Journal of Cleaner Production 274 (2020) 123005

Contents lists available at ScienceDirect

Journal of Cleaner Production

journal homepage: www.elsevier.com/locate/jclepro

Sustainable and smart product innovation ecosystem: An integrative status review and future perspectives

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ARTICLE INFO

Article history:
Received 29 February 2020
Received in revised form
11 May 2020
Accepted 21 June 2020
Available online 18 July 2020

Handling Editor: Cecilia Maria Villas Bôas de

Keywords:
Sustainable and smart product innovation ecosystem (SSPIE)
Sustainable and smart product (SSP)
Sustainable product innovation
Innovation ecosystem
Ecosystem

ABSTRACT

Sustainable and smart product (SSP) is a new generation of smart products characterized by servitization and sustainablility concerns. The ever-increasing complexity of SSP provides challenges for enterprises to conduct SSP innovation for sustainability. It is increasingly important for organizations to adjust the innovation strategy from organization-based innovation to ecosystem-based co-innovation. Innovation ecosystem a promising approach to improve SSP innovation and address cross-organizational collaboration issues in co-innovation for sustainability, as it promotes the flow, integration, and allocation of innovative resources and knowledge within ecosystem. However, SSP and innovation ecosystem were investigated separately. The purpose of this paper is to conduct integrative research on SSP innovation ecosystem (SSPIE) for understanding innovation ecosystem-based SSP innovation that lead to better innovation performance and sustainability. The birth, definition, and characteristics were elaborated. This paper contributes to the emerging field of SSPIE by highlighting research gaps for addressing the challenges and suggesting future research directions.

1. Introduction

Sustainable and smart products (SSP) is a new generation of smart products to achieve circular economy and sustainability. In addition to such features as intelligence, connectivity, human interaction, sensing, and autonomy (Tomiyama et al., 2019), SSP is characterized by servitization, sustainability objectives and environmental care(Miranda et al., 2017), such as sustainable smart product-service system (sustainable smart PSS) (Liu et al., 2020). In this context, it is increasingly important for organizations to adjust the innovation strategy for SSP development by implementing sustainable business model to reduce their environmental and social impacts (Evans et al., 2017).

Innovation tends to be knowledge-intensive (Aarikka-Stenroos and Sandberg., 2009; Gao and Bernard, 2018). As a kind of complex products, SSP innovation provides challenges for enterprises to design for sustainability: 1) SSP is a combination of product, service and sustainability; it calls for sustainable business model innovation; 2) Inorder to integrate sustainability into business and innovation, SSP innovation calls for multiple technologies, such as product development technologies, information technology, intelligent technology and green or sustainable technology.

Few firms can independently possess all the capabilities and resource needed in SSP innovation for sustainability. It calls for collaboration of multiple stakeholders (Sanna and Katri, 2019), providing sustainable complementary components and service. Therefore, enterprises must learn to build ecosystem around the products to gain competitive advantages and establish partnership with other firms for value co-creation and co-innovation. From this perspective, it is believed that the competition between enterprises is evolving from the firm level to the ecosystem level (Rong et al., 2019). Firm level competition puts emphasis on the competitive capabilities, resources, and market of a single firm, while ecosystem level competition focus on the performance of an ecosystem as a whole, such as sustainability and co-created value.The term "Innovation Ecosystem" (IE) (Granstrand and Holgersson, 2019) has received much attention from industrial organizations in recent years (Oh et al., 2016). The adoption of IE thinking brings about

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https://doi.org/10.1016/j.jclepro.2020.123005
0959-6526/

Nomenclature

IE	Innovation ecosystem
KIMS	knowledge-based innovation management system
PSS	Product-service system
SME	Small and medium enterprise
SPSE	Smart product service ecosystem
SSP	Sustainable and smart product
SSPE	Sustainable and smart product ecosystem
SSPIE	Sustainable and smart product innovation ecosystem

important transformation in the collaboration of product innovation, providing a broader and systemic view of innovation management beyond traditional firm-based and network-based innovation (Phillips and Ritala, 2019). It is a promising mode to improve product innovation and address cross-organizational collaboration issues in co-innovation, as it promotes the flow, integration, and allocation of innovative resources and knowledge within ecosystem (Xie and Wang, 2020).

The combination of SSP and IE can address the gaps of SSP innovation for sustainability and create more value through the interaction of interdependent actors. Sustainable value flows among stakeholders contribute to the collaborative innovation performance and the achievement of ecosystem sustainability goal.

However, to date, there was a lack of a comprehensive investigation of the innovation ecosystem-based SSP innovation for sustainability. Despite literature on SSP, innovation, and ecosystem(Tsujimoto et al., 2018) existed respectively, an integrative exploration of these three terms was missing. Most existing IE research focused on strategic management(Mohelska and Sokolova, 2016; Pellizzoni et al., 2019), technology management(Barrie et al., 2019), or technological platform(Cenamor et al., 2019). Studies discussing SSP innovation for sustainability from the perspective of IE were seldom documented. Therefore, an integrative review would contribute to deepen the understanding of ecosystem-based SSP innovation for sustainability, and provide guidance for practitioners to construct IE and adjust participation strategies in IE.

The motivation of this paper is to fill the gap and contribute to the research on SSP innovation ecosystem (SSPIE) by conducting an integrative review to extract the key aspects of this emerging subject. The current challenges and possible future directions outlined will provide guidance for future research.

The remainder of the paper is organized as follows. Section 2 described the research methodology and the literature review process. Section 3 introduced the birth of SSPIE from innovation ecosystem. In Section 4, the state-of-the-art was reviewed, including SSP, innovation, ecosystem, SSP innovation (SSPI), SSP ecosystem (SSPE), and IE. In Section 5, research gap was identifed from themes, methods, and theories perspectives. In Section 6, the current challenges and future directions were discussed. Section 7 discussed the implications and limitation.

2. Research methodology

The literature review aims to answer the following four research questions.

RQ1: How does SSPIE emerge?

RQ2: What is a SSPIE?

RQ3: How has SSPIE been studied by researchers?

RQ4: What is challenges and future directions for SSPIE?

The research questions were organized by timeline, namely origin, concept, status and trend, as shown in Fig. 1. RQ 1 is related to the birth of SSPIE, RQ 2 refers to the definition, characteristics, components of SSPIE and related terms. RQ 3 means the status and research gap. RQ 4 is focused on the future directions.

Integrative review methodology (Alcayaga et al., 2019) was adopted in this paper because it has advantage of generating knowledge through a holistic conceptualisation and literature synthesis. To cover a broad range of scope and ensure top journals within the scope, we searched 8 databases, namely Science Direct, Scope, Web of Science, Wiley Online Library, Taylor & Francis Online, IEEE Xplore Digital Library, EBSCOhost, and SAGE. According to (Ren et al., 2019; Fahimnia et al., 2015) and (Bastas and Liyanage, 2018), the searching and screening methodology was as follows, shown in Fig. 2 and Table 1.

First, extant review articles on SSP, innovation, and ecosystem were selected to define keywords and search strings. Seven search strings (see Table 1) were designed to acquire relevant peer-reviewed journal articles and conference papers documented in English.

Second, we searched representative literature related to the three binary and the ternay interrelationship. Web of Science and Scopus database were used for the search of SSPI, SSPE, IE, and SSPIE, because of its broad coverage. The search strings were article “Title, Abstract, Keywords” expect for the search of SSPIE-(“Sustainable Smart Product” OR “Smart Product” OR “Smart, connected products”) AND (“Innovation Ecosystem”)-that was limited to “Title”. The search period is from 2015 to 2020. In addition, Science Direct, Taylor & Francis Online, Wiley, IEEE, EBSCOhost, and SAGE were chosed for search of SSP, innovation, and ecosystem. The search strings were limited to “Title”. The search of seven strings resulted in 1005 articles.

Third, the search scope was narrowed to documents in “Engineering”, the number of documents was refined to 524. By removing duplicates, the number was reduced to 301. Topics out of the field (i.e. sustainable smart product or innovation ecosystem) were excluded, 198 relevant documents were extracted.

Finally in-depth reading of the content and references, the number was reduced to 92.30 additional relevant articles were supplemented, including 1 thesis, 1 book section and 28 journal articles. A total of 122 articles were selectd as the final literature of this review.

The research flow was designed as illustrated in Fig. 3. Firstly, six bodies of literature were reviewed. Then gap analysis was conducted to identify the current status of SSPIE. On basis of these two steps, key aspects of SSPIE was illustrated. Finally, challenges and future perspectives were outlined for researchers and practitioners in this field.

3. The birth and proposal of SSPIE: from IE to SSPIE

3.1. The birth of SSPIE

Fig. 4 depicted the evolution of SSPIE from innovation perspective and ecosystem perspective, respectively.

In the view of innovation perspective, it starts from product innovation, SSP innovation, and then to SSPIE. The world is undergoing transformation towards sustainablility, which promotes the shift from product innovation to sustainable product innovation. Enabled by new generation information technologies and intelligent technologies, the circle time of new product development is shortened. The outcome of open innovation ecosystem contributes to product innovation (Xie and Wang, 2020). However, with the growing complexity of product and service, SSPI calls for

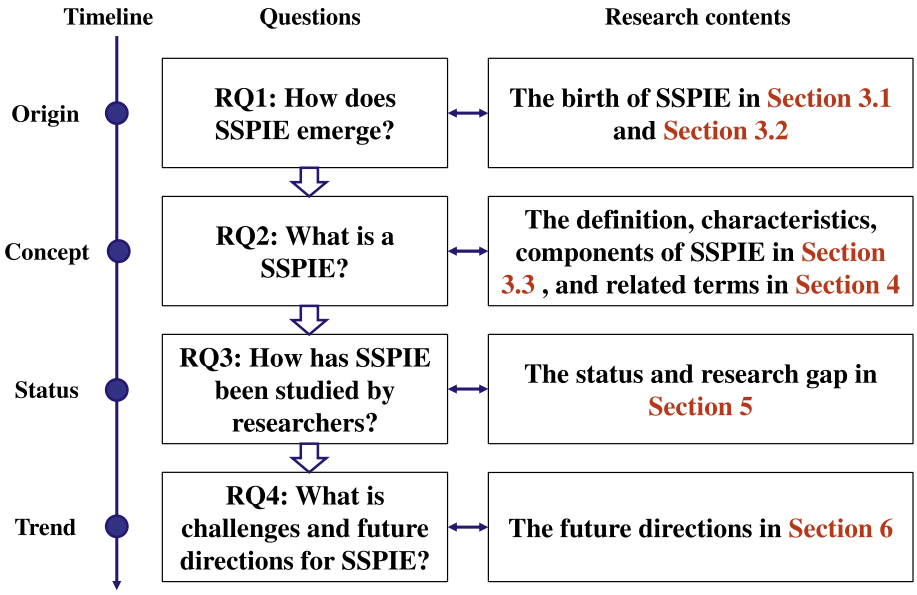

Fig. 1. The relationships between research questions.

