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Smart Cities and Product-Service Systems—A Conceptual Framework for Urban Sustainability

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ABSTRACT

This conceptual paper delves into the validity of product-service systems (PSS) in driving smart city development. Existing research often treats smart cities as primarily technology-driven constructs, overlooking how organisational measures and strategies such as PSS can contribute to their sustainability ambitions and, thus, smart city initiatives. Through an integrative literature review of selected 145 academic papers across smart cities, sustainability, innovation, digitalisation and product-service systems, this paper introduces a framework that maps PSS onto six core dimensions of the Smart City concept—dimensions identified from the previous research, never before presented together. The findings reveal that PSS enables organisations to transcend beyond isolated organisation focused sustainability driven solutions into wider smart urban surroundings and capabilities. The framework emphasises how PSS can contribute to environmental goals, governance reforms, social inclusion, and economic resilience, thus, being able to provide value for both private and public actors, and citizens. The paper addresses a key research gap and calls for empirical validation to further study how PSS can contribute as a scalable and designable enabler of smart city development.

1 | Introduction

The smart city concept has developed as a proactive solution to the increasing challenges of urbanisation. As more people move to cities, increasing pressure on resources, energy and infrastructure calls for smarter, more adaptable urban systems [1]. A smart city tackles these challenges by integrating smart energy solutions, sustainable mobility, co-creational innovation, inclusive governance, and stakeholder participation to enhance sustainability and resilience [2–4]. Additionally, emerging technologies, data analytics, and state-of-the-art Information and Communication Technologies (ICT) play a key role in this transformation, aiding cities to holistically address environmental, economic, social and cultural sustainability needs [4–6].

Although numerous studies explore how organisations adopt various ‘smart solutions’ to promote sustainability and smart city development, the role of product-service systems (PSS) in this context remains largely overlooked. PSS can enable organisations to take a more proactive role in shaping smart city initiatives by interconnecting innovation with stakeholder needs and long-term sustainability goals. Through collaborative governance, co-creation, and stakeholder engagement, organisations can help bridge the gap between technology-led solutions and user-centric outcomes [7, 8]. By participating in smart city initiatives, they can also generate internal and external value through more responsive and integrated offerings. As sustainability challenges intensify, organisations must recognise their environmental, economic, and social responsibilities and

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adopt strategies and measures that reflect these priorities. This directly fosters the smart city objectives, which emphasise innovation, inclusiveness, and sustainable economic growth [9].

Among the various operating models organisations adopt to advance sustainability, product-service systems (PSS) provide a viable and increasingly relevant option. Rather than relying solely on traditional product-based models, businesses are adjusting towards service-oriented approaches that drive environmental, economic, and social objectives. PSS enhances organisational adaptability by enabling flexible combinations of products and services tailored to changing customer needs and resource constraints [10]. This approach advances the transition from product-focused operations to service-dominant procedures (i.e., *servitisation*), in response to growing market segmentation and increasing customer expectations [11]. By integrating innovative business models with PSS, organisations can strengthen long-term customer relationships, improve and broaden value delivery, and contribute to wider sustainability targets [12, 13].

PSS modes act as enablers for organisations to reduce material consumption, lower emissions, and adopt circular economy principles. This is primarily due to PSS' versatility, adaptability, and embedded design capabilities [14]. When combined with advanced digital technologies, such as the internet of Things (IoT), artificial intelligence (AI), machine learning, and big data analytics, PSS enhances decision-making, optimises resource use, and improves cost efficiency. These utilisations and benefits drive greater openness, knowledge sharing, and trust among stakeholders [15, 16]. The connection between PSS and smart city objectives becomes evident in areas such as stakeholder engagement, life cycle management, and environmental awareness, all of which are necessary components in both domains [17–19].

Despite advances in sustainable urban development and smart city research, the role of PSS within smart city frameworks remains largely underexplored. This is notable given the clear overlap in their core principles: sustainability, innovation, digitalisation, and stakeholder engagement. The convergence of these themes suggests that PSS should be recognised as a relevant solution for advancing smart urban sustainability, particularly through the actions of organisations. This paper addresses the theoretical gap between smart city and product-service system concepts by emphasising how businesses and other organisational actors can contribute to smart city objectives through the implementation of PSS.

Few studies, such as [20] on PSS in urban planning and [21] on PSS innovation in smart cities, have delved into the connection between PSS and urban development. This paper advances the discussion by explicitly linking PSS with the multi-dimensional smart city paradigm. Based on an analysis of over 250 academic articles on smart cities and PSS, the study uncovers strong conceptual linkage between the two, identifying how PSS can promote smart city preconditions, goals, and initiatives. It provides a new perspective by indicating how organisations can contribute to 'shared smartness', a collective capability that promotes more integrated and responsive urban development.

The paper begins with a methodology section, outlining the literature-based approach that informs framework development and analysis. It applies integrative and review techniques to examine existing research on smart cities and PSS, with a focus on PSS. The literature review then explores the relationship between smart cities and PSS, particularly their role in businesses, organisations, and urban communities, thus including organisations. After the literature review, laying the foundation for this paper's framework, the 'Analysis' section presents the framework, followed by 'Discussion' that interprets its findings and relevance. Finally, the 'Conclusion' part summarises key insights, contributions, and directions for future research.

2 | Methodology

This research paper applies an integrative literature review approach to study the conceptual interconnection between the smart city and product-service systems (PSS) concepts. The review is based on a cross-disciplinary analysis of 264 initially selected articles, of which 145 were ultimately utilised, spanning fields such as smart cities, product-service systems, sustainability, innovation management, and urban development. The purpose was not to assess PSS or smart cities in isolation, separated from each other, but to critically scrutinise their potential overlapping themes and similarities in objectives and capabilities, particularly in issues, for example, sustainability objectives, value creation, stakeholder engagement, co-creation and innovation—and simply, what constitutes a smart city, what aspects and dimensions does this concept include. The initial literature search was conducted using Scopus and Web of Science, applying combinations of keywords such as '*smart city*', '*product-service systems*', '*PSS*', '*sustainability*', '*urban innovation*', '*urban development*'. Although early results expressed researched applications of PSS in industrial, product, and product-service innovation contexts, and smart city concept was indicated primarily through technological or governance perspectives, few research addressed the interconnection of these two concepts. This identified gap cemented the paper's objective and research problem: to conceptualise and argue that PSS should be considered a valid and relevant, though currently underused, measure for organisations contributing to smart city development.

