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TOWARDS SYSTEMATIC DESIGN OF CYBER-PHYSICAL PRODUCT-SERVICE SYSTEMS

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Abstract

Modern businesses are servitizing their offerings into product-service system to achieve customized value co-creation and superior customer satisfaction. PSS are evolving to incorporate cyber-physical capabilities to form a CPPSS. It enables real-time sensing, networking, and decision-making to enhance customization, sustainability, flexibility, and profitability. This paper presents a systematic literature review of CPPSS from which basic building blocks and principles are derived for the synthesis of a proposition for a new integrated definition and meta-model of its holistic design process.

Keywords: product-service systems (PSS), cyber physical systems, value co-creation, systematic literature review, design process

1. Introduction

Product-service systems (PSS) are primarily based on the idea that consumers, in general, do not demand a particular product but rather requires the utility of the product (Yang et al., 2009). As customer demands are evolving, businesses are realising that consumers are more interested in the solutions, experiential outcomes and benefits. As stated by the service-dominant logic, economic exchange now takes place via service (value) rather than product (Vargo and Lusch, 2008). Furthermore, the value is determined by the beneficiary, due to which value is not created but rather co-created by multiple actors (Vargo and Lusch, 2017). So, businesses are shifting from the product-oriented model to a service-oriented model (or servitization) which puts higher emphasis on customer involvement, feedback and equity (Mikusz, 2014; Annarelli et al., 2016; Wiesner et al., 2016). The value proposition is formed by the integration of the product and service in such a manner that it results in the most sustainable, economic, social, practical and efficient outcome. The service rather than the product has become the principal focus for the manufacturers to keep customers satisfied and loyal (Tan et al., 2010).
However, despite two decades of research, extant PSS lack real-time decision-making capabilities. Recent literature hints the inclusion of cyber-physical(CP) capabilities in PSS – creating a so-called cyber-physical product-service system (CPPSS) – can make PSS intelligent and robust (Scholze et al., 2016a). However, the literature has not dealt with CPPSS structure or design method which could leverage its technological superiority to deliver all its intended stakeholder benefits. This paper aims to contribute to closing the above knowledge gaps by conducting a systematic literature review (SLR).
From the SLR, this paper identifies the basic building blocks and conceptual principles of CPPSS from which its new integrated definition is proposed together with its corresponding holistic design method. The paper contributes to new knowledge on CPS and CPPSS. It helps researchers understand the relationships between various actors, implementation processes and design steps to create a CPPSS that can extend to a practical solution.
The organisation of this paper is as follows. Section 2 describes the background and research method. Section 3 and 4 elaborates on the PSS and CPS. Section 5 discusses the CPPSS with proposed definition

and design method. Section 6 concludes the paper with a summary of findings, limitations and a brief outline of a future research direction for CPPSS design.

2. Methodology

The CPS and PSS, although evolved from different backgrounds, can complement each other to form a technologically, environmentally and commercially superior system which can provide a competitive edge to the manufacturers and businesses alike. The PSS is a system that combines tangible products with intangible services by the collaboration of manufacturers and customers with the support from infrastructure and network for a superior solution. PSS offers mutual benefit to firms and customers while easing the exploitation of the environment (Minguez et al., 2012). Firms appreciate the new revenue streams and differentiation from the competitors while the customers enjoy higher level of flexibility, customisation, personalisation and solution alternatives. Concurrently, environmental sustainability and optimum use of resources is achieved. However, the next generation PSS demand immense technological support to solve the inherent complexities like sensing and processing of real-time data, remote monitoring/diagnosis and decision making (Evans et al., 2007; Isaksson et al., 2009; Flores-Vaquero et al., 2016). The inclusion of CP technologies seems as most suitable to address these issues (Scholze et al., 2016a). CPS is an intelligent combination of physical objects like sensors and actuators with the cyberspace like data processing, software and networking (Shi et al., 2011). By implementing CPPSS, the customers will be satisfied not only with a solution but also with continuous improvement in the service using the client specific data sensing and analysis (Wiesner et al., 2017), accelerated processing (Zheng et al., 2016b) and improved human-machine interactions (Wiesner et al., 2016). Following the above discussion, the SLR methodology is implemented with the view towards answering the following research questions.

