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Enhancing SME Competitiveness Through Coopetition Networks: A Service-Dominant Logic Approach

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Abstract
In the era of rapid globalization and digital transformation, small and medium-sized enterprises (SMEs) in the manufacturing sector encounter significant challenges in scaling operations, enhancing operational efficiency, and fostering innovation. This study focuses on manufacturing SMEs, where coopetition – a strategic blend of competition and cooperation – addresses these challenges. Despite its potential to drive innovation and value creation, coopetition networks often struggle to succeed, particularly under the pressures of advancing technology and the need for digital collaboration. To address these issues, this research develops a comprehensive framework that integrates Service-Dominant (S-D) Logic with technology-enabled coopetition networks. Utilizing the Design Science methodology, the study presents a framework that underscores the crucial role of technology in fostering value co-creation within SME networks. This framework is designed to enable sustainable and effective engagement in coopetition, significantly mitigating the risk of network failure by aligning technological innovation with coopetition principles. The proposed framework was evaluated through a targeted survey of managers from SMEs in the Portuguese stone manufacturing sector. The survey results confirmed the practical applicability and potential to promote robust and sustainable coopetition strategies. By integrating theoretical insights with practical applications, this research offers a roadmap for SMEs to effectively manage the complexities of coopetition within the digital supply chain environment.

Keywords
slowa Coopetition, Networks, S-D logic, Service Science, Internet of Things.

Introduction

SMEs face unprecedented challenges in today's rapidly globalizing and digitizing world (Di Bella et al., 2023). To navigate these complexities, SMEs are increasingly adopting coopetition strategies – a blend of competition and collaboration among firms (Rouyre et al., 2024). This strategy is praised for its potential to drive innovation and value creation, which are essential for SMEs struggling with issues of scale, efficiency (Ramírez-López et al., 2021), and limited resources for innovation (Bicen et al., 2021).

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However, despite the theoretical advantages, many coopetition networks fail to meet their objectives, leading to high failure rates and unmet expectations (Crick, 2019). This issue highlights a critical research gap in developing robust empirical frameworks for establishing and maintaining effective coopetition networks, particularly among manufacturing SMEs that play a vital role in the economies of developed nations (Muller et al., 2021).

Current academic discourse on coopetition focuses primarily on competitive dynamics (Meena et al., 2023) and the resource-based view, which emphasizes structural strategies and securing unique resources to gain competitive advantages (Maletič et al., 2020). These perspectives often overlook the mechanisms of value creation and sharing in coopetition (Xie et al., 2023), and they fall short of addressing the complexities and evolving nature of coopetition in the digital age. The significant impact of technological advancements on network interactions further complicates the coopetition landscape. Consequently, there is a pressing need for more sustainable business models that consider the role of technology as both a facilitator and a resource within these networks.

In light of these challenges, the S-D Logic literature offers a valuable perspective for understanding value co-creation in networks, particularly where technology acts as both an enabler and a resource in service ecosystems (Vargo et al., 2024). S-D Logic shifts the focus from traditional goods-centric views to a service-oriented approach that emphasizes value co-creation through service exchanges within a network of actors (Vargo et al., 2023).

To address the gap identified, this study aims to develop a sustainable and practical framework for coopetition among SMEs, grounded in the principles of S-D Logic and enhanced by technological integration. Under an S-D Logic view and utilizing the Design Science methodology, the research aims to construct a comprehensive framework combining theoretical insights with practical applications, where technology and S-D Logic intersect, enabling SMEs to effectively navigate the complexities of coopetition within the digital supply chain environment. The forthcoming sections will explore several key steps: applying S-D Logic foundations to address technological innovation and developing a framework for coopetition networks to facilitate coopetition.

To evaluate the framework, a targeted survey will be conducted with managers from SMEs in the Portuguese stone industry. This survey will provide insights into these companies' digital integration and coopetition strategies. The paper concludes by highlighting the study's limitations and suggesting directions for future research.

Literature review

S-D Logic, introduced by Stephen L. Vargo and Robert F. Lusch in 2004, emphasizes that service – the application of skills and knowledge for the benefit of others – is the core driver of value co-creation (Vargo & Lusch, 2004). According to this perspective, value is not created in isolation but co-created through interactions between service providers and beneficiaries, facilitated by the competencies each party brings (Vargo & Lusch, 2008).

In the context of S-D Logic, value co-creation is deeply embedded within institutional frameworks and arrangements. These institutions act as the rules and norms that guide interactions within service ecosystems, ensuring that co-creating value is structured and effective (Lusch et al., 2016). Despite some debates around its application (Campbell et al., 2013), S-D Logic has profoundly shaped discussions on business models since its inception, especially over the past decade (Kleinaltenkamp et al., 2023). It has contributed significantly to developing service-centric business models, providing a clear and cohesive framework that continues to evolve (Jaakkola et al., 2024).