This literature review adopts an *integrative literature review* approach, which is suitable for developing new conceptual perspectives by merging insights and doctrines from diverse and often very disconnected bodies of academic literature. Unlike systematic reviews, focussing on assembling empirical findings or tracing chronological developments, an integrative review seeks to reinterpret and reframe existing knowledge to propose novel theoretical advancements. This methodology enables the incorporation of both theoretical contributions and applied studies. Hence it was deemed as a valid and reliable method for bridging the found gap between smart city and PSS literature. In this context, the review did not follow a strict systematic protocol. Instead, it prioritised thematic relevance, conceptual complementarity, and analytical depth. This approach enabled the development of a framework that connects PSS with the

multi-dimensional Smart City concept. This model guided the literature selection process by targeting articles that would deliver clear conceptual or practical insight and value. Priority was given to sources linking smart city development and PSS through themes like sustainability, governance, digitalisation, organisational innovation, and stakeholder engagement.

3 | Literature Review

This section studies the multidimensional concept of the smart city, tracing its evolution in response to modern urban challenges. The literature review considers both academic research and industry perspectives, focusing on the key components that define a smart city and shape its development. Emphasis is placed on the coalescence of technology, organisational smart measures, and stakeholder-centric approaches. This perspective lays the foundation for investigating the connection between smart cities and PSS.

4 | The Smart City Concept

Cities, as centres of human activity, face growing challenges due to rapid urbanisation. More than half of the global population now lives in urban areas, putting increasing pressure on infrastructure, energy, transportation, and public services [22, 23]. Although cities drive economic growth and contribute significantly to global GDP, they also generate high greenhouse gas emissions and consume vast amounts of resources [6, 17]. This dual role requires comprehensive and targeted sustainability strategies. Hence, in the face of urban challenges and financial constraints, the smart city concept seeks to balance economic growth holistically with environmental, social, and cultural sustainability [18, 24].

Smart city development relies on advanced energy systems and digital technologies to optimise core urban functions, such as mobility, public services, and infrastructure management, thereby improving residents' quality of life and advancing more efficient business operations [2]. This 'green transition' extends beyond emissions reduction and resource efficiency to include systemic improvements in areas, such as transportation, water supply, waste management, and energy use [17, 18]. A key element of this transition is the creation of agile governance and operational structures that can respond to demographic shifts and harness human capital. Smart cities function as interconnected systems for their stakeholders, where citizens, businesses, and public sector operators interact to reinforce one another, creating a more efficient, inclusive, responsive, and smart urban environment [4, 25, 26]. In smart cities, companies depend on advanced digital technologies and ICT solutions to collect, analyse, and apply real-time data for optimising resource use, improving service delivery, and enhancing operational efficiency. These capabilities enable businesses to respond more quickly to demand fluctuations, reduce costs, and meet the sustainability targets. For organisations, this approach emphasises the importance of product-service systems, stakeholder engagement, and the potential of PSS in achieving smart city objectives [20, 21].

Although smart city literature has traditionally focused on smart energy, advanced digital solutions, and sustainable mobility there is growing interest in its human-centred aspects. Such academic perspectives emphasise a holistic approach to sustainability that extends beyond technology to include all economic, social, cultural, and environmental dimensions. The authors in refs. [27, 28] stress the importance of human-centred necessities such as inclusiveness, security, social relationships, and education in developing smart cities. Additionally, the authors in refs. [29, 30] emphasise social sustainability, stakeholder participation and engagement as keys to increasing quality of life, integrating human impact and well-being with energy efficiency and resource optimisation. Governance structures are also a focus point in these academic discussions, particularly in participatory 'smart governance' and citizen engagement—that is, 'smart people'. These perspectives emphasise co-creation and innovation, as well as collaborative governance as essentials to smart city development [31, 32]. This focus on participatory models and human centeredness in smart city design clarifies the role of businesses, organisations, and PSS in smart city development context. It brings focus to social sustainability, human capital, and stakeholder engagement, all necessary components for advancing smart city success.

Both refs. [33, 34] bring forward the important role of businesses within smart city context. Rather than considering companies solely as economic contributors, they call for an approach where also businesses actively participate in a city's holistic sustainability endeavours and decision-making processes. Such need resonates with the concept of participatory governance, positioning businesses among key actors in both the development and implementation of smart initiatives. Similarly, refs. [35, 36] emphasise the importance of collaboration among all economic actors in smart cities, driving innovation in business models across both the private and public sectors. They argue that businesses are not just contributors but essential innovators and co-creators of value within the smart city framework. This perspective reinforces the idea that organisational innovation can drive cities towards smart development. However, despite these insights, smart city literature lacks examination of PSS and its potential for organisations to enhance their participation in smart city initiatives and objectives. This gap demands further research on the role of PSS methodologies within the smart city paradigm.

4.1 | The Key Determinants of the Smart City Concept

To better understand the complexities and dimensions of the smart city concept, it is useful to start by identifying and categorising the concepts key determinants (Table 1) based on definitions from the studies/references thus far utilised. These determinants define both the functional and strategic dimensions of smart cities. The table list these core components into four main categories: technological foundations, governance and institutional aspects, social and human factors, and economic and business roles. Each category defines key attributes that structure smart cities and guide the analysis of their multidimensional impact.

As this paper presses ahead from the previously established conceptual groundwork, the focus now moves towards developing an all-encompassing smart city framework. This framework, based on a broad range of smart city research, will bring together the concept's key categories, principles, components, domains, factors, and key performance indicators (KPIs), all identified by previous research, yet never presented together. Initially, it will outline the complexity and various dimensions of the smart city concept in whole, laying the foundation for the later linkage of PSS into the smart city design.

The next sections delve into the key dimensions of the smart city framework. After discussing PSS in the final part of the literature review, the 'Analysis' section will introduce a framework that integrates all previous research established smart city concepts with PSS. This integration addresses a gap in existing research, concerning the role of businesses and organisations in smart city development.

4.2 | Smart City Framework

This section synthesises key dimensions of smart city frameworks from various studies, connecting them with the focus of this research. The aim is to integrate these dimensions into a comprehensive framework, serving as a foundation for the more detailed and comprehensive framework of this paper presented later in the 'Analysis' section.

4.3 | Integrating Smart City Categorisation and Principles

To clarify the foundational aspects of smart city development, Table 2 integrates two key dimensions: smart city 'categories' [37, 38], and 'principles' [30, 38]. This table compares different

categorisations of smart cities with the fundamental principles that guide each category's development.

4.4 | Smart City Components and Domains

This section divides the key 'components' of a smart city into hard and soft 'domains' (Table 3), indicating the dual nature of smart city development, including both tangible and intangible elements. The six essential components that define a smart city, as identified in previous research [1, 6, 17, 28, 39], are further divided to the mentioned domains [6, 40].

