Available online at www.sciencedirect.com

ScienceDirect

Procedia CIRP 64 (2017) 241 – 246

www.elsevier.com/locate/procedia

The 9th CIRP IPSS Conference: Circular Perspectives on Product/Service-Systems

PSS in healthcare: an under-explored field

Ke Xing[a], Mario Rapaccini[b]*, Filippo Visintin[b]

[a]University of South Australia, School of Engineering, Mawson Lakes Campus, Adelaide, South Australia, 5095, Australia

[b]University of Florence, IBIS Lab, Department of Industrial Engineering, V.le Morgagni 40 - 50131 FIRENZE (FI) ITALY

* Corresponding author. Tel.: +39 334 6565465. *E-mail address:* mario.rapaccini@unifi.it

Abstract

This paper reports the preliminary results of a research aiming at delineating the state-of-the-art literature concerned with the application of PSS in the healthcare industry. Following a structured literature review process, 23 studies are identified as the most relevant for the review. These studies are classified along the following dimensions: (i) research methods; (ii) motivations driving the development of PSS in healthcare; and (iii) focus and stakeholders of PSS applications. This paper reveals that despite the healthcare industry has always been conceived as an area where PSS can have a huge potential, studies on this topic is still very scant.

© 2017 The Authors. Published by Elsevier B.V. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).
Peer-review under responsibility of the scientific committee of the 9th CIRP IPSS Conference: Circular Perspectives on Product/Service-Systems.

Keywords: Healthcare; PSS; literature review; servitization;

1. Introduction

The rising demand for health services, mainly due to the population ageing, is making healthcare-related expenditure unsustainable [1]. In 2013, the United States spent $2.9 trillion on health, about $9.255 per person [2]. In 2013, in OECD countries health spending (excluding investment) as a share of GDP was 8.9%, ranking from 5.1% in Turkey to 16.4% in the United States [2]. Despite countless attempts to attack fraud, reduce errors, enforce practice guidelines, and implement electronic medical records, healthcare systems around the world continue facing rising costs [3].

This inevitably results in cuts in service capacity and poorer care. For example, from 1992 to 2008 in the US emergency visits increased from 89.9 to 123.8 million while at the same time the number of hospital emergency departments decreased from 4019 to 3833. As a result, it is estimated that approximately 90% of the US emergency departments suffer overcrowding problems [4, 5]. Similarly, in many OECD countries, the supply of diagnostic services no longer suffices to meet demand, which leads to unsustainably long waiting time [6]. In the meantime, overprescriptions and defensive medicines - extimated to cost $210 million per year in the US [7] - exacerbate the supply-and-demand imbalance.

Such an imbalance is worsening especially in those countries with sluggish economy where healthcare is based on the principle of universal coverage and financed by general taxation. In Italy, for example, health spending dropped - in real terms - by 3.5% in 2013 and had a further contraction of 1.4% in 2014 [8].

Analysts [9] agree that to prosper in the future, industry stakeholders will likely need to profoundly rethink their business models and strategies [3] and be ready to compete in markets which will be governed by multiple regulations, laws, and quality standards and where new competitors (e.g. big retailers such as Walmart) will soon offer basic services at very aggressive prices [3].

Setting against this context, Porter and Lee in their “landmark” work [3] posit that industry stakeholders should move from focusing on growing volumes and maintaining margins, as they have done in last decades, to strategically aim at “improving value for patients, where value is defined as the health outcomes achieved that matter to patients relative to the cost of achieving those outcomes”. Moreover, they argue that such a strategic shift will likely require: (i) converting

2212-8271 © 2017 The Authors. Published by Elsevier B.V. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).
Peer-review under responsibility of the scientific committee of the 9th CIRP IPSS Conference: Circular Perspectives on Product/Service-Systems.
doi:10.1016/j.procir.2017.03.068

organizations from vertical siloed ones, built around specific specialty departments or discrete services, to an Integrated Practice Unit, employing clinical and nonclinical personnel and able to provide a full care cycle for patient conditions (ii) measuring outcomes that matter to patients (e.g. if/how patients' clinical conditions are improved after a care cycle), and the cost of achieving certain outcomes, not just the volume of the services "unit" provided (e.g. how many surgery a patient underwent); (iii) being rewarded based on the value created instead of the volume of the delivered performance (e.g. the number of MRI scans, the number of surgeries etc..); (iv) transforming "loose confederations" of stand-alone units that often duplicate services into integrated systems with IPU specialized in certain "service line", each able to expand its geographic reach; and (v) creating IT platforms that support and encourage information sharing, implementation of expert systems and ultimately enabling integrated and multidisciplinary care.