Recent advancements in S-D Logic suggest that value co-creation in service ecosystems goes beyond merely exchanging tangible resources. It encompasses intangible assets such as knowledge, relationships, and institutional structures (Razmdoost et al., 2023). This approach positions S-D Logic as a metatheoretical framework that aligns with and enhances other mid-range theories by integrating shared concepts and narratives. This alignment promotes a more profound, performative understanding of business models, emphasizing how these models operate and evolve in practice (Hartmann et al., 2018).

By focusing on how ecosystems function through the lens of S-D Logic, businesses can gain valuable insights into value cocreation mechanisms and the importance of fostering dynamic, collaborative networks. This perspective is particularly relevant for understanding how coopetition networks can be designed and managed to leverage both tangible and intangible resources effectively.

Ecosystems for Value Creation

As businesses shift towards services, value cocreation has evolved significantly. (Maglio and Spohrer (2008) were instrumental in this transition, moving the focus from isolated, localized processes to a broader, technology-enabled global network (Demirkan & Spohrer, 2018). This evolution gave rise to service science, a discipline dedicated to understanding and innovating within service systems – seen as abstract entities engaging in economic activities (Breidbach & Maglio, 2015).

Service science asserts that any interaction between entities is inherently a proposition to co-create value, shaping business models around value proposition design and systemic patterns (Ng et al., 2018). The service system is at the heart of service science – a complex configuration of people, technologies, organizations, and shared information. These systems create and deliver value through services, engaging stakeholders such as suppliers, users, and other entities (Spohrer & Maglio, 2010).

Although service science and S-D Logic use different terminologies, they share a similar essence. Both view service systems as dynamic entities that play unique and interconnected roles within ecosystems and networks, facilitating the reconfiguration of resources and fostering interactions (Cellary et al., 2019).

Current discussions in service science increasingly emphasize the role of networks of service systems, where multiple actors interact to co-create mutual value (Breidbach & Maglio, 2016). This view aligns closely with the S-D Logic perspective, which sees networks as adaptive ecosystems focused on value creation and sustainability (Lusch & Nambisan, 2015).

S-D Logic and service science naturally complement each other, sharing common research interests, perspectives, and foundational philosophies (Spohrer et al., 2007). Both fields promote a holistic approach to understanding and scaling business activities, integrating insights from various disciplines and blending tangible and intangible assets (Cellary et al., 2019). Despite some differences in terminology, they converge on a shared philosophical viewpoint: the significance of context in value co-creation. This complex phenomenon arises from service exchanges, resource integration, and the concept of value-in-context, offering a strong foundation for designing empirical frameworks (Pohlmann & Kaartemo, 2017).

In essence, both S-D Logic and service science advocate for viewing business ecosystems as dynamic, interconnected networks where the interplay of various elements and actors leads to value co-creation, supporting sustainable innovation and growth.

The Transformative Role of Technology in Value Co-creation

Technology is recognized as an essential resource for innovation within service science, fundamentally transforming how service is delivered, innovated, and managed (Breidbach & Maglio, 2016). S-D Logic literature also emphasizes technology's significant impact on service innovation and value co-creation within service ecosystems (Razmdoost et al., 2023), viewing technology as both an enabler and a driver of innovation (Akaka et al., 2023).

Degani et al. (2017) explores technology through the concept of "operant" resources, describing it as something that "works" or is "engaged in action". This perspective highlights technology's capacity for self-governance, autonomy, and independence, characterizing it through three key aspects: authority to create and apply its rules, self-sufficiency, and freedom from external influence (Degani et al., 2017).

This understanding aligns with the rise of intelligent technologies capable of autonomously generating algorithms and undertaking actions without human intervention, representing a significant advancement in technological capabilities (Bodkhe et al., 2020).

In coopetition, technology is crucial for fostering collective understanding and collaboration among various actors (Rusko, 2014). This perspective aligns with both S-D Logic and service science, which view technology as an essential operand resource (facilitator) and operant resource (initiator) in the value cocreation process (Barile et al., 2019). The interaction between operant resources (intelligence and competencies) and operand resources (tangible assets) is crucial for innovation and value creation. This dynamic is facilitated through human interactions, technology, value propositions, and shared information, forming the foundation for effective co-creation (Matthies et al., 2016). By integrating technology into coopetition networks, businesses can enhance their ability to innovate and create value collaboratively. This integration supports the development of new business models and operational strategies that are responsive to the evolving demands of the digital era.

In summary, both S-D Logic and service science literature underscore the transformative role of technology in enabling and driving value co-creation. Technology facilitates collaboration and the efficient exchange of resources, serving as a critical driver in the continuous evolution and improvement of service ecosystems.