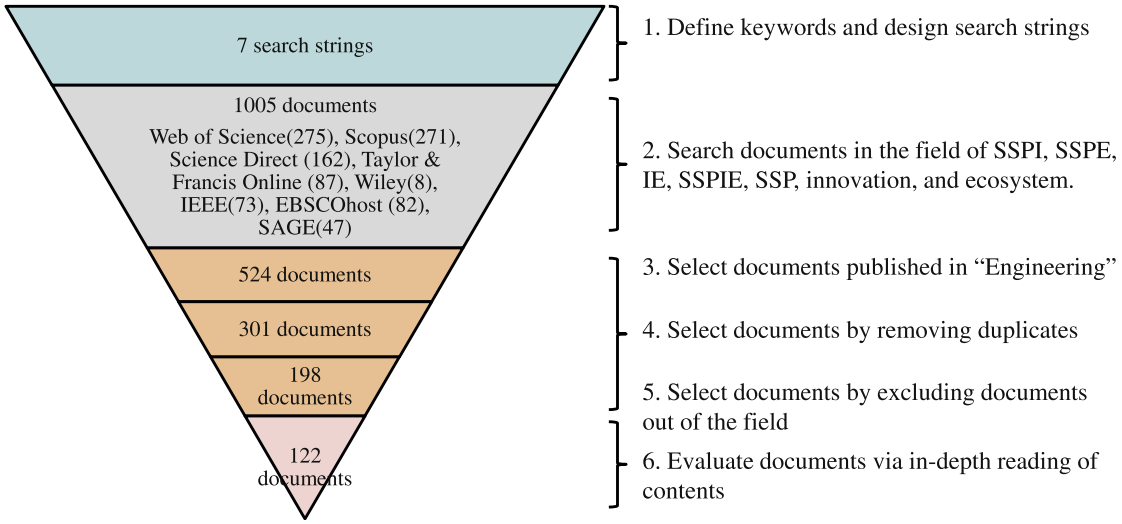

Fig. 2. The searching and screening process.

ecosystem thinking and platform strategy to tackle the risk and uncertainty in the sustainable future.

In terms of ecosystem perspective, it transforms from product to product ecosystem, SSP ecosystem, and to SSPIE. As customer needs are personalized and customized, single product can not meet the needs of users. Competition among firms has shifted from product to product ecosystem (Lee, 2018). With the increase of sustainable products and service, product ecosystem has evolved to SSP ecosystem. SSP ecosystem can be seen as a set of sustainable and smart product-service offerings, where the actors are out of the scope of ecosystem. The offerings rely on the value co-creation and co-innovation of actors through innovation activities. From this angle, SSP ecosystem can not guarantee sustainable competitiveness of the whole SSP ecosystem, so in order to deliver sustainable value to customers and all stakeholders of ecosystem, SSP ecosystem has to move towards SSPIE, which puts emphasis on the importance of actors, activities, artifacts, and their relationships within IE. The co-innovation and co-evolution of the actors enable the flow of sustainable value, this contributes to the sustainability of IE.

3.2. The proposal of SSPIE

A map of the three main bodies of literature showing the relationships between literatures on SSP, innovation, and ecosystem is depicted in Fig. 5. The binary interrelationships are SSP innovation, SSP ecosystem, and innovation ecosystem. The ternary interrelationship is SSPIE.

As the customer requirements for SSP tends to be an integration of product and service. As shown in Fig. 6, SSP innovation needs to take four dimensions into consideration, namely sustainability dimension, smartness dimension, product dimension, and service dimension. As a type of ecosystem, SSPIE has features in common with product ecosystem, service ecosystem, digital ecosystem,

Table 1
Searching strings in 8 databases.

Search strings	Limited to	Databases and results
SSPI: ("Sustainable Smart Product" OR "Smart Product" OR "Smart, connected products") AND ("Product innovation" OR "Process innovation" OR "Service innovation" OR "Business model innovation" OR "Open innovation" OR "Co-innovation" OR "Innovation process" OR "Innovation network" OR "Innovation platform")	Title, abstract, keywords	Scopus (15), Web of Science (9)
SSPE: ("Sustainable Smart Product" OR "Smart Product" OR "Smart, connected products") AND ("Business ecosystem" OR "Technological ecosystem" OR "Digital ecosystem" OR "Knowledge ecosystem" OR "Ecosystem")	Title, abstract, keywords	Scopus (10), Web of Science (4)
IE: ("Product innovation" OR "Process innovation" OR "Service innovation" OR "Business model innovation" OR "Open innovation" OR "Co-innovation") AND ("Digital ecosystem" OR "Platform ecosystem" OR "ecosystem")	Title, abstract, keywords	Scopus (245), Web of Science (261)
SSPIE: ("Sustainable Smart Product" OR "Smart Product" OR "Smart, connected products") AND ("Innovation Ecosystem")	Title	Scopus (1), Web of Science(1)
SSP: ("Sustainable and Smart Product" OR "Smart product-service system" OR "Collaborative product development")	Title	Science Direct (44), Taylor & Francis Online (61), Wiley(1), IEEE(50), EBSCOhost (24), SAGE(15)
Innovation: ("Product innovation" OR "Service innovation" OR "Business model innovation") AND ("Co-innovation" OR "Open innovation")	Title	Science Direct (25), Taylor & Francis Online (3), Wiley(2), IEEE(11), EBSCOhost (1), SAGE(24)
Ecosystem: ("Platform ecosystem" OR "Business ecosystem" OR "Technological ecosystem" OR "Digital ecosystem" OR "Innovation ecosystem" OR "Knowledge ecosystem" OR "Ecosystem evolution" OR "Ecosystem symbiosis")	Title	Science Direct (93), Taylor & Francis Online (23), Wiley(5), IEEE(12), EBSCOhost (57), SAGE(8)
Total number of documents		1005

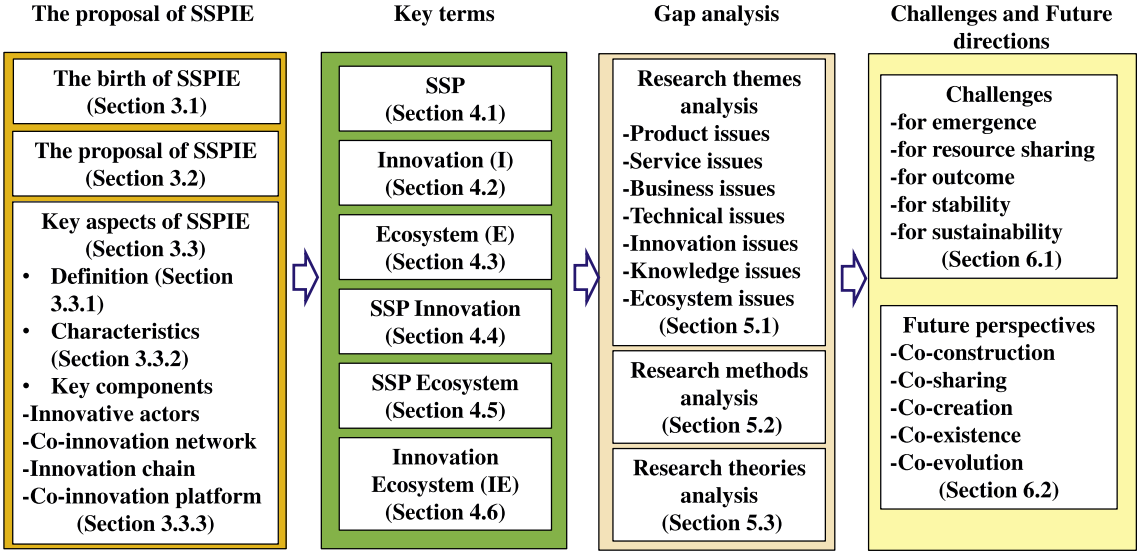

Fig. 3. The overall research flow of this paper.

knowledge ecosystem and business ecosystem, such as platform strategy, network management, co-evolution, etc.

3.3. Key aspects for SSPIE

3.3.1. Definition

The SSPIE is a new, multi-disciplinary concept, so it is difficult to be defined. On basis of the investigation of different ecosystems (i.e. innovation ecosystem, digital ecosystem, business ecosystem, knowledge ecosystem, service ecosystem) and SSP, this paper proposed a comprehensive definition for SSPIE as follows.

SSPIE is defined as a new open innovation paradigm for sustainable and smart product innovation that employs the innovation ecosystem theory to transform from value chain-based mode to ecosystem-based mode where actors interact with each other to achieve sustainability goal and shared value of all stakeholders.

3.3.2. Characteristics

Based on the characteristics of SSP, innovation, and ecosystem as mentioned, the main characteristics of SSPIE were introduced in the following paragraph as shown in Fig. 7, namely complexity and diversity, innovation resource decentralization, dynamic co-innovation, open collaboration, and co-evolution.

- Complexity and diversity. The complexity characteristic is mainly reflected in two aspects, namely the complex product with multiple components (i.e. hardware component, software module, service module, and apps), and complex interrelationships among stakeholders. The diversity characteristic embodies in four aspects, namely the diverse and dynamic customer requirements, the various stakeholders, multi-stages co-innovation process, and multi-platforms.
- Innovation resource decentralization. Innovation resources come from a wide range of sources, scattered among different innovative species, populations, and communities. Innovative actors share innovation resources through innovation chains, innovative networks and innovation platform.