Focusing on the *output* of production process (no matter if it is a service or a manufacturing one) to the *outcome* of the process and thus on the value (co)created (with)for customers, addressing customers' complex and sometimes latent needs with hybrid solutions [10], including tangible goods, service and information, reshaping vertical function-oriented organizations to horizontal cross-functional structures, creating ecosystems where specialised supplier deliver "building blocks" of solutions that are devised by focal companies acting as system and supply network integrators, establishing long-term relations with customers and with other suppliers in the network that extend throughout the solution lifecycle, as well as building IT platforms to enable and facilitate information sharing are, indeed, the challenges that former manufacturers delivering Product Service Systems (PSS) have been struggling with in the last two decades or so. While the literature concerned with PSS and related concepts such as servitization, service innovation, service dominant logic, etc., has been growing fast across multiple discipline (i.e. marketing, operations management, design) [11], studies investigating PSS in the healthcare industry are still very scant. Nonetheless, this sector has always been conceived as an area where PSS can have a huge potential [12].

This study aims at examining the state-of-the-art literature on applying PSS to the healthcare industry and delineating research opportunities in this area. As a working definition, in this study we consider the healthcare industry as "an aggregation and integration of sectors within the economic system that provides goods and services to treat patients with curative, preventive, rehabilitative, and palliative care. It includes the generation and commercialization of goods and services lending themselves to maintaining and re-establishing health." [13]. Adopting such an inclusive view about the scope of the healthcare industry to broaden the context of investigation, the sectors considered as relevant to this study include hospital, medical clinic, home care, aged care, telehealth as well as other forms of ambient assisted living.

The remainder of this paper is organized as follows: in the next section (Section 2) we define the method and selection criteria for screening the relevant literature on PSS applications to healthcare systems. Section 3 summarises the findings of this literature review, that are subsequently discussed in Section 4. Finally, Section 5 presents the conclusions.

2. Literature search

In this study, a systematic review approach is adopted. Scholarly articles concerned with PSS spread over a number of scientific disciplines. Google scholar, if queried with the keyword "healthcare", reports 4,290,000 search results. To cope with such a massive amount of papers, the following query ((\"product service system\" OR serviti*) AND healthcare OR *care) was used to search the fields of abstract, title, text and keywords in all of the most important databases (Emerald, Informs, Ingenta, Pubmed, Sage, ScienceDirect, Scopus, Springerlink, Taylor and Francis). In total, 261 papers were obtained after removing duplications.

For each paper, a record was created in a worksheet, containing the information of title, authors, date, keywords (when available) and abstract (when available). In the first round of review, all the authors separately read the title, keywords, and abstract of each paper and assigned a score ranging from zero (not relevant) to two (highly relevant). Papers rated zero by any authors were excluded by the sample. This left 26 papers that were subdivided among the authors to revise the assigned scores by briefly reading. 16 papers were subsequently discarded, but other papers found by performing less structured researches were added. As a result, the final sample includes 23 papers clearly arguing with PSS applications to the healthcare sector.

3. Finds of Review

Following the method and criteria described in the previous section, this section reviews and characterizes the 'landscape' of state-of-art research, methods and practices for integrating PSS with various forms of healthcare services as reported in the listed research papers (see Table 1). Particular interest is given to the research methods that have been employed, and to examining the key motivations and focuses of each contribution. As a result, the research questions that this paper intends to address are: a) why and how are PSS paradigms applied to healthcare systems? and b) what role does PSS play in the healthcare industry?

