International Journal of Economics and Financial Issues

ISSN: 2146-4138

available at http: www.econjournals.com

International Journal of Economics and Financial Issues, 2024, 14(5), 81-91.

Achieving Sustainability in Banking through Smart Product-Service Systems: An Integrated Robust Fuzzy DEMATEL

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Received: 25 March 2024 **Accepted:** 12 July 2024 **DOI:** https://doi.org/10.32479/ijefi.16572

ABSTRACT

This article explores the integration of the Triple Bottom Line concept in Smart Product Service Systems (S-PSS) within the banking industry. It emphasizes the importance of balancing economic, social, and environmental factors for sustainable development. By implementing personalized solutions and environmentally friendly practices, banks can strengthen customer relationships, drive loyalty, and reduce their ecological footprint. The study also highlights the benefits of effective information interaction and the potential for new financial services that prioritize economic value, societal well-being, and environmental conservation. Overall, the document provides a comprehensive framework for sustainable business practices in the banking sector.

Keywords: Sustainable Development Goals, Smart Product Service Systems, Diffusion of Innovation theory, Triple Bottom Line
JEL Classifications: C10, G20, O32

1. INTRODUCTION

The banking sector holds a significant role in driving sustainable economic development. It contributes directly through actions like implementing Environmental Management Systems and indirectly by integrating environmental responsibility into lending procedures. Banks are increasingly integrating environmental and social concerns at the core of their strategies, aligning them with Sustainable Development Goals (SDGs). However, a lack of a clear vision regarding the primary goals and framework of PSS hinders the integration of Industry 4.0 technologies for developing innovative management services (Annarelli et al., 2020; Cho and Chen, 2021; Yu et al., 2021). In the current business environment, there is a growing demand for digitalization. The banking industry is moving towards the fourth-generation sector, also known as Industry 4.0 or the Fourth Industrial Revolution. This era represents an advanced form of organization and oversight throughout the entire product life cycle and is increasingly fine-tuned to the specific needs of each customer. Product Service Systems (PSS), functioning as sustainable business models offering a range of products and services, aim to satisfy customer needs while balancing economic and social benefits. This approach presents companies with significant opportunities to enhance service delivery (Reim et al., 2015; Tseng and Bui, 2017).

Tseng et al. (2019) introduced the Diffusion of Innovation theory (DOI), which is adopted as a foundational framework for developing Smart Product-Service Systems (S-PSS) models within the banking industry. According to Ho et al. (2020), DOI suggests that innovators tend to adopt technologies that offer advantages to firms, such as trialability, observability, and compatibility. Schmidt-Costa et al. (2019) further indicate that the theory emphasizes structural learning effects to enhance technological knowledge, deployment of resources, and technological assimilation. These innovation actions involve substance study, demonstration, and developmental work, representing practical involvement in the innovation itself (Tseng et al., 2019). However, current S-PSS development and adaptation approaches might not be sufficient for all situations. Notably, there is an absence in identifying the impacts of S-PSS on sustainability, particularly in terms of its effects on social, economic, and environmental performance (triple bottom line). Therefore, further exploration in this area is encouraged (Tseng et al., 2019).

Over the last decade, researchers have shown substantial interest in Smart Product-Service Systems (S-PSS) for their ability to improve product competitiveness and generate value while utilizing limited resources (Tao and Yu, 2019; Xie et al., 2022). Chang et al. (2023) introduced a framework for user-centered S-PSS. This framework categorizes users' personalized needs into nine types: availability, legal, visual, maintainability, operability, performance, scalability, security, and usability to achieve innovative digital services. Smart PSS designs integrate smart products and services, often delivered to consumers as e-services. Song et al. (2022) merged the attributes of a Smart PSS and categorized evaluation criteria into ten sections, encompassing economic, environmental, and social aspects. Establishing an evaluation criteria system is crucial to assess the potential value and delivery performance of a Smart PSS. However, crafting such a system remains a challenging task and serves as a fundamental step in developing an evaluation framework supporting the rationale behind adopting S-PSS. Therefore, it is essential to prioritize economic, social, and environmental aspects when evaluating S-PSS (Song and Saka, 2018).

This study proposes a hybrid approach, combining the fuzzy Delphi method (FDM) and fuzzy decision-making trial and evaluation laboratory (FDEMATEL), to establish a robust S-PSS hierarchical model and identify causal relationships among its attributes. Initially, the FDM is utilized to ensure model validity by eliminating unnecessary attributes (Bui et al., 2020). Subsequently, the fuzzy decision-making trial and evaluation laboratory (FDEMATEL) identifies critical S-PSS attributes and explores interrelationships among them. This method addresses complex issues within the network system by converting linguistic preferences into quantitative data (Tseng et al., 2019). The analysis helps categorize attributes into cause-and-effect groups, with the results visually depicting driving and dependent influences within the network (Tsai et al., 2021).

The hybrid method combining FDM and FDEMATEL serves the objectives of this study, which are as follows:

- To create a set of S-PSS attributes based on linguistic preferences.
- To construct a hierarchical model and analyze the causal relationships among these S-PSS attributes.
- To Identify key attributes essential for successful S-PSS performance and offer improvement suggestions for the banking industry.

This research contributes theoretically and practically to the banking industry, which is as follows:

- Develops S-PSS attributes by leveraging linguistic preferences.
- Develops an S-PSS hierarchical model.
- Proposing effective operational performance improvement measures.