Framework Designing for Coopetition Networks

Design Science underpins this study's approach, emphasizing creating and evaluating artefacts – ranging from models and methods to tools and frameworks – that address and resolve concrete, practical issues (Hevner, 2007; Lacerda et al., 2013). This methodology is inherently iterative and interactive, marrying theoretical underpinnings with real-world applicability to produce innovative outcomes grounded in rigorous academic research (Pakkala et al., 2020).

To construct empirically robust frameworks within this framework, it is imperative for designers to deeply engage with and leverage the extensive body of existing academic knowledge and insights. As highlighted by vom Brocke et al. (2020), the infusion of rich academic understanding into the development process not only strengthens the relevance and efficacy of the resulting frameworks but also serves as a critical driver for the creation of advanced, sophisticated artefacts. These artefacts act as vessels for the emergence of novel insights, fostering an environment where new knowledge can be cultivated from their application and impact.

Peffers et al. (2007) further elucidate this concept, illustrating how artefacts derived from a profound engagement with scholarly work contribute significantly to the broader academic and practical domains. The iterative cycle of applying comprehensive academic knowledge to create practical solutions and deriving new theoretical insights from these applications exemplifies the dynamic synergy between theory and practice. This synergy is central to the Design Science methodology, illustrating its capacity to not only solve practical problems but also to propel the advancement of academic understanding and the generation of new knowledge (Hevner & Chatterjee, 2010).

Entities and Resources in Coopetition Networks

Understanding the dynamics of coopetition networks necessitates identifying the roles played by various actors and the resources they leverage for mutual benefit. Drawing from S-D Logic, the essence of these networks lies in the service exchange among entities aimed at reciprocal benefits (Barile et al., 2016). This exchange centres on two primary resource types: operant resources (people and organizations with the capacity to act) and operand resources (tangible assets such as technologies and knowledge). This distinction underscores that service is not merely an offering but the application of competencies for another's benefit (Joiner & Lusch, 2016).

Anchored on S-D Logic foundations, service science, with its interdisciplinary approach, seeks to unify the concept of resources, asserting that anything named and potentially valuable – physical or non-physical – constitutes a resource (Vargo & Akaka, 2009). These resources are characterized by their lifecycle (beginning, middle, and end), availability, creation cost, maintenance expense, and the cost of ceasing access or use. The dynamic interplay of these resources within coopetition networks, encompassing people, technology, organizations, and shared information, ignites actions that underpin the network's vitality (Maglio & Spohrer, 2013).

In the context of technology-enabled coopetition networks, the interaction among customers, providers, and coopetitors is intricate. These actors integrate multiple resources – market-facing, technological, financial, and public – to innovate or co-create value at different network levels (Vargo et al., 2023). This view posits customers as beneficiaries of value, evaluating offerings based on their experiences; providers as facilitators of value co-creation; coopetitors as collaborative competitors sharing resources under agreed conditions; competitors as independent entities vying for customer attention; and authorities as regulatory bodies ensuring sustainable and equitable interaction within the network (Vargo & Lusch, 2016).

Revenue expectations within these networks are shaped by value propositions, which, in turn, are driven by the perceived value and the co-creation process. This cyclical engagement fosters increased resource density, propelling the network towards innovative value propositions and enhanced co-creation opportunities (Ng & Wakenshaw, 2017). However, the success of this framework hinges on the seamless access to and sharing of resources among entities, with the understanding that value perception is inherently subjective and rooted in individual experiences (Akaka et al., 2013).

Anchored on S-D Logic and service science perspectives, technology-enabled coopetition networks must, therefore, consider customers, providers, rivals, competitors, and authorities as the main actors:

Customer Entity: Customers play a critical role in value networks by engaging with and assessing providers' value propositions. Their evaluation is deeply rooted in their experiences throughout the service process, shaping their acceptance or rejection of the offerings (Barile & Polese, 2010).

Provider Entity: The provider acts as a facilitator in co-creating value, working alongside customers. They offer value propositions by skilfully weaving together a constellation of activities and experiences, underlining the collaborative nature of service provision (van Riel et al., 2013).

Coopetitor Entity: Coopetitors are unique actors that, under agreed safety norms, willingly share and access specific resources among themselves to enhance mutual benefits. Viewed through the lens of S-D Logic and service science, coopetitors significantly enrich the network's resource density with each interaction, promoting a symbiotic environment for growth and innovation (Gast et al., 2015).

Competitor Entity: Competitors operate independently within networks, directly engaging with customers without collaborating with rivals. Their interactions are characterized by a competitive drive to offer distinct value propositions to the market.

Authority Entity: Official authorities strive to guide interactions among network actors towards sustainability and improved living conditions. They are crucial in fostering an ecosystem where all participants can thrive harmoniously (Boughnim & Yannou, 2005).

Upon joining a coopetition network, an actor anticipates revenue generation, with the process delineated by S-D Logic: initial expectations fuel the creation of value propositions, generating revenue, spurring further value propositions, and enhancing resource density for cocreation. This cycle necessitates mutual access to resources among entities, with the proposition's value uniquely shaped by each beneficiary's experience.