Table 1. List of references on PSS in healthcare

Ref.	Context	PSS Features	Method
[14]	General healthcare	Not specifically discussed	Literature Review
[15]	Personal wellness and sell-services	Not specifically discussed.	
[16]	Cancer care	While not specifically defined, the type of PSS represented is more akin to Result-oriented PSS	Exploratory Studies
[17]	Homecare and community nursing	Although there is no specific discussion on the type(s) of PSS suitable for the purposes, the emphasis on the holism and quality of homecare service provision and outcome is more akin to Result-oriented PSS.	
[18]	Mobility aids and active living for the elderly	Given its focus on value creation, the type(s) of PSS suitable for the purpose will be more in line with Use-oriented or even Result-oriented PSS	
[20]	General healthcare	Not specifically discussed. But, the types of PSS are to assist healthcare professionals with their care service jobs and improved patient outcomes and hospital efficiency results, akin to Result-oriented PSS.	
[34]	General healthcare	Result-oriented PSS is proposed for the case context in this paper	
[35]	Medical devices	Not specifically discussed	
[12]	General healthcare	Not specifically discussed	Design Science
[19]	Ambient assisted living	Not specifically discussed. However, with assisted living as the centre of focus, the type of PSS suitable for such a purpose is akin to	

		Result-oriented.	
[21]	Telehealth and health informatics	Not specifically discussed	
[22]	Healthcare in humanitarian aids	Not specifically discussed	
[23]	Aged care	Not specifically discussed	
[24]	General healthcare	While not specified, the type of PSS is more akin to Use-oriented PSS	
[25]	Drug delivery in healthcare	The business-to-customer scenarios represents a Result-oriented PSS paradigm and the business-to-business scenarios bears more resemblance of a Use-oriented PSS	
[26]	Assisted living for the elderly	The integrated model discussed in this paper is more akin to "offering technology for free, selling service content", which resembles Result-oriented PSS	
[27]	Medical devices	4 different business models are discussed, in which "Manufacturing hospitals buying product related services" and "Manufacturing hospitals paying per use of manufacturing equipment" represent Product-oriented PSS and Use-oriented PSS, respectively	
[36]	General healthcare and aged care	Although not specifically discussed, Servitization is mentioned as the type of PSS, facilitated by networked smart items, cloud platform and fog computing.	
[29]	Homecare and community nursing	While not specified, the type of PSS is more akin to Use-oriented PSS	
[30]	Assisted living for the elderly	The integrated model discussed in this paper is more akin to "offering technology for free, selling service content", which resembles Result-oriented PSS	Action Research
[31]	Assisted living for the elderly	While not explicitly defined, the integrated model discussed in this paper is more akin to "offering technology for free, selling service content", which resembles Result-oriented PSS	
[32]	General healthcare	Not specifically discussed. But, the characterisation from the internal stakeholder perspective includes Result-oriented, Product-oriented and Use-oriented.	Combined Methods
[33]	General healthcare	Not specifically discussed. But, the characterisation from the internal stakeholder perspective includes Result-oriented, Product-oriented and Use-oriented.	

3.1. Methodologies

It is important to probe into the research methods employed in the reviewed papers. Such an analysis can add valuable knowledge around the discourse on how PSS concepts are interpreted and tackled. By examining the relevant papers we find that the research methodologies can be largely classified into: a) *Literature Review*; b) *Exploratory Studies* (that use semi-structure interviews, surveys and in-depth case studies), c) *Design Science*, d) *Action Research* (which includes co-creation and 'Living Laboratory'), and *Combined Studies* (which combine two or more approaches). Literature reviews are used to explore PSS paradigms and theoretically discuss their application to specific problems of the healthcare industry [14, 15]. Exploratory Studies include contributions that investigate opportunities and mechanisms for PSS adoption with broader socio-economic-technological perspectives. Semi-structured interviews [16-18], in-depth case studies [19,20] as well as cross-sectional surveys [21] are used to explore uncertain phenomena, collect data from different actors (i.e. patients, healthcare professional, hospital managers). Design Science includes studies showing how design methods are applied to innovate the provision of healthcare services. Methods such as design thinking [22], systems innovation [12,23], systems design [12,22,24-27], and human/user-centric design [19] have been observed, which are typical of the research dealing with design in information systems [28]. Action Research includes a few studies that promote participatory approaches for building consensus, promote co-design and value co-creation [29]. For instance, 'Living Laboratories' are used for development and validation of contextual-specific solutions [30,31]. In this case, the focus of PSS is more on how to have divergent interests and capabilities of different healthcare stakeholders (e.g. patients, caregivers, medical experts, device providers, and public organizations) better engaged. Last, some contributions combine different research methods to avoid biases related to extant/prior research and to enhance validity of research findings [32,33]. Most contributions are based on qualitative research methods. This is in line with the fact that this field research is still in its infancy.

