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Value co-creation of Product-Service-System in multiple sclerosis: An ecosystem perspective

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Abstract

There is limited research on the connection between business models and the successful implementation of eHealth products and services involving different stakeholders, specifically considering (i) the potential contribution of each actor and (ii) their structural alignment with the ecosystem's value propositions. This study explores a model in which healthcare products and services are integrated, allowing patients and providers to co-create value through collaborative, personalized healthcare solutions, also known as the Product-Service-System. A Remote Gait Monitoring Product-Service-System is developed to facilitate the implementation of innovative technologies and practices, linking care providers, healthcare professionals, and patients within the ecosystem. To identify value creation potential, several semi-structured qualitative interviews were conducted among main multiple sclerosis stakeholders. Participants were asked about their perception of the value and future potential of a Product-Service-System for managing chronic multiple sclerosis. Interviews were coded and analyzed using qualitative methods. The findings reveal three significant constructs that create value for each actor in the ecosystem: the ecosystem's value proposition, value addition, and value network. The expected impacts in terms of innovation, sustainability, and social effects for the involved actors are related to value capture. Although this study focuses on a particular Product-Service-System for monitoring gait disturbances in real-life situations among patients with multiple sclerosis, the underlying principles could apply to other domains with similar critical factors.

Keywords: *Ehealth, Digitalization, Product-Service-System, innovation ecosystem, ecosystem business model*

JEL Classification: O35, M21, I15

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1 INTRODUCTION

In recent years, the digitalization of healthcare has been a topic of interest for both academics and practitioners (Agarwal et al., 2010; Kraus et al., 2021; Reis et al., 2018). EHealth is rapidly evolving and has the potential to become an important element of healthcare systems. A rapidly aging population, combined with restrictions on public spending, has created strong latent demands for eHealth. Therefore, eHealth innovations are expected to contribute to sustainable healthcare and societal development (Conboy et al., 2020a; Oh et al., 2005; Pappas et al., 2018).

Scholars have reported benefits such as offering a more cost-effective way of developing predictive, preventive, personalized, and participatory medicine (Almobaideen et al., 2017; S. Y. Lee & Lee, 2018; Wang et al., 2018). However, previous research has shown that there are challenges associated with the use of digital technologies (DTs) in healthcare (Anderson & Agarwal, 2011; Martin et al., 2011).

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In healthcare, many previous studies have addressed the technological aspects of eHealth innovations, but the business models (BMs) underpinning these innovations are often overlooked (Oderanti et al., 2021). Some empirical studies on the use of BMs in eHealth have focused on successful examples in different countries (Jiang et al., 2021; Kijl et al., 2010; Nguyen Dang Tuan et al., 2019; Pruthi et al., 2013; Visser et al., 2010), within both the general healthcare context (Nguyen Dang Tuan et al., 2019; Verhees et al., 2017) and for specific diseases (Jiang et al., 2021; Pruthi et al., 2013; Salimzadeh et al., 2019; Visser et al., 2010).

The findings of these studies deepen our understanding of the ongoing relationships among different actors in the successful implementation of eHealth BMs from the perspectives of (i) service providers (Jiang et al., 2021; Kijl et al., 2010; Nguyen Dang Tuan et al., 2019), (ii) customers (Chen et al., 2014), and (iii) users (Shah et al., 2013). However, little research has explored the connections between business models and the successful deployment of eHealth products and services (Pruthi et al., 2013), particularly in relation to the potential contributions of each actor and the structural alignment of partners with the ecosystem's value propositions (Chen et al., 2014). However, although BMs have been applied effectively in other sectors, such as digital services, user behavior and preferences have been associated with different design elements in specific usage contexts (Cong et al., 2020). Another limitation, as highlighted by Carrera-Rivera et al. (2022), is that current research does not sufficiently address how to exploit the data generated from devices and users to provide customized experiences and adaptable designs capable of reacting to different contextual sources. Therefore, this study aims to better understand co-creation in ecosystems serving healthcare applications.

The literature on value creation and capture within innovation ecosystems has garnered considerable interest from both scholars and practitioners over the past decade (Khademi, 2020). Recent studies have begun exploring different theoretical perspectives on the analysis of value creation and capture in innovation ecosystems (Santos & Zen, 2022). Both issues are essential within these ecosystems. Ritala et al. (2013) emphasized the significance of comprehensively understanding the mechanisms for value creation and capture within the innovation ecosystem framework, while Oskam, Bossink, and De Man (2021) highlighted the need to understand each actor's perception of the meaning of value.

This level of analysis involves generating innovations for different actors at various levels, including the micro and meso levels (patients, doctors, and DT providers) as well as the macro and mega levels (hospital managers and regional public healthcare systems). These actors have different organizational goals and, consequently, different types of values to be captured. This feature complicates the establishment of ecosystem value proposals, leading research to focus on collaboration and competitive relationships. We adopt the concept of an innovation ecosystem as defined by Klimas and Czakon (2022) as a collaborative environment that surrounds the innovation endeavors of its co-evolving participants. This ecosystem is structured around co-innovation processes and facilitates the collaborative creation of new value delivered through innovation.

Due to the different levels of analysis and conceptualization difficulties faced by various agents depending on the case, we decided to use a case study to analyze the meaning of digital transformation. In recent decades, an increasing number of manufacturers have shifted their strategies from selling products to providing integrated systems of products and services (Gaiardelli et al., 2021). These integrated systems are believed to yield economic,

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environmental, and social benefits, where decentralization, distributed leadership, intense interdependence, transparent performance measurements, and reciprocity are enforced. This phenomenon is also known as servitization, or the emergence of Product-Service-Systems (PSS)—a system of products, services, networks of players, and supporting infrastructure that continuously strives to remain competitive, satisfy customer needs, and reduce environmental impact compared to traditional BMs (Haber & Fargnoli, 2021; Rapaccini & Adrodegari, 2022).

Therefore, this study examines the potential of remote gait monitoring to address the sensitivity of multiple sclerosis (MS) progression to gait characteristics by adopting a Remote Patient Monitoring PSS approach to remotely quantify gait disturbances in the daily lives of patients with MS. In this context, we explore the following two interconnected research questions:

> RQ1: How to determine the significant factors of the PSS that allow creating value for each of the ecosystem agents?
> RQ2: When the PSS value proposition is considered, how can we identify the expected impacts in terms of innovation, sustainability, and social effects for the involved agents?

The paper is structured as follows. Section 2 provides a review of relevant literature on eHealth, focusing on PSS BMs centered on co-creation. Section 3 outlines the methodology adopted and its justification. Section 4 presents the primary findings from the methodology's application and interprets these findings to address the research questions. Finally, Section 5 summarizes the key aspects and additional perspectives on managerial and scientific dimensions, limitations, and potential avenues for further research.

2 THEORETICAL BACKGROUND

2.1 Service Dominant Approach to eHealth Services delivery

Servitization (Albert-Cromarias & Dos Santos, 2020; Cherif et al., 2021) entails a complete shift from the traditional product-based business model to a new strategy that focuses on meeting customer expectations and encouraging the sale of performance associated with product use (Vargo & Lusch, 2017). This approach has been applied in many industries, including healthcare (Annarelli et al., 2021; Samsa & Yüce, 2022; K. Xing et al., 2017).

A potential way to meet the requirements of servitization in the healthcare sector is through the provision of a PSS, due to its ability to create value within a complex social system. This involves utilizing a blend of both tangible and intangible assets, expertise, regulatory compliance, organizational strategies, funding models, and cutting-edge technologies (Marceau & Basri, 2001).

However, a PSS does not directly offer value to customers but rather proposes it. The service-dominant approach of a PSS emphasizes the role of knowledge transformation and value co-creation not only as an add-on to services but as their core feature (Osborne et al., 2012). Value co-creation is not limited to a firm and customer alone; it extends to a network of actors—the PSS ecosystem—including both vertical and horizontal relationships at various levels (micro, meso, macro, and mega) among these participants (Trischler et al., 2020). Studies investigating PSSs in the healthcare industry remain limited (K. Xing et al., 2017). PSSs have shown potential to foster closer relationships among healthcare providers, pharmaceutical companies, hardware

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suppliers, and patients, while promoting the integration of devices, clinical workflows, and additional value-adding services, such as consulting or training (Andreoni et al., 2012; Mittermeyer et al., 2011). However, potential barriers to adoption related to social, institutional, and organizational issues should be addressed (Grijalvo et al., 2024; Haber & Fargnoli, 2021; Zhang et al., 2021).

The need for a PSS in healthcare is also supported by the demand for better performance and cost-effectiveness of care services. Baines et al. (2007) defined a PSS as a service-led competitive strategy that addresses environmental sustainability issues, distinguishing its adopters from competitors who merely offer lower-priced products. More research is needed on this differentiation, particularly in sectors like healthcare, where advancements both within and beyond the field have introduced trade-offs between often competing goals, such as price and quality. These decisions frequently require moral judgments (Jayaraju et al., 2023; White, 2015). Such judgments must balance various ethical considerations, including affordability and accessibility, to ensure that PSS solutions are reasonably priced and available to those who need them (E. G. Roth et al., 2022). Additionally, these judgments must ensure that the chosen PSS contributes to positive health outcomes, improves the quality of care provided (Kever et al., 2021), promotes patient autonomy, and empowers individuals to make decisions that align with their values and preferences (Bayas et al., 2021).

