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Value Creation in Technology-Driven Ecosystems: Role of Coopetition in Industrial Networks

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Abstract: Coopetition, while offering significant strategic advantages, presents challenges in maintaining long-term collaboration among competitors, often due to a lack of perceived value for the participating actors. This study explores the role of technology in overcoming these challenges by applying the Service-Dominant Logic (S-D Logic) framework to investigate how technology-driven networks can enhance value co-creation among small and medium-sized enterprises (SMEs). The study hypothesizes that transitioning to technology-driven coopetition networks can substantially improve value co-creation. To test this hypothesis, the research critically evaluates existing theoretical approaches to coopetition, identifies gaps in understanding value creation mechanisms, and implements an experimental technology-driven coopetition network leveraging Internet of Things (IoT) technology. The research design is applied explicitly to the Portuguese ornamental stone industry, a significant economic and cultural sector. The findings confirm that technology-driven coopetition networks can enhance value co-creation and improve outputs. These results suggest that integrating technology into coopetition frameworks can provide a viable path to sustaining competitive advantages in SMEs.

Keywords: coopetition; internet of things; value networks; service-dominant logic; value co-creation



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1. Introduction

In today's globalized market, where resource asymmetry is prevalent, business networks have evolved significantly, giving rise to coopetition—a strategic blend of cooperation and competition among rival firms [1]. Coopetition offers a dual advantage: it enables firms to explore new opportunities while mitigating inherent risks, making it a crucial element in contemporary business strategy [2]. While recognized by both academics and industry leaders as a critical strategy for small and medium-sized enterprises (SMEs) to gain competitiveness in global markets, coopetition also presents significant challenges. These include the risks associated with collaborating with competitors [3] and the frequent premature dissolution of these networks [4]. Such challenges highlight the need for deeper academic exploration into the viability and effectiveness of coopetition.

A critical gap in the current literature is the limited exploration of value creation mechanisms and the role of technology within coopetition networks. Although various theoretical frameworks such as game theory, the resource-based view, paradox theory, transaction cost theory, and network theory have been extensively applied [5,6], there is still a significant lack of understanding about how value is created and distributed among stakeholders [7]. This gap is particularly concerning as unmet expectations regarding value often lead to the early dissolution of these networks [1].

Given technology's critical role in modern business networks, the following question arises: What framework is best suited for technology-driven cooperation networks?

The Service-Dominant Logic (S-D Logic) literature, which shifts the focus from a traditional goods-centric value perspective to a service-oriented approach, emphasizes

value co-creation through service exchange among multiple actors within networks [8]. S-D Logic provides a comprehensive lens for examining value co-creation by focusing on dynamic interactions and encompassing a broad spectrum of actors and resources in service ecosystems [9]. This perspective is particularly relevant as global supply chains become increasingly technology-driven and service innovation gains importance [10].

This study aims to address the question of technology in coopetition by examining it through the lens of S-D Logic, identifying the foundational elements necessary for effective technology-driven coopetition networks. The research design involves identifying key constructs and building blocks, hypothesizing that transitioning to a technology-driven coopetition network enhances value co-creation.

To test this hypothesis, this research critically evaluates mainstream approaches to coopetition, identifies existing gaps—particularly in value creation mechanisms and the role of technology, and experiments with IoT technology as a catalyst for value creation. It will also conduct an experimental technology-driven coopetition network focusing on ornamental stone SMEs, a key sector in the Portuguese economy.

Following this introduction, a literature review will explore the role of technology in value networks. The research design will then outline the plan to address the research question, focusing on the systemic convergence of coopetition, networks, and value co-creation. Based on this convergence, constructs and building blocks for technology-driven coopetition networks will be formulated, leading to an empirical test of the hypothesis.