3.2. Key motivations

One of the most prevailing motivations for applying PSS to the healthcare sector is that the latter is considered as a complex social system, in which value is created through the combination of tangible and intangible goods, highly professional skills, regulatory regimes and rules, organizational practices, funding mechanisms and advanced technologies [12]. The nature of such a system also means involvements of different stakeholders that collaborate for service delivery, although they may have divergences [24]. Santos and Wauben [22] point out that such a complexity can increase dramatically for healthcare during international emergency relieve in developing nations, when medical operations for care provision (including equipment and personnel) need to be transferred across geographical and social contexts. Due to the mentioned complexity, there is consensus that systemic thinking needs to be in place to design healthcare solutions that should consider and incorporate human factors, economic, social and environmental implications, costs of medical products, and advances of technologies. The emphasis is essentially set on the integration of products and services as well as between them and other resources/infrastructure [12]. A similar view is shared by other researchers, which claim that healthcare provision and infrastructures have become more pluralistic, customized and decentralized [14]. In this case, a combination of tangibles and intangibles such as products, hardware, services, facilities, professionals and patients, can offer greater opportunities for collaboration, innovation and performance improvement [15,20,25]. In such a context, the adoption of PSS paradigms can serve as a mechanism for solution design and integration, as well as for the embodiment of innovative technologies and practices that provide the desired cares and meet social expectations in the long-term.

PSS logics is also recognized as capable of enhancing the stakeholder engagement for personalized care services, medicines and environment/space [15,20,24-26,30]. This is especially important for ambient assisted living [26,30,31] to offer disabled and elderly people opportunities for self-determined and managed lifestyle at home, having medical treatments and assistive care services tailored to their individual needs and conditions. In these situations, PSS concepts are adopted to help in finding and exploiting synergies for integrating social and health services with hardware (customized monitoring devices and sensors) [24] and linking them with information communication technology (ICT) platforms, home automation systems and care environment/space [30,31] to support personal wellness solutions for autonomy enhancement and comfort. Some studies show that it is vital to bridge the gaps between implementing assistive technology and engaging patients through the provision of 'positive emotional experiences'

[16,29]. In this case a combination of goods and services, integrated into the design and operation of care facilities and space, can be effective in providing result management for both care recipients and other stakeholders.

The need for a PSS in healthcare is also supported by the requirements for better and more collaborative information and performance management, which is critical for telehealth and home/community care services. While point-of-care (POC) devices with wireless sensors are widely applied for continuous monitoring in a long distance, often than not they have limited informatics capabilities for real-time healthcare problem solving when operating as stand-alone products [21]. Connecting healthcare devices with service networks and flexible user interfaces, as presented in [12] and [34], is required to support effective and efficient long-term condition monitoring and management services. Such needs can be better realized by PSS-based approaches to fully exploit informatics and measurement functionalities of POC devices for user needs and preferences, enabling care givers and physicians to monitor and manage care recipients' situations efficiently, as well as keeping healthcare system cost-effective. Furthermore, some recent studies [17,20,21,34] underscore that homecare and assistive living needs to focus on patients, quality of processes, efficiency and cost. A PSS-enabled patient-centric healthcare network model integrating hardware platforms with software systems (include processes and interactions) is required for helping online interactions among patients and healthcare service providers in knowledge sharing and collaborative decision-marking. Tilman et al. [14] and Breitschwerdt et al. [17] postulate that an enhanced collaboration among multiple partners (healthcare professionals, patients, and IT providers) through PSS not only can improve performance and cost effectiveness of care services, but also can attract additional stakeholders, such as health insurance firms and public health organizations, to form public-private partnerships.