2.2 Value Co-creation within eHealth Service Ecosystems

In recent years, researchers have increasingly focused on the antecedents and consequences of value co-creation. This concept originated from co-production theory in the 20th century and has since evolved into two major schools of thought: one based on customer experience (Prahalad & Ramaswamy, 2004) and the other based on service theories, particularly service-dominant logic (Vargo et al., 2018) and Service Science (Maglio et al., 2008). Service-dominant logic views businesses as networks of relationships where value is collaboratively created through interactions between consumers and providers for mutual benefit (Vargo & Lusch, 2008). It emphasizes the importance of social dimensions and a multi-stakeholder perspective within the clinical environment in healthcare (Lusch et al., 2007). Conversely, Service Science highlights the role of technology, particularly digital health technologies, in enhancing resource integration and value co-creation (Mishra & Maheshwari, 2024). The evolution of these theories introduced the concept of a service ecosystem (Botti & Monda, 2020), characterized by four main components: actors, technology, institutions, and resource integration (Polese et al., 2018). However, although these elements drive value co-creation to a potential level, it is their integration that enables the actual value co-creation process through resource exchange and adherence to common rules (Botti & Monda, 2020).

The process of value specification extends beyond human-centered design by not only considering the usability of technology but also evaluating its intended purpose and practical applicability. When co-creation is the objective, the development and implementation of eHealth technologies become more complex, involving multiple healthcare organizations rather than a single entity. The inter-organizational dependencies that arise in such scenarios are often intricate, making it necessary to explore the benefits and value needs of all stakeholders involved, an approach that supports an ecosystem perspective (van Calis et al., 2023).

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Digitalization empowers stakeholders to interact, co-create value, and improve service outcomes (Botti & Monda, 2020; Grijalvo et al., 2024; Negash & Calahorrano Sarmiento, 2023). Nevertheless, it also presents significant challenges. The primary barrier to adopting these technologies is the clinical setting itself, which is characterized by a complex, multi-stakeholder environment and a fragmented decision-making process. This complexity arises from the diverse needs and requirements that must be addressed across various levels and actors within the ecosystem: (i) At the mega level, various major factors influence the healthcare ecosystem, including historical, cultural, political, and legal elements, the role regulatory bodies, or differing community philosophies on health (Frow et al., 2016); (ii) At the macro level, while eHealth technologies are often implemented using a top-down approach led by management, it is also crucial to include a bottom-up approach that incorporates input from specialists to enhance technology adoption (Borro et al., 2015; van Limburg et al., 2011). Despite these new insights, there has been limited research into how the dynamics of the ecosystem operate from the perspectives of various participants and their collaborative interactions (Balta et al., 2021; Oskam, Bossink, & de Man, 2021), as well as how these collaborations lead to value co-creation and innovation in the short term, alongside sustainable value co-creation in the long term (Botti & Monda, 2020).

2.3. Business Models in the healthcare industry

To effectively manage and balance these diverse value needs, healthcare organizations must transcend their traditional boundaries, necessitating a shift in perspective regarding the development process of eHealth technologies (Balta et al., 2021). This process requires the establishment of a new collaborative infrastructure (Latuapon et al., 2023).

Ehealth technologies for early detection and diagnosis are still underdeveloped, but hold significant potential for business opportunities, according to Moon and Lee (2024). Wearables and Artificial Intelligence (AI) facilitate early disease detection by monitoring symptoms and enabling self-assessment using mobile applications (Ndiaye et al., n.d.; Xie et al., 2018). Additionally, AI can ease the workload of medical professionals by enhancing diagnostic accuracy through comprehensive data analysis (Isabelle Lambert et al., 2023).

Developing sustainable business models is considered a key factor in enhancing health information technology and its implementation (Naeem et al., 2024; Yadav et al., 2024). In recent years, a growing body of academic research has examined the interplay between eHealth innovations and BMs, consistently highlighting the need for further investigation (J. Lee et al., 2019; Oderanti et al., 2021). This study adopts a dynamic approach to analyze how new business models evolve and how firms innovate them (Jorzik et al., 2024). This trend is particularly relevant for emerging eHealth businesses, which should capitalize on latent technological opportunities, such as AI and wearables, to address market demands for cost-effective and safe care methods (Carrera-Rivera et al., 2022; Oderanti et al., 2021).

Business modeling transforms the entire development process into one that is stakeholder-focused and value-driven. Stakeholders are engaged early in the process to identify the value drivers they expect from eHealth technologies (Lentferink et al., 2020; Moon & Lee, 2024). These value drivers are critical not only for the design of the technology but also for shaping the implementation strategy, which ultimately determines the effectiveness and sustainability of the technology (Urueña et al., 2016; van Limburg et al., 2011). Therefore, business modeling

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is a comprehensive approach that explores early opportunities for eHealth technologies, assesses requirements, develops a case-specific business model, and implements the technology accordingly. This value-driven process is continuous and requires ongoing research activities, including design, evaluation, and redesign (van Velthoven et al., 2019). Its dynamic nature is evident, as decisions made based on current facts may need to be revised as new information becomes available (Naeem et al., 2024). Additionally, the business model can represent an extension of a strategic network (Klimas & Czakon, 2022).

2.4. Research gap and Application case

To date, and according to the previous discussion, the analysis of PSSs has been linked to various design elements within specific usage contexts, often overlooking the need for adaptable designs capable of responding to diverse contextual factors. This requires varying levels of analysis and conceptualization, depending on the agents involved, while maintaining sufficient generalization to avoid constraining innovation potential through an overly narrow focus. Since the research questions addressed in this paper are general within the eHealth field and linked to innovative PSSs from an ecosystem perspective, it was considered that a PSS capable of serving several diseases could provide a level of abstraction and independence. Therefore, a gait monitoring use case was adopted because it can provide insights into several diseases such as MS, Parkinson’s disease, stroke, and muscular dystrophies. Because gait monitoring must include stakeholders, some of whom are linked to the disease itself, we decided to focus on MS while generalizing the discussion to address the research questions at the appropriate level.

Henceforth, the application case motivating this research is related to analyzing gait disorders that affect the lower extremities of patients with MS. MS is a chronic inflammatory neurodegenerative disease of the central nervous system that mainly affects young adults and is the most frequent cause of disability. According to the International Federation of Multiple Sclerosis Atlas, approximately 2,900,000 people live with MS worldwide, including about 700,000 in Europe and around 55,000 in Spain (Solomon et al., 2023; Walton et al., 2020). Each year, more than 2,000 new cases are diagnosed in Spain. MS frequently begins between the ages of 20 and 40 years (Dobson & Giovannoni, 2019; Gbaguidi et al., 2022).

The disease typically follows an initial relapsing course in 80-85% of patients, known as relapsing MS (RMS). Approximately 60-70% of these patients will suffer a steady, irreversible progression of their neurological deficits, predominantly involving gait, within the first 10-15 years of the disease. This stage is referred to as secondary progressive form (SPMS). Additionally, many patients develop silent disease progression from the initial onset, which can be highly incapacitating and greatly impact patients' quality of life.

Gait impairment is the main cause of disability in more than 90% of patients with SPMS (Boyko et al., 2021). Approximately 10-15% of patients experience clinical progression from the onset, known as primary progressive MS (PPMS), which also generally results in progressive gait impairment (Boyko et al., 2021). In the absence of validated biomarkers of progression, the transition from RMS to SPMS is difficult to define and identify, leading to a delay in diagnosis of two or more years (Pardo et al., 2022).

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Diagnosing and monitoring MS progression can follow different paths. Historically, the diagnosis of MS relied on clinical features linked to the Expanded Disability Status Scale (EDSS) and the Timed 25-Foot Walk (T25FW), both of which have limited sensitivity and reproducibility. However, with advancements in technology and the increased availability of magnetic resonance imaging (MRI), neuroimaging has become an important tool for diagnosis and monitoring (Goodin, 2014). While MS diagnosis has traditionally relied on clinical features supported by MRI, blood tests, and cerebral spinal fluid (CSF) tests, the reliance on MRI has grown significantly, making it uncommon to diagnose MS without MRI features suggestive of the condition (Amin et al., 2024).

Disability progression should be used to evaluate treatment response by examining the patient at each visit using the EDSS and T25FW. An increase of at least one point in the EDSS score is considered neurologically significant and should be used to confirm disability progression at both three and six months (Río et al., 2023). However, a significant limitation of these assessments is that they only provide a punctual measure obtained in a clinical setting without assessing gait in real-world conditions. Consequently, both early detection and reliable monitoring of disease progression are delayed (Pardo et al., 2022), justifying the need for treatment optimization. Optimization requires a more quantitative approach involving gait monitoring under different conditions, which can serve not only to improve the regular estimation of the EDSS but also to use AI-based technologies that are currently only applied to MRI images (Nabizadeh et al., 2022).

DTs applied to gait monitoring require the adoption of specific frameworks that can provide an effective context for the PSS. Figure 1 illustrates the Internet of Things (IoT) framework develops as a PSS based on a combination of physical products, and services, plus knowledge. This approach facilitates frequent assessments and remote monitoring of gait speed over time, presenting a cost-effective alternative to laboratory-based motion capture systems.