4.5 | Smart City Factors and Performance

A connection between smart city 'factors' and 'key performance indicators' (KPIs) is next established to clarify how smart city performance is assessed (Table 4). The table presents key factors driving smart city initiatives [40–42] and matches them with relevant KPIs [1, 43, 44]. This comparison provides a structured view of how these factors contribute to measuring and evaluating smart city development and effectiveness.

5 | Product-Service Systems (PSS)

As businesses and cities both pursue sustainable, user-centered solutions, product-service systems integrate products and services to address diverse customer and stakeholder needs [45, 46]. However, designing and implementing effective PSS requires addressing sustainability issues on economic, environmental, and social levels [11, 47]. This research examines PSS' potential across these levels holistically. As utilisation and customisation of PSS develop and grow, balancing customer needs with sustainability necessities becomes increasingly important. This emphasises the role that PSS' design capabilities

TABLE 1 | The determinants of the smart city concept.

A determinant for a smart city	Explanation
Technological foundations	<ul style="list-style-type: none"> – Information and communication technologies (ICT) and digitalisation – Data analytics – Standardisation and data sharing – Fostering environmental sustainability through emerging technologies and smart energy solutions
Governance and institutional aspects	<ul style="list-style-type: none"> – Interconnected ecosystem – Participatory governance – Stakeholder engagement – Holistic sustainability and its optimisation
Social and human factors	<ul style="list-style-type: none"> – Human-centric focus – Social and cultural sustainability – Quality of life enhancement
Economic and business roles	<ul style="list-style-type: none"> – Role of businesses and organisations – Sustainable economy

TABLE 2 | Integration of smart city categorisation and principles.

Smart city categorisation	Corresponding smart city principles
Technological smart city: Focus on the use of technology for urban infrastructure and solutions development and services.	– Holistic strategy implementation instead of merely technology lead.
Organisational smart city: Focus on new ways of organising and implementing initiatives and emphasising the role of organisational innovations.	– Introducing integrated smart solutions from the fields of ICT and digitalisation, smart energy and -mobility. – Governance with bottom-up approach, promoting comprehensive stakeholder engagement.
Collaborative smart city: Focus on stakeholder involvement including triple and quadruple-helix models.	– Promoting wide collaboration with helix models (i.e., triple and quadruple). – Promoting wide cross-sectoral collaboration with helix models.
Experimental smart city: Focus on holistic sustainability via exploratory pilot projects, RDI, and prototypes.	– Governance with bottom-up approach, promoting stakeholder engagement. – Introducing integrated smart solutions from the fields of ICT and digitalisation, smart energy and -mobility. – Fostering citizen-centric approach, entrepreneurial aspects, and open innovation.

TABLE 3 | Smart city components and their domains.

Smart city components	Hard or soft domain
Smart mobility and transport	Hard domain
Smart buildings and urban infrastructure	Hard domain
Smart environment and energy	Hard domain
Smart economy	Soft domain
Smart governance	Soft domain
Smart people and human capital	Soft domain

have in shaping innovative solutions [48–50]. Indeed, when considering traditional PSS models, this paper sees the concept's design capabilities as a powerful tool in enabling a new range of opportunities for innovation, stakeholder engagement, and digital data utilisation, enhancing both environmental and social sustainability, as well as the economic viability of PSS in smart cities [51, 52].

In the context of PSS, design plays an important role by making solutions more scalable, flexible, and targeted. This allows PSS to address complex interdisciplinary challenges while adapting to dynamic business environments and the diverse needs of stakeholders [53, 54]. Such volatility demands a solution-oriented yet context-sensitive approach, which is essential for the successful customisation and development of PSS. This approach not only drives innovation but also enables the design process to navigate and harness the complexities arising from users, stakeholders, markets, and operational environments, transforming these challenges into opportunities for novel and sustainable solutions that can drive smart city development [20, 55].

PSS provides a structured approach that integrates products and services into comprehensive solutions. PSS models can be

product-focused, use-focused, or result-focused, each suited to different customer needs and business strategies [56, 57]. Innovation in PSS is driven by the coalescence of offerings within a System-of-Systems (SoS) framework, which emphasises life-cycle management and sustainable production [58, 59]. This method leverages digital technologies to promote collaboration, increase product value, and advance circular economy practices [58, 60]. The future of PSS is increasingly shaped by advanced digitalisation and the use of smart technologies, connecting with sustainable development goals [61, 62].

5.1 | Designing PSS

Businesses adopt PSS to remain competitive, respond to changing customer needs, and address sustainability goals [63, 64]. This change requires rethinking traditional models by interconnecting service design with core competencies and infrastructure. Implementation often demands business model transformation and organisational restructuring [65, 66]. An important success factor is maintaining a functional balance between product, service, and resource layers to achieve efficiency, effectiveness, and sustainability [48, 67, 68]. The design process of PSS typically begins with an ideation and problem statement phase that identifies fundamental needs and requirements for PSS' design changes. This is followed by detailed product and service design, subsystem integration, and testing to ensure satisfaction for both providers and users [69–71]. In practice, however, PSS design is inherently iterative, requiring continuous refinement and feedback circuits [15, 72, 73]. Bridging theory and practice, functional analysis frameworks help annexing product and service development with stakeholder needs [74]. Multi-disciplinary collaboration is essential for effective knowledge sharing and the creation of cost-efficient, user-centred PSS solutions ([75]; [76]).

TABLE 4 | Linking smart city factors with KPIs.

Smart city factors	Smart city performance in KPIs
Natural environment	<ul style="list-style-type: none"> – GHG emissions reduction – Air quality – Resource utilisation – Circular economy ratio
Built infrastructure	<ul style="list-style-type: none"> – Infrastructural efficiency – ICT and advanced digitalisation
Technology and energy	<ul style="list-style-type: none"> – Technological adoption rates – Digital security measures – Energy efficiency – Renewable energy generation ratio
Economy	<ul style="list-style-type: none"> – Economic growth – New business creation – Innovation rates – Cost of energy and living
Governance	<ul style="list-style-type: none"> – Implementation and success rates of climate, energy and mobility – Strategies and action plans – Stakeholder engagement metrics
Policy	<ul style="list-style-type: none"> – Legal framework adaptability – Policy implementation success rates
People and communities	<ul style="list-style-type: none"> – Community and citizen involvement – Social equity – Quality of life indicators
Organisation and management	<ul style="list-style-type: none"> – Effectiveness of management strategies – Organisational performance metrics

5.2 | PSS Design Methodologies

The design methodologies for PSS include several approaches, each addressing the complex and multifaceted nature of PSS. By promoting systematic innovation, holistic sustainability, and customer-centricity, they emphasise the importance of seamless product-service integration in designing sustainable and user-focused PSS. Table 5 provides an overview of these methodologies.