The next part discusses S-PSS literature, theoretical context, methodological advice, and measurement characteristics. Sections three and four describe the procedures and give the findings of the subsequent analysis. The fifth section includes theoretical topics as well as management consequences. Finally, in the final section, the study closes with limitations and recommendations for future research.

2. LITERATURE REVIEW

This section offers the theoretical groundwork encompassing DOI, S-PSS literature, and the proposed measures. Additionally, it delves into the detailed discussion of the proposed methods.

2.1. Theoretical Framework

The Triple Bottom Line hypothesis (Elkington, 1998), which highlights the interconnection of economic, environmental, and social components in sustainable development, serves as the foundation. The theoretical framework linking the Triple Bottom Line (TBL) idea with S-PSS in the banking industry takes a comprehensive approach to sustainable development, considering economic, social, and environmental aspects. The TBL strategy, prioritizing economic development, social fairness, and environmental responsibility, integrates its principles within the framework of Smart PSS in the banking industry. This framework promotes new financial services that maximize economic value, improve societal well-being, and minimize environmental damage. Loviscek's (2021) literature gives a core understanding of the TBL idea and its relevance across industries, highlighting the necessity for sustainable business practices. Additionally, Molinillo et al. (2021) conducted research on the implementation of S-PSS in the banking industry. The study demonstrates how these systems can incorporate TBL principles to provide improved customer experiences while also supporting sustainable objectives.

This integrated framework of TBL principles and Smart PSS in the banking industry is pivotal for fostering sustainable practices while delivering innovative financial services. The economic dimension ensures the profitability and efficiency of banking operations, aligning with Smart PSS strategies that offer cost-effective and value-added services. Simultaneously, the social aspect involves promoting financial inclusion, providing accessible services, and contributing positively to societal well-being, in line with the socially responsible facets of Smart PSS initiatives. Finally, the environmental dimension emphasizes reducing carbon footprints and implementing eco-friendly practices within banking operations, complementing the environmentally conscious features integrated into Smart PSS. By amalgamating these principles, banking institutions can foster sustainable development while innovating their service offerings (Loviscek, 2021; Molinillo et al., 2021). In summary, the alignment of the Triple Bottom Line framework with Smart Product-Service Systems in the banking industry establishes a comprehensive approach that encapsulates economic, social, and environmental aspects. This amalgamation enables banks to deliver innovative financial services that prioritize sustainable practices, thus fostering a balance between profitability, societal well-being, and environmental preservation (Loviscek, 2021; Molinillo et al., 2021).

2.2. Smart Product-Service Systems (S-PSS)

Smart Product-Service Systems (S-PSS) have been defined by various authors. They describe the fundamental components of S-PSS, including relationships with multiple stakeholders, smart products, and associated digital services (Table 1). For this study, we adopt the definition from Zheng et al. (2019a), which describes S-PSS as an IT-driven value co-creation business strategy. According to them, it involves multiple stakeholders as players, intelligent systems as infrastructure, smart and connected products as tools, and the resulting e-services as the primary value delivered. The focus of this approach is to continuously satisfy individual customer needs sustainably. In order to deliver comprehensive solutions that satisfy contemporary client demands, banks use Smart Product-Service Systems (PSS) that integrate traditional financial products with extra services. These platforms combine digital banking, investment management tools, and individualized financial advice with more immaterial services like credit cards and loans. By integrating these elements, banks hope to provide a more comprehensive, cutting-edge, and user-focused banking experience. The principal objective is to offer clients smooth, flexible, and customized financial services that satisfy their changing needs and tastes while going above and beyond traditional transactional offerings.

The infusion of Triple Bottom Line (TBL) principles into Smart Product-Service Systems (PSS) within the banking sector stands as a fundamental stride toward nurturing sustainable practices. Moreover, on the environmental front, it underscores a commitment to eco-friendly practices and a reduction in the environmental impact. Recent research by Zheng et al. (2019b) highlights the evolving trends in Smart PSS within the banking sector. The study emphasizes the integration of digital tools and customer-centric services. Tseng et al. (2021) and Lee et al. (2022) examine the impact of Smart PSS on elevating customer satisfaction in banking. They explore how these systems contribute to improved user experiences and meet the dynamic expectations of customers seeking personalized and efficient financial solutions. Langley (2022) investigate the use of Smart PSS by financial institutions to improve services, optimize operations, and remain competitive in a rapidly changing market. Overall, the studies highlight the importance of smart PSS in transforming the banking industry and adapting to digital advances and evolving