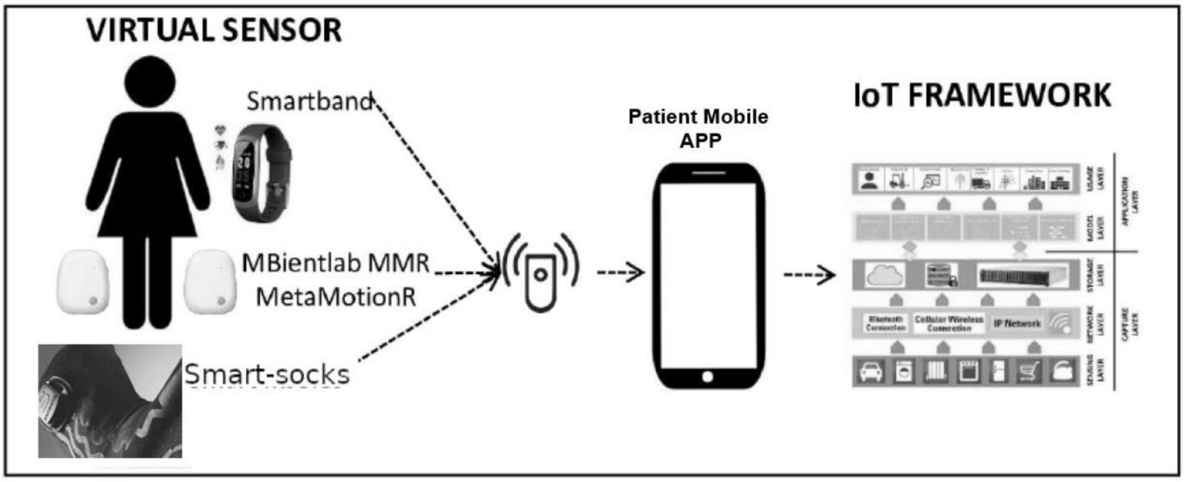

Figure 1 – IoT framework developed as a Smart PSS based on a combination of physical products and services plus knowledge. Source: Self elaborated.

To address the formulated research questions and determine the significant PSS factors that create value for each ecosystem agent, a comprehensive and scientifically justified

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methodology is essential. This methodology should integrate qualitative and quantitative research approaches while leveraging modern techniques and frameworks to ensure robust and actionable insights. A mixed-methods approach is highly recommended for this type of research, combining qualitative and quantitative data collection and analysis to provide a holistic understanding of the factors influencing PSS value creation.

Recent studies have underscored the importance of integrating qualitative and quantitative approaches in PSS research. For example, Reim et al. (2015) highlighted the need for a comprehensive approach to understand the dynamic and multifaceted nature of PSS. Their research emphasized the integration of customer insights and operational data to identify key value drivers.

Data collection should be systematic and comprehensive, encompassing both primary and secondary sources. Primary data can be collected through interviews, surveys, and observations, while secondary data can be gathered from existing literature, industry reports, and organizational records. Data analysis should involve thematic analysis of qualitative data and statistical analysis of quantitative data to ensure a thorough examination of the factors influencing value creation (Vargo & Lusch, 2016).

Because the success of complex interventions is highly dependent on the position of various stakeholders—which are heavily influenced by the environment provided by the health system—this research team chose an interview-based inductive qualitative study involving several participants organized by stakeholder type. Interviews are widely used in qualitative studies because they allow interviewees to express their experiences and understanding of the phenomena described (Al-Busaidi, 2008; DiCicco-Bloom & Crabtree, 2006; Janghorban et al., 2014).

Semi-structured interviews are an appropriate research method if there is: (a) some knowledge about the topic, but not enough to develop meaningful survey questions and answers applicable to many participants; (b) a need to understand the interviewee’s perspective; and (c) the opportunity to sit down one-on-one with someone who is an expert on the issue, such as a key informant (Ahlin, 2019).

3 RESEARCH OBJECTIVE, METHODOLOGY, AND DATA

3.1. Research Design

As noted in the Introduction and revisited in the Literature Review, current research on DTs in the healthcare context is limited (Ghosh et al., 2023). It does not convincingly consider patients’ support for improving traditional healthcare processes alongside new value-creation activities, nor does it clearly examine the structural changes that occur within healthcare organizations due to technologically driven change (Höpfl et al., 2023).

According to Ahlin (2019), reliability considerations are often balanced with those related to validity, which can be significantly enhanced through semi-structured interviews. These interviews allow researchers to gather rich details from a small number of people who are highly knowledgeable about the area under study. This approach enables sufficient understanding of

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perspectives within health services and organizational environments while maintaining a comparative perspective among various stakeholder groups.

The interview results will be moderated by the literature review findings, which provided insights into digitalization, ecosystem perspectives, value co-creation, and capture mechanisms. The key advantage of this methodological strategy is that it improves the robustness and broad analytical generalization through theoretical elaboration, while allowing us to investigate the complicated contextual quirks associated with various stakeholders (Ketokivi & Choi, 2014).

Additionally, the analysis and discussion will elaborate on the changes and approaches suitable for the health smartification ecosystem due to the digital integration of information.

3.2. Participant recruitment

Ethical approval was obtained from the Ethics Committee of the Polytechnical University of Madrid (project number: DYCDVEESSE-MG-DATOS-20230301). Consent forms were provided to potential participants, and signed forms were collected. The selection criteria encompassed the following key stakeholders in the ecosystem: hospital managers, doctors, nurses, patients, pharmaceutical representatives, and patients' relatives. Two issues were key to selecting these profiles: first, the classification of agents at the ecosystem level allowed us to identify which agents had the most relevance or influence on the value-creation process in MS.

The application of the Power-Interest grid tool (Figure 2) from the PMBOK framework (Guide, 2008) enabled the identification of agents' potential impact or support the project, as well as their relationship or response to certain stimuli. Agents were classified into four quadrants based on their level of interest (abscissa) and power (ordinate). This research focused on agents in the collaborative quadrant, characterized by high power and high interest, along with a single type of therapist in the communication quadrant.

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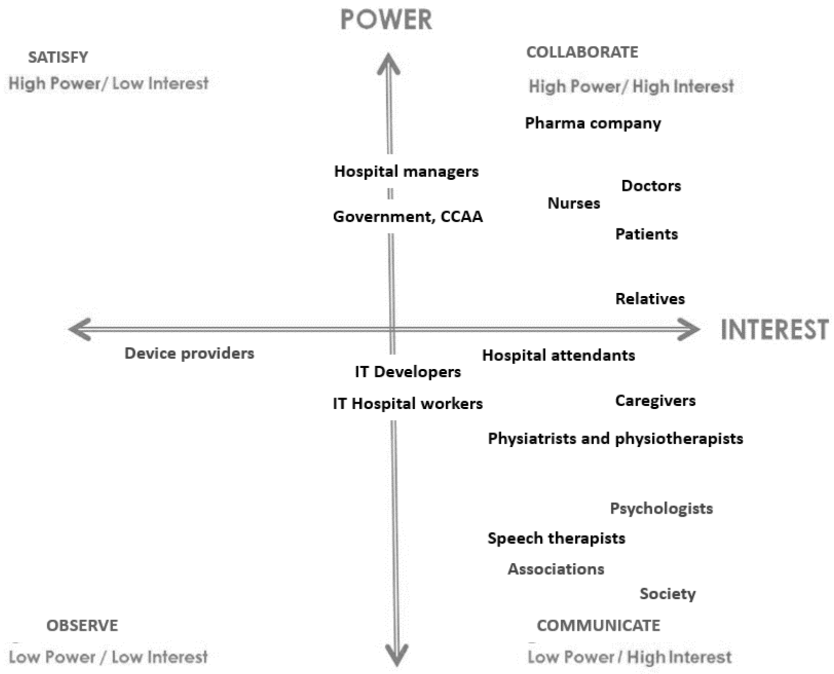

Figure 2 – Power versus Interest Framework for MS. Source: own research

Second, all information gathered from neurologists specializing in MS focused on selecting a variety of interviewees to avoid bias in the results. In total, 25 interviews were conducted with the following: patients with MS, family members of patients with MS, neurologists, MS nurses, physiotherapists, medical directors, and one pharmacist. Regarding physical therapists, the decision was made to focus on a single type of specialist, specifically the one most in demand for rehabilitation therapies (Forbes et al., 2007).

Table 1 – Class 1 Summary of interview participants. Source: own research

Role	Men	Women
Neurologists	1	6
Nurses	0	2
Patients	2	7
Family members of MS patients	0	2
Physiotherapist	0	2
Medical directors	1	1
Pharmaceutical Company	1	0

Furthermore, the neurologists’ selection criteria were to include physicians from different hospitals, since the approach to MS in Spain varies significantly due to hospital categorization. Eight first-class hospitals were selected, most of which were located in Madrid: (i) three third-level or high-tech hospitals and specialized institutes, (ii) four second-level or reference hospitals with intermediate complexity, and (iii) one first-level hospital, which is closest to the population. One of the neurologists worked in two hospitals (third- and second-level). With the chosen sample size, we met the scientific criteria for saturation as outlined by Hennink and

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Kaiser, (2022). Consequently, this provided us with the legitimacy to proceed with the analysis and discussion.

Finally, neurologists—both specialists and general practitioners—were responsible for selecting patients based on established criteria, such as clinical evaluation and age or sex ratios, as MS affects women three times more often than men. They also assisted in contacting individuals, such as pharmacists and healthcare staff.

