and 1 and 5. The search string for this review involves the key term from Component 1 and its related terms, connected by the boolean operator OR. Additionally, this search string was combined with the boolean operator AND, linking it to the key term from the other components along with its related terms, using the boolean operator OR as well.

	1	2	3	4	5
Terms	Business Model(s) OR	Mechanical Engineering OR	Industrial Product Service System(s) OR	Small and Medium-sized Enterprise(s) OR	Collaboration OR
Related Terms/ Synonyms	Business Model Innovation OR Business Model Development OR Business Model Framework OR Business Model Innovation Tool(s) OR Business Model Innovation Framework OR Business Model Design	Mechanical Engineering Firm(s) OR Mechanical Engineering Company(ies) OR Mechanical Engineering Sector OR Mechanical Engineeing Industry	IPSS OR IPS2 OR Product Service System(s) OR PSS OR Servitization	Small and Medium-sized Business(es) OR SME(s)	collaborative OR co-opetition OR coopetition

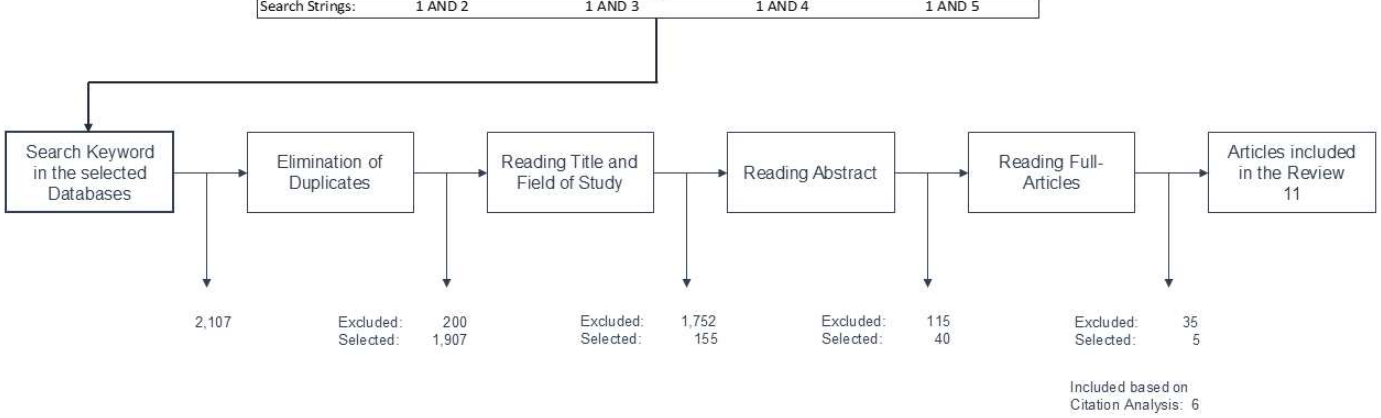

Figure 1. Integrated Overview - Terminology Matrix and Systematic Review Process Flowchart

3.5 Search Strategy Implementation

Formulating and implementing the search terms and search strategy in accordance with the research objectives was the first step in this systematic search. To facilitate understanding of the conducted search strategy and systematic literature process, Figure 1 also includes a flowchart visualization of our systematic review. This flowchart depicting our step-by-step-process has been developed by taking inspiration from the methodology outlined by Ghoreishi (2023). The data was methodically organized and sorted using Excel and Citavi for our data processing. Utilizing a title-only search approach, which is commonly used across various research field for minimizing the risk of irrelevant documents and reducing false positive results (Sweileh, 2018; Yeung et al., 2021; Moroz et al., 2021; Kopp et al., 2021), facilitated the handling of the large amount of information generated, resulting in a total of 2,107 outcomes from both databases containing the terms in the title. We excluded all publications published before 2003, providing an overview of the last two decades. The removal of 200 duplicates was an important step in the cleanup of the results and the assurance of data quality. This approach allowed us to work comprehensively as well as to include current and pertinent findings. To limit the selection of relevant literature, publications in languages other than English and German were excluded. We included German publications in our study due to the widespread discussion and numerous contributions to the concept of product service systems and industrial product service systems in German academic contexts.