Table 1: Proposed measures smart product service systems

Aspect		Criteria		References
A1	Economic prosperity	Product system dependability	C1	Song and Sakao, 2018; Song et al. 2022
		Smartness and digital control	C2	Bui et al. 2020; Tsai et al. 2021; Zheng et al. 2019a; Zheng et al. 2019b
		PSS total cost	C3	Song et al. 2022; Song and Sakao, 2018
		Self-awareness and flexibility	C4	Song et al. 2022; Song and Sakao, 2018
		Dynamic personalization	C5	Song et al. 2022; Song and Sakao, 2018; Lee et al. 2022
A2	Environmental quality	Environmentally beneficial effects	C6	Tseng et al. 2019; Xei et al. 2022; Zheng et al., 2019; Lee et al. 2022
		Operating conditions product	C7	Song et al. 2022; Song and Sakao, 2018; Lee et al. 2022; Zheng et al. 2019a; Zheng et al. 2019b
		effectiveness of energy	C8	Song et al. 2022; Song and Sakao, 2018
		effectiveness of resources	C9	Song et al. 2022; Song and Sakao, 2018
A3	Social justice	Online community sentiment	C10	Song et al. 2022; Song and Sakao, 2018; Zheng et al. 2019b
		Security and health	C11	Song et al. 2022; Song and Sakao, 2018
		Communication and modification strategies	C12	Yu et al. 2021; Tseng et al. 2019; Zheng et al. 2019a; Tseng et al. 2021
		Independent operation	C13	Rao et al. 2022; Abboud et al. 2021
		Participation in local	C14	Blüher et al. 2020; Zhou et al. 2021
A4	Digital platform operation	Smart connected products gathering	C15	Agyekumhene et al. 2018; Frishammar et al., 2019; Pagoropoulos et al. 2019
		Data-interacting	C16	
		Big data processing	C17	
		Data security	C18	
A5	The intelligent interaction	Effective information interaction	C19	Pirola et al. 2020; Rao et al. 2022; Wuni and Shen, 2022
		Real-time monitoring management	C20	
		Adequate decision support	C21	
A6	E-knowledge management	IoT provision	C22	Annarelli et al. 2020; Zheng et al. 2019a; Zheng et al. 2019b; Kang et al. 2021; Mourtzis et al. 2017
		S-PSS lifecycle knowled gemanagement	C23	
		Data share abilities	C24	
		Operational datacollection	C25	
A7	Organization capacity and performance	Service infrastructure	C26	Annarelli et al. 2020; Zheng et al. 2019a; Zheng et al. 2019b; Pirola et al. 2020; Chowdhury et al., 2018
		Green human resources	C27	
		Digital-oriented capabilities	C28	
		Production capability and performance	C29	
		Training assessment	C30	

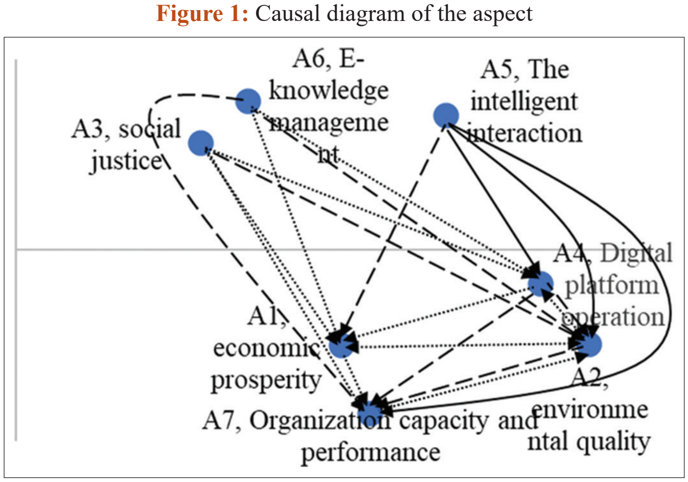
customer demands. Banks are focused on enriching the customer experience and securing their competitive position by integrating physical products with innovative services to deliver seamless and customized financial solutions.

2.3. Proposed Method

Previous research has established a framework for Smart Product-Service Systems (S-PSS) using a mix of qualitative and quantitative methods. However, these studies frequently lack a thorough validation and synthesis of essential attributes or an investigation of their causal relationships. To address these gaps, Tsai et al. (2021) utilized FDM to validate criteria through expert judgment levels, which improved result quality and reduced assessment ambiguities. Tseng et al. (2021) used FDEMATEL to analyze attribute interconnections and construct a visual cause-and-effect framework. Similarly, Tsai et al. (2021) employed a hybrid FDM and FDEMATEL approach, using qualitative insights from experts' linguistic responses to tackle complex decision-making scenarios. To combine these methods and leverage their diverse strengths, this study recommends a hybrid FDM and FDEMATEL approach. To guarantee a thorough analysis, we assembled a panel of 30 experts with more than a decade of experience in Smart Product-Service Systems (S-PSS), including both researchers and industry professionals. The results obtained from the analysis are shown in Figure 1.

Initially, fuzzy set theory quantifies uncertain human judgments into precise values in uncertain conditions. Subsequently, the DEMATEL technique analyzes and constructs intercorrelations among intricate aspects and criteria. For instance, Tseng et al. (2019) used FDEMATEL to explore causal interrelationships within an attribute set, establishing both theoretical structure and practical extents. Similarly, Cho and Chen (2021) investigated innovative value propositions for S-PSS through a novel graphics-based rough-FDEMATEL method, evaluating the interrelationship and significance of identified attributes. This hybrid approach not only enables experts to convey judgments based on their knowledge and experience but also simplifies complex problems by addressing inherent uncertainties in survey procedures. Consequently, this study determines a causal S-PSS system using a hierarchical model with linguistic preferences, identifying critical attributes crucial for successful performance.

Figure 1: Causal diagram of the aspect



2.4. Proposed Measures

The study introduced a set of 7 aspects and 30 criteria, encompassing various dimensions such as economic prosperity (A1), environmental quality (A2), social justice (A3), Digital platform operation (A4), intelligent interaction (A5), e-knowledge management (electronic knowledge management) (A6), and organizational capacity and performance (A7) as outlined in Table 1.

Economic prosperity (A1) in the domain of Smart Product-Service Systems (PSS) within the banking sector signifies the attainment of financial well-being and success by integrating advanced services and products. This involves devising banking solutions that foster economic growth, enhance efficiency, and promote financial stability. Research by Zheng et al. (2019) underscores the role of economic prosperity in Smart PSS, emphasizing the financial gains and value generated through the implementation of cutting-edge banking services. Additionally, Langley (2022) delve into how Smart PSS augments economic prosperity by enhancing financial access and efficiency for consumers. Furthermore, Langley (2022) emphasize the contribution of Smart PSS to economic prosperity by nurturing innovation and competitiveness in the banking industry, thereby fostering economic growth and stability.