The Role of Technology in Coopetition Networks

In coopetition networks, technology becomes an essential component that initiates and facilitates activities within these complex ecosystems. Motivated by the potential for significant gains, companies may share and integrate their resources with competitors. This sharing fosters service exchanges that increase resource richness and enhance value co-creation (Lusch & Nambisan, 2015). Such a strategy requires all participants to provide mutual access to their resources, establishing a business model based on coopetition (Seepana et al., 2020). Technology serves dual roles within these networks: As an operant resource, technology initiates actions and drives processes (Sklyar et al., 2019). For example, advanced analytics can identify new opportunities for collaboration, or automated systems can streamline shared operations. As an operand resource, technology facilitates actions by enabling the infrastructure and tools needed for efficient resource sharing and value co-creation (Lusch & Nambisan, 2015). This includes digital platforms that support communication and integration among network participants (Silva et al., 2020).

Integrating technology into coopetition networks significantly increases resource density, enhancing the capacity for co-creating value (Razmdoost et al., 2023). This enriched interaction fosters the development of innovative solutions that benefit all participants within the network and improve the quality of life for the stakeholders involved (Akaka et al., 2023).

The unique combination and application of technology in these networks underscore its essential role in advancing competitive collaboration. Technology enables companies to operate more efficiently and drives innovation and mutual benefits across the ecosystem. By leveraging technology effectively, businesses within coopetition networks can enhance their competitive advantage while contributing to the overall health and sustainability of the ecosystem.

The Institutionalization of Coopetition Networks

The paradigm of value networks elucidates that value creation is inherently collaborative, engaging many actors and their intricate interactions in a concerted effort to generate and deliver value. This view is complemented by the ecosystem concept, which introduces an environmental dimension to the discussion, highlighting the ecological challenges in sustaining such networks (Willis, 1997).

Drawing from these foundational concepts, the value creation transcends simple bilateral exchanges, necessitating a more comprehensive array of resources and the involvement of multiple actors within an intricate network (Normann & Ramirez, 1993). The notion of micro-exchange within these vast ecosystems suggests that customers and providers represent just a fraction of the entire network, which includes numerous actors engaging in reciprocal resource exchange to co-create value (Chandler & Vargo, 2011) (Fig. 1).

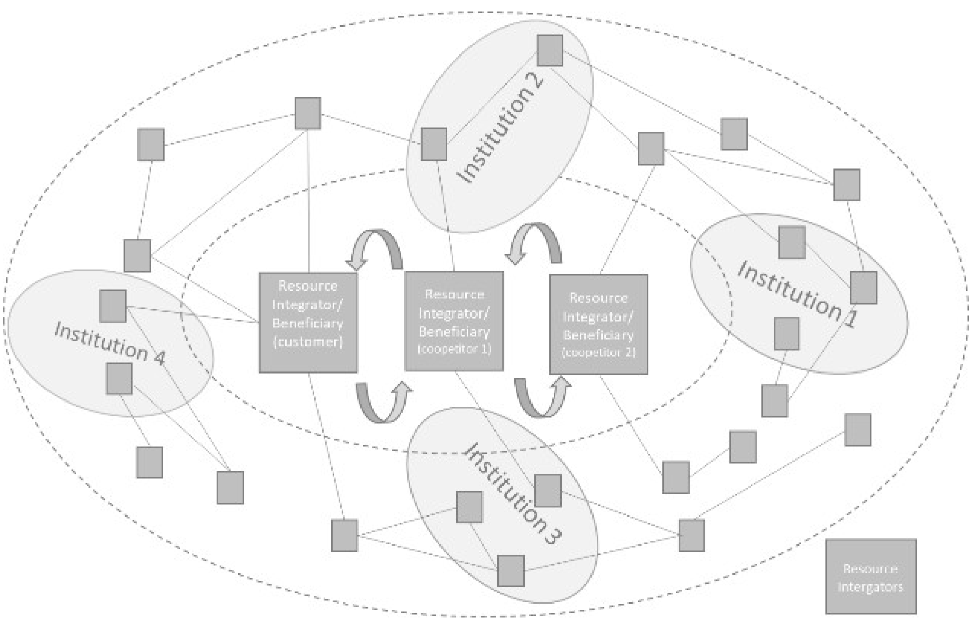

Fig. 1. Framework for coopetition networks, adapted from (Lusch & Vargo, 2014)

Such complex dynamics require a level of coordination facilitated by endogenously created institutions – comprising rules, norms, symbols, and practices that aid collaboration – and institutional arrangements, which are interdependent collections of these institutions, manifesting even at a societal scale (Meynhardt et al., 2016).