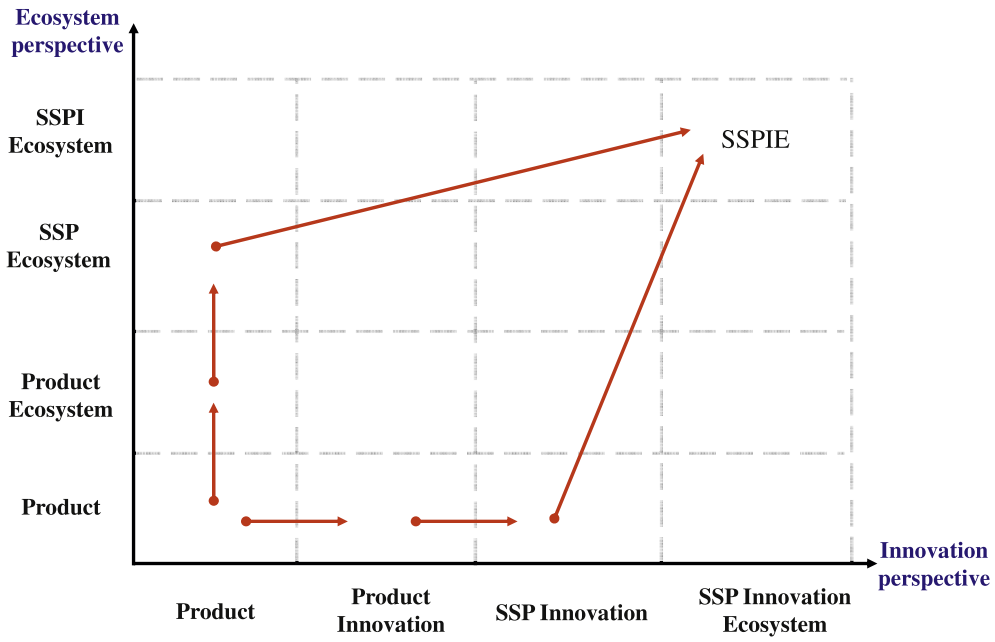

Fig. 4. The evolution of SSPIE.

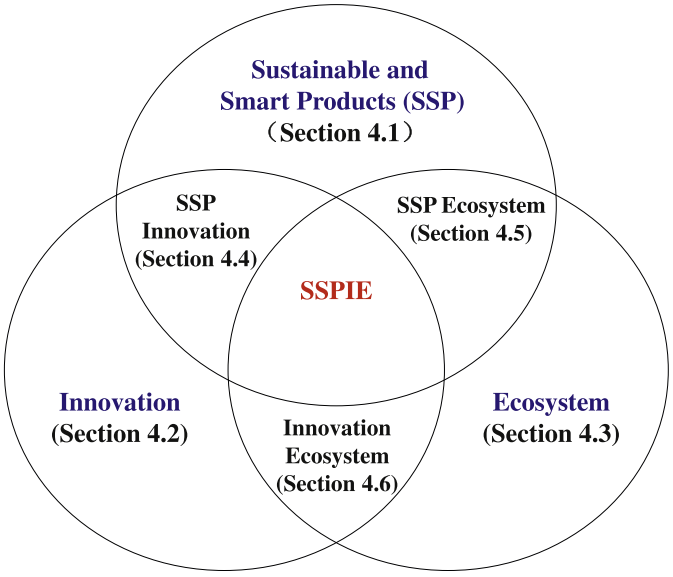

Fig. 5. Map of relationships between works on SSP, innovation and ecosystem.

- Dynamism of co-innovation. Innovative actors enter or exit the ecosystem, causing dynamic changes of nodes in the innovation network and the structure of innovation network.
- Open collaboration. Open collaboration lies in the collaboration among innovative species along the innovation chain (i.e. the co-innovation process). They mutually benefit one another in a manner of both competition and cooperation. The open collaboration is not limited to the collaboration between customers and focal firm. The collaboration of service providers and the collaboration of customers also belong to open innovation. The openness of the platform determines the scope of open collaboration.
- Co-evolution. Driven by a shared value proposition, the innovative species gather together around innovation orchestration platform to co-create value. The shared value promote the ecosystem move from an equilibrium to a new one. The process of co-evolution embodies self-organization.

3.3.3. Key components

Fig. 8 Depicted the components of SSPIE, including innovative actors, innovation chain, co-innovation network, and co-innovation platform.

The model is constructed to form a pentahedron with quadrilateral base by using "point-line-surface-body". The base represents co-innovation platform, which is the basis of SSPIE. The point stands for innovative actors. The lines represent the innovation chain. The surface is analogy to co-innovation network. The body represents the ecosystem.

(1) Innovative actors

Innovative actors in SSPIE are individuals and organizations. Table 2 shows the key actors and their roles in innovation ecosystem.

Borrowed from ecology ecosystem, they can be classified into innovation species, innovation population, and innovation community, as shown in Fig. 9.

- Innovative entity means independent innovation individual or innovation organization.
- Innovative species refers to a collection of homogeneous and innovative individuals. Such as customers, users, third-party developers, focal enterprises, upstream and downstream enterprises, universities, research institutes, industry associations, industry alliances, government, venture capital and other related stakeholders.
- Innovative Population is a collection of multiple homogeneous innovation individuals within a certain time and space.
- Innovative Community is a collection of innovative individuals formed by innovative populations and

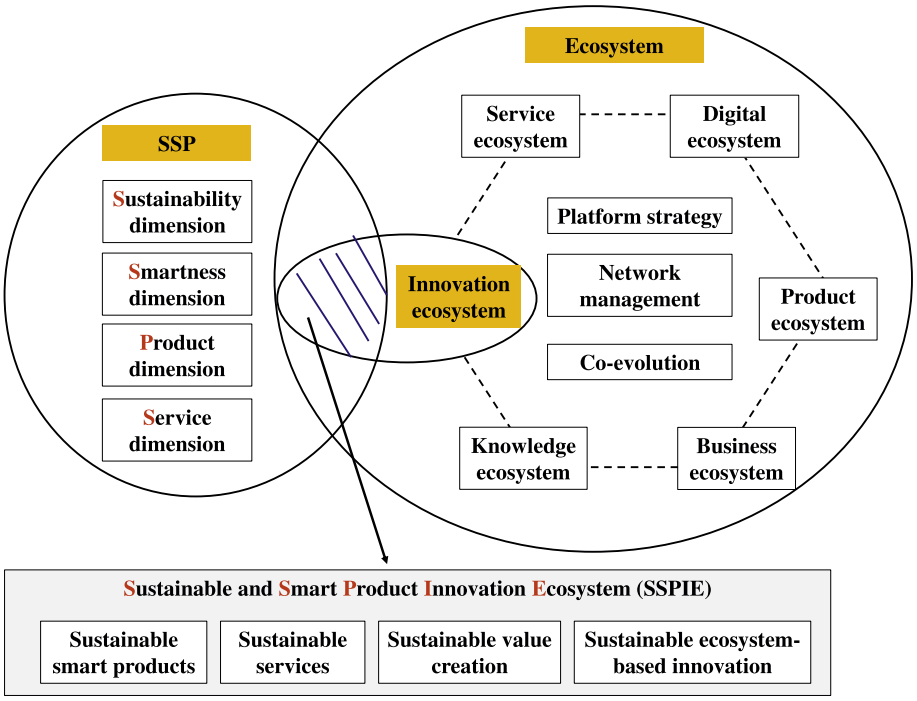

Fig. 6. The relationship between SSPIE and other ecosystems.

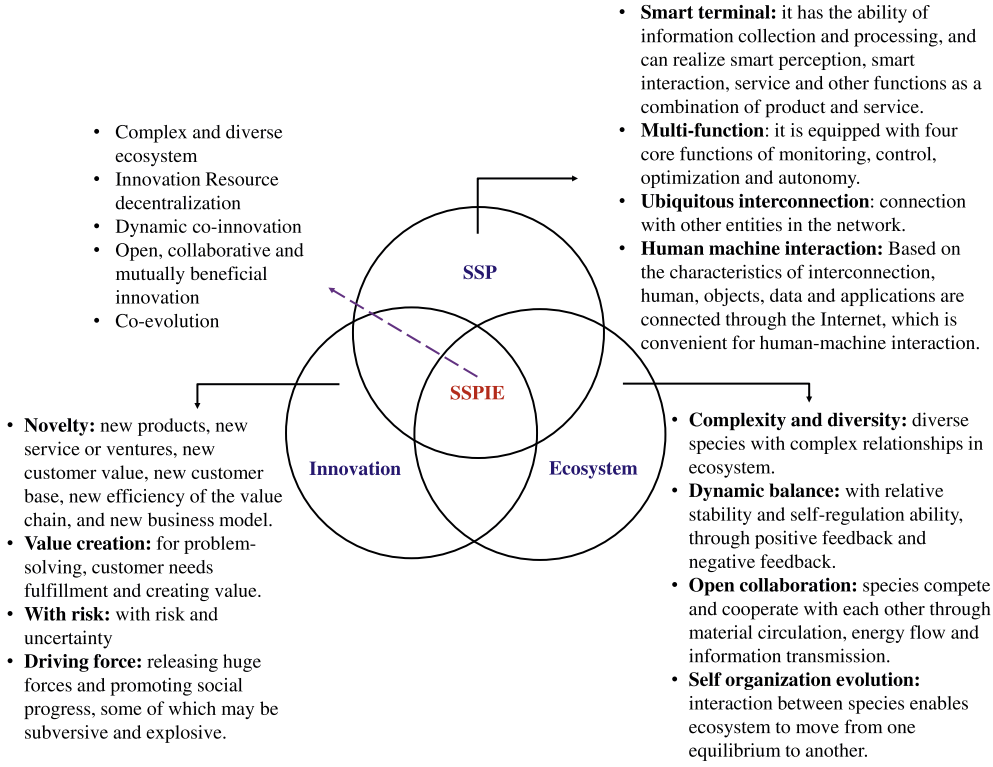

Fig. 7. Characteristics of SSPIE.

environmental roles within a certain time and space, such as user community, cooperation network, industry-university research ecosystem.