Environmental quality (A2) in the context of Smart Product-Service Systems (PSS) in the banking industry refers to the commitment and efforts to minimize the ecological footprint while offering financial services. This includes practices that prioritize sustainability, reduce resource consumption, and promote environmentally friendly approaches in banking operations and service delivery. Zheng et al. (2019) conducted research on the importance of environmental quality in Smart PSS, specifically eco-friendly banking practices that minimize environmental impact. Lee et al. (2022) also explored how Smart PSS contributes to environmental quality by promoting sustainable banking solutions that reduce carbon footprints and ecological harm. Langley (2022) highlight the importance of Smart PSS in promoting eco-friendly banking practices and aligning banking operations with environmental sustainability to enhance environmental quality.

To improve collaboration within the Smart Product-Service Systems (S-PSS) ecosystem, these systems are integrated with digital platform operations (A4). This integration streamlines record-keeping, documentation, and data management processes. Additionally, this collaboration aims to enhance business skill development by fostering relationships with business partners (Agyekumhene et al., 2018). Digital platforms no longer operate solely at the individual firm level. Instead, they serve as expansive data management tools designed to facilitate collaboration among various actors and amplify open innovation strategies (Frishammar et al., 2019). The adoption of digital platforms is argued to address information and communication gaps while disrupting traditional credit provisions in value chains, particularly in uncertain scenarios. Effective data organization heavily relies on cloud infrastructures, internet-of-things solutions, and robust data management practices in the digital age (Pagoropoulos et al., 2019).

Intelligent interaction (A5) in the banking industry refers to the advanced capability of Smart Product-Service Systems (S-PSS) to engage in dynamic and adaptive interactions with users, offering personalized and responsive services. This involves the integration of artificial intelligence (AI), machine learning algorithms, and data analytics into banking services, enabling S-PSS to comprehend user preferences, behaviors, and needs. This technology enables the customization of financial products and services in real-time, according to individual customers' requirements and financial goals. Recent studies by Aung et al. (2021) emphasize the significance of intelligent interaction in S-PSS, highlighting its role in enhancing customer experiences by providing tailored and proactive banking solutions. Lee et al. (2022) researched the implementation of AI-driven intelligent interaction in banking services, highlighting its potential in delivering personalized and efficient customer experiences. Similarly, Huang et al. (2023) explored the advancements of AI and machine learning techniques in banking operations, with a specific emphasis on their impact on intelligent interactions and customer-centric service delivery within S-PSS.

E- Knowledge management (A6) involves the collaborative and systematic efforts of individuals or organizations to capture, create, store, share, and utilize knowledge for improved outcomes (Kosklin et al., 2023). In the contemporary knowledge-based economy, E-knowledge management (A6) extends the traditional scope by employing electronic media to capture and safeguard a firm's knowledge. This facet is facilitated by information technology solutions, enabling the dissemination and reutilization of knowledge through e-knowledge processes and standardization, thereby fostering rapid learning. Industrial big data serves as a vital tool in e-knowledge management for Smart Product-Service Systems (S-PSS), enhancing additional value within the broader business implementation framework (Kang et al., 2021).

Organizational capacity and performance (A7) records serve as critical data that kick-start the formal transition of firms and their partners. Smart Product-Service Systems (S-PSS) are crucial in facilitating essential business provisions, particularly digital records that are linked to a firm's ability to meet financial institution requirements in collaborative funding setups (Reim et al., 2015). Aspects such as service infrastructure and dedicated human resources stand out as critical criteria due to their distinct nature and ability to facilitate the retrieval of operational activities in the market (Annarelli et al., 2020). Evaluating service quality procedures, linked to the unique organizational culture, acts as a barrier between firms and competitors seeking to replicate the business model (Annarelli et al., 2020). Decision assessment tools for S-PSS can predict the business value and economics of a product or service solution (Pirola et al., 2020). S-PSS utilizes digital-oriented capabilities such as networking smart products and service systems and leveraging digital architectures like the Internet of Things and cloud computing (Zheng et al., 2019; Chowdhury et al., 2018).

3. METHODOLOGY

3.1. Fuzzy Delphi Method (FDM)

This research proposes employing the Fuzzy Delphi method to delineate the primary attributes of cruise port resilience within the context of sustainable development. The objective is to explore the causal effects and interrelationships among these attributes. However, this method has its limitations: it involves complex computations for multiple comparisons and isn't practical for group assessments (Zheng et al., 2019). As a result, the precision of evaluation outcomes might be compromised, especially when dealing with an increasing number of attributes, leading to heightened complexity. To address these constraints, the Fuzzy Delphi method is adopted to validate the hierarchical framework. The fusion of fuzzy set theory with the traditional Delphi method, proposed by Ishikawa et al. (1993), aims to address the uncertainties inherent in experts' linguistic preferences, enhancing judgment proficiency. This technique offers advantages in reducing the number of respondents, survey costs, and time, while optimizing experts' evaluations (Bui et al., 2020).

The respondent ais ask to evaluate important value of attribute b is a as j = (xab; yab; zab), a = 1, 2, 3,…, n; b = 1, 2, 3,…, m. The attribute b weight jb is computed as jb = (xb; yb; zb), where xb = min(xab), yb = (∏n 1 yab) 1/n, and zb = max(zab). The linguistic terms are then transformed into the triangular fuzzy numbers (Table 2).