2. Literature Review

The term “coopetition” was initially coined by Ray Noorda, the founder and CEO of Novell, in the 1980s, gaining theoretical foundation through Nalebuff and Brandenburger’s (1997) game theory work [11]. They posited coopetition as a groundbreaking business strategy, advocating for its role in fostering innovation and enhancing the success of both individuals and organizations [12]. This conceptual framework suggests that competition allows rivals to benefit from a unique relationship characterized by simultaneous cooperation and competition, thereby driving competitive advantage and innovation [13]. Since its introduction, the discourse around coopetition has become an essential topic within the literature, emphasizing its relevance and application across various domains [1].

2.1. Approaches to Coopetition

At the core of various strategic approaches to coopetition is their fundamental alignment with innovation, equipping firms to close competitiveness gaps and tackle market challenges and business threats [5]. This orientation underscores coopetition’s value in navigating competitive landscapes and highlights its capacity to catalyze transformative growth and resilience [2].

Despite a consensus in the literature on the strategic significance of coopetition for innovation and competitiveness, there still needs to be more consistency in how value-creation mechanisms within coopetition are understood and articulated. Divergent findings across studies [14] underscore the complexity of coopetition’s impact on firms.

This variance is further illuminated by a comprehensive review by Abhilasha Meena, Sanjay Dhir, and Sushil Sushil (2023), which points out that although coopetition has been examined through various theoretical lenses [1]. Game theory, for instance, delineates coopetition as a structured analytical framework, elucidating the strategic choices confronting firms in competition [15]. While this view offers a pathway to optimizing mutual and individual gains in coopetition networks [16], real-world challenges such as information asymmetry and trust issues necessitate an adaptation of its models to the complexities of business practice [15]. The resource-based view champions coopetition as a strategy to access and co-develop a broader pool of valuable resources, enhancing firms’ innovation potential and market reach [14]. It posits that strategically managing these resources can fortify a firm’s competitive edge in a complex, dynamic business landscape [5]. Paradox Theory frames coopetition as a paradoxical relationship where firms

simultaneously collaborate and compete [1]. This perspective encourages firms to leverage these dualities as dynamic capabilities, fostering a nuanced strategy that capitalizes on the synergies of both aspects [17]. Transaction Cost Theory examines coopetition through the prism of economic exchanges, highlighting the balance between reducing transaction costs and safeguarding competitive advantage [7]. This theory accentuates the strategic significance of minimizing opportunism and protecting strategic assets within coopetition arrangements [18]. Network Theory underscores the importance of strategic positioning within networks, enabling firms to access resources and manage competitive dynamics [19]. It advocates for strategically analyzing positioning and relationship management within coopetition networks to optimize stakeholder benefits [20].

These theories collectively provide analytical frameworks for deciphering complex phenomena, offering perspectives through which the operations of organizations, transactions, and market dynamics can be scrutinized. Unlike game theory, which adopts a more strategic and competitive stance, the remainder focuses on value creation, acquisition, and distribution within various contexts. Resource-based [21] and Network Theories [5] specifically delve into how entities exploit resources or networks for value creation and dissemination. Meanwhile, apart from Paradox Theory [22], which navigates through conflicting yet interrelated concepts, these theories underscore the significance of interactions among entities—whether individuals, organizations, or resources—and the impact of these interactions on outcomes.

However, while each theoretical framework offers valuable insights into strategically navigating coopetition, thus allowing firms to tap into its potential for innovation, competitive advantage, and market success, there are noticeable gaps in understanding the value creation mechanisms and the role of technology in coopetition networks.

2.2. Value Creation Mechanisms in Coopetition Networks (Research Gap 1)

The theoretical mainstream frameworks often portray value creation within coopetition networks as a linear and somewhat static process, overly reliant on a firm's internal resources, pre-established market positions, or the outcomes from discrete strategic interactions [6]. This approach tacitly treats value as an intrinsic attribute of goods or services, capable of being transferred from producer to consumer in a unilateral flow [23]. This perspective neglects markets' complexities and fluid nature [24], particularly relevant in coopetition contexts where the lines between competition and collaboration are blurred and constantly evolving [7].