This comprehensive framework underscores the transition from micro-level interactions among actors, which foster behavioural patterns across the network, to a meso-level emergence of institutions and ecosystems (Wieland et al., 2017). In such an institutional environment, actors, including competitors, might collaborate for mutual benefits, showcasing the voluntary nature of cooperation even among rivals (Chandler & Vargo, 2011). The deployment of both operant and operand technologies facilitates this cooperation through resource liquefaction and enhanced resource density, further cementing the institutionalization of networks into fully-fledged service ecosystems (Lusch & Nambisan, 2015; Jaakkola et al., 2024). This narrative outlines a theoretical foundation for understanding and developing empirical frameworks for coopetition within networks, emphasizing the crucial role of institutional structures in facilitating value co-creation across service ecosystems (Vargo & Lusch, 2017).

Requirements for Enabling Coopetition in Networks

The advent of the Internet of Things (IoT) and embedded systems heralds a new era in which technology profoundly influences ecosystems, as recognized by S-D Logic (Ng & Wakenshaw, 2017; Lorenzo et al., 2017). This era is characterized by IoT's role within ecosystems, linking actors through advanced sensor technologies (Akaka et al., 2023). These sensors facilitate the localization and identification of actors and enable direct operations on or by these entities, thus significantly enhancing interaction and integration within technology-enabled networks (Müller et al., 2018).

Empirical evidence underscores the transformative potential of IoT in fostering novel service offerings. Companies leveraging IoT capabilities can extend their service portfolios to include remote control options and predictive maintenance solutions, advancing operational efficiency and opening new avenues for value co-creation within coopetition frameworks (Salih et al., 2022). This technological integration catalyzes the development of ecosystems where companies, by harnessing IoT, transcend traditional competitive boundaries, facilitating seamless exchange of resources and collaboration among once-competing entities (Mosch et al., 2023).

Under this view, the IoT is critical in enabling coopetition within networks, signifying a shift towards more interconnected, efficient, and innovative ecosystems. Through enhanced connectivity and data exchange, actors within these networks can unlock new potentials for collaboration, driving forward the principles of S-D Logic by expanding the scope and scale of value co-creation in the digital age.

Interoperability Mechanisms for Coopetition Networks

Interoperability is crucial for fostering effective collaboration within networks, allowing for the smooth achievement of shared goals and enabling the controlled dissolution of partnerships if needed ([x]Hoppe, 2023). In the context of coopetition, the seamless exchange of information between different technological resources is essential (Vargo et al., 2023). Therefore, any artefact that facilitates coopetition must include mechanisms to ensure interoperability, focusing on semantic and pragmatic aspects to maximize network capabilities ([x]Leal et al., 2019): (1) Semantic Interoperability ensures that the meaning of information exchanged between systems is consistently understood. This is essential for different technologies to interpret and process data accurately across various platforms (Cardoso et al., 2015). (2) Pragmatic Interoperability further ensures that the information exchanged is effectively utilized in practical, operational contexts. It involves appropriately understanding and applying the data to achieve the desired outcomes (Silva et al., 2016).

Addressing these mechanisms within IoT is critical for integrating diverse technologies and creating collaborative environments that support coopetition. Moreover, (Akaka and Vargo (2014) emphasize the need for systemic interoperability in digital technologies, highlighting the role of IoT in embedding service mechanisms that enhance interoperability (Coelho et al., 2022), including (1) Resource density mechanisms for processing and analyzing information to support decision-making and actions. By increasing the density of available resources, IoT provides a deeper response and facilitates more informed strategies for competition (Ng & Wakenshaw, 2017). (2) Digital materiality mechanisms referring the ability of the software embedded in physical objects to manipulate their digital representations, enabling new functionalities and interactions. Digital materiality bridges the physical and digital worlds, opening innovative avenues for collaboration and competition within coopetition networks (Lim et al., 2019).

By integrating these mechanisms, artefacts designed for coopetition can support the dynamic exchange of service information. This capability fosters an environment where both collaborative and competitive interactions can flourish. Such an approach enhances the effectiveness of coopetition networks. It aligns with the evolving needs of technology-enabled ecosystems, ensuring that networks are adaptable, responsive, and capable of leveraging the full potential of IoT for value co-creation.

Usability and Accessibility Mechanisms for Coopetition Networks

Usability and accessibility are crucial in coopetition networks to ensure secure and efficient service exchanges among competitors, enhancing value creation within the ecosystem (Kahkonen & Lintukangas, 2012). S-D Logic and service science emphasize the need for systemic structures and architectural modules designed specifically for managing transactions and services. These systems operate under the coordination of institutions and institutional arrangements, ensuring seamless and effective interactions ([x]Hietanen et al., 2018).

An effective coopetition network integrates a knowledge-based system with operant modules (such as artificial intelligence or cognitive assistant technologies) and operand modules. These technologies facilitate interactions within the network, acting on behalf of coopetitors. However, being non-sentient, these systems lack legal accountability and do not possess rights and duties (Ng et al., 2018). To mitigate this limitation, it is essential to incorporate human resources into the system who can operate, interact, and collaborate with these technologies. A designated individual within this team assumes the role of the legal and operational representative, ensuring accountability and overseeing the network's activities. Fig. 2, depicts the conceptual framework of the IoT system designed to facilitate coopetition (Ng & Wakenshaw, 2017).