The potential of PSS applications in healthcare has also been examined to emphasize social and environmental implications of the technology raise in home healthcare. For example, some studies [19,22] reveal that current ICT-based telemonitoring and eHealth practices for ambient assisted living are often less focused on human-technology interactions and environmental issues. Boerema et al. [18] also argue that mobility aids solutions for the elderly need to be more humanistic and address social, economic as well as psychological needs of end users, i.e. both economically and socially sustainable. The nature of such requirements advocates a shift from artifact-centric/product-dominant logic to user-centric/service-dominant logic in healthcare system design, which underpins the relevance and importance of PSS applications to the context. Using a local care for elderly people as a case context, Joore [23] test the proposition on how short-term commercial innovation interplays with a long-term sustainable vision of the society. A solution resembling PSS emerges as an outcome of the analysis that can better serve social sustainability visions and requirements. As said, PSS can also facilitate addressing environmental sustainability of design choices in the industry of medical devices [35]. The single-use business model adopted for medical devices requires a more systematic solution, not just focusing on devices in isolation. As a result, moving toward PSS offers potential for better addressing environmental concerns (related to the single-use goods) and improving cooperation among stakeholders (manufacturers, hospitals and healthcare facilities) beyond merely competitive and transactional relationship. This is in line with the number of research that has been devoted to improving the competitiveness of medical product manufacturers. Stantchev et al. [36] point out that novel technologies (e.g. cloud/fog computing and smart devices) can favour 'servitization', i.e. the shift to the service business of the manufacturers of medical devices. For instance, manufacturing firms can increase revenues and extend market offerings as they start to support medication treatments, assist eHealth service provision, and protect the privacy of patients' data. Meanwhile, other technologies can enable 'productization'. For instance, using additive manufacturing hospitals can extend their role and become a healthcare product producer [27]. Such prospect instigates a need for exploring the possibilities of changing business models and operations through the lens of PSS.

Summing up, this review show several factors that motivate the application of PSS concepts to healthcare systems. The rationales and enablers underpinning the diverse application are synthetized in Table 2. We can argue that, on one side, PSS concepts facilitate system thinking and dealing with the intrinsic complexity of healthcare systems. On the other side, PSS models can support design, development and testing of innovative forms of cares, irrespective of what drives the innovation (e.g. new business opportunities, novel technologies, emergent needs of patients and caregivers, etc.).

Table 2. Key motivations (rationales and enablers) of PSS applications

Rationales	Enablers (from PSS application)	References
Align divergences among actors having different objectives.	Adopt system thinking and multi-stakeholder perspective, embracing theory from different disciplines (e.g. marketing, institutional theory, service science, sustainable development)	[12,22,24] [15,20,25] [18,19,22] [23,35]
Reduce complexity due to exogenous (e.g. ageing population) and endogenous (e.g. budget cuts) factors	Take into account a variety of socio-technical aspects, human needs, advances of technologies, social and environmental considerations.	
Improve existing healthcare solutions, facilitate collaboration and integration of different resources and processes	Operational practices of PSS can help raise productivity, lower costs integrating skills, data and processes	
Design new healthcare solutions based on new cutting edge technologies (e.g. Ambient Assisted Living, cloud, IoT, smart sensors, connectivity).	Adopt user-centered design techniques, focus on the needs of care-takers and care-givers. Create better patient-experiences, increase engagement and satisfactions.	[24,25] [15,16,20,26,29,30,31] [17,20,21,34] [26,27]
Reshape radically the healthcare industry with disruptive solutions.	Support the development of business strategies and operational practices that are more appropriate to shift to service business.	

In the following section we describe the focuses of the reviewed applications and identify to which stakeholders they are directed.