1. What is the generic design method of cyber-physical systems (CPS)?
2. What is CPPSS and what is its generic design method?

The SLR methodology is considered appropriate as CPS and CPPSS are still in an embryonic and exploratory stage of research. This SLR uses the guidelines defined by Webster and Watson (2002), Kitchenham et al. (2009) and Annarelli et al. (2016). The SLR was divided into steps of planning, conducting and reporting. The planning stage sets the primary topic of research as CPPSS design with secondary topic as PSS and CPS designs. In the conducting stage, we chose the keywords and their synonyms such that they reflected these topics. For CPS related paper, CPS being a relatively more established concept, the selection criteria were stringent. Only English journal published papers with at least three citations were chosen. For the CPPSS, due to a small number of publications, the selection criteria were relaxed to include conferences. The reporting stage proposes the new integrated definition and design method for CPPSS based on the literature.

3. Product service systems

The term 'PSS' was proposed by the United Nations Environmental Program in the 1990s with the main aim to reduce the resource consumption and environmental impact (Qu et al., 2016). The literature describes PSS using various terms like full service, service package, integrated solution and functional sales (Park et al., 2012). Consequently, the definition of PSS remains a hotly debated concept with no consensus yet (Beuren et al., 2013). Some of the common terms used in defining PSS are integration (of product and service), fulfilment (of customer needs), impact (on the environment), network, value in use, competition, performance, offering, economic aspect, social aspect, lifecycle and solution (to a problem). Drawing from the extant literature, we define PSS as: *"A product-service system is a sociotechnical system, consisting a network of product and service offering that co-creates value-in-use by the provision of solution to customer needs while having improved impact on economic and environmental aspects throughout its lifecycle".* This definition incorporates all the terms found to be vital in the extant PSS constructs and satisfies the notion of PSS described by prior researchers.

The literature shows that the design method of PSS is divided into beginning of life (BOL), middle of life (MOL) and end of life (EOL). The BOL consist of inception and designing of a feasible PSS. Some BOL steps are customer needs, requirements, solution design/development, evaluation, value proposition and prototyping (Peruzzini and Marilungo, 2016). The MOL consist of activities during the implementation and deployment of PSS (Schweitzer and Aurich, 2010; Tran and Park, 2014; Sassanelli et al., 2016). The MOL also involve the repair, maintenance and remanufacturing process which recovers and reuses the PSS for higher economic and environmental benefits (Sundin and Bras, 2005). The EOL stage deals with the final fate of the PSS. Based on the business model, the PSS is recycled, retired or disposed (Sakao and Mizuyama, 2014; Sassanelli et al., 2016).

4. Cyber-physical systems

4.1. Overview

The term CPS was coined by Helen Gill of the National Science Foundation in 2006 (Gunes et al., 2014; Lee and Seshia, 2014). CPS has a broad range of application in healthcare (Lee and Sokolsky, 2010), transportation (Osswald et al., 2014), communication (Fink et al., 2012) and other critical infrastructures (Das et al., 2012). A simple search for "cyber-physical system" on SCOPUS yields 7,062 papers. These papers were filtered using the topic, abstract and keywords by looking for terms like design, framework, architecture and model to reduce the list to 49 articles. Comprehensive study of these 49 papers reduced the list to a total of 22 relevant papers.

4.2. Definition

CPS is defined as, 'an integration of computation with physical processes whose behaviour is defined by both cyber and physical parts of the system' (Lee and Seshia, 2017, p. 1). In manufacturing industry context, CPS is a technology for managing interconnected systems between its physical assets and computational capabilities (Lee et al., 2015). It actualizes a ubiquitous system that adapts to the context by learning, reconfigurating and co-operating (Broy et al., 2012). It is akin to some similar terms like the internet of things (IoT) and system of systems (Gunes et al., 2014). Some researchers consider CPS as a part of IoT (Hehenberger et al., 2016) while some others the vice versa (Wang et al., 2015). Furthermore, CPS is considered as an American term and IoT as European (Horvath and Gerritsen, 2012). The IoT is based on the concept that objects around us be connected using unique addressing and work towards a common goal (Atzori et al., 2010). On the contrary, CPS consists of sensors and actuators specifically deployed to control the desired environment. The generic CPS meta-model shown in Figure 1 is based on the CPS structure explained by Lee (2015). The components of the CPS meta-model are explained as follows:

- Physical - Natural/environmental components, sensors and actuators (Lee and Seshia, 2017). The variables are temperature, light intensity, motion, energy, heartbeat, size, weight and so on.
- Cyber - The combination of computation resources (Cardenas et al., 2008; Gunes et al., 2014), control algorithm (Cheng et al., 2016), data storage (Sanislav and Miclea, 2012), network (Wang et al., 2015) and decision-making capabilities (Horvath and Gerritsen, 2012) creating the virtual world of a multitude of interconnected actors and stakeholders.
- Communication Network - Connecting the cyber and physical using the mobile network (Wang et al., 2012), converters (Gunes et al., 2014) and wireless sensor/actuator network (Cheng et al., 2016) to facilitate communication and feedback. However, the internet may not be necessarily part of it (Wang et al., 2015).

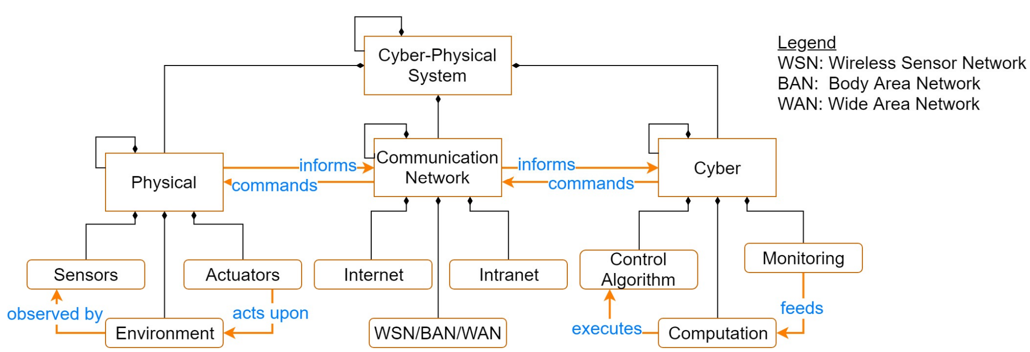

Figure 1. CPS meta-model

4.3. CPS design

The 22 papers (Table 1) are divided into implementation(I) and design(D) phases. The implementation phase consists of CPS architecture covering its processes or layers. Here, the CPS is perceived as a system that uses real-time communication and computation among the value-chain participants with socialisation, personalisation, servitisation and mass collaboration to satisfy the customer needs (Jiang et al., 2016; Colombo et al., 2017). The papers on design phase discuss the processes from ideation to deployment. This phase is changing the role of customers from buyers to prosumers by their collaboration in the lifecycle, development, production and usage (Jiang et al., 2016).

Table 1. Articles on CPS design

	Article	Phase	Application	Contribution
1	(Lee et al., 2015)	I	Industry 4.0	5 level architecture – Smart connection, data-to-information conversion, cyber, cognition, configuration
2	(Bagheri et al., 2015)			
3	(Jin et al., 2014)	I	Smart city	Three domain infrastructure – Network, Cloud and Data
4	(Wan et al., 2014)	I	Park vehicles	Context-awareness logic
5	(Hu et al., 2013)	I	Crowdsensing	Two platform architecture - mobile and cloud (knowledge base)
6	(Dillon et al., 2011)	I	Web of things	Three-layer framework – Physical environment, cyber-physical interface and WoT (Device, Kernel, Overlay, Context and API)
7	(Lai et al., 2011)	I	Digital home	Three-layer architecture – Physical, Service and Application.
8	(Hu et al., 2016)	I	Healthcare	6 level framework – sensing, processing, modelling, decision fusion, human and actuator
9	(Xiong et al., 2015)	I	Social systems (Transport)	CP social system architecture – ACP, parallel control & management, application
10	(Liu et al., 2017)	I	Review	Three-layer architecture – physical, information and user.
11	(Wan et al., 2013)	I	UAV platform	Architecture – IoT (sensing, processing, application, access) and Decision-control (processing, decision-making, real-time control)
12	(Cao et al., 2013)	I	HVAC system	Optimizing errors, delays, constraints and capabilities in cyber (including user), physical and wireless network.
13	(Sampigethaya and Poovendran, 2013)	I	Aviation	Bridge (integration) and interaction between cyberspace and physical world using sensor, actuator and controller
14	(Leitão et al., 2016)	I	Manufacturing industry	Cloud-based service-oriented multi-agent system for real-time responsiveness, intelligence and adaptiveness in manufacturing
15	(Wang et al., 2011)	I	Healthcare	Three core system – Communication and sensing core, computation and security core, scheduling and resource management core.
16	(Sangiovanni-Vincentelli et al., 2012)	D	Airplane braking	V model – design and integration phases are parallel (merge contract-based and platform-based design)
17	(Sztipanovits et al., 2012)	D	UAV	3-layer design process – computation/communication, platform & physical
18	(Eyisi et al., 2013)	D	Control	
19	(Banerjee et al., 2012)	D	Body Area Network	Seven steps – model (requirements, parser, variants), compute (cyber-physical interactions, variation), requirements verification, results
20	(Hehenberger et al., 2016)	D	Production systems	2 phases design process – conceptual and system modelling. Three disciplines – physical, computation and integration
21	(Zeng et al., 2016)	D	CP social systems	4 step Design framework – functional specification, intermediate representation model, architecture platform and design solutions.
22	(Kumar et al., 2015)	D	UAV	3 stage framework for design and validation of systems – concept design, detailed design and recursive refinement.