2.3. The Role of Technology in Coopetition Networks (Research Gap 2)

The conventional theoretical mainstream typically needs to fully encapsulate the intricate complexity and interconnectivity of today's technology-infused coopetition networks [5]. In the context of coopetition networks, technology plays a dual role as both an operant [25] and an operand resource [26], fundamentally shaping the dynamics of collaboration and competition among firms. This dual role underscores the intricacy of technology's impact on coopetition networks. Recognizing the significance of operant and operand technology challenges traditional views that overlook the dynamic, networked essence of contemporary economic and social exchanges [16]. It calls for a theoretical recalibration that appreciates the multifaceted role of technology in enhancing the interconnectedness and complexity of coopetition networks, thereby contributing to a richer understanding of value creation and exchange in the digital age [7].

2.4. Approaching Coopetition through Service-Dominant Logic

The exploration of "service" as a cornerstone of economic exchange has deep roots, reaching back to the mid-19th century with intellectual pioneers such as Frederick Bastiat (1848). However, in Lusch and Vargo's seminal work in 2004, a significant paradigm shift occurred, propelling S-D Logic to the forefront of contemporary economic discourse [27]. This innovative perspective elevates operant resources—intangible assets like knowledge

and skills—above tangible goods, or operand resources, traditionally seen as the primary sources of value. S-D Logic redefines goods as mere facilitators of service delivery, emphasizing the role of specialized competencies in serving others [8,28]. This framework positions service and the co-creation of value it entails as central to economic exchange, thereby challenging earlier, more static views of value [26].

Historical economic theories, particularly those espoused by Adam Smith (1776) and David Ricardo (1817), predominantly framed value through labour theory. However, contemporary dialogues have transitioned toward a co-creation perspective, acknowledging the collective contributions of suppliers, partners, allies, and customers to the value creation process [29]. This shift from coproduction to co-creation, and ultimately to value co-creation within service ecosystems, underscores a growing recognition of value's complex nature [30]. Through S-D Logic, the focus on perpetual value derivation and evaluation within service ecosystems portrays these networks as complex adaptive systems [31]. Within these ecosystems, value propositions serve as the conduits for interactions among actors, moving beyond the notion of fixed value deliveries [32]. This approach distinguishes between value-in-exchange and value-in-use, showcasing the dynamic and processual essence of value creation and realization [8]. The alignment of S-D Logic with foundational theories such as the Resource-Based [33], Competencies Core [34], and Corporate Core Competencies theory [35] underscores its broad applicability and relevance to contemporary discussions on value creation.

2.5. *The Role of Technology in Value Networks*

Historical analyses of networks, drawn from sociology and organizational theory, have primarily focused on the structural aspects of value creation [23]. However, contemporary research calls for a reassessment of these frameworks to align theoretical constructs more closely with their practical applications across various industries and management practices [36]. Pioneers such as Granovetter (1985) and Uzzi (1996) argue that economic activities are intricately tied to network relationships, pushing for a sophisticated comprehension of how cooperation and competition intertwine at different levels [37]. Building on this, Mariotti (2002) introduces the concept of the value network as an ecosystem where information, technology, and human interactions meld to create value throughout its nodes, spotlighting technology's pivotal role in bridging spatial and temporal gaps in exchange processes [38].

The shift toward a service-dominant logic in recent business discourse mirrors a growing consensus on the utility of value networks as frameworks for deconstructing the intricate processes of value creation through services [39]. This paradigm shift accentuates the fluid process of value co-creation, wherein participants within customer service networks amalgamate resources through cooperative endeavors and interactions [40].

In contemporary economic and social ecosystems, the concept of a “network” serves a dual purpose, embodying both the act of networking and the structural composition of the networks themselves. This dual nature emphasizes networks as platforms where various actors, from individuals to organizations, pursue economic and social goals [41]. Within the S-D Logic framework, networks are seen as vast, interconnected systems. In these systems, actors not only bring specialized competencies to the table but also engage in mutual value propositions, underscoring the importance of relationships and collaborative interactions that extend beyond mere transactions of goods and services [28,42].