(2) Co-innovation network

Different from value network and supply chain network, co-innovation network is a complex adaptive network formed by different innovation chains, within which the innovation actor plays as a network node. The co-innovation network can be viewed as collaborative network focusing on innovation activities

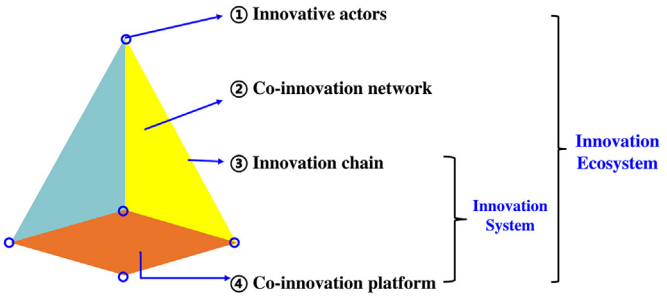

Fig. 8. The components of SSPIE.

supported by multiple innovators. Co-innovation network deals with the flow of innovation resource, such as data, information, knowledge, capability, service, etc.

(3) Innovation chain

In comparison with supply chain and value chain, innovation chain describes the chain structure of the entire innovation process from creation, transformation to commercialization. It is market demand-oriented, reflecting the flow, transmission, transformation and value-added effects of innovative resources such as knowledge and technology in the innovation process. It also reflects the relationship between the innovation actors.

(4) Co-innovation platform

Co-innovation platform is an open crowding platform providing service based on the internet. It plays role as infrastructure is to bring together innovative resources form innovative resource network, integrate and aggregate innovative resource elements, and promote the efficient allocation and share innovative resources within the innovation network. The actors on co-innovation platform can be divided into four types according to their roles, namely supply side of platform, demand side of platform, platform provider (or platform sponsor), and platform complementary. The basic function of platform consists of transactions, exchanges, and co-innovation.

4. Key related terms for SSPIE

4.1. SSP

SSP is smart product (Porter; and Heppelmann, 2014) that balance their social, economical, and environmental performance (Miranda et al., 2017). SSP development calls for new architectures and capabilities enabled by advanced approaches, methods, technologies, and models (Tomiyama et al., 2019) that adhere to sustainability objectives (Nunes et al., 2017). studied smart product development approaches in context of industry 4.0, such as Augmented Reality and Virtual Reality (Rauch et al., 2016). proposed a lean and smart product development process based on axiomatic design methodology (Filho et al., 2017). reviewed the state of art of smart products and discussed the conceptual design and implementation of self-aware smart products (Zheng et al., 2019). proposed an IT-driven co-creation paradigm for SCP, but the co-innovation process for sustainability from the perspective of innovation lack sufficient exploration.

However, most existing works of SSP innovation focused on technological innovation by using novel technologies, such as digital twin, artificial intelligence, big data analytics, etc. The research on SSP innovation from the perspective of co-innovation for sustainability has not yet received sufficient concerns.

4.2. Innovation

Innovation paradigm (Lee Sang, 2012) has evolved from closed innovation paradigm (i.e. Innovation 1.0), to collaborative or symbiosis Innovation paradigm (i.e. Innovation 2.0)(Heil and Bornemann, 2018), to open innovation paradigm (i.e. Innovation 3.0), and co-innovation paradigm (i.e. Innovation 4.0). Literatures on co-innovation were shown in Table 3.

Recently, some scholars proposed a new paradigm termed

Table 2
Key actors involved in innovation ecosystem.

Key actors		Description	Role
Individual	Users (prosumers)	Being a co-creator, the work is to provide demand and participate in the whole process of the product, playing a role of both consumers and producers.	Important participant
	Customers	the buyers of smart product and service	Important participant
	Third-party developers	Software developers, APP developers or solution providers	Participant
Enterprise	Focal firm	the Ecosystem orchestrator, the providers of smart product and service, who performs a leadership role in the innovation ecosystem	Leader, orchestrator
	Suppliers	Hardware or software suppliers, providing material, parts, software or APP, etc.	Participant
	Manufacturers	Smart product manufacturer	Participant
	Service providers	Smart product service provider	Participant
	Start-ups	Small innovative firm, providing key techniques	Participant
organization	Financial agent	Financial support for innovation, including venture capital, venture capital, etc.	Participant
	University	Conduct basic research and provide technical services during the product development phase.	Participant
	Consortium	A large number of companies in a certain industry sector or cross sectors, in the form of alliances.	Participant
	Government	A policy maker influencing innovation, sometimes providing financial support	Participant

Fig. 9. A schematic of the relationship of innovative entity.

holistic innovation (Chen et al., 2018) Innovation has moved from linear form to networked form and ecosystem form (Madsen, 2019). presented business model innovation from the ecosystem view. Tsujimoto et al. (2018) reviewed literatures using the ecosystem concept in the field of technology and innovation management. These studies covered four streams, namely industrial ecology, business, platform management, and multi-actor network perspective.

However, most existing literature focus on product innovation or service innovation. The integration of product innovation and service innovation from the perspective of ecosystem for sustainability is seldom investigated. Despite innovation network (Desmarchelier et al., 2019) has been researched by a group of scholars, the innovation management mechanism and co-innovation infrastructure (i.e. innovation platform) in the context of digital era have not been clarified. For example, knowledge-based innovation management system (KIMS) (Ribiere Vincent, 2010) in the context of open innovation (Huggins and Thompson, 2017) is not sufficient to support SSP innovation for sustainability to create shared sustainable value for all stakeholders.

4.3. Ecosystem

Table 4 shows the comparison between product ecosystem, service ecosystem, knowledge ecosystem (van der Borgh et al., 2012), business ecosystem (Moore, 1993), innovation ecosystem(Adner, 2006), and digital ecosystem. Multi-agent system and complex adaptive systems are often adopted in ecosystem modelling, operation mechanism, emergence (Roundy et al., 2018) and evolution (Zhang et al., 2017; Chae, 2019) of ecosystem (Phillips and Ritala, 2019). proposed a methodological framework for ecosystem research design based on complex adaptive systems from three perspectives, namely ecosystem boundary, structure, and dynamics.

Concerning ecosystem structure and elements (Rong et al., 2015), proposed a 6C framework for IoT-based business ecosystem (Graça and Camarinha-Matos, 2017). illustrated the key properties and structure of generic ecosystem, biological ecosystem, digital ecosystem, business ecosystem, social ecosystem, and knowledge ecosystem, except innovation ecosystem.

As for ecosystem governance, network management (Aarikka-Stenroos and Ritala, 2017) and platform strategy (Ding et al., 2019; Pellizzoni et al., 2019) are the most commonly used methods. More and more ecosystem are becoming platform-based ecosystem (Mukhopadhyay and Bouwman, 2018), presented three key attributes of platform ecosystem, namely modular architecture, technical openness, and ecosystem network structure. Platform

Table 3
Literatures on co-innovation.

Co-innovation	Focus	Examples of references	Description
Purpose of co-innovation	Creating value for stakeholders	(Heil and Bornemann, 2018; Lee and Trimi, 2018)	new products, new service or ventures, new customer value, new customer base, new efficiency of the value chain, and new business model
	Value creation and value capturing in innovation ecosystem	(Yaghmaie and Vanhaverbeke, 2019; Chesbrough et al., 2018)	Components of Innovation ecosystem, open innovation
		Aarikka-Stenroos and Jaakkola (2012)	Value co-creation for joint problem solving
		Frow, McColl-Kennedy, and Payne (2016)	Co-creation in health care ecosystem
		Marcos-Cuevas et al. (2016)	Value co-creation in Business-to-Business systems
		Sanna and Katri (2019)	Innovation ecosystem for value co-creation
		Adner and Kapoor (2010)	Value co-creation in innovation ecosystem
Collaboration for co-innovation	Crowd innovation	Heil and Bornemann (2018)	Value creation through collaborative innovation
	Crowdsourcing	Jespersen (2018)	Integrating crowdsourcing into innovation system
	Crowdsourcing	Presenza et al. (2019)	Social crowdfunding business ecosystem
Network	Collaborative network	Fayoumi (2016)	Collaborative and networked manufacturing systems
	Collaborative network	Camarinha-Matos and Afsarmanesh (2018)	Nature-inspired collaborative networks
	Collaborative network	Sargolzaei and Afsarmanesh (2017)	Service oriented collaborative network architecture
	Network management	Aarikka-Stenroos and Ritala (2017)	Ecosystem network management framework
	Open Innovation Networks	(Lee et al., 2010; Song et al., 2016; Barrie et al., 2019)	Innovative network
	Innovation network	Desmarchelier et al. (2019)	Servitization of innovation networks
	social network	Presenza et al. (2019)	Social crowdfunding platform
	Service network	Ekman et al. (2016)	Service network value co-creation
	Business network	Battistella et al. (2013)	Business ecosystem network analysis
Platform	Co-innovation platform	Lee Sang (2012)	Co-innovation for organizational value
		Gawer and Cusumano (2014)	Industry platform
		Grobbelaar (2018)	University coordinated innovation platform
		Ding et al. (2019)	Platform strategy for automobile manufactures
	Crowdsourcing platform	(Assis Neto et al., 2018)	Crowdsourcing platform for worker management and task management in crowdsourcing projects
Complex theory	Complexity	Russell and Smorodinskaya (2018)	Leveraging complexity
	Complex adaptive system and agent-based modelling	Roundy et al. (2018)	Entrepreneurial ecosystems as a complex adaptive system
Innovation Resource	Knowledge	Amitrano et al. (2017)	Knowledge sharing
	Knowledge	Gupta et al. (2019)	Knowledge cross sharing among business ecosystem, innovation ecosystem, and digital ecosystem
Co-innovation Organization	Customer collaborative community	Cui and Wu (2016)	Customer involvement in new product development
	Collaboration with customers	Gemser and Perks (2015)	Co-creation with customers
	Collaboration with Developers	Parker et al. (2016)	The effect of developers on platform firm

Table 4
Comparison among six types of ecosystems.