This decision was made to ensure a comprehensive review of relevant literature, considering the significant insights and developments present in German publications (Kölsch et al., 2019, Meier et al., 2010b). As a result, we utilized the terms IPSS, IPS2, and PSS in our terminology matrix, aligning with the predominant terms used in German publications within this scientific field (Herzog et al. 2017; Boßlau et al. 2017). In the same way, gray literature such as master's or bachelor's theses and publications on websites and platforms such as LinkedIn were also excluded. Additionally, literature to which the authors lacked access was excluded to guarantee the verifiability and availability of the sources[1]. Publications that focused on unrelated industries or research areas were excluded during the content selection process. This was done to ensure that the selected literature was coherent and relevant to the topic of the research. In addition to some exclusion criteria, certain inclusion criteria were applied. Notably, a range of publications is included, including scholarly journal articles, book chapters, and conference papers. A conscious effort was made to avoid ranking or prioritizing based on peer review or specific journal rankings. This approach aimed to encompass a broad spectrum of research sources, while avoiding subjective evaluations or rankings in scientific journals. This provided a more comprehensive view of the research framework and encouraged the exploration of multiple scholarly perspectives and contributions.

3.6 Literature Selection Process

The process of selecting relevant literature consisted of several steps, beginning with a screening of titles and an assessment of the relevance of each publication to the field of study. Based on these criteria, 155 publications proceeded to the next stage. An in-depth review of each abstract was then carried out, whereby qualitative measures were employed to assess compliance with the requirements. The result of this process was the selection of 40 highly relevant publications. These 40 selected results were subjected to an intensive review and evaluation to ensure their consistency with the previously established focus and selection criteria.

After a thorough review, five publications that show significant potential for further investigation and research were selected. To ensure that no important authors or relevant publications were overlooked, the bibliographies of the 40 papers were also reviewed. Following the 'snowballing' principle from Greenhalgh and Peacock's (2005) way of reference tracking, this method aimed to trace additional valuable insights. The search included prominent and widely recognized works that were perceived to provide dedicated contributions to the understanding of business model development, which resulted in an additional six relevant publications.

Through the extensive selection process, eleven publications have been identified. These publications have been closely analyzed in the following section to make a significant contribution to the chosen topic. Applying the concept matrix method developed by Salipante et al. (1982) and adapted by Webster and Watson (2002) refines our literature analysis, providing a structured tool for evaluating scientific papers based on predefined key concepts. Systematically utilizing the matrix enhances our understanding of the

[1] The authors utilized resources accessible through the University of Mannheim's Database-Infosystem (Databases | University of Mannheim (uni-mannheim.de)) to conduct the literature review, ensuring transparency and replicability. Any literature inaccessible through these means was excluded from the review.

literature landscape, facilitating effective comparison between publications (Lubbe et al., 2007). This tailored approach aids in identifying research gaps specific to business model development for industrial product service systems in mechanical engineering and serves as a foundation for the focused examination of our selected eleven publications, ensuring a targeted and insightful analysis aligned with our research objectives.

4. Key Findings

The results section seamlessly integrates findings from the systematic literature review, utilizing a concept matrix to compare eleven identified papers on collaborative IPSS in mechanical engineering. The analysis highlights diverse approaches' strengths and shortcomings, leading to the identification of key phases in IPSS business model development. Based on these insights, a proposed systematic approach, illustrated in Figure 2, synthesizes best practices for a structured and adaptable framework, enhancing our understanding of the complexities in developing effective IPSS business models.

4.1 Results from Literature Review

In initiating our exploration of the key findings derived from the systematic literature review, we employed a visual approach to facilitate comparison among the identified papers. The analysis has been conducted utilizing a concept matrix, as outlined in Table 1 and 2, employing a scoring procedure based on a dichotomous nominal scaling methodology, in which the characteristic under consideration is divided into two different classes, yes and no. This system makes it possible to determine unambiguously whether a particular topic has been dealt with in each paper. We apply the methodology introduced by Dreyer et al. (2019), offering a visually intuitive representation of the data.

The study focused on business model development strategies in collaborative industrial product service systems. Notably, the analysis prioritized Cooper's (2022) latest work due to its consistent updates, and papers by Meier and Boßlau (2013) and Rese et al. (2013) were treated as a unified entity based on shared thematic elements and joint authorship. The evaluation of these eleven identified papers focuses on the consideration of criteria, which have been identified and elaborated in the theoretical background. Specifically, our concept matrix is divided into two distinct tables: Table 1 and Table 2. This is followed by a detailed presentation of the results of this literature review. The selected approaches have different focuses, resulting in differences in how well they meet the defined criteria. Based on the literature review, these approaches cover different aspects of business model development. This provides a wide range of options.