Enabled by IoT, a coopetition network incorporates three types of critical resources (1) physical-with-no-rights, including the ICT infrastructure and hardware that provide the system's essential technical foundation and operational capabilities; (2) physical-with-rights offering necessary oversight, decision-making abilities, and legal accountability within the network. They ensure that the system functions smoothly and complies with legal and operational standards and (3) non-physical-with-no-rights encompassing data and software components (operant and operand) for enabling the digital interactions and processes that drive the coopetition network.

By equipping the system with these diverse resource types, coopetition networks can effectively manage usability and accessibility. This ensures secure and productive service exchanges, enhancing the ecosystem's capacity for value creation. Additionally, addressing

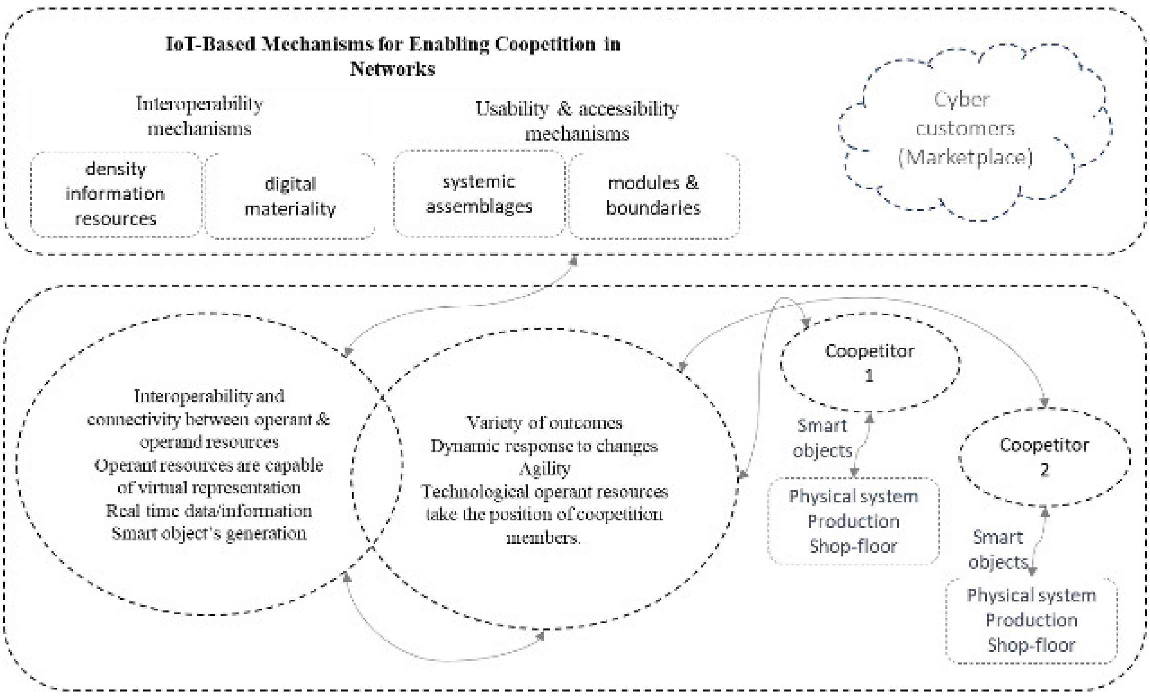

Fig. 2. IoT Mechanisms for Enabling Coopetition in Networks (Adapted from Ng & Wakenshaw, 2017)

the legal and operational challenges associated with advanced technologies like IoT in coopetition strategies is crucial for the system's success. This comprehensive approach fosters innovation and collaboration, aligning with the evolving requirements of technology-enabled ecosystems and supporting sustainable and scalable coopetition practices.

Framework Evaluation: A Survey in the Portuguese Stone Industry

To evaluate the proposed framework for coopetition networks, a survey was conducted with managers from SMEs within the Portuguese stone manufacturing industry. As of 2022, this sector plays a vital role in the Portuguese economy, directly employing over 16,600 individuals and contributing significantly to private sector employment, particularly in the country's inland regions (Machado et al., 2021; Silva & Marques Cardoso, 2023).

Despite numerous challenges, the Portuguese stone manufacturing sector has demonstrated remarkable resilience and sustained growth, especially in exports (Silva & Pata, 2022). This resilience has established Portugal as a prominent global player in the ornamental stone market. A targeted survey was carried out to explore how SMEs within this industry perceive and implement technology-enhanced collaboration networks. A convenience sample of thirty Portuguese stone manufacturing SMEs was selected for the survey. The insights gathered from these interviews were essential in understanding how technology can be strategically leveraged to improve SMEs' performance and competitive positioning in the stone manufacturing sector.