5.3 | PSS Design Benefits and Challenges

The change to PSS, and to take in to account its design capabilities, represents a big transformation for businesses, providing both vast opportunities and tricky challenges. Table 6 presents a comprehensive overview of key benefits and challenges within six categories. The table emphasises the need for balanced strategies and operating models that leverage benefits while effectively addressing challenges.

The benefits and challenges of designing PSS, outlined in Table 6, provide insights bearing kinship with smart city objectives. Academically, the most recognised benefits include enhanced customer experience, business growth, and improved operational efficiency. Customisation, market differentiation, and value enhancement drive customer experience, while diversification and new market opportunities advance business growth. Additionally, operational and service efficiencies, as well as ability to promote circular economy initiatives—all vital for economic and environmental sustainability—associate with smart cities' goals of fostering innovation, competitiveness, stakeholder engagement, as well as job and business creation.

On the other hand, many of the challenges encountered in implementing PSS reflect the structural and organisational difficulties found in smart city development. Both involve complex systemic transitions that demand changes in institutional logic, business models, and actors' behaviour. A notable obstacle in both contexts is the transformation of organisational culture to foster sustainable and innovation-oriented practices. Resistance can originate from entrenched attitudes, low trust in new operating models, and limited interdisciplinary competence. These factors can prevent both PSS implementation and smart city governance reforms on a larger scale. Furthermore, financial constraints and budgetary pressures can affect small and medium-sized enterprises (SMEs) in particularly, in deploying PSS. The same constraints may hamper municipalities as well as other urban stakeholders and public sector actors attempting to adopt and maintain smart and inclusive infrastructure and services. In both contexts, demonstrating the economic viability of new models, whether PSS offerings for businesses or smart city solutions for municipalities, requires overcoming uncertainty related to investment returns, adoption rates, and evolving regulatory frameworks. These structural parallels emphasise the relevance of PSS not only as a sustainability-enabling measure for organisations but as a targeted response to some of the wicked problems that smart cities face. Thus, PSS provides structured potential to advance smart city development by tackling systemic barriers such as organisational inertia, fragmented service delivery, and lack of linkage between business models and long-term urban policy goals.

Beyond the challenges outlined in Table 6, additional hurdles can impact the implementation and operation of PSS. One of the most significant concerns is financial and operational risk, particularly for small and medium-sized enterprises (SMEs), as briefly mentioned before. Limited resources and capabilities often make the transition to PSS models more financially and logistically demanding for these organisations. Additionally, privacy and ethical concerns are also an issue, especially as PSS models require and seek deeper customer engagement and data collection. As businesses move towards closer interactions with customers, they must address issues related to for example, data privacy, ethical data use, and regulatory compliance to maintain trust and transparency. Moreover, research and methodological gaps in PSS and its various designs indicate the need for ongoing studies and refinement of existing frameworks. Developing more effective methodologies will help organisations navigate the complexities of PSS and transition successfully to these measures.

TABLE 5 | Various PSS design methodologies.

Methodology	Key objectives	Core features
Systematic innovation method [49, 77]	Enhancing value creation and capture, seamless integration with physical products.	Focus on systematic innovation, integration of services and products.
Sustainability-focused design aka sustainable product-service system (S. PSS) [50, 77]	Promoting sustainable production and consumption, aligning with societal change.	Evaluation of environmental, economic, and social impacts: Sustainability-driven design.
Customer-centric design [78]	Incorporating customer requirements and preferences from the outset.	Tools like the kano model and FAHP (fussy analytic hierarchy process), user-focused design approach.
Holistic service supportability [79]	Maximising customer value, minimising life-cycle costs.	Integration of usability, quality, and maintainability in design.
Comprehensive approach method [80]	Ensuring PSS designs are customer-centric and contextually relevant.	Topic analysis, persona, and scenario development.
Efficiency and competitiveness model [51, 81]	Facilitating customisation and optimising performance.	Leveraging common functions across configurations, PSS family model.
Strategic insights framework [82]	Understanding PSS capabilities' impact on corporate performance.	System dynamics, simulation-based business case analysis.
Iterative refinement process [69, 83]	Continuous refinement based on consumer feedback.	Emphasis on consumer needs, adaptive PSS solutions.
Product-service system lean design methodology (PSSLDM) [51, 81]	Enhance efficiency, reduce waste in PSS design.	Incorporate lean principles, focus on waste reduction.

TABLE 6 | Benefits and challenges in PSS design.

Category	Benefits	Challenges
Business growth	Diversification, market opportunities, revenue diversification and stability [66, 80, 84, 85]	Economic pressures, market acceptance, strategic positioning [49, 50, 86]
Environmental sustainability	Reduction in ecological footprint, promoting a circular economy [86–89]	Sustainability and environmental concerns, including rebound effects [50, 86]
Customer experience	Customisation, market differentiation, value enhancement, strengthened relationships, improved service delivery [64, 68, 77, 80]	Consumer adoption, understanding and influencing user preferences [83, 90, 91]
Operational and service efficiency	Operational efficiency, resource optimisation [68, 80]	Design complexity, systemic perspective, interdisciplinary collaboration [55, 55, 77, 92]
Inclusivity and accessibility	Financial inclusivity, accessibility to a wider customer base [84, 93]	Cultural and organisational change, transforming organisational culture [86, 94, 95]
Innovation and continuous improvement	Continuous refinement of offerings, fostering innovation [11, 81, 86]	Technological expertise requirements, digitalisation challenges [55, 86]

5.4 | PSS Design in Manufacturing

In manufacturing, the adoption of PSS enables lifecycle-based resource efficiency, promoting circular economy practices such as reuse and remanufacturing, and reduces environmental impacts by transitioning value creation from material output to service delivery ([96]; [97]). PSS promotes circular economy practices by decoupling value creation from material consumption, enabling models such as product leasing, sharing, maintenance, and end-of-life recovery, which extend product lifespans and minimise waste [89, 98]. Each level of PSS (i.e., product, product-service, built environment and social, and

socio-technical), contributes to sustainable urban development making PSS designs powerful tools and enablers of innovation, also in the smart city context [87]. Different types of PSS provide distinct environmental benefits. Function-oriented PSS, for example, encourage sustainable consumption patterns, finding ground from the shared resource models [99]. Additionally, PSS-based business models, which are integral to the circular economy, drive economic growth, resource efficiency, and enhanced customer value [14]. In heavy industries such as mining, for instance, PSS models promote circularity through services such as leasing and material recovery [89]. The interconnection and potential between circular economy models and

smart cities requires companies to adopt PSS mentality and operating models that are digitally enabled and service oriented. Rather than selling products, firms can offer usage-based or performance-based services, such as predictive maintenance or product-as-a-service, which reduce waste and extend product lifecycles. These models rely on advanced digital technologies (e.g., IoT, sensors, data analytics) to monitor usage, optimise performance, and ensure timely interventions. In doing so, PSS and its design capabilities enables continuous value creation and capture while reducing environmental impacts, thus operationalising the core sustainability goals of smart cities [92].