3.3. Focuses and stakeholders

Most of the reviewed contributions employ PSS to address problems of extant healthcare systems. Especially in situations where the relations among stakeholders are competitive and transactional [35] and the emphasis of the

provided solutions are overly skewed toward medical equipment, healthcare facilities, and ICT devices, the adoption of System Thinking approach can be beneficial. This can be observed in a number of research that, through the use of service-dominant logic, service science or other interpretative theories, promote a holistic view about value-creation in healthcare and a whole-of-system approach for service outcomes and quality [12,14,15,18,22,23,29,35]. Such studies often mainly present a high level analysis which examines healthcare as a complex socio-technical system [12, 14,15,18,22,29] and covers a broad spectrum of compositions and roles of PSS in healthcare as a new phenomenon and way of thinking, without drilling down to specific technical design or business model aspects. This approach is applied to instigate systems innovation and transform traditional healthcare systems. Combining services with products, technologies, process, and facilities can produce results in a more context-appropriate manner to fulfil social needs [12,22,29] and sustainability requirements [23,35]. Irrespective of the specific scope, these applications are all focused to achieve consensus and set strategic decisions around given problems. Contributions from this research stream are primarily and inherently directed to policy-makers and society, and to healthcare professionals that take strategic decisions (e.g. general and medical directors).

In other cases, PSS plays a role as an enabler or vehicle for conveying hybrid and holistic solutions to both care providers and patients [17]. This kind of application shows a higher degree of intervention and help in solution development and provides means for collaboration and integration. Examples demonstrated in the literature generally focus on facilitating actions for establishing: 1) closer relationships among healthcare providers, pharmaceutical firms, hardware providers, and patients [19,21,25]; 2) integration between devices, clinical workflows, and additional value-adding services, such as consulting, training, education [17,19,25]; 3) integration between different forms of devices and products, including drugs [17,21,25,27]; and 4) integration of healthcare products and healthcare infrastructure/facilities [17,27,36]. In some studies, PSS clearly serves for proposing new and more conducive models for business-to-business and business-to-customers interactions, as seen in [25,27,36] for cost efficiency, quality management, and risk mitigation in developing and delivering healthcare products and services. In addition to providing mechanisms for solving contextual problems, some PSS applications are intended to support innovative system design. The discourse around the embodiment of business model and functionality configurations is notably facilitated by PSS concepts, especially in cases a particular emphasis on the interactions with smart devices and digital platforms can be set [16,24,30,31,34]. Meanwhile, the design solution can be an outcome of integrating different healthcare solutions or systems. For instance, in [26] a PSS model is realized through combining ICT solutions of two social and health services (T-seniority and Long Lasting Memory) for independent living and linking them with a range of additional cognitive and physical support service components. The solution for a new cancer care system by exploring and capturing synergies between care service operations and care facility/space design in [16] is also an example of PSS in healthcare as an integration of solutions. As another research stream that uses PSS to facilitate design of novel healthcare solution, PSS can be applied to guide the servitization of firms producing medical products [36], and/or to evaluate and justifying changes to the resources directly produced by hospitals for delivering healthcare services [27]. As a result, these contributions are directed to designer, consultancy firms, entrepreneurs, as well as healthcare professionals, instead of policy makers and communities. Table 3 summarizes these findings.

Table 3. Focuses and stakeholders of PSS applications

Focuses	Stakeholders
Create consensus in policy-making. Set and support strategic decisions.	Policy-makers and communities Managing and medical directors, healthcare professionals
Support ideation, design and development of novel healthcare solution. Support 'servitization' of firms producing medical products. Justifying changes to the resources directly produced by hospitals for delivering healthcare services.	Designer and consultancy firms, entrepreneurs Managing and medical directors, healthcare professionals.

4. Discussion

Typically, the construct of a PSS in healthcare involves a constellation of products, services, facilities and space, policies and procedures, and players to enhance positive emotional reactions, quality lifestyle, and sense of empowerment for patients [12,16]. Despite such commonalities, the actual forms of PSS developed and implemented for healthcare sectors can vary greatly, as analyzed by Yip and colleagues [20,32,33], in relation to their roles in facilitating healthcare service and to suggest proper or more sustainable strategies to the service providers.

Based on how they interact with the development and delivery of healthcare solutions reported in the literature, it is understood that applications of PSS in healthcare can play diverse roles. However, our review of the extant literature on this topic suggests that two roles prevail. On one side, PSS is viewed as a tool for helping system thinking. Its applications are strategically directed to policy-makers and whoever can influence the decision making process. On the other side, PSS is leveraged as a design tool. In particular, we observe that PSS is particularly adequate to guide the (re)design of novel and integrated product-service healthcare solutions. Facilitating new forms of value creation to emerge, the adoption of PSS can eventually lead to reshaping the whole industry in the long term.