	Product ecosystem	Service ecosystem	Knowledge ecosystem	Business ecosystem	Innovation ecosystem	Digital ecosystem
Selected references	Lee (2018)	(Alaimo et al., 2020; Zheng et al., 2017)	van der Borgh et al. (2012)	(Rong et al., 2015; Presenza et al., 2019)	(Gomes et al., 2018; Granstrand and Holgersson, 2019)	(Gupta et al., 2019; Subramaniam et al., 2019)
Aims	Product development and delivery	Service design and delivery	Knowledge generation	Value creation and value capture	Value-creation, innovation generation	Digital product or service
Stakeholders	Developers, designers, customers, manufacturer, suppliers	Enterprise, Service providers, suppliers, customers	University, institutions, enterprise, government	Enterprise, customers, government, suppliers	Enterprise, Research institutions, capital, government,	Enterprise, research organizations, developers
Flow	Info/knowledge	Info/knowledge	Knowledge	Value	Knowledge/value	Data/info/knowledge
Linear relationship	Product chain, value chain	Service chain, value chain	Knowledge chain	Supply chain, value chain	Innovation chain,	Data chain
Networked connectivity	Value network	Service network, social network	Knowledge network	Value networks	Innovation networks	Information network, Collaborative network
Infrastructure	Product development platform	Service platform	Knowledge management platform	e-commerce platform	Innovation platform	Digital platform, software platform
Sharing Resource	Technology resource	Service resource	Knowledge resource	Value	Knowledge, value	Software resource
Value focus	Value creation	Value creation	Value creation	Value capture	Value creation and value capture	Value creation
Dynamics	Co-evolution	Co-evolution	Co-evolution	Co-evolution	Co-evolution	Co-evolution

design (Tura et al., 2018) studied four key elements, namely platform architecture, governance, platform competition, and value creation logic. Network effects and synergy effects of platform were also investigated by researchers(Schmeiss et al., 2019).

Literatures on ecosystem management focus on strategic management. However, issues on trust management, risk management, security management, uncertainty management, resource management and conflict management lack sufficient investigation to keep the stability and equilibrium of ecosystem, especially in the field of digital innovation ecosystem, where cyber space, social space, and physical are involved.

4.4. SSP innovation

Most scholars focus on conceptual framework of SSP development. For example (Miranda et al., 2017), conducted a review on sensing products, smart products, and sustainable products, and then proposed a reference framework for the development of sensing, smart and sustainable products (Zhang et al., 2019). proposed a framework of smart product through-life design considering the environment interaction (i.e. physical environments, human environments, and cyberspace environments). Some researchers explored SSP innovation via empirical research (Vitali et al., 2017). presented a case study of the user centred design of a smart networked product via crowdfunding platform which strengthened the ties between users and designers.

Co-development of SSP innovation attracted interest of academia in resent years (Zheng et al., 2018). studied the co-development process of personalized SCP in cloud-based context by using a data-driven cyber-physical approach (Liu et al., 2018). proposed a framework for smart product-service system (Smart PSS) from the perspective of value co-creation, including co-exist, co-design, co-implement, and co-evaluate. But the innovation process was not explored (Zheng et al., 2019). viewed Smart PSS as a socio-technical ecosystem and outlined Smart PSS solution design with three hybrid concerns, namely design methods enabled hybrid design, intelligence systems enabled hybrid intelligence, and value co-creation enabled hybrid value.

However, to the knowledge of the authors, SSP innovation for sustainability from the perspective of innovation ecosystem lack sufficient study. The actors, activities, and artifacts concerning about SSP co-innovation for sustainability in the context of innovation ecosystem have been seldom investigated.

4.5. SSP ecosystem

Literatures on SSP ecosystem were few. The ecosystem of smart product was portrayed by (Tomiyama et al., 2019), which was made up of stakeholders, physical environment, and connected product devices. They presented a conceptual architecture of smart product ecosystem and gave a very concise description about the value generation mechanisms. However, the interactions within ecosystem and ecosystem dynamics were not discussed.

There has been a large amount of research into the subject of smart product-service systems by many researchers. On basis of Smart PSS (Zheng et al., 2017), proposed a framework for smart product service ecosystem (SPSE) from the perspective of service ecosystem. The characteristics and mechanisms of a generic smart product ecosystem were missing (Liu and Ming, 2019). investigated smart industrial PSS from the perspective of system of systems. The interaction mainly focused on systems, the stakeholders interactions were missing.

4.6. Innovation ecosystem

IE was firstly proposed by Adner (2006), drawing on business ecosystem. Some other literatures were based on biological ecosystems (Shaw and Allen, 2018). IE was viewed as a set of actors, activities, and artifacts (Granstrand and Holgersson, 2019). The actors in IE included individuals, organizations, communities, etc. Most literatures focus on IE orchestrated by large company, a handful of work investigated the innovation of SMEs (Mei et al., 2018). The three typical IE (Gomes et al., 2018) were digital innovation ecosystem (Chae, 2019), open innovation ecosystem (Xie and Wang, 2020), and platform-based ecosystem (Su, 2018).

Research streams on IE can be classified into five categories,

namely concepts (Adner, 2006) and framework (Pombo-Juárez et al., 2017), modelling and construction, management and governance, value creation, and evolution. To gain a better understanding of IE, many scholars have offered theoretical framework and conceptual model. Wang (2009) proposed an integrative framework for depicting the whole picture of IE in terms of production and use of innovations.

In terms of ecosystem modelling and construction, complex adaptive system approach was mostly employed (Russell and Smorodinskaya, 2018). (Talmar et al., 2018) developed a strategy tool named Ecosystem Pie Model for mapping, analysing and designing innovation ecosystem. Ecosystem-as-structure was employed to construct a two-part model of Innovation Ecosystem for value co-creation activities (Sanna and Katri, 2019).

With regard to the governance of ecosystem, platform strategy was adopted by scholars to investigate the management of IE (Gawer and Cusumano, 2014). (Ding et al., 2019) studied the platform strategy for IE, combining IE with platform theory, such as mutualism symbiosis and predation symbiosis (Yaghmaie and Vanhaverbeke, 2019). studied IE from the perspective of open innovation focusing on strategic management, and conducted a comprehensive literature review on constituents of IE. However, a framework of IE was missing. The uncertainty management and risk management were explored by a handful of scholars (Vasconcelos Gomes et al., 2018). studied how entrepreneurs cope with collective uncertainties in IE.

As for value co-creation in IE (Adner and Kapoor, 2010), investigated the effects of technology interdependences on performance in technology innovation (Smorodinskaya et al., 2017). compared IE with innovation system in terms of value co-creation. Walrave et al. (2018) combined internal alignment with external viability to study socio-technical viability of IE from a multi-level perspective for path-breaking innovation(Sanna and Katri, 2019). proposed that IE palyed the role as structure for value co-creation.

As to evolution of IE, most existing literatures focused on co-evolution (Gomes et al., 2018). presented the co-evolution process of business ecosystem and IE, but did not propose a conclusion on the co-evolution process (Chae, 2019). proposed a framework for the evolution of digital innovation ecosystem, which was specific to big data.

There is a lack of systematically review on IE covering the aspects of definitions, structure, components, infrastructure, mechanisms, dynamics, lifecycle and outcome. Existing review literatures or survey literatures covered two or more aspects aforementioned. Studies on IE for sustainability were few. Literatures on IE were shown in Table 5.

5. Research gap for SSPIE

In this section, the research gap was analyzed from three perspectives, namely research themes, research methods, and research theories. A summary of research gap was given in the end of this section.

5.1. Themes in SSPIE research

Considering the features of SSP and innovation ecosystem, research themes can be mainly divided into seven categories, namely product, service, business, technology, innovation, knowledge, and ecosystem, as shown in Table 6.

5.1.1. Product issues

Existing work in this theme mainly focused on the innovation process and methodologies of smart product design or sustainable product development. Some scholars examined user-centric new product development in the context of crowdfunding. However, the integrative study on product innovation, service innovation and sustainability innovation remained limited. Some researchers emphasized the importance of involvement of suppliers and customers in the early phase of product development. But the proposed framework was conceptual and other actors were missing.

Thus, we argue that future work should study the SSP innovation for sustainability from a systematic perspective by integrating product, service, smartness and sustainability concerns.

5.1.2. Service issues

Articles in service issues discussed digital service and SSP-related service innovation in form of service-dominant logic, product-service system, service network, and service ecosystem. The topics covered service innovation strategies, knowledge management in service innovation, evaluation approaches and methods for service innovation performance, collaborative innovation in service-dominant logic. Numerous researchers studied PSS and smart PSS, including the framework design, modelling, methods and tools.

There is a trend of study on smart product-service ecosystem by combining ecosystem service approach with service-dominant logic. However, SSP innovation processes of value co-creation has not been exhaustively researched. The relationship between the service lifecycle and product lifecycle calls for clarification.

Despite service innovation design approach of smart PSS has been investigated. Combining product innovation and service innovation in SSP innovation for sustainability in service-dominant logic requires further research.

5.1.3. Business issues

Literatures on business issues focused on business model innovation, business ecosystem, digital business ecosystem. Work on business model innovation has discussed value proposition, value creation, value delivery, and value capture. Despite value proposition for all stakeholders was proposed by a handful of researchers, the components of shared value proposition calls for further research. A large number of related work investigated value co-creation and value capture. Some scholars distinguished business ecosystem with innovation ecosystem by using value creation and value capture. As to value co-creation, user participation was emphasized by literatures. In IE, value co-creation network was concerned by researchers. However, as to value capture, the risk of value uncapture was seldom investigated, which was vital for the success of the whole ecosystem. The target of IE was to create value for all stakeholders, but sustainable business model innovation in the field of IE lacked sufficient research. Hence, we calls for the study on co-innovation mechanism that integrate sustainability into business and innovation.

5.1.4. Technological issues

Technological issues mainly discussed digital technologies, technology innovation, and technological ecosystem. Numerous researchers were devoted to investigate the leverage of digital technologies for product innovation and service innovation in SSP innovation, the fusion of digital technologies with sustainability lack sufficient research.

To facilitate the interaction and knowledge sharing, digital platform was explored by researchers. Prior work discussed big data platform, cloud platform, and industrial internet platform. But these digital platform focused on manufacturing resource management and service resource management, innovation resource management was missing. The governance of platform was seldom explored.

With regards to technological ecosystem, existing work

Table 5
Literatures on innovation ecosystem.