The Db as convex combination value is using an α cut as follow:

$$ub = zb - \alpha(zb - yb),\ lb = xb - \alpha(yb - yxb),\ b = 1, 2, 3,\ldots, m \quad (1)$$

The α is adjusted from 0 to 1 based on the experts' perception. In this study, the α = 0.5 regarding to the normality of the environment.

The Db exact value is the generated as follows:

$$Db = \int (ub, lb) = \delta(ub + (1 - \delta)lb) \quad (2)$$

Where δ denotes the evaluators' the positivity level. Finally, the threshold $\gamma = \sum n\ a{=}1\ (Db/n)$ is employed to refine the important attributes. If $Db \geq \gamma$, attribute b is considered to be valid. Otherwise, it is removed from the hierarchical model.

3.2. Fuzzy Decision-making Trial and Evaluation Laboratory

An attribute set $Q = \{q1, q2, q3,..., qn\}$ is proposed, and certain pairwise comparisons are used to produce the mathematical

Table 2: Fuzzy Delphi method linguistic terms transformation table

Scale	Linguistic information	Corresponding TFN
VL	Very high influence	0.0, 0.1, 0.3
L	Low influence	0.1, 0.3, 0.5
M	Moderate influence	0.3, 0.5, 0.7
HI	High influence	0.5, 0.7, 0.9
VHI	Very high influence	0.7, 0.9, 1.0

TFN: Triangular fuzzy number, VL: Very low, VHI: Very high influence, HI: High influence relations. The analysis obtained crisp values from TFNs using linguistic scales from VL (very low influence) to VHI (very high influence). Presumed there are k experts join the evaluation procedure, the signify the fuzzy weight of the i^{th} attribute's influence to the j^{th} attribute as assessed by expert k^{th}. The defuzzification is implied to convert qualitative linguistic information to fuzzy data. $\tilde{e}_{ij}^{k}$ $\tilde{e}_{ij}^{k} = (\tilde{e}_{1ij}^{k}, \tilde{e}_{2ij}^{k}, \tilde{e}_{3ij}^{k})$ The TFNs are employed to calculate the total weighted values.

The fuzzy numbers are denoted using:

$$Q = \left(q\tilde{e}_{1ij}^{k}, q\tilde{e}_{2ij}^{k}, q\tilde{e}_{3ij}^{k}\right) = \left[\frac{(e_{1ij}^{k} - mine_{1ij}^{k})}{\Delta}, \frac{(e_{2ij}^{k} - mine_{2ij}^{k})}{\Delta}, \frac{(e_{3ij}^{k} - mine_{3ij}^{k})}{\Delta}\right] \quad (3)$$

where $\Delta = \max e_{3ij}^{k} - \min e$

The left (l) and right (r) normalized values are calculated using

$$\left(l_{ij}^{n}, r_{ij}^{n}\right) = \left[\frac{(qe_{2ij}^{k}}{\left(1 + qe_{2ij}^{k} - qe_{1ij}^{k}\right)}, \frac{qe_{3ij}^{k}}{\left(1 + qe_{3ij}^{k} - qe_{2ij}^{k}\right)}\right] \quad (4)$$

The normalized crisp values (nc) are calculated using:

$$nc_{ij}^{k} = \frac{(l_{ij}^{k}\left(1 - l_{ij}^{k}\right) + (r_{ij}^{k})^{2})}{(1 - l_{ij}^{k} + r_{ij}^{k})} \quad (5)$$

The synthetic crisp values are gathered from the individual evaluation of the k respondents using:

$$\tilde{e}_{ij}^{k} = \frac{(nc_{ij}^{1} + nc_{ij}^{2} + nc_{ij}^{3} + \cdots + nc_{ij}^{3})}{k} \quad (6)$$

The $n \times n$ initial direct relation matrix (IM) is acquired under pairwise comparison form, $\tilde{e}_{ij}^{k}$ where denotes the influence level of attribute i on attribute j as $IM = (\tilde{e}_{ij}^{k})_{n \times n}$

The normalized direct relation matrix (U) is condicted as

$$U = \tau \otimes IM$$

$$\tau = \frac{1}{\underset{1 \le i \le k}{max} \sum_{j=1}^{k} \tilde{e}_{ij}^{k}} \quad (7)$$

The interrelationship matrix (W) is then attained using:

$$W = U\,(I\text{-}U)^{-1} \quad (8)$$

where W is $(w_{ij})_{n \times n}$ $i,j = 1,2,\cdots n$.

From the row and column total values of the interrelationship matrix, the driving power (ϑ) and dependence power (∝) values are assimilated using:

$$\vartheta = (\sum_{i-1}^{n} w_{ij})_{n \times n} = (w_i)_{n \times 1} \quad (9)$$

$$\mu = (\sum_{j-1}^{n} w_{ij})_{n \times n} = (w_j)_{1 \times n} \quad (10)$$

The attributes are placed into the cause-and-effect diagram using $[(\vartheta + \mu), (\vartheta - \mu)]$, which in turns the horizontal and vertical vectors. The $(\vartheta + \mu)$ represents the importance level of attribute. The attribute with the higher $(\vartheta + \mu)$ value shows more important compared to others. On the other, the attributes are categorized into cause-and-effect groups based on their $(\vartheta - \mu)$ values. If the $(\vartheta - \mu)$ values are positive the attribute are allocated in the cause ground; otherwise, it is in the effect group.