Table 1 encapsulates the papers focus on the five key requirements. These requirements were meticulously elaborated from our primary research question, serving as the foundational pillars guiding our systematic literature review. By aligning the content of each paper with these key requirements, we gained invaluable insights into the general thematic coverage and depth of exploration within the literature.

	Mechanical Engineering	SME	Business Model	Collaboration	(I)PSS
Cooper, 2022	●			●	
Osterwalder & Pigneur, 2011			●		
Annarelli et al., 2019			●		●
Barquet et al., 2015			●		●
Meier & Boßlau, 2013 **Rese et al.**, 2013			●	●	●
Lee et al., 2011			●	●	●
Gassmann et al., 2014			●		
Kaplan, 2012			●	●	
Johnson et al., 2008			●		
Chesbrough, 2007			●		

● indicates that the specific requirement has been dealt with in the paper

Table 1. Concept Matrix – Comparison of Papers Focus on five key requirements

On the other hand, Table 2 delves into the papers centered on the five specific requirements derived from our first subordinal research question. This question addresses the specific challenges faced by small and medium-sized enterprises in mechanical engineering when developing collaborative business models for industrial product systems. The inclusion of these specific requirements in our analysis offers a nuanced perspective, allowing us to ascertain whether the identified papers adequately address these intricate challenges of IPSS.

	Alignment with the value proposition	Integration of the customer	Iterative Process	Life-Cycle Orientation	Support for Creative Thinking
Cooper, 2022		●	●	●	●
Osterwalder & Pigneur, 2011	●	●			
Annarelli et al., 2019					
Barquet et al., 2015	●				
Meier & Boßlau, 2013 **Rese et al.**, 2013	●	●	●	●	
Lee et al., 2011	●	●	●	●	●
Gassmann et al., 2014	●				
Kaplan, 2012		●	●		●
Johnson et al., 2008	●		●		
Chesbrough, 2007	●	●			

● indicates that the specific requirement has been dealt with in the paper

Table 2. Concept Matrix – Comparison of Papers Focus on five key requirements

A key requirement of the study was to address the field of mechanical engineering, which exposed limitations in most analyzed approaches. It has become evident that most of the assessed approaches fall short of meeting this requirement. Generic models, such as Gassmann et al. (2014) or Osterwalder and Pigneur (2011), lacked direct relevance, requiring adaptation for mechanical engineering. The sole exception is Cooper, who released a distinct document evaluating his (Agile) Stage-Gate system exclusively for manufacturers (Cooper and Sommer, 2016). Notably, none of the approaches analyzed specifically focused on SMEs. The absence of specific insights regarding SMEs indicates a gap in the literature that limit our ability to provide direct contributions in this area. Without a thorough understanding of the challenges and requirements unique to SMEs in collaborative IPSS business model development for mechanical engineering, it becomes challenging to offer tailored solutions or recommendations. Consequently, our findings here cannot directly address the needs of SMEs or provide targeted guidance for their participation in IPSS. Nevertheless, it is encouraging to note that almost all of the

methodologies presented, address the issue of the development of a business model in their own unique way. This highlights the diversity and breadth of the available approaches. While addressing the development of IPSS elements, collaboration, and customer integration, it became evident that only a subset of the examined approaches fulfilled these criteria. The transition from product-oriented to customer-oriented development was emphasized, with Cooper's Stage-Gate model (2022) standing out for its iterative approach. However, the majority of models followed a linear process without incorporating feedback loops, neglecting the benefits of iteration.

The analysis also identified a gap in considering the lifecycle orientation, crucial for establishing long-term relationships within an IPSS. Creative ideation techniques, as provided by Gassmann et al. (2014), Osterwalder and Pigneur (2011), and Lee et al. (2011), primarily targeted small-scale innovators, lacking specific focus on service-based ideas.

In summary, the existing models fell short of fully meeting the specified requirements for collaborative IPSS business model development. Limited attention was given to the integration of an iterative approach and the establishment of value creation networks, underscoring the crucial significance of these aspects. Furthermore, detailed requirements of the engineering industry and SMEs were overlooked. While most models emphasized general business aspects and specific topics like value proposition and customer integration, only Lee's approach (2011) came close to meeting collaborative conceptualization requirements, necessitating the development of a customized methodology.