Technology plays a central role in shaping and evolving these value networks [8]. Historically regarded as a tool to meet societal needs [43], technology is now acknowledged for its dual function as both an enabling tool (operand resource) and a source of knowledge and skills initiation (operant resource) within S-D Logic [44]. This sophisticated perspective views technology as an essential driver of value co-creation, facilitating unprecedented resource integration and innovation [45]. Wieland (2017) highlights the synergy between digital transformation and technological innovation, illustrating how

the fusion of technological progress and service innovation is a powerful force for value creation in contemporary networks [46].

Based on the critical evaluation of value creation mechanisms and the role of technology in coopetition networks, a framework can be formulated to test the hypothesis that transitioning to technology-driven coopetition networks enhances value co-creation.

3. Research Design of a Technology-Driven Framework for Coopetition Networks

The design of empirical research relies heavily on a solid theoretical foundation, guiding the exploration of complex phenomena in fields as varied as medicine, computer science, engineering, management, and economics [47]. Integrative approaches are praised for their ability to dissect individual components and entire complex systems [48], making them ideal for investigating the nuanced nature of coopetition networks [10].

Recent developments in service ecosystems, propelled by S-D Logic, call for a comprehensive approach that integrates S-D Logic with other frameworks [39]. This holistic view shifts focus from firm-centric to service-centric perspectives, emphasizing the need for wide-reaching institutional changes and the important role of coopetition in fostering innovation through mechanisms like knowledge transfer [42,49].

Coopetition is characterized as a driver of multiple innovation processes within ecosystems [39], creating an environment conducive to resource sharing and amplifying the network's innovation capacity [50]. This ecosystemic view suggests that innovation results from and contributes to the dynamic reconfiguration of institutional spaces, focusing on ongoing interaction and co-creation [51]. Therefore, an integrative framework for developing coopetition networks, informed by S-D Logic, might include the following: (1) Understanding the transformation of networks into service ecosystems for value co-creation; (2) Elucidating coopetition's role in enhancing innovation and value within these ecosystems; (3) Bridging identified gaps in coopetition literature using insights from service ecosystems. This approach aligns with S-D Logic's theoretical advancements and provides practical strategies for re-envisioning coopetition, underscoring the endless cycle of innovation and value co-creation in institutional coopetition networks.

3.1. Framing Networks and Ecosystems

Service ecosystems, introduced by Ruokolainen and Kutvonen (2009) as socio-technical and complex adaptive systems, marked a significant advancement in our understanding of network coordination [52]. Defined by sets of metamodels guiding interactions, these ecosystems are noted for their capacity to evolve spontaneously and through strategic planning, necessitating governance principles that align intentions with operational coherence [53]. While the transition from value networks to service ecosystems marked a significant shift in vocabulary, the foundational perspective initially remained anchored in traditional views of value exchange.

This narrative began to transform significantly with Vargo and Lusch's advocacy (2011) for a paradigmatic shift toward service ecosystems within the S-D Logic. They proposed a resource integration framework emphasizing service exchange as a means of value creation, thus connecting people and technology meaningfully [54]. A cornerstone of this evolution is acknowledging institutions and institutional arrangements as vital enablers of value creation. Lusch and Vargo (2014) illustrated how service ecosystems are self-regulating entities composed of resource-integrating actors united by shared institutional logic and objectives of mutual value creation [8]. Referencing Scott (2001), it is noted that institutions provide the frameworks of rules, norms, and beliefs that govern actions, making social interactions predictable and meaningful. According to Koskela-Huotari and Vargo (2016), institutional logic facilitates governance and coordination across the ecosystem through a material-symbolic language, underscoring the transition toward a network-centric view where value is co-created through shared institutional logic and resource integration [55].

By embracing the systemic and adaptive nature of service ecosystems, S-D Logic offers a comprehensive lens through which the intricate dynamics of actors, resources, and institutions in value co-creation processes can be examined [42].