6 | Analysis

This section presents the previous page's stacked Venn diagram (Figure 1), which visually represents the study's framework, 'PSS in Smart City Construct.' The comprehensive diagram illustrates multiple layers of smart city dimensions, including categorisation, principles, components, domains, factors, and performance indicators (KPIs). Green checkmarks highlight where PSS applies within each layer, emphasising its potential role in smart city development. More than just a visual tool, the diagram acts as a conceptual map, indicating how PSS contributes to various aspects of the Smart City concept as well as to the development and objectives of these sustainability driven cities. It expresses the role of PSS in integrating and enhancing technological, governance, social, and economic elements within urban environments. By illustrating the synergistic

relationship between PSS and various smart city dimensions, the framework emphasises the transformative potential of PSS and its various design capabilities and approaches for organisations to take part in the development of smart, sustainable, and stakeholder-centric urban development.

To provide clarity and depth to the framework presented in Figure 1, the following section systematically analyses each smart city dimension identified in the literature. The analysis now focuses on explaining how product-service systems (PSS) contribute to each layer; categories, principles, components, domains, factors, and performance indicators (KPIs). This dimension-by-dimension approach enables a focused and critical analysis of how PSS can serve each smart city layer, particularly through the actions and long-term strategies of organisations. The emphasis is placed on concrete connections, useful relevance, and the capacity of PSS to help operationalise smart city objectives.

6.1 | Smart City Categorisation on PSS Integration

PSS aligns ably with each category of smart city development by offering organisation tools to operationalise their involvement across strategic and functional domains [100]. In the 'Technological Smart City', various PSS designs enable the integration of physical and digital infrastructure by providing combined solutions that enable service delivery and efficiency improvements, for example, in transportation, ICT, smart grid activities,

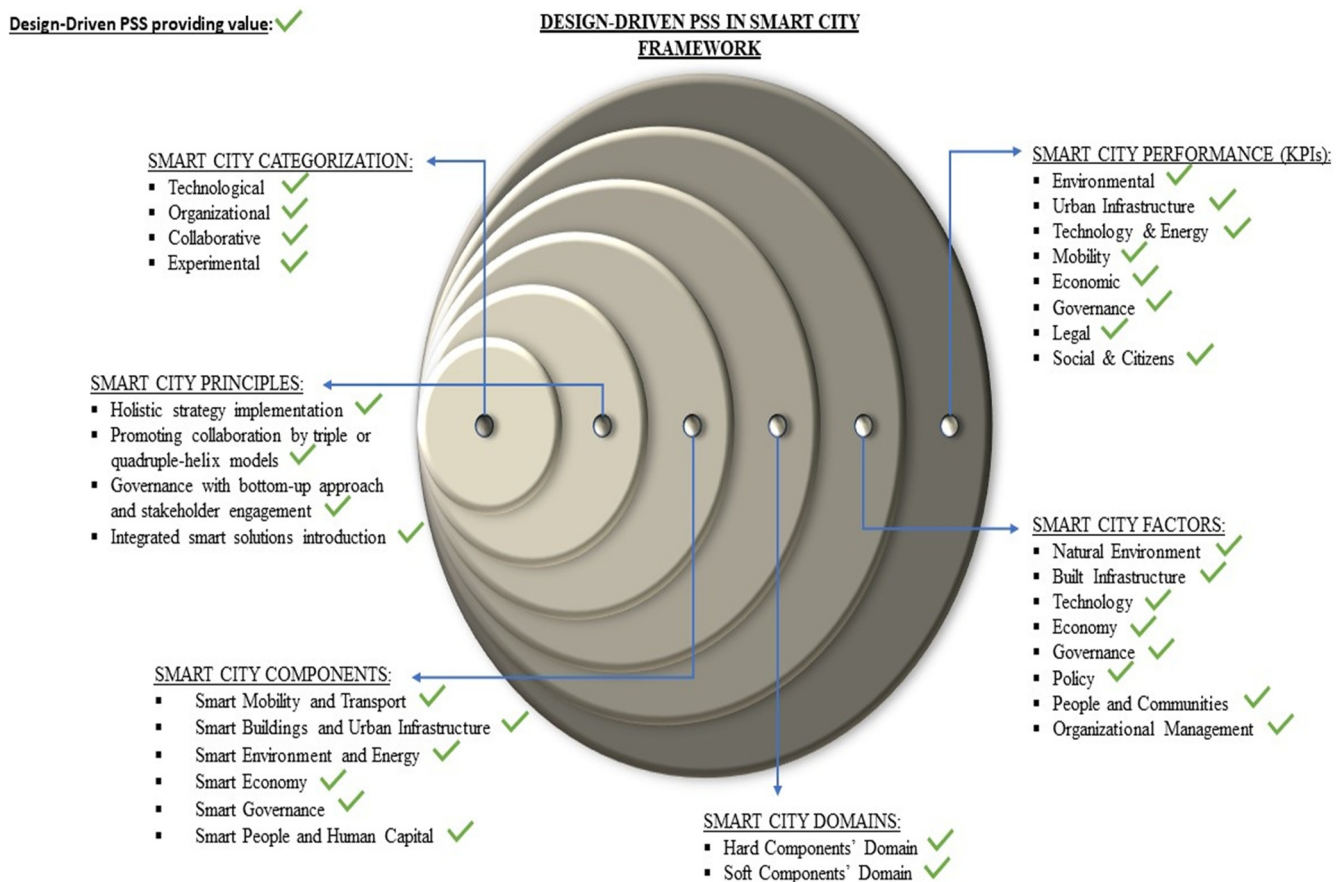


FIGURE 1 | All-encompassing framework of PSS in smart city construct.