The CPS implementation literature clarifies that it aims to deliver intelligence and autonomy in the devices that directly or indirectly serve customers (Sanislav and Miclea, 2012). Due to this, the service tier (La and Kim, 2010) or service layer (Wang et al., 2012) was introduced in the CPS using the service-oriented architecture (SOA). SOA defines service as a self-contained, reusable software component, which is provided by the provider and consumed by the customer (Zhang et al., 2007). Consumption occurs when the usage of service component creates value for the customer, and the provider captures value in return. In addition to the software components, CPS consists of physical devices, which are abstracted as services using substitution and application rebuilding techniques (Yu et al., 2012). Thus, the cyber and physical components are represented as interoperable services that realise business functionalities (Wang et al., 2012). Service requirements are used to describe, manage and compose the physical devices that serve the customers (Yu et al., 2012). The customer requests for a service through the network and the data (or knowledge base) are used by the CPS to take necessary actions (Zhang et al., 2007; Hu et al., 2013; Jin et al., 2014).

The CPS design and implementation depend on the context (Wan et al., 2014), domain (Wang et al., 2012) and information (Hehenberger et al., 2016). The manufacturer designs a CPS platform consisting of reusable components and service modules that are variably integrated to form customer specific solutions by combining the resources of the collaborating providers (Broy et al., 2012; Sztipanovits et al., 2012; Eyisi et al., 2013). The combination depends on the factors like why (motivation), who (customer/user), where (location /environment), how (solution process), what (information/knowledge) and when (service delivery time) (Shafighi and Shirazi, 2017). The constraints depend on the cost and guarantees that define the contract/pricing among the actors in form of a business model (Sangiovanni-Vincentelli et al., 2012; Liu et al., 2016).

In the CPS design phase, the customer interaction and adaptation to co-create value influence the CPS design (Broy et al., 2012; Zheng et al., 2016a). In line with SDL, the customers become the co-designers (Tseng and Hu, 2014) or prosumers (Jiang et al., 2016). The customer problem and its appropriate requirements form the starting point of the CPS design method (Lee, 2008; La and Kim, 2010; Tariq et al., 2014; Karvonen et al., 2016). Customers either interact with the provider regarding their requirement or directly design the solution using the provider's tools (Tseng and Hu, 2014). The requirements are iteratively defined and redefined based on the contract, context and constraints (Cheng and Atlee, 2007; Banerjee et al., 2012; Sangiovanni-Vincentelli et al., 2012). The process also addresses the variability of stakeholders and their conflicting goals (Penzenstadler and Eckhardt, 2012). The iterations lead to a solution that directs the CP system design. The modules, interfaces and integration are designed to include the physical and computational components (Zheng et al., 2016a). Accordingly, the system specification and component specifications are described (Slomka et al., 2011). The modularisation approach composes each layer/part in a 'plug & play' fashion (Wang et al., 2011; Baheti and Gill, 2011; Schuh et al., 2014; González-Nalda et al., 2016). The finished CPS is then deployed after validation (La and Kim, 2010). Figure 2 shows a generic meta-model of the service-based CPS design method discussed above.