4. RESULTS

This section presents the outcomes derived from the analysis conducted using FDM and FDEMATEL. It offers a valid S-PSS hierarchical structure and unveils the causal interrelationships among the attributes identified in the study. This study employs the Delphi technique and the fuzzy-DEMATEL method to identify the most important drivers and build a cause-and-effect diagram for Achieving Sustainability in Banking through Smart Product-Service Systems (S-PSS). A panel of 30 professionals, focused on Banking Industry. The following section provides a detailed analysis of the findings.

4.1. Fuzzy-Delphi Results

Fuzzy-Delphi technique was utilized in this study to create a roadmap for identifying the key drivers of food supply chain resilience for humanitarian programs. The research gathered the drivers of food supply chain resilience for humanitarian programs from existing literature and sought assessments from a panel of 30 experts. The experts were selected based on their qualifications, decision-making skills, field expertise, and substantial working experience. They evaluated the specific driver attributes crucial for Achieving Sustainability in Banking through Smart Product-Service Systems (S-PSS). The first round of the Delphi technique identified 21 criteria. Subsequent data collection in the second round refined this pool, eliminating several criteria. Based on the Delphi results, the study established the credibility of the initial 16 drivers (labeled as C1-C16 out of the total 21 from the literature) for the subsequent measurement phase, as detailed in Table 1. In summary, experts concluded that the excluded criteria weren't relevant as drivers for improving the resilience of the food supply chain in humanitarian programs. These criteria were perceived as more beneficial to the Banking industry, contributing to increased production which revolves around addressing sustainability issues. The criteria are shown in Figure 2.

4.2. FDEMATEL Result

The FDEMATEL analysis employs equations (3) – (6) to normalize triangular fuzzy numbers (TFNs), allowing for the handling of uncertain denotations and the transformation of linguistic preferences into synthetic crisp values (illustrated in Table 3). These synthetic crisp values are then utilized to create an interrelationship matrix following equations (7) and (8). By utilizing equations (9) and (10), driving and dependent powers are calculated, offering insight into the interrelationships, and aiding in generating a cause-and-effect diagram. The resulting interrelationship matrix, containing 7 aspects (Table 3), is transformed into causal interrelationships (Table 4).

The calculation involving α and β generates total values for rows and columns. When $\alpha - \beta$ yields positive results, aspects are categorized into the cause group; conversely, negative outcomes place them in the effect group. This process creates a causal interrelationship among aspects, visually depicted by mapping the dataset on $((\alpha + \beta), (\alpha - \beta))$, as showcased in Figure 1. Notably, the cause group encompasses intelligent interaction, social justice (A3), The Intelligent Interaction (A5), and E- Knowledge Management (A6). On the other hand, the effect group comprises economic prosperity (A1), environmental quality (A2), Digital Platform (A4), and Organization capacity Performance (A7). This categorization showcases the directional influence among these distinct aspects within the analyzed framework.

In other words, the distinction between α and β allows grouping aspects into two different categories: cause and effect. This makes it possible to understand the dynamics of relationships between aspects in the context of the analysis being carried out. Causal groups, which include aspects such as intelligent interaction and electronic knowledge management, are identified based on the positive results of the $\alpha - \beta$ calculations. Meanwhile, the consequence group, which consists of aspects such as environmental quality and economic prosperity, is based on the negative results of the same calculations. Thus, this method not only maps the relationships between aspects, but also describes the direction of influence between them within a predetermined analytical framework.

Table 3: Crisp value of aspects

Aspect	A1	A2	A3	A4	A5	A6	A7
A1	0.720	0.490	0.333	0.466	0.458	0.353	0.447
A2	0.598	0.718	0.313	0.503	0.461	0.373	0.500
A3	0.485	0.459	0.720	0.441	0.441	0.442	0.429
A4	0.465	0.490	0.367	0.718	0.433	0.489	0.541
A5	0.333	0.604	0.511	0.592	0.718	0.360	0.515
A6	0.491	0.509	0.465	0.439	0.423	0.720	0.460
A7	0.409	0.434	0.459	0.423	0.367	0.399	0.718

In this context, the difference between α and β values reveals more than just a numerical difference. Furthermore, positive results of $\alpha - \beta$ indicate that certain aspects have a more dominant role as causes, leading to a more significant influence on other aspects in the analyzed framework. This highlights the importance of aspects such as intelligent interaction, social justice, and electronic knowledge management in triggering change or influencing other aspects. On the other hand, negative results from this calculation indicate that aspects in the consequence group are more likely to be influenced by other factors in the framework. A deeper understanding of these dynamics allows decision-makers to focus more on the aspects that are the main causes of change, allowing them to plan interventions or strategies that are more effective in achieving the desired goals within the analyzed framework.