4.2 Key Phases of IPSS Business Model Development

After synthesizing the results of our systematic literature review, we encountered a nuanced challenge: while individual papers provided valuable insights for certain requirements, none of the papers fully met all the requirements simultaneously. However, it is worth noting that each requirement, with the exception of SME, was addressed by at least one author, demonstrating the breadth of coverage across the literature. Therefore, in order to get a comprehensive understanding, we were required to gather insights from different sources. Recognizing this challenge, we meticulously dissected the content of each paper, extracting key insights to ensure that no critical information was overlooked.

In organizing this wealth of information, we devised Table 3, a comprehensive overview that horizontally aligned the content from each paper. It is noteworthy to mention that the visualization of our phase model is inspired by the work of Wirtz and Daiser (2018), who conducted a literature review on Business Model Innovation Processes.

Authors	Processes				
Cooper, 2022	Idea Generation; Scoping			Build Business Case; Development;	Test & Validation
Osterwalder & Pigneur, 2011	Mobilize; Comprehend			Design	Design
Annarelli et al., 2019	Design of the Offering; Value Co-Creation		Functional Integration with Partners		Degree of Servitization; Pre- and Post-Sale Value Communication; Short-Term and Long-Term Commitments
Barquet et al., 2015	Inputs: Analysis of Strategies, Ideas, Concepts and Opportunities	Help via Examples of Companies that adopted PSS; Methods and Tools		Steps and business model dimentsions; tasks: select predefinded options and perform specific actions to include additional information	Outputs: PSS Proposal
Meier & Boßlau, 2013 **Rese et al.**, 2013	Identifying the Problem Situation	Quantitative Modeling and Simulation; Scenarios & What-Ifs	Team Building through the Combination of various Competences and Qualifications of Policy Makers, Managers from Providers and Customers	Generation and Transfer of Insights; Archiving of Know-How of Different Protagonists;Key PSS Business Model Dimensions	
Lee et al., 2011	Identifying Product/Service Element; Business Model Theming		Identifying Value exchanges between Stakeholders (Value Creation Mechanism)	Identifying the overall Values	Designing Operation System of the Business Model
Gassmann et al., 2014	Initiation: Define a Starting Point and Rough Direction, Describing Value Logic			Ideation: Process of Adapting	Integration: Ideas are going to be gradually elaborated into full-blown Business Models that Describe all Four Dimensions
Kaplan, 2012	Connect: Catalyze something bigger; Enable random collisions		Connect: Collaboration; Build purposeful networks; Together we can design	Inspire	Transform: Into the real world; Design for your users

Johnson et al., 2008	Identify a Clear Customer Value Proposition	Identifying New Competencies and Key Processes	Identifying Key Resources		Identifying the Profit Formula
Chesbrough, 2007	Identify Market Segments; Articulate Value Proposition; Structure Value Chain	Value Network	Linking Suppliers and Customers, including identification of potential Complementors and Competitors		Formulate Competitive Strategy; Specify Revenue Generation Mechanism(s)
Phases	**Idea Generation and Evaluation for IPSS**	**Competence Development Strategy**	**Collaboration Strategy**	**Design of Individual Service Components**	**Design of IPSS Business Model Concept**

Table 3. Phase Model

This structured approach allowed us to systematically compare and contrast the insights extracted from different sources. Upon aligning the content, we observed similarities and patterns emerging, which prompted us to categorize it into five general subjects. By categorizing the content, we uncovered underlying patterns and relationships within the literature. This process not only facilitated a deeper understanding of the individual papers but also revealed broader trends and themes emerging across multiple sources.

Moreover, our analysis unveiled a natural progression of ideas, suggesting a logical sequence that could be organized into distinct phases. These phases, namely:

1. Idea Generation and Evaluation for IPSS,
2. Competence Development Strategy,
3. Collaboration Strategy,
4. Design of Individual Service Components, and
5. Design of IPSS Business Model Concept,

represent key milestones in the development of IPSS business models, each contributing unique insights and considerations. By outlining these phases, we aim to provide a structured framework for understanding the complexities of IPSS business model development.