Digital Level Determination and Assessment

In the survey, each of the thirty surveyed SMEs was assigned a digital level to gauge their digital maturity. This assessment was conducted through face-to-face interviews and on-site visits, evaluating several critical aspects of their digitalization. The criteria for this evaluation included the deployment of digital production equipment, the integration of digital management processes, and the use of collaborative digital tools within their operations. Based on their degree of digitalization, companies were classified into five distinct Digital Levels (DL#): No Digital Level (DL#0) – companies in this level need to utilize computerized systems in their production processes, indicating a complete lack of digitalization initiatives. First Digital Level (DL#1) – companies have begun their digital journey by employing computerized production systems for over a year. This level marks the initial phase of integrating digital technology into their operations. Second Digital Level (DL#2) – at this stage, companies use digital equipment in production and have at least two computerized machines operational on the shop floor. This level reflects a more significant commitment to digital technology in their production processes. Third Digital Level (DL#3) – companies achieving this level integrate data from computerized machines on the shop floor with their management information systems. This integration enhances operational efficiency and improves coherence between production and management processes. Fourth Digital Level (DL#4) – represents the highest level of digital maturity; companies at this stage merge shop floor data with management systems and incorporate collaborative data across all organizational levels. This seamless flow of information optimizes overall operational synergy and strategic decision-making.

This classification system provided a clear framework to assess and understand the extent of digital integration within the Portuguese stone SMEs.

Inquiry to the Respondents

The interviews began with an overview of the industry's evolving landscape, particularly the impending adoption of Building Information Modeling (BIM) in the construction market. BIM transforms how materials are procured and utilized, emphasizing the need for precise and efficient processes in the construction industry. This shift highlights the necessity for stone fabricators to enhance their operations by scaling up, maintaining price flexibility, and increasing delivery speed. To remain competitive, firms were encouraged to consider collaborative strategies with competitors, leveraging coopetition to meet these new demands effectively (Shao & Cao, 2024).

To explore the potential benefits of competition, a hypothetical scenario was presented to the respondents: Companies are invited to utilize a system comparable to home banking designed to facilitate seamless collaboration with their competitors. This system would enable stone companies to achieve significant improvements in various operational aspects: (1) Scale – enhanced production capacity and ability to handle larger projects through shared resources; (2) Efficiency – streamlined operations leading to cost reductions and improved product quality; (3) Supply Chain Efficiency – better on-time delivery, more value-adding operations, optimized capacity utilization, and the ability to meet commercial demands without facing raw material shortages, thanks to resource sharing; (4) Customer Satisfaction – improving ability to meet customer expectations due to enhanced operational capabilities and resource availability. This scenario assessed how coopetition could help stone manufacturing companies adapt and thrive in a competitive market driven by BIM requirements.

To gather detailed insights, the participants were asked to evaluate the importance of these potential improvements for their companies. They were provided with a Likert scale ranging from 1 to 5, where 1 indicated "Not Important at All", 2 indicated "Slightly Important", 3 indicated "Moderately Important", 4 indicated "Very Important", and 5 indicated "Extremely Important".

Each respondent rated the significance of the following aspects: How crucial is it for "your company" to increase its scale through collaboration? How important is streamlining manufacturing processes? How critical is optimizing supply chain operations and ensuring on-time delivery? How essential is it to prevent raw material shortages and meet market demands? Increasing Customer Satisfaction: How significant is improving customer satisfaction through better resource and operational management?

The responses provided a comprehensive view of how the respondents perceived the impact and importance of integrating cooperative strategies with their competitors to address the evolving challenges and opportunities within the industry. The data gathered from this inquiry will help shape strategies for effective coopetition in the context of the BIM-driven future of the stone manufacturing sector.

Results and Discussion

The empirical evaluation of technology-enabled coopetition networks in the Portuguese stone SMEs reveals significant insights summarized in Table **??**. These findings are based on the averaged responses from all participating SMEs, demonstrating a link between their digital maturity (categorized by Digital Level, DL#) and various performance improvements.

The survey data reveals that respondents perceive significant benefits in scaling operations through technology-enabled coopetition networks as their companies progress in digital maturity. Notably, companies at the highest level of digital integration (DL#4) report the most substantial improvements in their ability to scale. These respondents gave an average rating of 4.9 out of 5 for their enhanced scaling capabilities. DL#4 companies also noted remarkable gains in operational efficiency, with an average rating of 4.8 out of 5. This underscores the pivotal role of advanced digital integration in leveraging technology to collaborate effectively with competitors.