3.3. Data Collection

The interviews were conducted online in 2023. Participants were invited to meetings at their convenience. Each interview lasted an average of 50 minutes, totaling 21 hours and 30 minutes. The interviews were exploratory and semi-structured, allowing for focused questions while providing space for exploration and unexpected answers. Open-ended questions, which were slightly tailored for each target group, structured the interviews and enabled respondents to share their expertise on the topic and context of the PSS project. Furthermore, their roles as experts eliminated the need for complicated sampling techniques (Ahlin, 2019).

The sessions were run by researchers who had received support from a neurologist regarding the disease process, including diagnostic tests, clinical procedures, and the relationships between agents. It was important for the researcher to have sufficient background information on MS to evaluate the impact of PSS and to generate a semi-structured interview schedule to collect data and begin the conversation (Ahlin, 2019). Furthermore, a pilot test of the designed interview model was conducted to ensure correct formulation of the interviews.

The interview process began with an explanation of the PSS configuration, including the technology to be used and its objectives. The researcher then asked several questions, grouped into two blocks of interest. The first block included questions about the interview participants (roles, responsibilities, and experiences with MS, etc.), while the second block focused on questions on the PSS value-creation process, exploring both aspects of PSS: value creation and value destruction.

Finally, the interviews and their recordings were conducted using Microsoft Teams (Singh & Awasthi, 2020) and occasionally through Google Meet. However, since Google Meet's basic package does not include voice or video recordings, OBS Studio (Kristandl, 2021) was used to capture these sessions. The semi-structured interview instrument was administered in Spanish, the native language of all participating stakeholders. The outcome of the process was translated into English when needed for presentation in the paper.

3.4. Data Coding

The interviews were transcribed using Sonix software to prepare the corpus for each study included in the analysis. Data were categorized using two multivariate techniques. The Descending Hierarchical Classification (DHC) allowed us to identify and confirm thematic categories, with a dendrogram displaying stable word classes that have similar vocabularies and differ from other classes.

Five variables were considered: (i) Scope: Health (hospital manager, doctor, nurse, physiotherapist, or pharmacist) or No Health (patient or relative); (ii) Role: Gender (male or

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female); (iii) Role (hospital manager, doctor, nurse, physiotherapist, pharmacist, patient, or relative); and (iv) Comments on aspects related to their perceptions of PSS regarding value creation and value destruction.

3.5. Data Analysis

The analytical software facilitated quantitative analysis, allowing for the identification of agents, in-depth exploration of their characteristics, examination of the relationships among them, and analysis of their PSS perceptions regarding value creation and value destruction. The software IRaMuTeQ version 0.7 alpha 2 (http://www.iramuteq.org/) was used to analyze the interviews, as suggested by various authors (Chaves et al., 2017; Costa et al., 2018; Ramos et al., 2019; Rizzoli, 2018; Sabeh et al., 2023).

IRaMuTeQ is a freely accessible software designed for the multidimensional analysis of texts and questionnaires, utilizing the R and Python languages. Python is primarily responsible for lexical analysis, text processing, and generating cloned tables, while R handles all statistical analyses and produces the graphics available through the interface.

IRaMuTeQ is particularly beneficial for analyzing large sets of texts. When confronted with substantial amounts of information that are difficult to cover manually, IRaMuTeQ serves as a valuable tool (Ramos et al., 2019). Notably, this tool offers a dual-analysis approach. On one hand, it conducts quantitative analysis through statistical calculations, comparisons, and visualizations based on the presence or absence of certain elements. On the other hand, it allows for a qualitative approach, enabling users to interpret and contextualize data to derive meaningful insights from the results obtained. This analytical approach aligns with certain studies (Costa et al., 2018; Sabeh et al., 2023) and adheres to the recommended minimum of 20 to 30 texts (Camargo & Justo, 2013). Before analyzing the texts, it was essential to prepare them:

- Documents should be in plain text format (.txt) and preferably saved in UTF-8 encoding.
- Each analysis should merge all texts into a single text file, using multiple files for different analyses.
- The beginning of each text in the corpus should be denoted by four asterisks (***), followed by variables, each preceded by an asterisk (*), an underscore, and its corresponding modality.
- Grammatical restrictions prohibit the use of certain special characters, indentations, margins, tabulations, or text justifications.
- When terms are written separately but used together (e.g., eHealth 4.0), an underscore should be inserted to ensure that the software recognizes them as single words (e.g., eHealth_40).

Among the analyses provided by IRaMuTeQ, the following were utilized for the current project:

- Word Cloud: This preliminary analysis arranges frequently occurring words in a visual cloud based on their frequency in the input texts. This tool restricts the number of words to 100 to ensure clarity and representativeness. Certain word groups, such as verbs and their complements, or adjectives like 'good', 'both', or 'much', are excluded as they do not significantly contribute to the meaningful content. This analysis serves as the starting point for further exploration.

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- The Descending Hierarchical Classification (DHC): This dendrogram visualizes classes of words sharing similar vocabulary, facilitating the observation of similarities and differences. It helps identify associations or disparities between texts and words, aiding in the identification of explanatory factors for the utilized groups or variables. This analysis also offers detailed lexicon profiles within each class, including the position, grammatical category, and form. To ensure effective classification, text fragments should retain over 75% (Camargo & Justo, 2013); our study exceeded 80%.
- Correspondence Factor Analysis (CFA): Depicted on a Cartesian plane, this analysis complements the interpretation of the DHC. It illustrates the associations and contrasts between words and texts. The x and y axes represent the two factors indicating the percentages explaining the differences between classes, words, and variables. Moreover, it facilitates the identification of associations between classes from the DHC and the defined analysis variables. Factors serve as latent dimensions that summarize or explain observed variables (Hair et al., 2006).

Finally, IRaMuTeQ offers a supplementary feature to its analyses: for each form, two visualizations are accessible—concordance and associated forms. The associated forms exhibit lemmatized variations in the selected words (e.g., 'doctor' and 'doctors'). Concordance reveals the text segments within the class where the chosen form appears in our corpus. This feature proved valuable for enhancing and directing the previously described analyses.

4 RESULTS: ANALYSIS OF PSS VALUE CREATION IN HEALTHCARE

The 25 interviews were processed using IRaMuTeEQ, where the corpus analyzed only included the responses to the following questions posed to the interviewees:

- How do you believe the project will impact the perception of the identified care quality?
- How do you believe PSS destroys and/or creates value?

This study sought information about actors' subjective opinions on PSS value creation potential. The Person-Centered Care approach was consistently shared by all the ecosystem actors interviewed, with the word “patient” now accompanied by the word “sock,” the PSS product driver chosen. The natural language processing analysis carried out after removing stopwords and lemmatization processes showed other representative issues, such as those related to the disease, like “treatment or progress,” and care-related issues such as “information,” “data,” or “value.” The DHC (see Figure 3) generated four classes representing 31.5%, 29.4%, 12.2%, and 26.9% of the analyzed content, respectively. It should also be noted that an analysis of 85.37% of the total text entered was analyzed, with the optimal standard for efficient analysis being above 75%.

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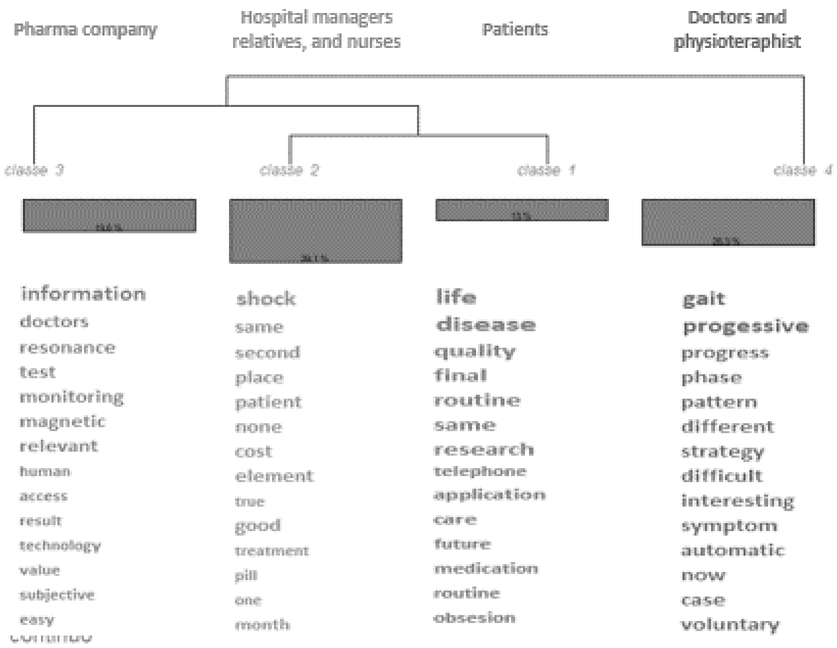

Figure 3 – Descending Hierarchical Classification (DHC) of the Healthcare PSS value creation answers. Source: own research

Classes 1 and 2 are the closest in the dendrogram, and the analysis of the words in these classes confirms this proximity. Class 1 features the expression "Quality of life" (see Table 2), with associated words including "life," "disease," "quality," "care," "medication," "future," "telephone," and "application." Class 2 references the "PSS solution" (see Table 3), with associated words such as "shock," "patient," "cost," "element," and "treatment." Class 1 focuses on the patients' perspective regarding PSS value creation potential, while Class 2 represents the approach of hospital managers, relatives, and nurses' approach, evaluating the PSS impact on users' health and well-being in both in the short and long term.