and energy systems in general [62, 101]. These systems enhance adaptability by enabling modular service upgrades, facilitating predictive maintenance through real-time data analytics, and tailoring services based on usage patterns, ensuring that technological investments are directly associated with user needs and smart city demand [45, 73]. In the ‘Organisational Smart City’, different PSS models aid organisations in transforming from linear product delivery to service-oriented operations by promoting lifecycle thinking, modular offerings, and efficient resource use. This enables organisations to reorganise processes around long-term customer value, while interconnecting daily operations with sustainability and circular economy objectives [47, 67, 98]. This evolution enables a detachment from rigid, siloed operational models towards more integrated, service-based governance structures that are responsive to stakeholder needs and capable of adapting to evolving social sustainability demands [102, 103]. The ‘Collaborative Smart City’ benefits from PSS through its facilitation of collaborations between public entities, private firms, research bodies, and civil society. The many PSS models and their design capabilities inherently require and thrive from co-creation and stakeholder engagement, thus promoting triple and quadruple helix collaboration and diffused innovation, which is in the core of smart city identity and development [87, 104, 105]. Finally, in the ‘Experimental Smart City’, PSS models enable controlled urban experimentation by providing modular service bundles that can be tested and refined through real-life pilots. Such models enable iterative development cycles by capturing user feedback, measuring environmental performance, and stress-testing service resilience under varying conditions. Thus, this approach not only improves solution relevance but also provides empirical evidence to inform adaptive policymaking and long-term smart urban planning [13, 72, 106].

6.2 | Smart City Principles on PSS Integration

Again, PSS concept finds strong similarities from the key principles that foster smart city development, providing functional means for their operationalisation within organisational operating models and strategies. The principle of ‘Sustainability’ is deeply embedded in the PSS concept’s logic, in its DNA, which encourages organisations to transition from linear, product-based business models to circular, service-oriented systems [35, 107]. Such transition fosters resource efficiency, lifecycle thinking, and reduction of environmental impacts, all also important to smart city concept’s sustainability ambitions [47, 96]. The principle of ‘Collaboration’ is indeed natural to PSS, as its implementation demands active engagement with customers, stakeholders—private and public actors equally, in the co-creation and delivery of services. This advances multi-actor governance and strengthens public-private partnerships, depending on the PSS, within the smart city context [21, 106, 108, 109].

The ‘Openness’ principle is operationalised in PSS through measures that cherish both data transparency and distributed value creation. For example, open data interfaces and interoperable service platforms allow external actors to contribute to and co-develop service offerings [109, 110]. PSS also fosters user

participation by embedding stakeholder control loops into service lifecycles, ensuring that PSS evolves in response to real-time needs and collective input. The principle of ‘Innovation’ is fostered in PSS through modular architectures that allow organisations to iteratively test and adapt service configurations without overhauling core infrastructure. This enables context-specific experimentation with new value propositions, such as pay-per-use models or performance-based contracting, while also integrating emerging digital technologies such as IoT and predictive analytics to refine offerings based on real-world usage patterns [65, 73, 92, 111]. The principle of ‘Justice’ is reflected in PSS through service customisation and accessibility requirements, addressing the diverse needs of different user groups. By enabling flexible access models (e.g., shared ownership, tiered service levels, localised delivery), PSS can reduce economic and social barriers, thereby promoting inclusion and equitable participation in smart city services [112–114].

7 | Smart City Components on PSS Integration

The six widely recognised smart city components—smart people, smart mobility, smart environment, smart economy, smart living, and smart governance—provide a structured framework through which the contributions of PSS can be systematically evaluated. Starting with ‘Smart People’, PSS facilitates structured collaboration between providers and users by embedding feedback paths, adaptive service models, and usage-based data insights. This enhances not only personalisation but also empowers users to influence service evolution, reinforcing a participatory culture and enhancing digital and civic literacy as core components of smart citizenship [9, 83, 115]. This enables organisations to better understand user needs and preferences, building solutions that reflect real-life challenges and aspirations, thus, enhancing human capital utilisation and digital literacy [60, 116]. In ‘Smart Mobility’, PSS contributes by enabling service-based transportation models for example, vehicle-as-a-service, multimodal mobility subscriptions, and shared logistics platforms. These models rely on real-time data and digital interfaces to meet the demand with capacity, reduce reliance on private vehicle ownership, lower emissions, and improve infrastructure utilisation. By moving mobility away from ownership to access, PSS enhances system flexibility, boosting modal integration, and makes urban mobility more inclusive, responsive and smart [117, 118].

Regarding the ‘Smart Environment’, PSS promotes circular economy procedures by transitioning consumption from ownership-based models to access- and performance-based services. This reduces material throughput by encouraging reuse, refurbishment, and longer product lifecycles, minimising waste generation and resource depletion. In smart cities, such change drives integrated environmental monitoring, improves emission control through optimised usage patterns, and enables data-driven ecological footprint tracking, all essential components of smart cities’ sustainability objectives [96, 119, 120]. In the domain of the ‘Smart Economy’, PSS contributes by transforming traditional product-based businesses into service-oriented models that emphasise value-in-use. Such transition promotes servitisation in legacy industries by allowing organisations to

offer ongoing, customised solutions instead of one-time sales. For SMEs, PSS models reduce capital intensity and allow easier market entry through scalable, modular service offerings. Moreover, the coalescence of digital tools, for example, such as real-time usage monitoring and predictive maintenance, enables new value creation logics, encouraging agile, customer-responsive innovation and fostering multifaceted digital entrepreneurship within the smart city context [16, 121, 122]. In the ‘Smart Living’ domain, PSS enhances quality of life by enabling service delivery models that are personalised, adaptive, and responsive to individual and community needs [23, 123]. In housing, for example, PSS allows for integrated living solutions that combine modular housing units with maintenance, energy, enhanced circular economy measures, and sustainable mobility services, creating flexible living arrangements that adapt to demographic and lifestyle changes [124, 125]. In healthcare [126, 127], PSS can contribute to remote monitoring, preventive care, and home-based support services through sensor-enabled devices and data platforms, improving patient outcomes while reducing systemic costs. By embedding data-driven feedback loops into service provision, PSS promotes continuous improvement, accessibility, and user-centeredness, thus operationalising the smart city objectives of inclusive, human-centric housing and living [5, 73, 80]. In the ‘Smart Governance’ domain, PSS can provide collaborative service designs that embed users and stakeholders directly into the design, delivery, and evaluation of for example, public services [128]. For example, municipalities can apply PSS frameworks to co-develop mobility, waste, or energy services with local businesses and residents, switching from top-down delivery to demand-responsive solutions. Such applications support adaptive and open governance by integrating real-time data feedback and performance metrics, enabling swifter policy adjustments and iterative service improvement [129, 130]. Moreover, by linking public sector objectives with private-sector innovation capabilities through contractual or platform-based PSS schemes, cities can foster trust, distribute responsibility over sector lines, and create governance structures that foster transparency, resiliency, and user-centeredness [131]. Focus on participatory governance favours the smart city aspirations of transforming citizens from just passive recipients to active co-creators and co-producers of public value.