5. Conclusion

Healthcare is a globally relevant industry, subject to raising demand for personalized cares and budget limitations. Healthcare solutions integrate tangible and intangible resources, such as medical products, information and data, equipment and facilities, practices, knowledge and skills. Although PSS applications can have a huge potential in this industry [12], research around this topic are very scant. In this paper we present findings from a literature review on 23 papers. The paper draws some considerations about the

motivations behind PSS applications in healthcare systems. We also delineate the major roles that the research on this field actually consecrates to PSS applications: a) instigating system thinking, and b) guide the design of novel healthcare solutions. Clarifying the diversity of the applications, this paper can have implications for policy- and decision makers of healthcare systems at local, regional and national level, as well as for entrepreneurs and engineers engaged in the development of novel healthcare solutions. In fact, as far as PSS concepts spread, there could be relevant modifications in the way healthcare products and services are procured. The shift from product-dominated to use- and result-oriented view in setting up healthcare solutions could largely favour the servitization of firms competing in this industry. The paper also confirms that the research in this field is still - as expected - in its infancy, and mostly descriptive. More qualitative and quantitative investigation should be undertaken to move into «normal science». Case studies, surveys, action research could be leveraged to replicate and test normative hypothesis and confirm the benefits that can be achieved from PSS applications in the healthcare sectors. Most promising topics to be investigated concerns, in line with Baines et al. [37], PSS applications that are disruptive for the healthcare sectors, customer acceptance of PSS providing new forms of cares, and how manufacturers can create and leverage ecosystems to provide PSS to the healthcare industry.

References

[1] World industry outlook: Healthcare and pharmaceuticals, The Economist Intelligence Unit, May 2014

[2] http://www.oecd.org/els/health-systems/health-data.htm

[3] Porter, ME, Lee TH. The strategy that will fix health care. Harv Bus Rev 91.12 (2013): 24.

[4] Trends and Characteristics of U.S. Emergency Department Visits, 1997-2007, JAMA, 304: 6, August 11, 2010.

[5] National Hospital Ambulatory Medical Care Survey: 2006 Emergency Department Summary, Centers for Disease Control and Prevention, Number 7, August 6, 2008, http://www.cdc.gov/nchs/data/nhsr/nhsr007.pdf

[6] Nuti, S., Vainieri, M., & Frey, M. (2012). Healthcare resources and expenditure in financial crisis: scenarios and managerial strategies. The Journal of Maternal-Fetal & Neonatal Medicine, 25(sup4), 40-43

[7] The Price of Excess: Identifying Waste in Healthcare Spending, PricewaterhouseCoopers LLP Health Research Institute, 2008

[8] OECD Health Statistics 2015, Country Note: How does health spending in Italy compare?, www.oecd.org/health

[9] Deloitte 2015, Global health care outlook Common goals, competing priorities

[10] Rapaccini, M.and Visintin F.. Devising hybrid solutions: an exploratory framework.Production Planning & Control 26.8 (2015): 654-672.

[11] Brax, SA., Visintin F. Meta-model of servitization: The integrative profiling approach. Industrial Marketing Management (2016), http://dx.doi.org/10.1016/j.indmarman.2016.04.014.

[12] Marceau J, Basri E. Translation of innovation systems into industrial policy: the healthcare sector in Australia. Industry and Innovation 2010; 8(3):291-308.

[13] https://en.wikipedia.org/wiki/Healthcare_industry

[14] Tilmann PA, Tzortzopoulos P, Formoso CT. Redefining healthcare infrastructure: moving toward integrated solutions. Health Envir Research & Design J 2010; 3(2):84-96

[15] Salamati F, Pasek ZJ. Personal wellness: complex and elusive product and distributed self-services. Procedia CIRP 2014; 16:283-288.

[16] Stacey PK, Tether BS. Designing emotion-centred product service systems: the case of a cancer care facility. Design Studies 2015; 40:85-118.