Table 2 – Class 1 Patients' approach. Source: own research

Topic	Words	Interviews	Issue	Attribute	References
Quality of life	life, disease, quality, care, final, medication, future,	Patient 4: "And the fact that they monitor us can help us to have another type of quality of life in the future."	eHealth and mHealth	Enhanced individual and clinical patient care	(Alenoghena et al., 2022; S. Lee et al., 2015; Rotstein & Montalban, 2019; Salimzadeh et al., 2019; Schepici et al., 2019)
		Patient 6: "Both in terms of care and quality of life, or if you are giving him medication, and you see that it is not working, change it quickly and you do not waste time or money, change to another that works better for him."			
	telephone, application, routine, research,	Patient 5: "I see it as a habit, a routine. But I don't know, that would have to be considered in some way. In other words, you don't believe that addiction of being aware of the disease, which I think is not good	Technology has the potential to be an experience-enriching	Co-creation healthcare value	(Allen-Philbey et al., 2020a; Buhalis & Sinarta, 2019a; Kar & Dwivedi, 2020; Lim et al., 2018; McColl-

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		for us."	and value-creating component		Kennedy et al., 2012; Nordgren, 2008; Thirumalai et al., 2018; Trabucchi et al., 2018)
		Patient 4: "A lot of research has been done on the disease for some time now, and I think that it benefits us; little by little it is helping us."			
		Patient 8: "I have no problem carrying another mobile, in the end we are super localized with the phones, the WhatsApp".			

In the short term, PSS evaluation focuses on acceptance and usability by people with MS, as a positive attitude alone is not sufficient to drive successful implementation (Thirumalai et al., 2018). Interviewers' answers aligned with Rubin and Chisnell's (2008) definition of usability: (i) effectiveness (i.e., the ease with which people can use the product as intended), (ii) usefulness (i.e., the extent to which a product can enable users to achieve their goals and willingness to use it), and (iii) satisfaction (i.e., users' perceptions and opinions of the product). Patients noted that PSS adaptation, apps, and products need to match their preferences and technical abilities (Manuli et al., 2020) to enable a value co-creation process, whether passive or active (Trabucchi et al., 2018). Additionally, they emphasized the importance of sharing information, competencies, and resources within the ecosystem, as certain limitations associated with MS (e.g., poor dexterity and memory problems) may affect usage (Gromisch et al., 2021).

The long term focus of the PSS evaluation is to find accurate and reliable outcome measures to early identify transition from relapsing to progressive multiple sclerosis (PMS) and monitor treatment responses in various forms of MS. Each interview assessed the participants' roles within the ecosystem and always considered the chronic degenerative nature of the disease. Patients' and relatives' views were framed in their personal contexts, discussing improvements in the diagnosis and development of new PMS treatments that may them benefit now or in the future (Pardo et al., 2022).

Moreover, health professionals' views were situated within the healthcare context, with two competing logics at play: care logic and managerial logic. Care logic is represented by nurses and relatives, while manager logic is represented by hospital managers. These two institutional logics provide different interpretations of reality (Andersson & Liff, 2018).

Table 3 – Class 2 Hospital managers', relatives', and nurses' approaches. Source: own research

Topic	Words	Interviews	Issue	Attribute	References
PSS solution	shock, patient, cost, element, treatment	Nurse 2: "For example, start a treatment that is no longer for MS, but rather helps to improve the patient's mobility. It is prescribed for two weeks, and if effectiveness is noted, it can be continued chronically. But if he doesn't notice anything, there's no point in taking a pill".	Development of predictive, preventive, and personalized medicine	Patient best care	(Bresciani et al., 2021; Forbes et al., 2007; Meehan & Doody, 2020; I. Pappas et al., 2018)

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		Nurse 1: "Being able to measure the reality of the patient's disease seems positive to me, because all of this will help us in its entire context, namely, how the patient is really doing and accordingly providing treatment."			
		Director 1: "It seemed to me that it is an element that contributes value in decision-making and that the key may even lie in whether that contribution of value that the socks give me is more cost effective than others."	Development of ways to prioritize health services underpinned by a process of health technology assessment for MS patients.	Socially and economically sustainable healthcare	(Bacanoiu & Danoiu, 2022; Balta et al., 2021; Pappas et al., 2018; E. G. Roth et al., 2022)
		Director 1: "The socks, which have a cost, but in exchange they will allow me to avoid decision-making errors, because these measurements in the patient walking are not correct."			

Research indicates a strong interest in providing the best patient care, but from the perspective of 'asymmetry' in power resources. Public sector healthcare organizations are confronted with growing health and social care alongside significant resource constraints. Therefore, while nurses show deep involvement in PSS co-production (i.e., co-design and co-delivery), motivated by their understanding of service needs as empowered frontline personnel working closely with patients, managers and directors highlight a particular challenge in promoting the legitimacy of a complex and multifaceted vision of PSS within public healthcare (Bacanoiu & Danoiu, 2022).

Although some critical technical issues were identified, the focus was primarily on the opportunities and challenges posed by the new digitalization context, with an analysis of cost-effective and secure use (E. G. Roth et al., 2022). However, discussions on supporting infrastructure (Petrova-Antonova et al., 2020) and privacy and data security (Voigt et al., 2020) were notably absent, even though these aspects are essential to the benefits and challenges of using DTs (Balta et al., 2021). Participants considered that PSS will add long-term value to the healthcare system through better resource management, improved service quality, and increased patient satisfaction (Aujoulat et al., 2008). However, they did not conduct an in-depth analysis of the potential reduction in healthcare provision costs that a PSS can bring, especially considering its transfer to other needs of patients with MS, to avoid value destruction, such as promoting shorter appointment times with neurologists. IRaMuTeQ generated another graph, the CFA (see Figure 4), which presents a factorial plan. In this graph, Factor 1 (X-axis) accounts for 39.47% of the difference between the variables, while Factor 2 (Y-axis) explains 33.34%.

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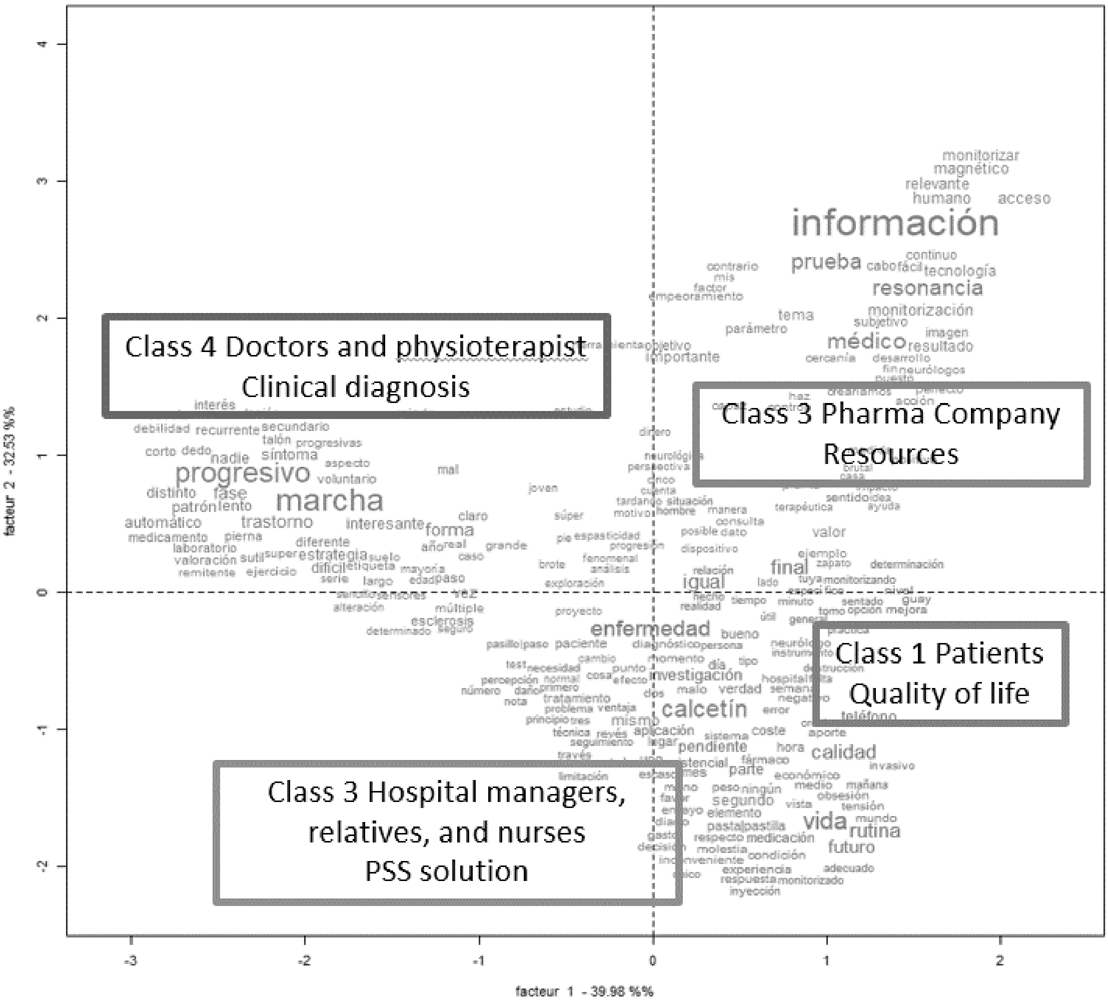

Figure 5 – Descending Hierarchical Classification (DHC) of the Healthcare PSS value creation answers. Source: own research

This corroborates the juxtaposition of Classes 1 and 2. Additionally, Class 4 is clearly distinguished from the other three classes on the vertical axis. Some words associated with this class include “progress,” “pattern,” “phase,” “automatic,” “symptom,” “different,” “voluntary,” “progressive,” “strategy,” and “interesting.” It was named “Clinical diagnosis” because it reflects the approach of doctors and physiotherapists, who focus on the advantages that PSS can offer in the diagnosis and evaluation of patients with MS (see Table 4).