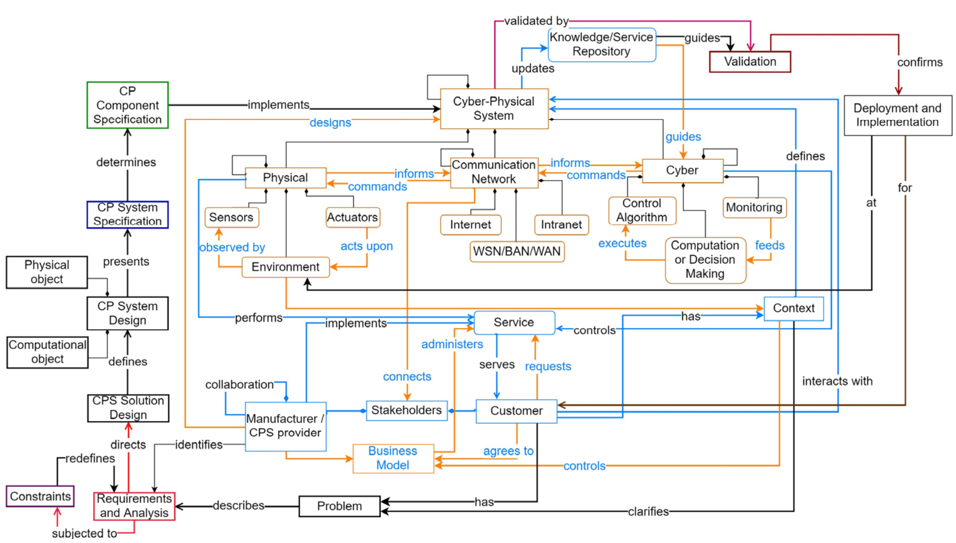

Figure 2. Generic design method for service-based CPS

5. Cyber-physical product-service systems

5.1. Overview

As CPPSS is a new concept, the research output is small. A search on the Scopus with appropriate keywords yields 28 papers. On comprehensive reading of each paper, the list reduces to 14 papers (Table 2). Most papers focus on manufacturing industry with case study as the research method.

Table 2. Articles related to cyber-physical product-service systems

	Article	Perspective	Application	Contribution
1	(Wiesner et al., 2017)	Requirements Engineering	Whitegoods, plastic extrusion	CPSS consists intelligent product that provides diverse services. It connects the customers, providers, suppliers, and other third parties
2	(Wiesner et al., 2016)		Video Surveillance	Game approach considers stakeholders, environments, innovative ideas and visualises the consequences of the defined requirements
3	(Kuhlenkötter et al., 2017b)	Value creation Lifecycle	Creation of research centre named ZESS	Different engineering perspectives for design of smart PSS (systems, system of system, PSS, smart object, product and service)
4	(Kuhlenkötter et al., 2017a)	Customer integration		Engineering lifecycle development, planning (manufacturing, product use, service provision, reconfiguration/end of life)
5	(Uhlmann et al., 2017)	Value creation	Manufacturing Industry	Onion architecture of CPS, IPS2 business model, lifecycle monitoring system structure, industry cockpit, modular factory control
6	(Marilungo et al., 2017)	CPS design for PSS	Plastic extrusion pipes	Five step method – analyse scenario, map tangible & intangible assets, model ICT infrastructure, define new process and analyse CPS benefit
7	(Scholze et al., 2016b)	Context/ scenario sensitivity	automation equipment	Two-platform product extension service – development (product) and deployment (services). Design method for PSS having CP features
8	(Scholze et al., 2016a)	Feedback for new PSS	Machine industry	Collaborative development environment and context sensitivity using stakeholders, supply chain and product network
9	(Zheng et al., 2016b)	Intellectualization of industrial PSS	Manufacturing Industry	7-module PSS framework – customer need centred product lifecycle, stakeholders, service abilities, business model, CPS and resources. A 5-layer CPS supported intellectualised PSS – physical resource, virtual resource, management platform, service and interface.
10	(Valencia et al., 2015)	Value of Smart PSS & design	General	Seven characteristics of smart PSS – consumer empowerment, service individualisation, community feeling, service involvement, product ownership, individual/shared experience and continuous growth
11	(Herterich et al., 2015)	Service innovation	Manufacturing industry	Identified seven affordances for the service business and its impact on manufacturers, operators and service organisations.
12	(Mikusz, 2014)	Business-oriented CPS	Manufacturing industry	Conceptualisation of industrial software PSS with three perspectives – solution, value chain and software part.
13	(Mehrsai et al., 2014)	lifecycle, cloud, flexibility.	Manufacturing Industry	Make-to-Xgrade and avatar concept for manufacturing industry at product, manufacturing, service and user cycles. Discusses the interaction between the products, manufacturers and end users.
14	(Lee and Kao, 2014)	Innovation	Manufacturing Industry	Proposed the dominant innovation design approach for smart PSS using innovation matrix, application space map and QFD