3.2. Framing Coopetition and Value Creation

In business literature, coopetition is recognized for its dual dynamics: cooperation and competition. Raza-Ullah et al. (2014) describe these dynamics as parallel paths where firms collaborate with rivals in specific contexts and compete in others, presenting challenges and opportunities for strategic balance [17]. Moving beyond the concept of separate pathways, some scholars argue for a syncretic, rent-seeking approach [56]. This view posits coopetition as a continuum where firms strive to reconcile the interplay between collaboration and competition, demanding an integrated strategy to manage the inherent tensions [14].

These tensions underline the need for cooperative norms, rules, and other institutions within coopetition networks, aligning with the S-D Logic perspective. S-D Logic suggests that value co-creation thrives within ecosystems governed by shared institutional logics [39], where institutions act as frameworks to enable and regulate collaborative and competitive network actions [8].

According to this view, in such networks, value co-creation arises from service exchanges between actors, including firms, rivals, and customers [8]. This experiential process encourages continual learning and adaptation, guiding entities to refine their actions and interactions in response to changing values and expectations [57]. As with any adaptive system, this dynamic learning environment is crucial for the sustainability and growth of coopetition networks, promoting a cycle of continuous innovation and adaptation [46].

3.3. Systemic Convergence on Coopetition, Networks, and Value Co-Creation

Exploring cooperation networks through the S-D Logic lens becomes essential to understanding institutions' multifaceted role [58]. These institutions are characterized by their regulative, normative, and cultural-cognitive elements [59]. These elements are instrumental in shaping the behavior of network participants, fostering an environment conducive to innovation and value co-creation [60].

Coopetition networks enable firms to enhance their competitive advantage and innovation capacity by acquiring and integrating new resources and capabilities [61]. It aligns with S-D Logic, which views all social and economic actors as resource integrators, with institutions [58], defined as rules, norms, and meanings, playing a crucial role in coordinating interactions for value co-creation within ecosystems [39].

S-D Logic identifies service ecosystems as complex adaptive systems where institutions facilitate and regulate value co-creation actions. These ecosystems are dynamic, with patterns emerging from actor interactions, showcasing the unpredictable nature of resource integration and service provision [62]. Within this context, coopetition networks are seen as avenues for resource integration, creating new, exchangeable resources through service exchanges. The effectiveness of value co-creation depends on coordinated ecosystem governance.

However, coopetition networks face challenges, such as the paradoxical nature that may lead to premature dissolutions. Institutions and institutional arrangements are vital in overcoming these challenges by providing the necessary structure for actor coordination [63], collaboration, and cooperation [39]. Successfully navigating coopetition involves balancing collaboration and competition, with network sustainability relying on proper coordination mechanisms [64]. It demands a transition toward service ecosystems, viewing business opportunities as ongoing service processes where shared institutions have collaboratively managed and supported resource integration and value proposition development [26]. Institutions thus act as both coordination mechanisms and evaluative frameworks to discern the outcomes of collaboration and competition [60]. Adopting this service ecosystem lens provides insights into the processes of value co-creation or

destruction in coopetition networks, illuminating paths for more effective management and sustained operation.