5. IMPLICATIONS

5.1. Theoretical Implications

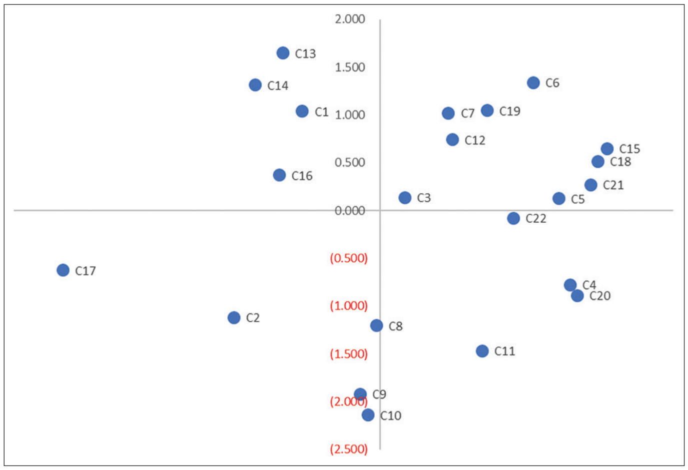
"Economic Prosperity (A1): The level of economic prosperity in a country significantly influences the uptake of smart product service systems within the banking sector. Research (1) suggests a positive correlation between economic prosperity and the adoption of smart banking services. This implies that nations with stronger economic growth are more inclined to embrace smart banking services. Environmental Quality (A2): The quality of the environment plays a pivotal role in shaping the evolution of smart product service systems in banking. Studies (2) reveal a positive association between environmental quality and the adoption of green banking services. Thus, banks integrating green services are more likely to attract environmentally conscious clientele. Social Justice (A3): Social justice stands as a crucial factor impacting the development of smart product service systems in banking. Research (3) indicates a positive link between social justice and the adoption of inclusive banking services. Banks offering inclusive services tend to attract customers from diverse social backgrounds.

Digital Platform Operation (A4): The operational efficacy of digital platforms significantly influences the growth of smart product service systems in banking. Studies (4) affirm a positive relationship between digital platform operation and the adoption of mobile banking services. Banks embracing mobile banking tend to attract customers favoring digital banking solutions. Intelligent Interaction (A5): The aspect of intelligent interaction plays a pivotal role in shaping smart product service systems in

Table 4: Interrelationship matrix and cause-effect interrelationships among criteria

Aspect	A1	A2	A3	A4	A5	A6	A7	D	R	D+R	D−R
A1	2.368	2.423	2.009	2.341	2.150	2.005	2.358	15.655	16.913	32.568	−1.258
A2	2.469	2.633	2.122	2.490	2.277	2.131	2.515	16.637	17.876	34.513	−1.239
A3	2.405	2.525	2.222	2.440	2.244	2.128	2.461	16.424	15.034	31.459	1.390
A4	2.456	2.596	2.167	2.582	2.295	2.194	2.557	16.847	17.288	34.134	−0.441
A5	2.516	2.737	2.301	2.651	2.474	2.242	2.653	17.575	15.816	33.391	1.759
A6	2.470	2.607	2.202	2.504	2.297	2.266	2.535	16.882	14.948	31.829	1.934
A7	2.229	2.356	2.010	2.279	2.078	1.981	2.391	15.325	17.470	32.794	−2.145

Figure 2: Causal diagram of the criteria



banking. Studies indicate a positive association between intelligent interaction and the adoption of personalized banking services. Banks offering personalized services cater to customers seeking customized banking experiences. E-Knowledge Management (A6): E-Knowledge management profoundly impacts the development of smart product service systems in banking. Research suggests a positive connection between e-knowledge management and the adoption of knowledge-based banking services. Banks offering knowledge-based services attract customers valuing expert-driven banking solutions. Organizational Capacity and Performance (A7): The capacity and performance of an organization significantly influence the evolution of smart product service systems in banking. Studies suggest a positive correlation between organizational capacity and the adoption of innovative banking services. Banks embracing innovative services tend to attract customers seeking cutting-edge banking experiences."

5.2. Managerial Implication

Integrating smart connected products (C15) into banking operations strategically leverages cutting-edge technology to enhance efficiency and elevate customer experiences. S-PSS (Smart Product service system) plays a vital role in deciphering complex data generated by these smart products, allowing banking managers to analyze transaction patterns, customer behaviors, and preferences. This integration enables real-time data collection, empowering banks to anticipate maintenance needs, forecast service demands, and gain insights for targeted decision-making. Managers can use S-PSS-driven insights to identify new customer segments, optimize operations, and deliver personalized services, ultimately enhancing overall customer satisfaction and loyalty. In essence, employing S-PSS with smart connected products revolutionizes data analysis, informs better decisions, and enriches customer experiences within the banking sector.

Ensuring data security (C18) is of paramount importance in banking, especially with the integration of smart product service systems. Banking organizations handle highly sensitive customer information, requiring strict data protection protocols. Managers have a critical role in implementing robust cybersecurity measures, standards for encryption, and access controls to protect this data from unauthorized access or exposure. Moreover, the interconnected nature of smart product and service systems amplifies the risks, as any breach can jeopardize customer privacy, financial data, and the bank's reputation. It is crucial to establish a culture of data privacy and compliance among employees, as human error or oversight can introduce vulnerabilities. In addition to protecting sensitive information, strong data security measures maintain customer trust, ensure regulatory compliance, and maintain the bank's credibility in the ever-evolving financial technology landscape.

Sufficient decision support (C21) stands as a crucial asset for banking managers, especially within the realm of smart product service systems. These systems generate extensive data that, when effectively utilized, provides vital insights. Decision support tools empower managers to navigate this data influx, extracting essential intelligence pivotal for strategic decision-making. In banking, precision in decision-making is paramount, notably in customer service, risk management, and innovation. Robust decision support systems enable a proactive approach, allowing managers to anticipate market changes, optimize products, and improve operational efficiency. As smart product service systems escalate data complexity, a robust decision support structure becomes indispensable. It enables banks to harness this vast data, fostering agility and informed decision-making amidst evolving customer needs and technological advancements.

Dynamic personalization (C5) in banking involves tailoring services to individual customer preferences in real-time, made possible by smart product service systems. These systems enable banks to gather extensive customer data, allowing managers to offer personalized services, optimize products, and boost satisfaction. Leveraging data analytics and agile methods, banks can swiftly adapt to market shifts, providing tailored solutions that meet evolving customer demands. This personalized approach fosters stronger relationships, drives loyalty, and enhances the overall banking experience.