4.3 Proposed systematic approach for an IPSS Business Model Development

As we approach the conclusion of our exploration into IPSS business model development, we find ourselves at a pivotal point. Having carefully dissected the landscape of existing literature and outlined five key phases, we now stand ready to construct a systematic approach tailored to our unique context. In our analysis, we draw inspiration from the work of Cooper (2022), particularly his Agile Stage Gate Model, which is among the 11 papers examined in our study. Notably, Cooper's model is the sole paper explicitly focused on Mechanical Engineering, a core topic within our research scope. We have therefore chosen to align with Cooper's general framework, as the phases identified

in our study share notable similarities with his stages, providing a solid foundation for our proposed systematic approach.

The Agile-Stage-Gate model, spanning from its inception in 1990 to the latest version in 2022, emerges as a robust technique for systematically designing the innovation process. Cooper's model facilitates step-by-step idea development, verification, and validation, addressing the evolving needs of business and the innovation landscape. It stands out for its ability to cater specifically to mechanical engineering requirements while seamlessly integrating collaboration, iterative processes, customer integration, lifecycle orientation, and creative thinking into the development process (Cooper, 1999, 2016, 2022).

Based on solid understanding of the Stage-Gate model, we next focus on drawing upon key insights gathered from earlier findings, synthesizing a specialized reference methodology. This methodology is meticulously crafted by integrating best practices identified from the literature and informed by a detailed review of eleven scholarly papers, guiding the structure of the framework.