Innovation ecosystem	Focus	Examples of references	Description
Definition and concepts	Definition	Jackson (2011)	Introduction of innovation ecosystem
	Concept	Oh et al. (2016)	A critical review of the concept of innovation ecosystem
		Tsujimoto et al. (2018)	A review of ecosystem concept
		Smorodinskaya et al. (2017)	The difference between innovation ecosystem and innovation system
Framework	Theoretical model	Wang (2009)	An integrated framework for innovation ecosystem including both production and use of innovation
	Layered Structure	Pombo-Juárez et al. (2017)	Multi-layer of innovation ecosystem
	Multilevel perspective	Walrave et al. (2018)	A multi-level perspective for path-breaking innovation
Components	Constituents	Yaghmaie and Vanhaverbeke (2019)	Constituents identification and description of innovation ecosystem
Categories	National innovation ecosystem	Beckmann et al. (2016)	National digital manufacturing innovation
	Regional innovation ecosystem	Reynolds and Uygun (2018)	Innovation ecosystem in manufacturing
	Firm innovation ecosystem	Grobbelaar (2018)	Local innovation ecosystem
		Ding et al. (2019)	Innovation ecosystem for Automobile manufacturers
		Huang et al. (2019)	Innovation ecosystem for high-speed railway
	Digital innovation ecosystem	Kolloch and Dellermann (2018)	Digital innovation ecosystem in energy industry
	Open innovation ecosystem	Bacon et al. (2019)	Knowledge transfer in open innovation ecosystem
Platform strategy	Platform-based innovation ecosystem	Parker and Van Alstyne (2018)	Openness and platform control
		McIntyre and Srinivasan (2017)	Network and platform strategy
Innovation Process Modelling	Product innovation process	Zhan (2017)	An ACE framework for product innovation
	Complex adaptive system	Russell and Smorodinskaya (2018)	A complex adaptive system approach
		Rabelo and Bernus (2015)	A holistic model
	Ecology theory	Shaw and Allen (2018)	Ecology theory
	System-based theory	Giannopoulos and Munro (2019)	System-based theory innovation
	Pie model	Talmar et al. (2018)	Innovation ecosystem Mapping, analysing, and design
	Social business model	Carayannis et al. (2019)	Social innovation ecosystem
SMEs innovation ecosystem	Small and Medium enterprises innovation	Mei et al. (2018)	Open innovation of SMEs
		Radziwon and Bogers (2019)	inter-organizational relationships among SMEs
Governance	Orchestration	Marin (2012)	Orchestration of innovation ecosystem
	Sharing	Amitrano et al. (2017)	Knowledge sharing and management
	Openness of the ecosystem	Parker and Van Alstyne (2018)	Openness of platform ecosystem
	Ecosystem management	Durst and Poutanen (2013)	Success factors analysis
Evolution	Evolution mechanism	Zhang et al. (2017)	Evolution mechanism of manufacturing service system
		Gomes et al. (2018)	Innovation ecosystem construction and evolution
		Chae (2019)	the evolution of digital innovation ecosystem

investigated IoT ecosystem enabled by internet of things technologies and digital platform. However, digital technological ecosystem on SSP lack sufficient exploration. The smart design approaches and technologies for SSP are seldom investigated.

5.1.5. Innovation issues

Literatures on innovation issues focused on innovation and innovation ecosystem. The definition, categories, paradigms, model, evolution, process and organizational forms of innovation have been investigated. Especially, collaborative innovation network and digital innovation ecosystem have attracted interest of academia and industries. The definition, type, feature, element, structure, operation mechanism, construction, evolution, orchestration, framework of innovation ecosystem have been discussed by prior work.

Despite some scholars studied user-centric innovation through value network or social network analysis, data-driven SSP innovation were not exhaustively explored. The generation of innovation from the perspective of conversion among data, information, and knowledge was seldom discussed.

Innovation management and co-innovation were discussed from the strategic management perspective. Innovation resource management were seldom explored. The process of innovation proposed by prior studies was mostly on basis of value chain or value creation, few researchers investigated the product innovation from the perspective of ecosystem, especially the innovation ecosystem forSSP.

Some scholars studied business model innovation concerning value proposition, value creation, value delivery and value capture. However, IE for SSP innovation for sustainability from an integrative perspective was seldom explored. In the context of open collaborative innovation, the combination of product innovation, service innovation, and digital innovation calls for further research.

5.1.6. Knowledge issues

Research on this issue mainly discussed knowledge management and knowledge ecosystem. Some scholars investigated knowledge management systems in the collaborative environment, including generation, transfer, sharing, integration, network, and reuse of knowledge. Literatures on knowledge ecosystem focused on knowledge-based R&D collaboration and university-coordinated innovation.

The integration issues of knowledge from different source was concerned by scholars. Data-driven and knowledge-driven framework for manufacturing was found in existing work. However, in the field of innovation, despite researchers investigated knowledge management, a comprehensive knowledge-driven framework for SSP innovation was missing. Knowledge management and knowledge generation in SSPIE lacked sufficient exploration.

Table 6
SPIE research themes.

Research Themes	Focus	Examples of references
Product issues	Smart product design	Experience-based smart products design(Bilal Ahmed et al., 2019)
	Smart product development	Development capabilities(Tomiyama et al., 2019)
Service issues	Digital service	Data-based service(Alaimo et al., 2020)
	Service network	Sargolzaei and Afsarmanesh (2017)
	Service innovation	Service innovation of smart PSS(Zheng et al., 2018),service-dominant logic(Lusch and Nambisan, 2015)
Business issues	Value network	New product development innovation network(Song et al., 2016)
	Value creation	Value co-creation(Sanna and Katri, 2019)
	Value capture	Value capture in open innovation(Chesbrough et al., 2018)
	Value co-creation	(Gemser and Perks, 2015), (Sanna and Katri, 2019) co-creation with customers
Technological issues	Platform	Crowdfunding platform(Presenza et al., 2019), digital platform(Wei et al., 2019), Co-innovation platform(Lee Sang, 2012)
	Digital technologies	Blockchain technology (Schmeiss et al., 2019)
	Digital innovation	Selander et al. (2010)
Innovation issues	Innovation process	Value chain architecture(Lee Sang, 2012)
	Open innovation	Computer aided innovation(Hüsig and Kohn, 2011)
	Collaborative innovation	Collaborative innovation for knowledge generation(Heil and Bornemann, 2018)
	Co-innovation	Evolution of innovation and Co-innovation platform (Lee Sang, 2012)
	Crowdsourcing	Crowdsourcing in innovation system (Jespersen, 2018)
Knowledge issues	Knowledge management	Knowledge-based ecosystem(van der Borgh et al., 2012)
	Knowledge transfer	Knowledge creation and diffusion (Pombo-Juárez et al., 2017)
	Knowledge sharing	New product development(Gao and Bernard, 2018),
	Knowledge network	Knowledge network for partner selection(Han et al., 2019)
Ecosystem issues	Orchestrator	Commercial enterprise as orchestrator, social enterprise as orchestrator (Hota et al., 2018), university as orchestrator (Grobbelaar, 2018)
	Boundary	Ecosystem boundary determination (Phillips and Ritala, 2019), platform openness(Wei et al., 2019)
Ecosystem issues	Components	Key actors and roles (Phillips and Ritala, 2019),
	Structure and architecture	Platform design framework(Tura et al., 2018), Methodological framework for ecosystem hierarchy and relationships(Phillips and Ritala, 2019),
	Modelling	Pie model for designing innovation ecosystem(Talmar et al., 2018) MBBWNA for analysing and modelling business ecosystem (Battistella et al., 2013) agent-based models
	Operation and governance	Outcome control, behavioural control and input control for platform ecosystem (Mukhopadhyay and Bouwman, 2018),
	Capability	Digital platform capability and network capability on entrepreneurial SMEs(Cenamor et al., 2019)
	Ecosystem co-evolution	Methodological framework for system dynamics and co-evolution(Phillips and Ritala, 2019)
	Ecosystem lifecycle	four evolutionary phases of Business Ecosystem: birth, expansion, leadership, self-renewal (Moore, 1993) S-curve of the ecosystem lifecycle (Lee and Trimi, 2018)
	Platform ecosystem	Platform strategy for innovation ecosystem (Ding et al., 2019)
	Digital ecosystem	Digital foundation, digital hybrids and digital monopolies for digital ecosystem (Subramaniam et al., 2019)
	Digital business ecosystem	The impact of interdependence in digital business ecosystem (Senyo et al., 2018)
	Digital innovation ecosystem	Evolution of digital innovation ecosystem (Chae, 2019)

5.1.7. Ecosystem issues

Literatures on ecosystem issues have discussed ecosystem boundary, orchestrator, components, structure or architecture, modelling, mechanisms, operation mechanism, governance, capability, dynamics and comparisons among some typical ecosystems. Network analysis, multi-actor network, and graph-based approaches were used to map the relationship among actors in ecosystem. Platform strategy was mostly adopted to facilitate the interaction between actors, which had network effects.

However, existing studies covering all the aforementioned research themes were few. They were researched in the field of business ecosystem, digital ecosystem, knowledge ecosystem or innovation ecosystem, separately. Most existing literatures focused on strategy management, such as ecosystem strategy, innovation strategy, management strategy, orchestration strategy, network management, etc. The emergence and evolution of SSPIE were seldom explored. The co-evolution mechanism of IE lacked sufficient investigation, for example, the co-evolution mechanism between actors and environment, co-evolution mechanism among actors within ecosystem, and co-evolution of the whole ecosystem calls for further research.

5.2. Methods in SSPIE research

The findings on methods in existing studies were presented in Table 7.

Conceptual framework, case study and review were the most used methods. They were used to study business ecosystem, innovation ecosystem, digital ecosystem and platform ecosystem.

Although prior study summarized the research methodologies and methods in digital business research and presented the results from the qualitative and quantitative perspective, the details concerning the application of methods were missing. Existing literatures lacked a summary of methods analysis in innovation ecosystem research, especially in the field of SSPIE. Hence, we conducted a summary of the methods in SSPIE research. And we call for more empirical study in SSPIE research.

5.3. Theories in SSPIE research

The findings on theory adopted in examined studies were shown in Table 8.

Network theory, system theory, complexity theory, ecological

Table 7
Research methods in SSPIE research.

Research methods	Description	Examples of references
Conceptual orientation	Framework	6C framework for business ecosystem(Rong et al., 2015), integrative framework for innovation ecosystem(Wang, 2009)
	Modelling	Multi-agent modelling,(Dorigatti et al., 2016), Agent-based modelling methodology (Roundy et al., 2018), Qualitative comparative analysis (Xie and Wang, 2020), Pie model for innovation ecosystem(Talmar et al., 2018)
Case study	Multiple case study	The influence of modules features on digital platform openness (Wei et al., 2019)
	Single case	Enterprise innovation ecosystem based on the case of China's high-speed railway(Huang et al., 2019)
Survey	Empirical survey	A survey on business ecosystem, digital ecosystem and innovation ecosystem(Gupta et al., 2019)
Simulation	Agent based simulation	Agent-based simulation for collaborative supply chains(Dorigatti et al., 2016)
Experiments	Computational experiment	Computational experiment of supply chain network collaboration (Long, 2017)
Literature review	Review	Construction of innovation ecosystem (Gomes et al., 2018), review of innovation ecosystem(Oh et al., 2016), review of ecosystem(Tsujimoto et al., 2018)

Table 8
Theories adopted in SSPIE literature.