Simultaneously, the integration of environmentally (C6) beneficial practices within banking operations is facilitated by smart product service systems. Banks can optimize resources, reduce waste, and embrace eco-friendly processes. Managers can implement green initiatives like energy-efficient operations and digitalization to minimize paper usage. These efforts not only shrink the ecological footprint but also align with societal expectations and regulatory standards, enhancing the bank's reputation as an environmentally conscious institution and appealing to customers seeking eco-friendly services.

Effective information interaction (C19) involves the seamless exchange and utilization of data within and across organizational boundaries. It encompasses not just transmitting information but also understanding its meaning and applying it purposefully to achieve specific goals. This process relies on efficient communication channels, clear data-sharing protocols, and tools facilitating smooth information flow. In practice, it necessitates employing diverse communication mediums, such as digital platforms or collaborative software, to ensure accurate and comprehensive information transfer. Moreover, it fosters an environment encouraging active listening, open discussions, and idea sharing to tap into collective knowledge.

Additionally, this concept highlights the significance of data accessibility and usability. It involves organizing data for easy access by relevant stakeholders, presenting information in an understandable format, and utilizing technology for data processing, analysis, and deriving actionable insights. Ultimately, effective information interaction cultivates a culture where information flows efficiently, enabling teams and organizations to leverage collective intelligence for informed decision-making and agile adaptation to changing operational landscapes.

Managing the operating conditions (C12) of a product involves a comprehensive approach to ensuring its optimal performance across diverse environmental settings. It encompasses setting stringent design standards that account for various conditions the product might encounter. Additionally, it involves establishing maintenance protocols, which might include routine maintenance schedules and the potential integration of predictive maintenance utilizing IoT sensors. Managers overseeing these aspects need to ensure compliance with industry standards and regulations while emphasizing the importance of reliability and safety across different operational environments. This comprehensive approach aims to maintain consistent performance and longevity of the product across varied and sometimes challenging conditions.

Managing the operating conditions (C7) of a product involves a comprehensive approach to ensuring its optimal performance across diverse environmental settings. It encompasses setting stringent design standards that account for various conditions the product might encounter. Additionally, it involves establishing maintenance protocols, which might include routine maintenance schedules and the potential integration of predictive maintenance utilizing IoT sensors. Managers overseeing these aspects need to ensure compliance with industry standards and regulations while emphasizing the importance of reliability and safety across different operational environments. This comprehensive approach aims to maintain consistent performance and longevity of the product across varied and sometimes challenging conditions.

Within the Product-Service System (PSS) framework, managing the total cost (C3) requires a comprehensive managerial strategy. Balancing cost concerns with value creation is vital, emphasizing the optimization of lifecycle expenses over initial outlays. Strategies include embracing sustainability, improving resource efficiency, fostering advantageous supplier partnerships, and deploying innovative pricing models that meet customer expectations while ensuring profitability.

6. CONCLUSION

The study's analysis delves into the pivotal role various factors play in shaping the evolution and success of smart product service systems (S-PSS) within the banking industry. Interrelationships among attributes such as economic prosperity, environmental quality, social justice, digital platform operation, intelligent interaction, e-knowledge management, and organizational capacity and performance unveil critical insights into their influence on S-PSS adoption and development. The distinction between cause and effect aspects, as discerned through α and β calculations, underscores the directional impact among these attributes. Factors like intelligent interaction, social justice, and e-knowledge management emerge as key drivers (causes) shaping the S-PSS landscape. Conversely, attributes like economic prosperity, environmental quality, digital platform operation, and organizational capacity and performance are identified as elements influenced by these causal factors within the S-PSS framework. From a managerial viewpoint, this analysis yields crucial implications.

Integrating smart connected products enhances banking operations, enabling data-driven decision-making and personalized customer experiences. However, ensuring robust data security remains paramount, given the sensitivity of customer information in S-PSS. Decision support becomes a critical asset for managers, aiding in navigating complex data and facilitating proactive decision-making. S-PSS also opens avenues for dynamic personalization and environmentally beneficial practices, offering tailored services and sustainability initiatives within the banking sector. Moreover, effective information interaction fosters seamless data flow, encouraging collaborative knowledge utilization for informed decision-making. Managing product operating conditions and total costs within the PSS framework necessitates a comprehensive strategy for optimal performance and value creation. In summary, this in-depth analysis provides a roadmap for banking managers to effectively leverage S-PSS. By understanding key drivers, cause-and-effect relationships, and prioritizing critical aspects, managers can navigate the evolving banking technology landscape, enhancing operations, customer experiences, and sustainability initiatives.

The study's limitations stem from its focused scope within the banking industry, potentially restricting the broader applicability of findings to other sectors employing smart product service systems (S-PSS). Engaging a panel of 30 professionals might limit the diversity of perspectives within the banking industry, affecting the comprehensiveness of insights. Methodologically, while the Delphi technique and FDEMATEL analysis were effective, other methodologies could offer additional perspectives, warranting exploration in future studies. Future research avenues could involve cross-industry comparative analyses to discern differences in attribute influence on S-PSS adoption across various sectors. Longitudinal studies tracking attribute impact over time can provide insights into evolving trends. Qualitative exploration with stakeholders and customers could complement quantitative findings, offering deeper contextual understanding. Additionally, global comparative analyses considering regional variations and integrated frameworks utilizing diverse methodologies can contribute to a more comprehensive understanding of S-PSS adoption dynamics.

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