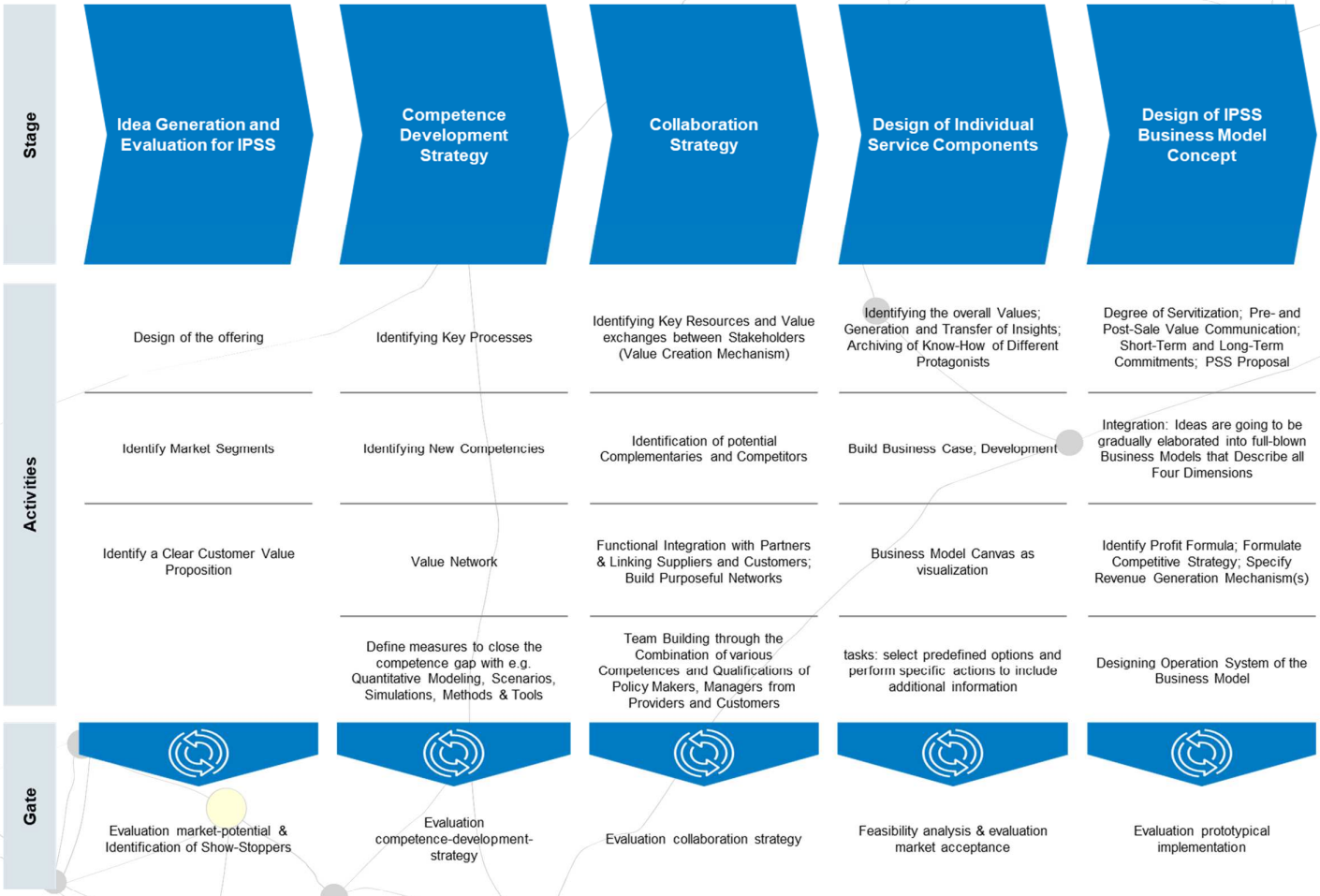

Figure 2. Reference Method

Figure 2 visually encapsulates the developed reference methodology, showcasing its adaptability and integration, especially aligned with Cooper's model. This iterative

process manages uncertainties by allowing adaptations to new information and customer feedback, ensuring continuous stakeholder engagement (Cooper & Sommer, 2016).

The subsequent discussion provides an in-depth analysis of activities and gates within each phase of the Agile-Stage-Gate model, starting with the "Idea Generation and Evaluation for IPSS", which involves creating a visionary concept of the future value proposition and business model, emphasizing creativity and idea development without delving into technical or corporate specifics. Here, innovation impulses, "offering design," and customer value proposition play pivotal roles, with a gate assessing market potential and identifying obstacles, prompting adjustments if necessary (Annarelli et al., 2019; Chesbrough, 2007; Johnson et al., 2008).

The following phase, "Competence Development Strategy" aims to identify the competencies required to realize the envisioned IPSS and assess the company's existing resources. The approach involves analyzing current capabilities and outlining actions such as training, hiring, and collaborations to address competency gaps. This involves identifying key processes, analyzing the company's position in the value network, and closing competency gaps, with a gate evaluating the strategy's acceptance and feasibility (Johnson et al., 2008; Chesbrough, 2007; Meier and Boßlau, 2013; Rese et al., 2013; Barquet et al., 2015).

Moving to the "Collaboration Strategy" phase, the focus is on forming partnerships to bring the IPSS into reality, integrating external partners into the development process. The approach includes selecting suitable partners, drafting agreements, and leveraging collaborations for resource enhancement and market entry. Potential partners are identified, classified, and integrated into purposeful networks. Teamwork is enhanced through specific actions, with a gate assessing partner dedication to the collaboration strategy (Johnson et al., 2008; Lee et al., 2011; Kaplan, 2012; Annarelli et al., 2019; Chesbrough, 2007; Meier and Boßlau, 2013; Rese et al., 2013).

After identifying missing competencies and developing a collaboration strategy, the subsequent "Design of Individual Service Components" phase aims to break down the visionary IPSS into concrete components and detail their design. The approach involves identifying key functions, establishing technical specifications, and defining service levels, laying the groundwork for technical execution. The emphasis here lies within establishing mutual understanding, creating, and refining ideas, and utilizing tools like the Business Model Canvas. A gate reassesses market potential after selecting suitable solutions (Meier and Boßlau, 2013; Rese et al., 2013; Lee et al., 2011; Cooper, 2022; Osterwalder and Pigneur, 2011).

The final phase involves merging service components into an IPSS and shaping the, "Design of IPSS Business Model Concept" which is then delivered to technical development. The approach includes combining developed components, establishing pricing, marketing strategy, distribution channels, and value chain, providing the foundation for IPSS implementation and customer value creation. This involves integrating service components, prioritizing financial aspects, developing an implementation plan, and testing the prototype for economic and technical feasibility. Revisions are made if necessary, resulting in the final IPSS business model concept

(Annarelli et al., 2019; Gasmann et al., 2014; Johnson et al., 2008; Chesbrough, 2007; Lee et al., 2011).