8 | Hard and Soft Smart City Domains on PSS

The division of smart city development into hard and soft domains enables a clearer understanding of how PSS contributes across infrastructural and societal dimensions. In the hard domain, which includes energy systems, buildings, mobility, and city/environmental infrastructure, PSS can provide concrete solutions that integrate physical assets with embedded services [20]. For example, in energy and building management, PSS allows service providers to provide packaged energy efficiency solutions, for example, heating-as-a-service or integrated building maintenance, that move the emphasis from ownership to optimised performance [132]. These solutions reduce energy consumption and mitigate emissions while enabling adaptive service enhancements. In mobility, shared service models like vehicle-as-a-service and other car sharing

schemes, maintenance-inclusive leasing, and smart fleet operations reflect how PSS enables sustainable transportation goals’ achievement [133]. In the environmental domain, PSS contributes by embedding circular economy principles into service delivery models, enabling cities to move from linear consumption patterns towards closed-loop systems. For instance, PSS-based municipal services can include equipment leasing and take-back schemes, incentivising product reuse, modular repair, and material recovery. These models reduce landfill dependency and raw material extraction while increasing operational efficiency in waste and resource flows [134–136]. Additionally, PSS enables environmental monitoring as a service, for example, air or water quality tracking platforms offered as integrated service solutions, enhancing urban environmental governance [88]. By joining service models with environmental KPIs, PSS fosters measurable reductions in emissions, energy use, and ecological footprint, directly advancing smart city sustainability objectives [82, 137].

In the soft smart city domain, encompassing economic systems, governance structures, and societal actors, PSS can enable organisational models that focus on responsiveness, adaptability, and inclusive value creation. PSS models can allow dynamic stakeholder engagement through participatory service co-design, fostering co-creation practices, reflecting diverse needs and local contexts [1, 128, 138]. Additionally, in public governance, modular PSS platforms can foster citizen-driven service configuration, allowing communities to influence how services, such as mobility, healthcare, or education are delivered [20]. Economically, PSS facilitates the growth of servitised business models that prioritise long-term relationships over transactional exchanges, helping both private and public actors connecting with local socio-economic goals [91, 139]. Furthermore, service personalisation, enabled through real-time data utilisation, ensures inclusivity by adapting customised delivery measures to all user groups, without forgetting marginalised or underserved populations [73, 140]. Such capabilities help level structural barriers, strengthen trust in institutions, and embed resilience as well as equity into the governance dimension of smart city development. In economic terms, PSS enables the development of digitally enabled, service-oriented business models that reduce dependence on physical product sales, allowing organisations, particularly SMEs, to generate recurring value through usage-based or performance-based services [16, 121]. This transition fosters digital entrepreneurship by lowering entry barriers, encouraging platform-based innovation, and enabling data-driven service customisation [101]. By aligning business incentives with resource efficiency and user value, PSS strengthens economic resilience and diversification in ways that directly contribute to smart cities’ long-term sustainability and competitiveness goals [33]. Additionally, in the social domain, that is, ‘smart people’, PSS can promote the development of services that are not only user-oriented but also adaptive to varying social needs and contexts [27, 141]. By enabling co-creation practices and exploiting user feedback sources, PSS drives the customisation of services that reflect demographic diversity, improve accessibility for marginalised groups, and foster greater civic participation [142]. Such solutions enhance community cohesion, increase digital capabilities, and empower citizens to take an active role in co-creating the services they utilise and need.

9 | Smart City Factors on PSS

Smart city development is formed by multiple factors, determining how technological, institutional, social, and economic factors and their dynamics interact in real life [36]. PSS can provide a targeted and game-changing impact in addressing many of these interrelated factors by providing organisationally focused, stakeholder-oriented, and sustainability outcome-driven models [52]. That been said, under technological factors, PSS models utilise and enable real-time data utilisation, remote diagnostics, and performance-based service delivery [45, 73]. Such initiatives are vital for basic smart city infrastructures such as energy solutions and grid structures, transportation networks and mobility, as well as urban logistics systems on a wider scale [20]. PSS enables the utilisation of ICT, AI, and automation, as well as other emerging technologies, into service architectures by connecting physical assets with advanced digital intelligence [110, 143]. This unity favours predictive maintenance through real-time monitoring and data analytics, enabling early detection of possible system inefficiencies or failures. In addition, it advances dynamic resource allocation by adjusting services to actual demand patterns and trends, thus, for example, reducing waste and optimising energy use ([144]; [68]). The mentioned measures improve the operational responsiveness of wider urban systems and development, for example, transport and logistics, utilities, and energy systems, but also contribute to long-term smart system resilience by minimising downtime, extending asset/solution/product life-spans, and ensuring service continuity under fluctuating conditions due to for example, renewable energy source utilisation, crowd movements, traffic congestion etc.

Regarding institutional and organisational factors, PSS provides an approach to modernise service governance and delivery by bringing together the objectives of public institutions, private actors, and end-users [128, 138]. Organisations adopting PSS models take a leap from transactional product delivery to managing long-term service relationships. Hence, they can address the systemic complexity of urban service supply and demand head on [116]. Instead of providing stand-alone solutions, PSS promotes the coalescence of service delivery across domains such as mobility, energy, and circular economy tied solutions. This fosters continuous value co-creation between providers, users, and stakeholders—public and/or private. These models also provide tools for performance monitoring and adaptive feedback paths, enhancing transparency and linking tightly with smart city governance goals, for example, outcome-based accountability, citizen responsiveness, and cross-sector coordination [21]. In this context, PSS not only drives organisational innovation and enhances co-creation but also establishes shared responsibility for the planning, delivery, evaluation, and continuous development of public services.

On the economic level, PSS models enable SMEs to transform from linear, product-based models to service-oriented value creation by monetising product use rather than ownership. The transition fosters more stable revenue streams, reduces dependency on for example, raw material costs, and by extended product lifecycles and service-linked remanufacturing operating models, even new revenue stream possibilities. Additionally,

PSS designs favour circular economy principles and aid in waste management pressures [121]. Finally, in terms of social and cultural factors, PSS can enable more inclusive service design, as well as participating and engaging co-creation and innovation activities between cross-sectoral set of stakeholders. By co-developing services together with users, organisations can customise their offerings, respecting actual wider community needs, rich cultural contexts, and equity issues. This raises PSS as a relevant enabler of smart cities' human-centred goals [102, 123]. It can, on its behalf, ensure that smart technology initiatives and development steps translate into meaningful social outcomes.