5.2. Definition

The literature uses various terms to denote the PSS-CPS combination. However, this paper adopts the term CPPSS since it signifies the presence of cyber and physical components in the PSS, in contrast to other terms. Apart from several benefits mentioned earlier, the CPPSS offers enhanced equipment engineering, optimised operations, remote control, remote diagnosis, information-driven service and optimised service (Herterich et al., 2015). It also forms the human-product collaborative network that brings about higher automation and data interchange in the industry (Scholze et al., 2016a). This capability enables idea competition, customer immersion, product platforming, collaborative design and innovation network in an open environment (Marilungo et al., 2016). Although the possibilities of CPPSS are immense, gaps exist in its definition and design method. The industry needs a design method which describes the procedures starting with customer requirements and leading to solution delivery (Dutra and Silva, 2016; Zheng et al., 2016b). Based on the extant literature, we propose to a preliminary "work-in-progress" definition for CPPSS as '*a product-service system equipped with cyber, physical, networking, computing and communication components to offer built-in intelligent capabilities to attain higher collaboration, interaction, efficiency, usability, appeal an value co-creation for the customers and all other stakeholders*.' The meta-model derived from this definition is shown in Figure 3. It is interesting to note that CPPSS may seem closely related to smart products which is described as an entity designed for providing improved simplicity and openness through improved interaction (Mühlhäuser, 2007). However, the CPPSS is a broader field which adds the service, value, actor network and environmental aspects to the smart products. Thus, smart products are more like the CPS from a technological perspective.

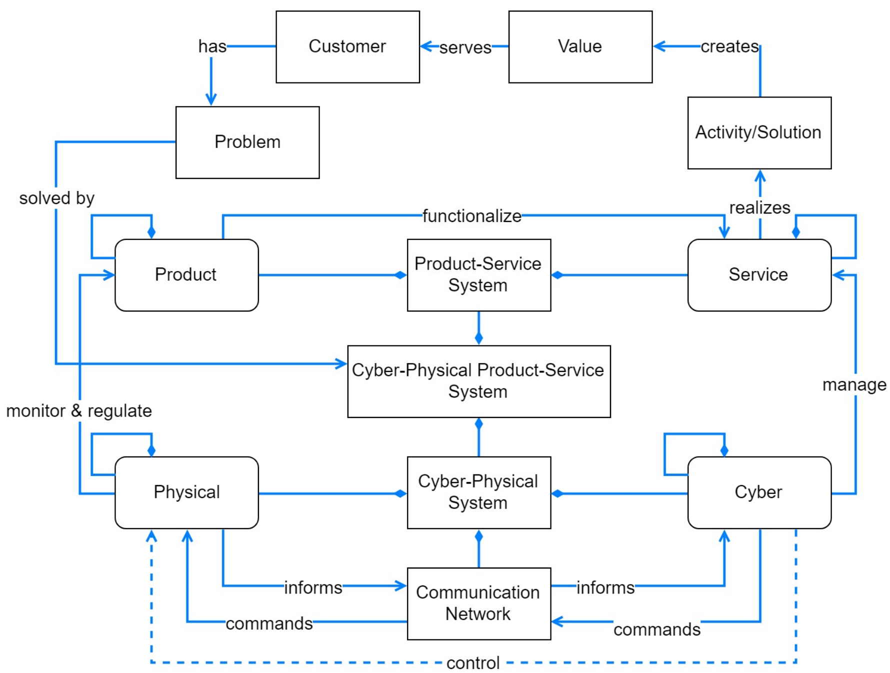

Figure 3. CPPSS meta-model

5.3. CPPSS design

The literature on CPPSS design emphasises on value creation, feedback, customer integration, innovation, context sensitivity and requirement analysis. However, the interaction and interconnection between the PSS and CPS components are either missing or only partially addressed. Some have treated the CPS as solely software component in CPPSS (Mikusz, 2014) while some treated the PSS only as a product-service bundle (Wiesner et al., 2017). Furthermore, some tried to use the CPS approach to form the PSS (Marilungo et al., 2017) while others tried to design PSS with CP features (Scholze et al., 2016a). This contrast makes the design method confusing and irregular.