5. Discussion

The insights obtained from our research will be elaborated upon by explaining the specific contributions of the current study, comparisons with previous research, methodological considerations and limitations. It provides a comprehensive analysis of the study's findings in the context of existing literature, highlighting areas of innovation and methodological rigor. By synthesizing insights from the systematic literature review and proposing a systematic methodology, the discussion aims to advance understanding in business model development for IPSS within the industrial sector. This section critically evaluates the implications of the study's findings, offering valuable insights for researchers, practitioners, and decision-makers involved in IPSS business model development.

5.1 Contributions to IPSS Business Model Development

The current study contributes to the understanding of business model development for IPSS in the industrial sector. By synthesizing insights from a systematic literature review and proposing a systematic methodology, this study advances understanding in several key areas. Firstly, the study emphasizes the integration of collaborative elements into the business model development process for IPSS. Recognizing the importance of collaboration among stakeholders in the industrial sector, the study highlights the need for business models that foster partnerships to ensure the successful implementation of IPSS initiatives. Additionally, the study makes a significant contribution by adapting business model development approaches specifically for the mechanical engineering domain. This recognition of the unique requirements and challenges within mechanical engineering enhances the applicability and relevance of the proposed methodology, resonating with practitioners and researchers operating in this field. Moreover, by proposing a systematic approach based on the Agile-Stage-Gate model, the study provides a structured framework for guiding business model development efforts for IPSS. This contribution facilitates clarity in the development process, enabling organizations to navigate the complexities of IPSS effectively and efficiently. Furthermore, while the study did not immediately yield a relevant focus on SMEs, it indirectly addresses the challenges faced by SMEs in developing business models for IPSS. Despite the identified lack of research in this area, the study's emphasis on systematic methodologies and collaboration can be particularly beneficial for SMEs operating in the industrial sector. By offering practical insights and structured guidance, the study indirectly contributes to filling this gap and provides SMEs with valuable resources for navigating the complexities of IPSS business model development.

5.2 Comparative Analysis with Prior Research

Comparing the current study's findings with previous research sheds light on the evolution of business model development for IPSS in the industrial sector. Like earlier studies (Müller et al., 2018a; Müller et al., 2018b), this study underscores the necessity of tailoring business models to the unique characteristics of IPSS, emphasizing

collaboration, innovation, and customer-centric approaches for success. While previous studies may have explored broader aspects or specific sectors (Müller et al., 2018b), this study focuses on IPSS within mechanical engineering. Methodological differences, such as search strategies and analytical frameworks, can lead to varying findings (Boßlau et al., 2017; Müller et al., 2018b), highlighting the impact of research methodologies. Discrepancies between studies may stem from contextual differences, including industrial sectors, regions, and time periods (Müller et al., 2018a). Furthermore, evolving knowledge and methodologies contribute to these differences (Boßlau et al., 2017), alongside methodological variances impacting research outcomes (Müller et al., 2018a). Meier et al. (2011) emphasized the need for new methods in IPSS development, particularly in the planning and development phase. Their findings underscored the importance of addressing the unique characteristics of IPSS and the necessity for innovative solutions to overcome challenges related to resource constraints and delivery processes. Similarly, Pezzotta et al. (2016) highlighted the demand for tools and methods to design and assess PSS offerings and related service delivery processes in industrial companies. Their insights align closely with our research objectives, emphasizing the importance of developing systematic approaches to enhance the effectiveness of IPSS business model development. By critically comparing findings, we deepen our understanding of business model development for IPSS, acknowledging the role of context, methodology, and research evolution in shaping insights.

5.3 Methodological Considerations and Limitations in IPSS Business Model Development Research

The methodological choices made in the study are critical in shaping the research outcomes and their alignment with the research objectives. Adopting a SLR framework provides a structured approach to gathering and synthesizing existing knowledge on business model development for IPSS in the mechanical engineering domain. This approach ensures comprehensive coverage of relevant literature, minimizing the risk of bias and enhancing the reliability of the findings. However, despite its thoroughness, the SLR approach may face constraints due to the availability and accessibility of relevant publications. Additionally, reliance on electronic databases like Lens.org and Google Scholar may introduce selection bias, as these databases may not include all relevant publications in the field. Furthermore, the title-only search approach, while commonly used to minimize the risk of irrelevant documents and false positives, may overlook literature that does not include relevant keywords in the title, potentially excluding valuable insights and perspectives from the review. Establishing clear inclusion and exclusion criteria ensures the relevance and coherence of the selected literature, effectively aligning with the research objectives. The rigorous screening process, including title screening, abstract review, and full-text assessment, enhances the quality and reliability of the selected publications, minimizing the risk of bias. Nonetheless, the exclusion of publications before 2003 may overlook foundational literature that could provide valuable insights into the historical development of IPSS business models, potentially affecting the comprehensiveness of the literature review. The use of a concept matrix for comparing and synthesizing findings from selected papers provides a structured framework for analysis, facilitating the identification of key themes and patterns. This systematic organization of findings into key phases of IPSS business model development offers a clear and coherent narrative, enhancing the clarity and coherence