[17] Breitschwerdt R, Robert C, Thomas O. Mobile application systems for home care: requirements anaysis and usage potentials. AMCIS 2011 Proceedings - All Submissions; 152.

[18] Boerema ST, van Velsen L, Vollenbroek-Hutten MMR, Hermens HJ. Value-based design for the elderly: an application in the field of mobility aids. Assist Tech 2016; DOI:10.1080/10400435.2016.1208303.

[19] Andreoni G, Arslan P, Costa F, Muschiato S, Romero M. Ergnomics and design for sustainability in healthcare: ambient assisted living and the social-environmental impact of patients lifestyle. Work 2012; 41:3883-3997.

[20] Yip MH, Phaal R, Probert DR. Stakeholder engagement in early stage product-service system development for healthcare informatics. Eng Manage J 2014; 26(3):52-62.

[21] Flores-Vaquero P, Tiwari A, Alcock J, Hutabarat W, Turner C. A product-service system approach to telehealth application design. Health Inform J 2016; 22(2):321-332.

[22] Santos ALR, Wauben LSGL. Systems design perspective of healthcare provision in humanitarian aid. FORMakademisk 2014; 7(3):1-19.

[23] Joore P. The V-cycle for system innovation translating a broad societal need into concrete product service soutions: the multifunctional centre Apeldoorn case. J Clean Prod 2008; 16:1153-1162.

[24] Landolfi G, Alge M, Cinus M, Menato S, Canetta L, Pedrazzoli P. Human-centric data model and data integration platform enabling personalized product service systems for healthcare. Proceedings of Int'l Conf on Eng, Tech and Innov 2014.

[25] Mittermeyer SA, Njuguna JA, Alcock JR. Product-service systems in healthcare: case study of a drug-device combination. Int J Adv Manuf Tech 2011; 52:1209-1221.

[26] Bamidis P, Alborg M, Moumtzi V, Koumpis, A. Synergy between social and health services under an ambient assisted living environment for the elderly. eChallenges e-2010 Conf Proceedings. Cunningham P, Cunningham M, editors.

[27] Pourabdollahian G, Copani G. Development of a PSS-oriented business model for customized production in healthcare. Procedia CIRP 2015; 30:492-497.

[28] Henver, A. R., March, S. T., Park, J., and Ram, S. Design science in information systems research. MIS quarterly, 28(1) (2004): 75-105

[29] Groeneveld BS, Boess SU, Freudenthal A. Community-based co-design for informal care: bridging the gap between technology and context. Proceedings of 12th IFAC Symposium on Analysis, Design, and Evaluation of Human-Machine Systems 2013; 266-273.

[30] Moumtzi V, Farinos J, Wills C. T-seniority: an online service platform to assist independent living of elderly population. Proceedings of PETRA'09 2009.

[31] Moumtzi V, Wills C. Utilizing living labs approach for the validation of services for the assisting living of elderly people. Proceedings of 3rd IEEE Int'l Conf on Digit Ecosys and Tech 2009; 552-557.

[32] Yip MH, Phaal R, Probert DR. Characterising product-service systems in the healthcare industry – an internal stakeholder perspective. Proceedings of IEEM 2012; 1736-1740.

[33] Yip MH, Phaal R, Probert DR. Characterising product-service systems in the healthcare industry. Tech in Society 2015; 43:129-143.

[34] Adeogun O, Tiwari A, Alcock JR. Informatics-based product-service systems for point-of-care devices. CIRP J of Manuf Sci and Tech 2010; 3:107-115.

[35] Moultrie J, Sutcliffe L, Maier A. Exploratory study of the state of environmentally conscious design in the medical device industry. J of Clean Prod 2015; 108:363-376.

[36] Stantchev V, Barnawi A, Ghulam S, Schubert J, Tamm G. Smart items, fog and cloud computing as enablers of servitization in healthcare. Sensors & Transducers 2015; 185(2):121-128.

[37] Baines T, Ziaee Bigdeli A, Bustinza OF, Shi G, Baldwin JS, Ridgway K. Servitization: revisiting the state-of-the-art and research priorities. International Journal of Operations & Production Management 2017, 37(2).