10 | Smart City Performance and KPIs on PSS

Smart city success is often evaluated through performance indicators that measure the effectiveness of urban systems across technological, environmental, economic, and social dimensions. PSS provides a functional and valid means for interconnecting organisational sustainability actions with these key performance indicators (KPIs), enabling measurable accomplishments and contributions to wider smart city development.

For technological performance, PSS models can enhance technology adaptability, data system coalescence, and real-time digital data service responsiveness. Embedded technologies such as IoT, AI, and data analytics, integral to advanced PSS models, contribute to KPIs related to ICT maturity, digital service penetration, and smart infrastructure usage. These indicators track how effectively smart city technologies are deployed and maintained, areas where PSS-enabled organisations can deliver significant value through service optimisation and predictive operations [110, 145]. On the environmental side, PSS can benefit from KPIs related to emissions reduction, resource efficiency, and circularity. By transferring business logic from product ownership to resources of customisation-friendly services, organisations can extend product life cycles, promote shared resource models, and reduce environmental impacts. These outcomes and abilities fit perfectly with smart city concept's identity and goals, for example, net zero objectives, energy efficiency, and sustainable mobility.

From an economic perspective, PSS can contribute to KPIs such as job creation in high-value service sectors, SME innovation and revenue expansion, and public-private partnership and co-creation effectiveness. Organisations transitioning to PSS models often generate new service-based revenue streams, which can enhance local economic resilience, and communities on a larger scale, and diversify the business landscape within cities [108, 137]. Finally, social KPIs, such as citizen engagement and satisfaction, inclusiveness, service accessibility, and stakeholder participation, are strengthened by the participatory and user-focused nature of PSS—a truly essential part of its nature [83, 108]. Organisations delivering personalised, accessible, and co-created services can contribute to improving quality-of-life metrics and fostering inclusive and smart urban development. Consequently, PSS is not just a conceptual fit but a performance-oriented measure that promotes the operationalisation and tracking of smart city goals.

11 | Discussion

This paper strives to conceptualise how Product-Service Systems (PSS) can and should be embedded across the multidimensional framework of smart city development—to be perceived as a valid and relevant measure for its concept. The analysis demonstrates that PSS does not merely resonate with smart city principles and components but quite actively contributes to operationalising them; technologically, organisationally, economically, and socially. This conceptual contribution addresses a research gap by detaching and reframing PSS from a predominantly industrial or product-based organisation strategy to an innovative, smart, and scalable urban development measure capable of supporting broader sustainability transitions and smart city initiatives.

The findings indicate that PSS can enable organisations to function as active and innovative drivers in smart city ecosystems. Through PSS concept's modularity, wide-capability providing digital integration, and inclusive stakeholder-orientation, it provides new perspective for connecting organisational and business activities and responsibilities with smart city dimensions and wider urban sustainability targets. PSS fosters, for example, co-creation, participatory governance, lifecycle-based service provision, and circular economy logic, just to mention a few of its benefits. These elements are in the core of smart city concept. Thus, PSS should be considered as a complementary smart measurement, and as a structuring component in smart city design, in all of its dimensions. Importantly, the presented framework provides value beyond academic theory. For public administrators and planners, PSS provides a path to engage private actors in co-creating smart city identity possessing services and infrastructure. For industries and companies PSS modes introduces tools to expand into service-dominant, sustainability-fostering markets, being able to meet the demands of tightening climate regulations and sustainability development goals (SDG's) and ever-changing consumer preferences. For civil society and citizens, themselves, PSS-based urban services provide the promise of more adaptable, inclusive, and user-sensitive solutions and services that interactively reflect and evolve from the real needs of the users, rather than passively provide top-down assumptions with no engagement and co-creational possibilities.

Although the framework provides a insightful analytical structure, several limitations must be acknowledged. First, as a conceptual paper, it lacks empirical grounding. Although built on a cross-disciplinary literature base, the absence of case studies, field data, or applied validation limits the paper's immediate applicability. Second, while the framework maps extensive points of PSS and Smart City integration, it does not differentiate between levels of maturity or context-specific adaptability across different city sizes, geographical locations, cultures, resource capabilities or governance models. Third, the paper largely prioritises organisational and infrastructural perspectives over individual behavioural or cultural dynamics, which are equally important in smart city literature.

Future research should address these gaps by validating the framework through empirical studies across diverse smart city contexts and organisational types. Additionally, comparative

case analyses could evaluate how PSS is already (formally or informally) used within smart city projects. Further work should also focus on the role of policy instruments, digitalisation standards, and digital data governance mechanisms, either in enabling or hindering PSS adoption in modern city development.

In short, this paper reframes PSS as a system-level mean capable of driving collaborative, sustainable, and innovation-driven urban development. It contributes both to Smart City literature, by expanding its organisational and operational scope. It also contributes to PSS literature, by positioning it within a complex multi-dimensional smart city concept.

12 | Conclusion

This paper reconceptualised product-service systems (PSS) as a relevant and underutilised method for advancing smart city development. By mapping PSS across all core dimensions of various smart city frameworks, the paper introduces its potential to promote sustainability, and stakeholder engagement, as well as embed innovative service-based thinking into smart city development and initiatives. Here, the role of organisations is paramount: they are not to be considered as peripheral actors but rather key agents and enablers of implementing smart city objectives through scalable and sustainable, inclusive and innovative, and user-oriented models.

The novelty of the paper is in its argument of the importance of connecting the two concepts that have evolved and existed in parallel but rarely intersected. They share a kinship. They have similar personality traits. The conceptual framework presents PSS not as a relevant system-level contributor to smart urban development and innovation. It provides useful insights for industry and business, public sector planning, and policy design. This been said, this is purely a conceptual contribution. Its next step, its evolution requires empirical validation. Future studies should delve into how PSS is already being used in urban development and where its integration potentials can be improved. Comparative case analyses, policy assessments, and sector-specific research will be essential for enhancing and testing this paper's framework in real-world.

Author Contributions

Tomi Paalosmaa: conceptualization, data curation, formal analysis, investigation, methodology, resources, supervision, validation, visualization, writing – original draft, writing – review and editing.

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The author has nothing to report.

Consent

The author has nothing to report.

Conflicts of Interest

The author declares no conflicts of interest.

Data Availability Statement

Data available on request from the authors. The data that support the findings of this study are available from the corresponding author upon reasonable request.

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