of the discussion. However, the reliance on existing literature may restrict the novelty and originality of the findings, as the study primarily builds upon established theories and methodologies, potentially limiting the potential for theoretical contributions and innovative insights. In summary, while the methodological choices made in the study demonstrate several strengths in terms of rigor, relevance, and clarity, they also have inherent limitations that need to be acknowledged and addressed. By critically reflecting on these choices, the study can enhance the validity and reliability of its findings, contributing to the advancement of knowledge in the field of IPSS business model development.

During the systematic literature review, a significant finding emerged, prompting further investigation. Despite Müller et al. (2018a) already identifying a lack of tailored solutions addressing SMEs, our SLR also revealed the limited focus on SMEs in collaborative IPSS business model development, notwithstanding their significance in the industrial sector. Potential explanations include research agendas favoring larger enterprises and SMEs facing barriers to participation. However, recent work by Renz et al. (2024) has addressed this limitation by empirically validating the proposed methodology, including testing it with SMEs. Renz et al.'s (2024) results provide valuable insights and validation for the practical applicability of our proposed methodology, thereby mitigating potential limitations.

To conclude, the findings of this study offer valuable insights for advancing business model development in the domain of IPSS, providing practical guidance and strategic recommendations for stakeholders across the industrial sector.

6. Conclusion

In conclusion, this study contributes to the field of business model development for IPSS in mechanical engineering. By synthesizing existing literature and proposing a systematic methodology, we have addressed critical gaps and provided practical insights for industry practitioners and researchers.

Through critical comparisons with previous research, this study has highlighted the evolving landscape of IPSS business model development, emphasizing the need for context-specific solutions and innovative methodologies. Accordingly, our research underscores the importance of context-specific solutions and innovative methodologies in business model development, shedding light on emerging trends and challenges in the field.

One of the key contributions of our study is the demonstration that innovation in business models doesn't always necessitate entirely new frameworks. Instead, by adapting and modifying existing models to meet the specific needs of a particular industry or sector, researchers and practitioners can achieve more tailored and effective solutions. This approach allows for the integration of general business model principles with industry-specific requirements, facilitating a more comprehensive understanding of business model development.

Furthermore, by exploring the intersections between general business model principles and industry-specific requirements, our study provides a framework for exploring these intersections and offers a roadmap for future research endeavors. It encourages scholars

and practitioners to adopt a nuanced approach that integrates foundational business model theories with sector-specific insights, thereby fostering a more holistic understanding of business model development. This nuanced perspective not only enhances the applicability of business model research across diverse industries but also drives innovation by encouraging the exploration of novel methodologies and frameworks tailored to specific contexts.

Looking ahead, future research endeavors should prioritize addressing the specific challenges and opportunities faced by SMEs in collaborative IPSS development. Despite their significance in driving innovation and economic growth, SMEs remain underrepresented in the literature on IPSS business model development. Therefore, there is a pressing need to conduct targeted studies or surveys focused explicitly on SMEs, exploring their unique contexts, capabilities, and needs. By understanding the barriers hindering SME participation in collaborative IPSS initiatives and identifying strategies to overcome them, future research can foster a more inclusive and holistic approach to IPSS business model development.

Furthermore, future research should aim to validate proposed methodologies through empirical studies involving SMEs, as demonstrated by the work of Renz et al. (2024). By testing the applicability and effectiveness of tailored methodologies in real-world settings, researchers can provide practical insights and recommendations for SMEs seeking to engage in collaborative IPSS development.

In summary, while this study represents a step forward in advancing the understanding and practice of business model development for IPSS within the industrial sector, there is still much work to be done, particularly concerning the inclusion and support of SMEs. By embracing these future research directions, scholars and practitioners can collectively contribute to the creation of sustainable and effective IPSS solutions that drive economic growth and societal impact.

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