Doctors and physiotherapist interviewees emphasized the need for personalized treatment for MS because the clinical course varies considerably among individuals. However, without validated biomarkers of progression, detecting and monitoring these variations remain challenging (Rotstein & Montalban, 2019). On the other hand, the number of MS treatments available has increased significantly in recent years, including treatments for PMS. Although these treatments can be effective in suppressing clinical disease activity, they are not effective for all patients and many are associated with an appreciable risk of significant side effects. Therefore, the healthcare professionals interviewed considered that PSS could help discover an accurate, objective way to

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measure overall disease severity or status, and many lessons could be learned for its use in other chronic neurological disorders, such as Parkinson’s disease. A PSS creates value by decreasing uncertainty related to future disease progression (Deetjen & Powell, 2016; Dennison et al., 2011; Rezaallah et al., 2019), decisions about having children (Arenas-Ramirez et al., 2015; Kehne, 2007), and fears of becoming a burden (Virdis et al., 2019). However, it could also destroy value, as alleviating uncertainty for some might mean removing a source of hope that one's condition is not as severe as that of other patients with MS (Pestian et al., 2007).

Table 4 – Class 4 Doctors and physiotherapists. Source: own research

Topic	Words	Interviews	Issue	Attribute	References
Clinical diagnosis	progress, pattern, phase, automatic, symptom, different, voluntary, progressive, strategy, interesting	Doctor 5: "When you ask them to walk, they are not walking automatically, they are walking voluntarily."	Current tools for MS clinical diagnosis	Current diagnosis limitations	(Rotstein & Montalban, 2019; Zheng & Ordieres-Mere, 2015)
		Doctor 1: "There are several circumstances in which we fall short with our exploration, and the transition from the normal form during outbreaks to the progressive form, is another example of this."			
		Doctor 3: "There it would be very useful, they usually notice the outbreaks when they are clear, but not in the progressive forms."			
		Doctor 2: "We have changed the strategy a bit. Before, we tried not to diagnose anyone in a progressive way, because as soon as you diagnosed him, he was a patient who had no treatment. Now it is the other way around, now you try to get as far forward as possible to be able to treat better as soon as possible".	Digitalization opportunities and challenges for progressive MS clinical diagnosis	Better health choices with less errors	(Alexander et al., 2021; Berg-Hansen et al., 2022; Deetjen & Powell, 2016; Jackson et al., 2020; Petrova-Antonova et al., 2020; Rezaallah et al., 2019; Rotstein & Montalban, 2019)
		Doctor 7: "I think that the negative point of all the devices is the use, it is difficult for the patient to wear the socks all day, maybe you can wear them all day, a day or two days, but if the patient uses the sock every day it is difficult".			
		Physio 2: "I think it is a very valuable tool that gives us a lot of information, and with this, treatment strategies that are much more adapted to the patient would be carried out."			

Their responses to PSS revealed two key issues. The limiting factors to consider when developing wearable technologies are adherence and usability for both patients and healthcare professionals (Alexander et al., 2021). Their first consideration is smartphone apps, wearable devices, and sensors, which aligns with Jackson et al. (2020) regarding the value of using such devices, especially when they are less invasive in daily situations and provide real-time feedback. The second consideration involves advanced analytical applications for processing and analyzing of the

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collected data, which is in line with Alexander et al. (2021). Key issues included troubleshooting hardware and software, technical support, and ease of implementation within patient charts. Again, PSS could create value by assisting healthcare professionals in making decisions based on existing evidence, resulting in better patient healthcare (Berg-Hansen et al., 2022). However, it could also destroy value, as most participants did not describe themselves as proficient in technology and expressed concerns about the knowledge and skills required (Bouwman et al., 2023).

Finally, the pharmaceutical approach is represented by Class 3. Some words associated with this class include “information,” “resonance,” “monitoring,” “result,” and “technology,” which are named “Resources” (see Table 5), because it identifies value at both the micro level and macro levels. At the micro level, this includes (i) providing an accurate prognosis at the time of diagnosis, (ii) optimizing initial treatment decisions, and (iii) enabling greater precision in monitoring treatment response and early detection of the need to modify specific treatment regimens. At the macro level, MS diagnosis is based on a combination of clinical features and information obtained from diagnostic tests, most notably MRI. PSS represents the possibility of finding candidates that might complement, or even replace, expensive, invasive, and time-consuming MRI (Petrova-Antonova et al., 2020). Additionally, affected individuals are often of working age, making timely diagnosis crucial for proper treatment and prevention.

Table 5 – Class 3 pharmaceutical approach. Source: own research

Topic	Words	Interviews	Issue	Attribute	References
Resources	information, resonance, monitoring, result, technology	"I think that provides a lot, a lot, a lot of information to the doctor, and it's not just how they interpret it, it's that this monitoring is much more continuous" "Perhaps you can have this information from the insoles and as soon as you detect a worsening, then yes, make a resonance. This would save costs: humans, the person who is doing an MRI, and then the doctor who has to interpret it, time, and money."	Development of new procedure to diagnose and prioritize health services underpinned by PSS.	New tools for better diagnosis and treatment	(Javaid et al., 2022; Petrova-Antonova et al., 2020)

Moreover, pharmaceuticals have adopted traditional approaches based on data-driven innovations (Bresciani et al., 2021). They recognized the need to activate direct processes of interaction, dialogue, and collaboration among ecosystem actors (S. Lee et al., 2015). A PSS enables the development of passive co-innovation processes, permitting the extraction of information and knowledge about MS contained in the data generated by patients with MS during their normal activities in physical IoT sensors (Chae, 2019).

5 DISCUSSION AND CONCLUSIONS

5.1. Theoretical contributions

EHealth is emerging as a promising vehicle to address the limited capacity of the healthcare system to monitor MS progression with reliable and effective tools. The rapid growth of IoT, cloud computing, and Big Data, along with the proliferation and widespread adoption of new technologies and miniature sensing devices, has brought forth new opportunities to change how patients and their healthcare providers manage health conditions, thus improving human health and well-being (Ziadi et al., 2024).

According to the findings, the IoT framework developed as a PSS can be considered valuable not only in terms of innovation and social effects, because it allows frequent assessments and remote monitoring of gait speed over time, but also in terms of sustainability, as it presents a cost-effective alternative to lab-based motion capture systems.

However, the potential impact of integrating remote gait monitoring is crucial. The PSS approach for patients with MS should be considered within an ecosystem framework, where key constructs can help determine the following (Beverungen et al., 2019; Costa-Saura et al., 2022; van Calis et al., 2023):

- Significant PSS factors that create value for each ecosystem actor, including service customers and service providers.
- Expected impacts in terms of innovation, sustainability, and social effects for the actors involved in the short and long term.

Steen and Vanhaverbeke (2018) developed the Open Innovation Project Canvas (Figure 5), which combines the main benefits of two key tools while avoiding their limitations. First, the Business Model Canvas illustrates how to configure a business model and serves as a visual guide; however, it was originally designed for operational use rather than for early innovation stages, such as the current prototyping phase in PSS. Second, the Value Proposition Canvas focuses on defining customer needs and aligning the offering to these needs, although it was designed to be used by a single company rather than a network of collaborating companies, such as in PSS.

In the following paragraphs, we describe the different elements in detail:

A- Idea

The project aims to improve the diagnosis and treatment in clinical operations through IoT devices for gait monitoring and AI services. To achieve this, it explores the connections within a health ecosystem that includes patients, doctors, hospital administrators, pharmaceutical companies, and other stakeholders, leveraging products and AI services to drive medical innovation and enhance patient well-being.

B- Market/Demand side

The range of potential customers for the PSS under study is very broad due to its nature—based on the integration of agents and the co-creation of value—which engages numerous stakeholders. According to the study of the target market for PSS, along with their gains and disadvantages, the findings are as follows:

- Patients are the core segment of a PSS because they will be the users of the IoT devices. Their gain is “Quality of life,” while their pain points relate to “PSS adoption, acceptance, and usability.”
- Doctors and physiotherapists are key ecosystem actors due to their direct interactions with patients. They will be the main users of the AI services for the diagnosis and

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treatment of MS. Their gain is "Clinical diagnosis," whereas their pain points relate to "PSS adoption and proficiency with technology."