Theories	Specific field	Examples of references
Network theory	Collaborative network	Innovation network(Barrie et al., 2019), supply chain network(Long, 2017), service network(Ekman et al., 2016), Value network(Suominen, 2019)
	Actor-network theory	Digital innovation (Kolloch and Dellermann, 2018)
	Social network analysis	The affects of position in network on performance(Pellizzoni et al., 2019)
	Network management	Ecosystem network management (Aarikka-Stenroos and Ritala, 2017)
System theory	System thinking	System-based innovation ecosystem (Giannopoulos and Munro, 2019)
	System of system	Smart product service system (Liu and Ming, 2019)
Complexity theory	Complex adaptive system	Complex adaptive system for ecosystem (Phillips and Ritala, 2019), complexity for ecosystem innovation (Russell and Smorodinskaya, 2018)
Ecological theory	Ecology theory	Innovation ecosystem (Shaw and Allen, 2018)
	Ecosystem theory	A theory of ecosystem (Jacobides et al., 2018)
Evolution theory	Co-evolution	Evolution mechanism of ecosystem (Zhang et al., 2017)
Niche theory	Niche management	Strategic niche management(Walrave et al., 2018)

theory, and evolution theory were discussed by researchers. Network theory and complex adaptive system were the most theories to analyze the relationship among actors within ecosystem.

Despite some scholars presented the theories used in digital business ecosystem and discussed the theories from the perspective of usage percentages, the description of the applications for specific theories were missing. In addition, the classification of the theories used in digital business ecosystem was ambiguous and lacked a clear classification criteria.

Niche theory was employed in biological ecosystem and business ecosystem. However, innovation ecosystem research lacked its own niche theory to address the symbiosis issues of innovators. S-curve for the co-evolution of innovation ecosystem and resource-based theory for the innovation resource management and sharing of innovation ecosystem were also missing. We argue that the theory for SSPIE calls for further research in aspects related to the innovation resource, innovation activities, ecosystem sustainability and ecosystem co-evolution.

6. Summary

So far, researches on the structure, elements, typical features, and functions of IE were documented, but there were relatively few systematic publications devoted to architecture, model, methods, lifecycle, and co-evolution mechanism for SSPIE.

The definition of the SSPIE was missing in prior publications to date. Most existing researches investigated the relationships among actors from the perspective of value creation (or business domain), lacking a comprehensive consideration of business, innovation, knowledge, digital technology and biological ecology.

No systematic research on the framework of SSPIE has been published yet, the relevant theoretical literature was relatively scattered. Existing research on value co-creation mainly focuses on value creation and value capture, while the researches on value proposition and value delivery were few. There is a lack of research on the process of value co-creation for SSPIE.

As to the innovation process, there is no clear and unified definition of innovation chain. In terms of mechanism of value co-creation, there is a lack of theoretical research on crowdsourcing model in the context of innovation ecosystem. In terms of dynamics of SSPIE, few studies explored the mechanisms of symbiosis, co-evolution and renewal, with actors in relationship of both competition and cooperation throughout the lifecycle of ecosystem.

7. Challenges and future perspectives for SSPIE

7.1. Challenges for SSPIE

Despite SSPIE is promising and will accelerate the speed of SSP innovation, there remains challenging to construct and governance the ecosystem. The challenges are relavent to the literature review results in Section 5. As emerging research subject, the discussion of the challenges on the emergence is necessary (Section 6.1.1). The construction of ecosystem is the foundation for operation of SSPIE. Resource sharing is critical for the SSP innovation activities (Section 6.1.2). To ensure the innovation performance and value shared by all the stakeholders, influencing factors of the outcome of SSPIE should be considered (Section 6.1.3). Involvement of multiple actors in innovation for sustainability makes the conflicts inevitable, it is necessary to keep the stability of SSPIE (Section 6.1.4). To achieve

the goal of SSP innovation for sustainability, sustainability of SSPIE is also important (Section 6.1.5). The challenges can be divided into five aspects, namely emergence, resource, outcome, stability, and sustainability.

7.2. Challenges for the emergence of SSPIE

The challenges for the emergence of SSPIE lie in the key actors. How to attract capable key actors and how to select appropriate partners in the birth stage of SSPIE are challenging. A shared value proposition is critical for gathering innovation actors with shared goal and complementary resource and capabilities. When dealing with this challenge, the complexity and diversity of SSPIE need to be taken into account.

The complexity embody in the complexity of SSP itself, the process of SSP development, the relationship among actors, and the structure of the ecosystem, etc. The complexity reveals that the success of SSPIE depends on diverse actors with complementary resource. The diversity is reflected in the various actors, resources, roles, relationships, etc.

The openness of innovation platform influences the diversity of complementary products, service, technologies and resource. The higher the openness, the larger diversity. But the ecosystem complexity and the stability are affected. So, to address the challenges for emergence of SSPIE, the shared value proposition, partners selection criteria, and openness of platform calls for concerns.

7.2.1. Challenges for the resource sharing in SSPIE

Challenges for the resource sharing lie in the resource management, intellectual property and willingness to share. As the innovation activities depends on the supply of innovation resource, such as data, information, knowledge, capability, service, etc, resource configuration plays important role in facilitating innovation process.

Innovation ecosystem is different from knowledge ecosystem and business ecosystem. Its aim is to fill the gap between knowledge economy and commercial economy. Each innovation actor has its own resource. The operation of co-innovation platform depends on the innovation resource pool. To cope with challenges for the resource sharing in SSPIE, trust is also to be addressed. Because the willingness to share innovation resources is affected by the trust between actors and platform.

7.2.2. Challenges for the outcome of SSPIE

Challenges for the outcome of SSPIE refer to the value capture of ecosystem. The aim of SSPIE is to create value for all stakeholders as the shared value proposition promised. The success of the ecosystem or the value capture of the ecosystem depends on the value co-creation and value capture criteria. To maxize the outcome, the collaboration among innovation actors and governance of the platform needs to be concerned.

The healthy state of the whole ecosystem relays on the actors and relationship among actors. Factors influencing the quality of ecosystem are critical to avoid the value uncaptre of SSPIE, such as the vicious competition of actors for the same innovation resource. The quality of the whole ecosystem includes the quality of product innovation, quality of service innovation and the dynamics and governance. The role of ecosystem orchestrator is vital to monitor the state of the ecosystem. So, to handle challenges for the outcome of SSPIE, the process of innovation activity and the governance call for attentions.

7.2.3. Challenges for the stability of SSPIE

Challenges for the stability of SSPIE means the conflicts between actors and the equilibrium of the ecosystem. When different innovation entities compete for the same innovation resources, there will inevitably be conflicts. How to balance the conflicts and solve the overlap of the innovation resource is challenging. In addition, the entering of new actors and exiting of old actors will influence the structure of the innovation resource pool. The state of ecosystem is changing dynamically. When the number of actors or resources is out of the scope of reasonable interval, the structure and function of the ecosystem will suffer losses. To maintain stability of ecosystem, the threshold of the attributes of the ecosystem should be concerned, such as the volume and categories of resources, capabilities, and services.

7.2.4. Challenges for the sustainablity of SSPIE

Challenges for the sustainablity of SSPIE come from the actors, activities, and artifacts. Actors means the loosely-connected stakeholders during each stage of ecosystem lifecycle, who construct the ecosystem in the emergence stage, who provide innovation resource in the operation stage, and who share the value in the final stage. Activities means the co-innovation activities, in which actors will leave and the resource will run out. Artifacts means the infrastructure and tools actors used for co-innovation. The operation of co-innovation platform affects the sustainablity of ecosystem. These are the risk to be concerned to deal with challenges for sustainablity of SSPIE.

To ensure the sustainablity of the ecosystem, SSPIE has to evolve, moving from one equilibrium to another. The two equilibriums are quiet different. The success of the renewal depends on the co-evolution of actors within the ecosystem and co-evolution between actors and environment.

7.3. Future perspectives for SSPIE

The challenges mentioned above provide opportunities for further research in the future. In this subsection, we outlined five future perspectives, namely co-construction for challenges of the emergence, co-sharing for challenges of the resource sharing, co-creation for challenges of the outcome, co-existence for challenges of the stability, and co-evolution for challenges of the sustainablity, as shown in Fig. 10.

From system engineering perspective, by adopting the input-process-output model, the ecosystem can be seen as a complex adaptive system. The input of the whole ecosystem is the shared ecosystem value proposition derived from the customer requirements for SSP. The output of the ecosystem is the shared value by all innovative actors. The process is the convert from ecosystem value proposition to shared value in ecosystem.

The lifecycle of SSPIE can be divided into three phases, namely emergence, operation, and evolution. The emergence of the ecosystem relays on the co-construction of stakeholders. The operation deals with resources co-sharing, value co-creation, and co-existence symbiosis. The evolution refers to co-evolution of SSPIE. Co-construction, co-sharing, co-creation, co-existence, and co-evolution are five key aspects of SSPIE. The relationships among them are as follow.

Co-construction provides foundation for resources co-sharing via co-innovation platform. Co-sharing supports the functioning of co-creation and co-existence by offering innovative resources needed in innovation activities. Co-creation means co-innovation practices of interdependent actors connected by co-creation network, which generate added value for sharing by all actors. Co-existence aims to keep the ecosystem healthy and solve conflicts among actors. It works as safeguard for co-creation. Co-creation and co-existence support co-evolution. Co-evolution is a mechanism for self-renewal and achieving sustainability of the ecosystem.