CPPSS design must include the constituting perspectives of both CPS and PSS design method. CPPSS must accomplish the SDL co-creation approach by the collaboration of concerned actors. The feedback provides valuable information for continuous improvement of design and operation of the CPPSS (Dutra and Silva, 2016; Marilungo et al., 2016; Scholze et al., 2016a; Wiesner et al., 2016). The feedback also leads to a customer-centric framework that co-creates value for all the stakeholders alike (Zheng et al., 2016b). This framework must also fulfil the vital PSS characteristics identified by Valencia et al. (2015), namely: consumer empowerment, individualized services, community feeling, shared experience, product ownership, service involvement and continuous growth.

Similar to PSS, the CPPSS lifecycle consist BOL, MOL and EOL (Herterich et al., 2015; Kuhlenkötter et al., 2017b). BOL starts with the customer problem which is analysed to extract the requirements (Wiesner et al., 2016). It provides a concept map consisting of PSS and CPS components involving the stakeholders and third-party entities (Wiesner et al., 2017).

The stakeholders and entities are chosen to harness the value co-creation through the recognition of shared purpose, trust, inclusiveness, openness, reputation enhancement and relationship building (Pera et al., 2016). The requirements are divided into CP and PS to initiate the ideation. The requirements are evaluated using innovation matrix, QFD techniques (Lee and Kao, 2014). The planning stage then follows, where the modules, up/down-gradeability, constraints, business model and resources requirements are planned (Mehrsai et al., 2014; Kuhlenkötter et al., 2017a; Kuhlenkötter et al., 2017b). The CPPSS is realised by integrating the system, component, product and service level specifications. The functional CPPSS is then capable of value creation through the solution delivery (Wiesner et al., 2016).

During the MOL, the CPPSS is continuously monitored and updated using the collaborative feedback and reactions to solve evolving problems and improve performance (Zheng et al., 2016b; Wiesner et al., 2017). The products and services are also reused, repaired and remanufactured to meet the dynamic customer demands (Sundin and Bras, 2005). Additionally, the value creation relationship between the provider and customer is improved with regular maintenance of the actor network and service value chain (Numata et al., 2015). This step is enhanced by the knowledge repository that analyses the user characteristics and product-service information. In the EOL, the CPPSS is disposed or retired, based on the requirement and business model to assure its environmental sustainability. The derived CPPSS design method is shown in Figure 4.