- Nurses and hospital managers are ecosystem actors with two competing logics: care and managerial, respectively, although they share the same view of the PSS. Their gain is "Best care for patients," while their pain points relate to "Sustainable healthcare."
- Pharmaceutical companies are potential collaborators within the ecosystem networks for the PSS. Their gain is "Resources," representing an opportunity to better utilize existing resources. Their pain is also related to "Resources," but in this case, it refers to the challenge of updating the portfolio of products and services to improve care quality within a fixed budget.

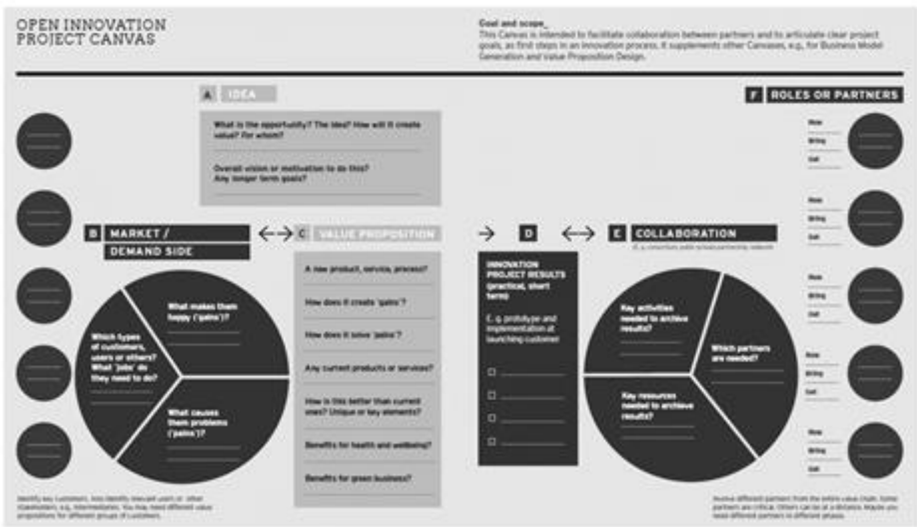

Figure 5 – PSS Business Model Framework. Source: Steen and Vanhaverbeke (2018)

The selected stakeholders helped the researchers explore different dimensions of the PSS project, offering insights into the following: (i) what micro-practices need to be developed at the micro level and how managers' praxis within the institutional environment shapes PSS at the macro level (Trischler et al., 2020); and (ii) the interplay between the micro and the macro levels, since an in-depth understanding of the macro-micro interplay is also important (Y. Xing et al., 2023).

C- Value proposition

Value proposition is characterized by smart socks to remotely monitor gait patterns and speed in the daily lives of patients with MS, enabling the co-creation of smart services based on reliable clinical measures to detect and monitor disease progression.

Smart socks collect raw data from both legs to extract semantic information about step execution. These high-frequency data enable a detailed step analysis that can be used to generate key performance indicators (KPIs). By analyzing and comparing these KPIs over time, patients with MS and their physicians receive updated insights that help track and characterize

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patient progression in clinical practice. Additionally, the PSS provider can create new business opportunities by partnering with or acting as a service aggregator for third-party providers of complementary services. By proactively addressing service needs and leveraging data collected from the smart socks, the provider can enhance and improve the PSS offering.

The focus of a PSS will be to bundle products and services in a way that generates greater use-value for customers. Pricing will be based on the value provided and a company's capabilities will be aligned to prioritize a customer-centric approach.

Currently, numerous downloadable applications exist for smartphones (Giunti et al., 2018; Midaglia et al., 2021; Zayas-García & Cano-De-La-Cuerda, 2018), as well as tools and platforms (Alexander et al., 2021; Allen-Philbey et al., 2020a; Lapshin et al., 2012; Maillart et al., 2020; Petrova-Antonova et al., 2020; Villarejo et al., 2014; Voigt et al., 2021) aimed at supporting patients and healthcare professionals in the treatment of MS. However, these tools lack the ecosystem vision provided by the PSS solution, where the relationships involve more than just efficient information flow and data sharing (Buhalis & Sinarta, 2019b). In the PSS business ecosystem, partners do not merely add value at each stage of the chain; they collaborate to create new value for patients with MS through an integrated, seamless offering that extends each of their capabilities.

Within the PSS ecosystem, the transfer of value can therefore be bi-directional, flowing toward and away from user segments (Baines et al., 2007; Lim et al., 2018) and delivering environmental and societal benefits, thereby driving global, economy-wide change. At the firm level, patients and healthcare professionals cooperate to co-create value, while at the ecosystem level, hospital managers or pharmaceutical companies compete to capture value due to a mix of economic and societal issues. The cost of MS depends on the degree of disability, and since it primarily affects people between the ages of 20 and 40, it is a disabling disease with costly treatment. The value proposition at this level refers to the societal values that lead to sustainable healthcare and societal development (Conboy et al., 2020b; H. Roth et al., 2022).

D- Innovation projects results

In line with the idea and the needs of the market demand, we articulated the PSS value proposition and the practical results we aimed to deliver in the project. Smart products can be interpreted differently by service consumers and service providers.

1. In the front stage, smart socks are used to create and capture value-in-use
   - For patients, by enhancing health and preventive care for ongoing conditions,
   - For healthcare professionals, by monitoring patients' well-being to guide treatment.

2. In the backstage, smart socks can produce value in exchange based on patient data, which the PSS or other actors, such as hospital managers, pharma, or insurance companies, within the ecosystem can leverage to deliver additional value, either within or beyond the ecosystem.

From the value co-creation at the micro level in the front stage, innovation can be generated in the backstage (Botti & Monda, 2020):

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- New resources: Operand resources such as socks, socks for gait monitoring, AI services, and operant resources such as patient data, know-how, and digital competences.
- New uses of technologies: Strategic use of technology for assessing overall disease severity or status, monitoring and adjusting rehabilitation or physical therapy programs, evaluating the effectiveness of treatments developed by pharmaceutical companies, and improving resource management by avoiding unnecessary MRI scans or medical consultations.
- New institutions: Formal rules related to privacy and data security, as well as informal rules governing remote monitoring and patient empowerment.

All contribute to a more effective and efficient healthcare service. When maintained over time, this generates sustainable value co-creation, leading to benefits in terms of healthcare system costs and social care needs.

However, research has highlighted some limiting factors to consider when enabling this innovation process. These include adherence and usability at the micro level for both patients, whether passive or active, and healthcare professionals (Alexander et al., 2021), as well as privacy and data security, since PSS in healthcare often involve the collection and processing of sensitive patient data (Voigt et al., 2021). Additionally, affordability and accessibility are critical, as healthcare providers need to consider the price of PSS offerings to ensure they are accessible to a wide range of patients with MS. This involves balancing the cost of the system with patients' financial constraints, insurance coverage, and healthcare budgets (H. Roth et al., 2022).

E- Collaboration

The PSS value network is determined by how actors interact within the ecosystem. The goal of creating the PPS business ecosystem is to arrange all elements into a massive, interconnected value network around the IoT MS framework (see figure 1 - physical products and smart services system), and two different frameworks can be identified:

The first focuses on the value of implementing PSS in the healthcare system as support for diagnosing and monitoring MS. The second is oriented toward the value that patient data can provide to third parties, enabling them to develop complementary services and new product-integrated functions by leveraging data collection and predictive analysis, thereby minimizing uncertainties about customer preferences.

Based on this study, it can be concluded that some of the key activities and resources necessary for the successful implementation of PSS in the healthcare system, as well as its proper adoption by patients and healthcare professionals, should include the following.

- A call center to assist patients in their interactions.
- Training programs for clinicians and nurses involved in the program.
- A network of Original Equipment Manufacturers capable of repairing or replacing devices in close proximity to device owners.

The data collected through PSS have the potential to generate significant economic benefits for various stakeholders. Among those who could benefit are:

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- Pharmaceutical companies: These companies can utilize data to develop new treatments, enhance existing ones, and demonstrate the efficacy of their products, thereby increasing confidence among healthcare professionals and patients and driving greater demand.
- Health insurers: Data can be used to predict disease progression, reduce the need for hospitalization, and verify the accuracy of claims, leading to cost savings. Additionally, insurers may offer discounts to patients who maintain a healthy lifestyle.
- Technology companies: Corporations such as Google and Amazon, including Google Health and Fitbit, can leverage data to improve their health-related products by developing sophisticated algorithms and offering personalized health recommendations.
- Manufacturers of ergonomic products: Companies that produce chairs, desks, footwear, or foot care products can adapt their offerings to meet the specific needs of patients, thereby improving comfort and health outcomes. In the sports sector, these data can also be used to enhance athletic performance and prevent injuries.
- Other medical diseases: Applying AI to selectively and coordinately exploit data generated by the PSS for gait monitoring can extend its utility to pathologies other than MS. This differentiation between data capture and interpretation within the context of MS would facilitate the establishment of a market for PSS monitoring, as well as a market for data utilization tailored to individual diseases such as Parkinson's disease or stroke.