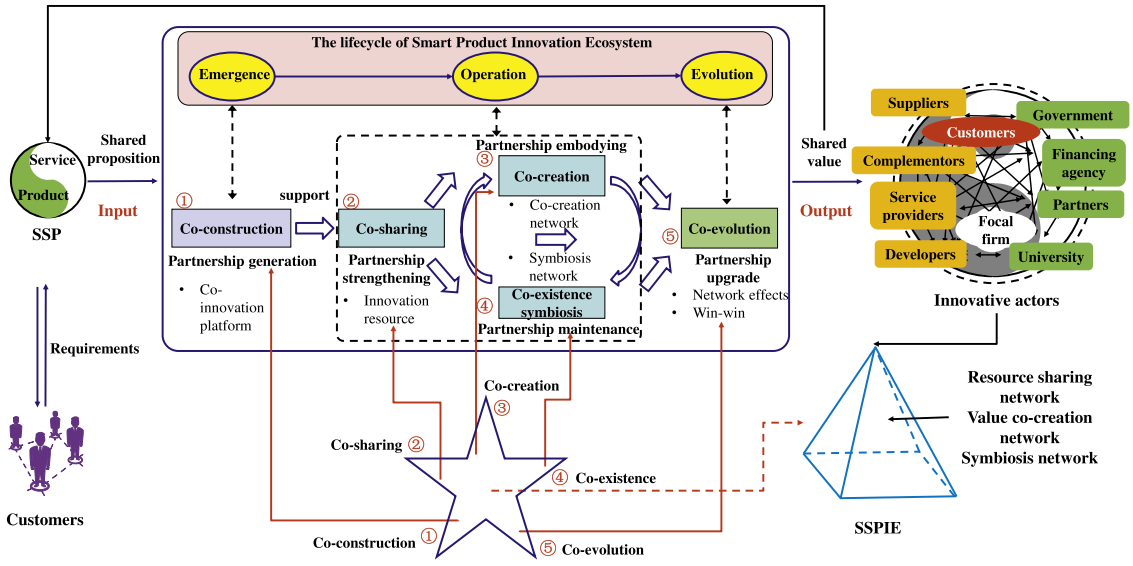

Fig. 10. Mapping of five future directions for SSPIE.

From the perspective of partnership management, the lifecycle can be divided into five steps, namely partnership generation, partnership strengthening, partnership embodying, partnership maintenance, and partnership update, which is corresponding to co-construction, co-sharing, co-creation, co-existence, and co-evolution, respectively.

7.3.1. Co-construction

Establishment of SSPIE depends on the joint efforts of multiple actors. The stakeholders or partners selection is a key step for building innovation ecosystem. The criteria, process, evaluation of selection is a direction for future research. In addition, as a matter of fact that SSPIE is a type of platform-based ecosystem, the infrastructure construction (i.e. the Co-innovation Platform or orchestration platform) is core of co-construction. How to attract partners to join the ecosystem, and how to facilitate the resource sharing and the interaction of multiple actors are concerned. The research on platform in the context of SSPIE, such as the IT architecture, functions, operation mechanism, etc. are promising and deserve further exploration to promote end-to-end innovation ecosystem.

7.3.2. Co-sharing

SSPIE can be viewed as a complex adaptive system. The outcome of innovation depends on the input and Co-innovation process. As input of the co-innovation, innovation resources play significant role in supporting innovation process. Each innovator in ecosystem own unique innovation resource. Sometimes idle innovation resource of one innovator is what another innovator in urgent need of. Resource co-sharing is a solution to address the mismatch between supply side and demand side of innovation resources. The shared innovation resource consists of knowledge resource, technology resource, creativity resource, etc. Resource management, matching of complementary resources, and configuration of resources are directions for future research.

7.3.3. Co-creation

On basis of innovation platform, resource co-sharing, the preparation for co-innovation has been completed. Co-ceration is the backbone of innovation ecosystem. It covers both Value co-creation process and Knowledge creation process (i.e. co-innovation). Despite value proposition, value creation, value delivery, and value capture have been studied by scholars in terms of business ecosystem. However, in the context of SSPIE, the Co-ideation, co-design, co-development, co-production have not been explored. In the future, the co-creation process (including value generation, innovation generation, and knowledge generation), co-creation organization, co-creation network, co-creation mechanism need more detailed research.

7.3.4. Co-existence

The relationship between innovators is an integration of cooperation and competition. Through the lens of niche theory, each innovator in SSPIE has its niche, which means the environmental condition and resource it needs to survive. The degree of innovation resource overlap among innovators affects the relationship. In order to maintain the equilibrium of the whole SSPIE, co-existence of species in ecosystem is an issue to be concerned. The condition of symbiosis, the balance between value creation and value capture is key factors to maintain the ecosystem's equilibrium. Value co-destruction may appear if the relationship among innovators is not well managed. Ecosystem may collapse only if the equilibrium was broken. So, niche management theory can be adopted to investigate the co-existence condition to avoid the extinction of ecosystem.

7.3.5. Co-evolution

Although evolution has been explored by numerous researchers. The co-evolution of SSPIE has something different from other ecosystem. During the lifecycle of SSPIE, the state of the ecosystem changes dynamically, such as the actors, relationship, structure of the innovation network, the state of innovation resource, stability, and the equilibrium. To keep the sustainable competitiveness of the whole ecosystem, the ecosystem has to evolve, moving from one equilibrium point to a new one. The mechanism of reborn of a new innovation ecosystem and the way a new innovation ecosystem spill off from an old one needs more theoretical and practical exploration. Existing literatures focuse on the co-evolution of actors. In the future, there is a trend towards ecosystem of ecosystems, co-evolution among different sub ecosystems is a direction to address the collaboration among ecosystems.

8. Discussion and conclusion

8.1. Discussion

Many countries around the world are investing heavily in IE and hope to be at the forefront of the global competition. As the world is towards sustainablility and smartness, more and more SSPs are emerging, a sustainable and smart future is around the corner. SSPIE is a new way to facilitate SSP innovation for sustainability from ecosystem perspective and promote the social collaboration from co-innovation perspective. It is promising to be devoted to this filed, as SSPIE is multidisciplinary, covering the research on product ecosystem, service ecosystem, digital ecosystem, knowledge ecosystem, business ecosystem, and innovation ecosystem.

As smart products integrate internet-based services, they are also viewed as smart PSS (Tomiyama et al., 2019), therefore, SSP can be seen as sustainable smart PSS (Liu et al., 2020). In this context, SSPIE is new mode supporting sustainable smart PSS innovation for sustainability from innovation ecosystem perspective. Sustainable smart PSS is at system level, while SSPIE is at ecosystem level or system-of-systems level.

The contributions of this paper are threefold, Firstly, we examined literatures on three aspects, namely SSP, innovation, and ecosystem. And then the binary interrelationships, namely SSP innovation, SSP ecosystem, and innovation ecosystem. The research gap was identifed from themes, methods, and theories perspectives.

Secondly, we proposed a definition of SSPIE on basis of literature review and gap analysis. The characteristics, and key components were described.

Thirdly, challenges and future perspectives were outlined from five directions for further research, namely co-construction, co-sharing, co-existence, co-existence and co-evolution, which will guide the future exploration in the field of SSPIE.

8.2. Theoretical contributions

This review contributes to sustainable and smart product development research by offering an innovation ecosystem perspective. The new generation information and communication technologies, ecosystem thinking and platform strategy have promoted the emergence of SSPIE.

In the field of innovation ecosystem research, the comparision between six types of ecosystems indicate that SSPIE cover the characteristics of product ecosystem, service ecosystem, business ecosystem, innovation ecosystem, knowledge ecosystem and digital ecosystem. It contributes to the understanding of definition, characteristics, and components of SSPIE.

This review also contributes to SSPIE research by offering a mapping framework of five future directions. The framework outlined opportunities in the field of the emergence, operation mechanism, and evolution mechanism of SSPIE.

8.3. Practical implications

The findings in this paper can work as reference for practitioners to adopt suitable innovation strategy that matches the SSPIE according to their roles. Some feasible solutions for practitioners to achieve sustainability goal via SSPIE are as follow.

For large companies, who are often the orchestrator of SSPIE, it is feasible to select partners from supply chain network as actors in the early stage of SSPIE. In the short term, the focal firm cooperates with them based on mutual trust. Then, ecosystem value proposition should be designed to attract more key actors participating the ecosystem and sharing complementary resources needed in SSP innovation. Platform strategy is employed to manage the innovation activities and protect intellectual property. In the long term, the success of SSPIE relys on the governance and sustainable value flowing among actors.

For SME, on one hand, they can choose to participate in suitable existing SSPIE that matching their capabilities and resources. On the other hand, they can build partnership with each other and construct innovation ecosystem for sustainable and smart components. The components can be tangible hardware or intangible service components.

8.3.1. Limitation

As the aim of this paper is to review literatures on SSPIE systematically and portray what SSPIE is, including the definition, key components, structure and characteristics. The implementation framework of SSPIE was not explored. The future direction of this paper will be devoted to an implementation framework for SSPIE.

8.4. Conclusion

With the development of digital technologies and the emergence of SSP. The development of SSP has attract great attention from industries. Innovation ecosystem has been explored by numerous scholars. However, the term “sustainable and smart product innovation ecosystem” has not been explored to date. Hence, firstly after introducing the birth of SSPIE, we proposed a definition for SSPIE and illustrated the characteristics, and components. Then, we conducted a survey on literatures related to SSP, innovation, ecosystem, and their binary interaction, namely SSP innovation, SSP ecosystem, and innovation ecosystem. The research gap was analyzed from three aspects, namely themes (i.e. product, service, business, technological, innovation, knowledge, and ecosystem), methods, and theories. Finally, the challenges concerning the emergence, resource sharing, outcome, stability, and sustainablity were presented. Accordingly, five future perspectives were outlined, namely co-construction, co-sharing, co-creation, co-existence, and co-evolution.

CRediT authorship contribution statement

Dao Yin: Conceptualization, Investigation, Methodology, Writing - original draft, Writing - review & editing. **Xinguo Ming:** Funding acquisition, Supervision, Resources, Investigation. **Xianyu Zhang:** Data curation, Validation, Formal analysis.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgements

This work was supported by National Natural Science Foundation of China [Grant No. 71632008] and Major Special Basic Research Projects for Aero engines and Gas turbines [Grant No. 2017-I-0007-0008, Grant No.2017-I-0011-0012]. The author would like to thank SJTU Innovation Center of Producer Service Development, Shanghai Research Center for industrial Informatics for the support to this research.

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