Table 1
Survey Outcomes

Performance Metric	**DL#0**	**DL#1**	**DL#2**	**DL#3**	**DL#4**
Operational Scale	2.9	2.8	3.2	4.1	4.9
Production Efficiency	3.3	3.2	3.2	3.9	4.8
Sup. Chain Efficiency	3.1	2.7	3.6	3.6	4.9
Customer Satisfaction	2.9	3.9	4,2	4.8	5.0
Average Rating	3.1	3.2	3.6	4.1	4.9

Furthermore, DL#4 respondents highlighted the potential to significantly boost customer satisfaction, achieving a perfect average score of 5 out of 5. This score emphasizes the critical role of digital maturity in meeting and exceeding customer expectations. It also underscores how advanced digital integration fosters stronger customer relationships and enhances customer experience.

As depicted in Fig. 3, the trend line represents the linear correlation between digital maturity (x) and performance improvement ratings (y).

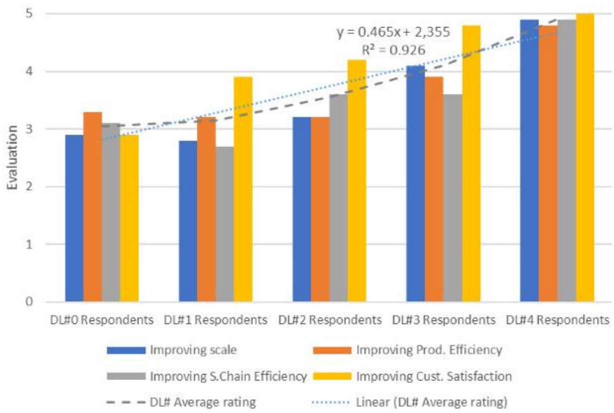

Fig. 3. Framework Evaluation in the Portuguese Stone SMEs

A slope of 0.465 reveals a positive and moderate performance improvement rate as the digital level increases. This implies that higher levels of digital integration are potentially associated with substantial enhancements in operational and competitive capabilities within the coopetition network. The increase of 0.465 units per level of digital maturity is significant, indicating that as companies adopt more advanced digital technologies, they experience marked improvements in various performance metrics, such as scaling, production efficiency, supply chain efficiency, and customer satisfaction. The R^2 value of 0.926 indicates a high level of explained variance among the respondents. This means that the digital maturity level can explain 92.6% of the variability in the performance improvement ratings. A high R^2 value suggests a strong fit of the linear model to the data, indicating that the digital maturity level is a significant predictor of performance improvements in the context of technology-enabled coopetition.

As companies progress through higher levels of DL#, there is a growing tendency to engage in coopetition networks. This trend indicates that technological advancements encourage a more open and collaborative approach to competition, facilitating mutual benefits and shared successes. The overall average rating of 3.8 out of 5 reflects a positive evaluation of the framework for technology-enhanced coopetition networks.

This empirical study supports the foundational framework as a potentially viable strategy for ornamental SMEs in Portugal. By adopting a technology-enabled cooperation network, these SMEs can leverage collective strengths to navigate market challenges, build resilience, and secure a competitive edge on the international stage. This strategy aligns with current technological trends and prepares firms for future industry developments, ensuring agility and strategic foresight in their long-term planning.

Conclusions

This research addressed the critical gap in developing effective coopetition frameworks by integrating S-D Logic with technological advancements. The framework developed in this study provides actionable strategies for SMEs to navigate the complexities of coopetition within the digital supply chain landscape. Continued exploration and application of this framework will contribute to its refinement and the broader understanding of coopetition in various business contexts.

The framework was evaluated through a survey involving Portuguese stone manufacturing industry managers. The findings support the Design Science methodology's effectiveness in addressing real-world challenges. With 76% of participants endorsing the framework and its sources of innovation, the results affirm its potential capacity to improve operational efficiency, scalability, supply chain management, and customer satisfaction within SMEs. The positive reception underscores the framework's strength in promoting robust and sustainable coopetition strategies, significantly reducing the risk of failure and effectively integrating technological innovation with the principles of coopetition.

Incorporating S-D Logic into technology-enabled coopetition networks represents advancements in both theoretical and practical contexts. This innovative framework redefines how technology is perceived and utilized as a critical facilitator of value co-creation in service ecosystems. By addressing the identified gaps, the proposed framework provides SMEs with a robust framework to leverage coopetition for competitive advantage and significantly contributes to scholarly discussions on coopetition.

Despite the promising results, several limitations of this study should be acknowledged. Firstly, the survey was limited to a specific sector within a single country, which may affect the generalizability of the findings. Future research could broaden the scope by applying the framework across different industries and geographical regions to test its applicability and robustness.

Future research directions include exploring the framework's responsiveness to emerging technologies and its potential for continuous refinement in alignment with technological advancements.

In conclusion, this research merges academic theory with practical applications, charting a path where technology and S-D Logic converge to empower SMEs to adeptly manage the complexities of coopetition within the digital supply chain landscape. Continued exploration and application of this framework will contribute to its refinement and the broader understanding of coopetition in various business contexts.

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