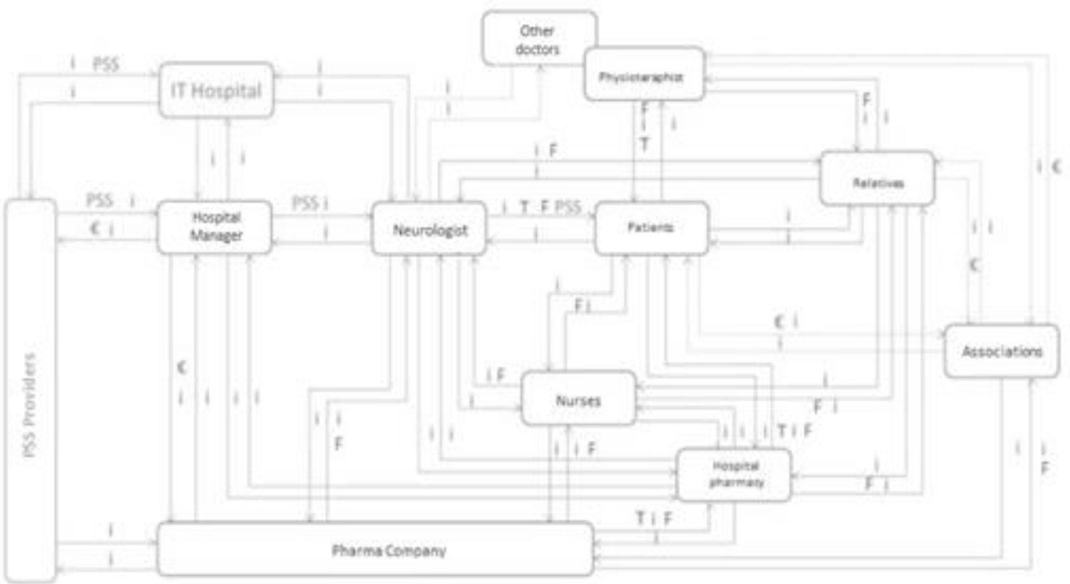

Figure 6 – Process model derived from the designed PSS for gait monitoring within the ecosystem view. Source: Self-elaborated.

A PSS thus evolves into a smart Product-Service System, a digital-based ecosystem where several agents pursue their interests within a value generation network. A smart PSS not only delivers functional benefits but also adapts to user needs, enabling the development, personalization, and enhancement of products and services (Negash & Calahorrano Sarmiento, 2023). An ecosystem comprises both vertical and horizontal relationships in which stakeholders

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share information, knowledge, skills, and experience, thereby actively facilitating the transformation of existing knowledge into new insights (Santos & Zen, 2022).

This becomes evident when the process model is visualized (see Figure 6), where the various flows between stakeholders—represented as blocks in the diagram—are highlighted. Our analysis reveals primary and interrelated value drivers such as novelty, lock-in, competition, coopetition, and efficiency. The discussion of the value proposition underscores the key factors of the PSS from the perspective of ecosystem agents, effectively answering the first research question.

Furthermore, aspects related to innovation and collaboration have also been discussed regarding their impacts, addressing the second research question.

5.2. Managerial contributions

This study enhances our understanding of how health systems can benefit from technology when a well-structured business model is applied. In this case, an ecosystem perspective was found to be the most suitable, with different stakeholders contributing insights on the gait-monitoring service aimed at increasing value for patients with MS.

It is crucial to recognize that while technology offers valuable resources for the entire healthcare value chain, implementing such solutions beyond the pilot phase requires a comprehensive management analysis. This analysis should account for all agents and relationships that can optimize system deployment. This is particularly relevant in complex systems involving multiple agents and is even more critical when technology is a key factor due to its inherent fragility and susceptibility to security risks.

The approach adopted in this study helps identify the necessary processes to operate the system effectively under a servitization model by examining the various perspectives of all involved agents. Similar systems can be further explored through parallel architectures to refine ecosystems, making servitization a viable strategy to enhance value for patients.

Finally, digitalization technologies can significantly promote fairness and equity in providing patient support services (Pulimamidi, 2024). Using these technologies, delivering services to all patients—regardless of socioeconomic factors or other demographic characteristics—can be simplified. This ensures equal access to the support and care required for effective condition management (Bacanoiu & Danoiu, 2022). These competing goals necessitate moral judgments that balance various ethical considerations.

- Affordability and Accessibility: Healthcare providers must consider the price of PSS offerings to ensure that they are accessible to a wide range of patients. This involves balancing the cost of the system with patients' financial constraints, insurance coverage, and healthcare budgets. Moral judgments must be made to ensure that PSS solutions are reasonably priced and available to those who need them (E. G. Roth et al., 2022).

- Quality of Care and Patient Outcomes: The primary goal of healthcare providers is to deliver high-quality care and improve patient outcomes. When evaluating PSS options for a disease, decision-makers must assess the effectiveness, safety, and reliability of the system.

They must make moral judgments that prioritize the best interests of patients, ensuring that the chosen PSS supports positive health outcomes and enhances the quality of care provided (Kever et al., 2021).

- Informed Consent and Patient Autonomy: When implementing a PSS, healthcare providers must respect patient autonomy and obtain informed consent. Decision-makers must ensure that patients are well informed about the benefits, risks, and potential outcomes of using a specific PSS. Moral judgments must promote patient autonomy and empower individuals to make decisions aligned with their values and preferences (Bayas et al., 2021).

- Equity and Fairness: Ethical considerations around equity and fairness arise when making decisions about PSS implementation. Decision-makers should assess whether adopting a particular PSS creates disparities in access to care among different patient populations. They must strive for an equitable distribution of resources and make moral judgments that promote fairness in providing PSS to all individuals with the targeted disease, irrespective of socioeconomic factors or other demographic characteristics (Bacanoiu & Danoiu, 2022).

- Privacy and Data Security: PSS in healthcare often involves collecting and processing sensitive patient data. Decision-makers must prioritize patient privacy, confidentiality, and data security. They should assess the potential risks associated with data breaches, make moral judgments that protect patient information, and ensure compliance with relevant data protection regulations (Voigt et al., 2020).

- Transparency and Accountability: Decision-makers should consider the transparency and accountability of PSS providers. This includes assessing the providers' reputation, track record, and ethical practices. Moral judgments must be made to select trustworthy and responsible PSS providers who prioritize patient well-being and adhere to ethical standards (Salahuddin et al., 2022).

5.3 Concluding remarks

The healthcare industry holds global importance, facing increasing demands for personalized care outside traditional hospital settings, all while grappling with budget constraints. In the context of this study, which focuses on the case of MS, PSS applications are identified as a valuable tool for bridging this gap. A PSS facilitates the implementation of innovative technologies and practices that connect care providers, healthcare professionals, and patients within a coordinated ecosystem. This study centered on monitoring gait disturbances in real-life scenarios for patients with MS, but the same principles may apply to other areas with similar key factors.

The methodology employed in this study allowed for a comprehensive exploration of ecosystem-level aspects, including considerations such as acceptance, usability, accuracy, and reliable outcomes in operational processes. These aspects were pivotal in addressing the research questions presented in the discussion section, emphasizing the role of the PSS-enabled ecosystem in driving innovation and contributing significantly to societal value, ultimately fostering sustainable healthcare and societal development.

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This study successfully addressed the research questions by illustrating how a PSS generates value within a healthcare ecosystem, specifically in managing chronic conditions such as MS. In response to RQ1, which sought to identify the key factors of a PSS that enable value creation for each ecosystem agent, the findings demonstrate that a PSS facilitates co-creation among diverse stakeholders—including patients, healthcare professionals, hospital administrators, and pharmaceutical companies—by integrating innovative, data-driven approaches. The implementation of smart socks for remote gait monitoring serves as a prime example of how technological advancements can enhance diagnostic precision and improve patient outcomes, particularly in overcoming the challenges associated with monitoring MS progression.

For RQ2, which aimed to assess the anticipated impacts of the PSS in terms of innovation, sustainability, and social implications, this study revealed several noteworthy findings. A PSS model, leveraging the capabilities of the IoT and AI, promotes cutting-edge healthcare solutions that extend beyond conventional clinical environments, offering a more sustainable alternative to traditional, resource-intensive diagnostic tools such as MRI scans. Furthermore, this study highlighted broader societal advantages, including improved access to healthcare, cost reduction, and more efficient resource management within the healthcare system—all of which contribute to enhanced social welfare and economic viability.

While this study has provided valuable insights, certain limitations should be acknowledged. A deeper analysis of costs is necessary to precisely define the boundaries of stakeholder relationships in value co-creation. Additionally, the challenges associated with institutional and organizational factors, such as resistance to change and increased pressure on IT departments, warrant careful consideration. On a positive note, streamlining workflows through automation has the potential to significantly reduce bureaucratic obstacles when appropriately designed and maintained.

As highlighted in this study, innovation does not occur in isolation. Therefore, a sociotechnical system approach is essential to enable the development, diffusion, and utilization of technologies across all organizational levels. In this context, PSS emerges as a comprehensive tool that unites ecosystem stakeholders through specific processes, fosters value co-creation, and stimulates innovation.

This analysis has some limitations. Despite showing significant results, it is important to note that the selection of a single PSS may impose constraints when addressing broader contexts, and this limitation is inherent to the method proposed. Nevertheless, the identified factors remain consistent with existing literature and are highly relevant. Additionally, stakeholder analysis plays a crucial role in identifying significant impacts both within and beyond the ecosystem, while governance in the ecosystem remains an interesting topic for further investigation.

Declaration of Competing Interests

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

Besides, we inform that this research is part of a broader project, and the interviews conducted encompassed other issues that have been analyses. A paper has been submitted to a journal and it has published.

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