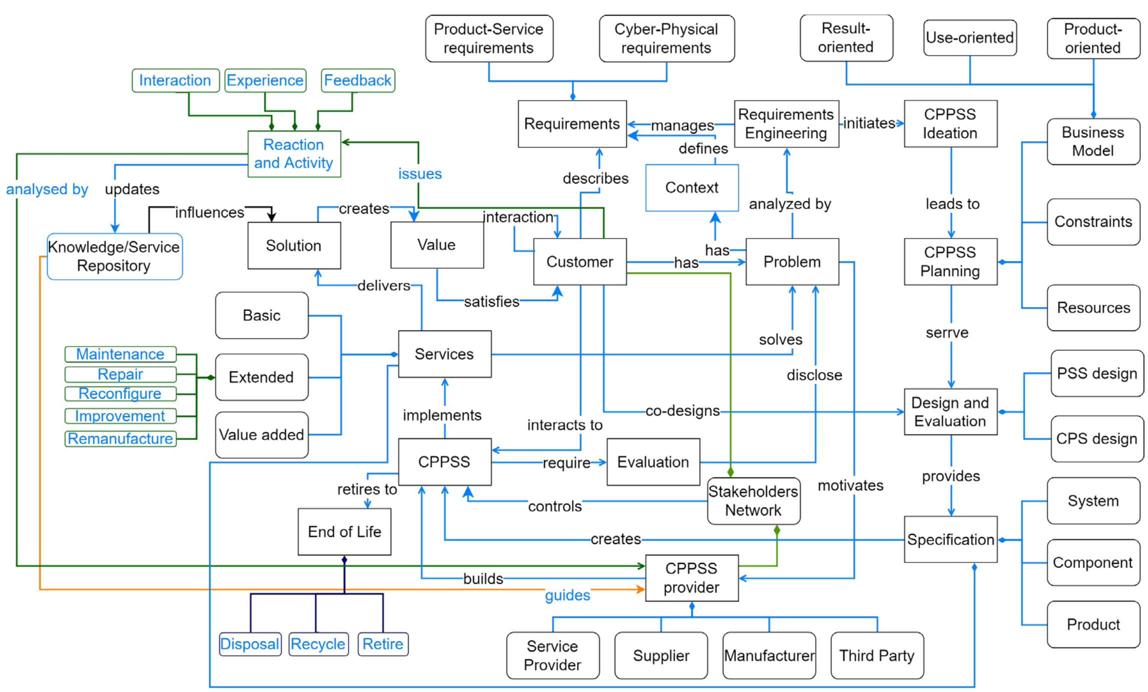

Figure 4. CPPSS design method

6. Discussion and conclusion

The focus of every business is to make a profit by efficiently delivering customer value. To obtain better profit, continuous revenue and a competitive edge, modern businesses have combined the offerings of products and services into their business model to form the PSS. PSS integration with the CPS can further advance this advantage through intelligence (analytics) and smartness. The CPPSS will enable the providers to gain significant customer insights and deepen customer intimacy with continuous data and non-data communication between them. It will provide the consumers (as prosumers) with fit-for-purpose solutions that satisfy their evolving needs efficiently, while simultaneously fulfilling the environmental sustainability requirements. Typical functions that the CPPSS include are: (a) monitoring product/service usage dynamically using sensors; (b) processing data analytics to make timely and efficient decisions; (c) institutionalize real-time feedback loop from and for all stakeholders; (d) actuating decisions using actuators; (e) connecting to a global network ecosystem of consumers, partners and manufacturers; (f) exchanging data and services globally.

Being an emergent new field, an end-to-end CPPSS design remains scarce in the literature. The proposed CPPSS design method contributes to closing the knowledge gap. It is observed that the operational effectiveness of CPPSS depends critically on the stakeholders jointly co-creating business model that delivers economic, social and environmental values. The co-creation directs the technical aspect to determine the requirements, usage, service and solutions. The design method must be holistic by performing tasks starting from the point of customer demand to the point of solution delivery.

This paper answers RQ1 by deriving a CPS design method from the extant literature. The RQ2 is answered by proposing a new integrated CPPSS definition and the associated design method. The core of the CPPSS is the PSS, on which CPS is mounted to provide the technological upgrade. The common ground of the PSS and CPS is finding solutions to customer problems by following the lifecycle approach. The product segment of PSS embeds the physical part of CPS which executes monitoring and actualizing through sensors and actuators. The service segment of PSS is controlled by the cyber part of the CPS that enables the smart capabilities by actor network management, data analysis, personalised decision and service delivery.

The definitions and design methods proposed in this paper contribute to theory building and opens new understanding in the field. The managerial implication of this research is the procedure to design CPPSS to better the customer satisfaction and value creation. Managers can proposition CPPSS solutions to customer problems by analysing the customer value, context and requirements. The steps involved in developing the CPPSS solution are also clearly discussed with their sub-steps and constraints. The inclusion of lifecycle approach enables the managers to pre-plan the development, implementation and termination of the CPPSS. Managers are made aware of various kinds of services in CPPSS context and the use of knowledge repository to understand the customer demands/reactions to deliver personalized services. Managers are also expected to regularly maintain/evaluate the CPPSS to ensure the actor network is co-creating the expected value.

The practical verification of design and development of CPPSS remains an open question that needs further research. Our future research would study the CPPSS design method implemented by designers and practitioners through case studies approach. The study would help improve and enhance the design method proposed in this research. The design method would embrace all stakeholders' contributions and define how they would co-create value resulting in a sustainable business solution.

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