4. Addressing Research Gaps in the Light of S-D Logic

4.1. Value Creation Mechanisms in Coopetition Networks

S-D Logic positions value creation as an inherently dynamic, interactive process that unfolds over time through reciprocal and iterative exchanges among all participants within a network [9]. S-D Logic fundamentally challenges the traditional view by proposing that value is not dormant, waiting to be unlocked from products or services [27]. Instead, it emerges from the co-creative practices of firms, customers, and other stakeholders engaging in mutual and ongoing interactions [54]. This paradigm shift highlights the role of operant resources—such as knowledge, skills, and information—which become the primary means through which value is co-created [45]. From this S-D Logic view, in coopetition scenarios, the interaction between competing firms can lead to novel forms of value creation that were previously unattainable through solitary efforts. By acknowledging and leveraging each other's competencies and resources, competitors in a coopetition framework can jointly explore new market opportunities, innovate in product and service development, and enhance their adaptability to changing market dynamics. This fluid and evolving conceptualization of value creation underscores the necessity for firms engaged in coopetition to foster an environment where open dialogue, shared learning, and collaborative innovation are encouraged [8]. It posits that the competitive advantage in today's complex marketplace no longer lies in merely possessing unique resources but in the ability to dynamically integrate and recombine resources across organizational boundaries to meet consumers' and other stakeholders' ever-changing needs and preferences [65].

4.2. The Role of Technology in Coopetition Networks

S-D Logic profoundly reimagines how value is created and sustained within service ecosystems [64]. It conceptualizes these ecosystems as platforms where value is co-created through the collective efforts and interactions of all actors coordinated by endogenously generated institutions and institutional arrangements [8]. Unlike traditional theories that view markets as battlegrounds for competitive advantage, S-D Logic sees them as forums for collaborative value creation [39], where competition and cooperation coexist and complement each other within a more extensive, more intricate network of relationships [66].

S-D Logic underscores ecosystems' systemic and emergent properties, acknowledging that the value is not a static outcome of individual actions but an emergent property of the network's collective interactions [42]. This perspective invites a deeper exploration of how coopetition—strategic cooperation among competitors—functions within these ecosystems. It opens avenues for understanding how firms can navigate and leverage the complex interplays of competition and collaboration to foster innovation, access new markets, and create superior customer experiences [49].

Furthermore, the S-D Logic perspective illuminates the role of technology as a facilitator and amplifier of these ecosystem dynamics [46]. In an era where digital networks increasingly mediate economic and social interactions, understanding the role of technology in enabling, shaping, and scaling the co-creative processes of service ecosystems becomes crucial [67]. Adopting an S-D Logic approach to study the complexity and interconnectedness of coopetition networks offers a richer, more nuanced understanding of value co-creation in contemporary markets. Through this lens, the strategic interplay of coopetition is seen not just as a tactic for individual firms but as a fundamental principle shaping the evolution of the entire service ecosystem. This service ecosystems perspective helps elucidate the mechanisms through which value is co-created or co-destroyed in coopetition networks, offering insights into how these networks can be more effectively managed and sustained over time.

4.3. Framing Technology-Driven Coopetition Networks

The framework concept provided by Scott (2001) introduces cognitive institutional arrangements as interconnected sets of institutions that underpin the transformation of coopetition networks into arenas of rich, meaningful value co-creation experiences [58]. These arrangements offer governance and evaluation mechanisms, guiding the interactions within nested and overlapping service ecosystems. This perspective emphasizes the importance of dynamic, meaningful interactions among network actors, supported by a robust institutional framework that encourages collaborative innovation and ensures network sustainability [63].

For Lusch & Vargo (2016), networks are envisioned as fluid configurations of institutions, marked by reciprocal connections that facilitate technological and market innovations [60]. This view aligns with Wieland et al. (2017), who argue that institutional innovations play a crucial role in sustaining individual actors and enhancing the resilience of coopetition networks. Such innovations are not merely structural changes but are deeply embedded in the network's cultural and normative fabric, driving evolution and adaptation [46]. To illustrate, consider the case of the renewable energy sector, where firms often coopetition to develop new technologies and standards. Institutional arrangements include shared research initiatives, joint ventures, and common regulatory advocacy groups [8]. These collaborative efforts, guided by shared norms and values, accelerate technological advancements and establish market practices that benefit all participants, demonstrating the transformative potential of institutional coopetition networks.

This enhanced focus on the systemic and institutional underpinnings of technology-driven coopetition networks within the context of S-D Logic invites a deeper examination of how governance structures, shared values, and cultural norms influence value co-creation [31]. By recognizing the significance of these institutional constructs, firms can better navigate the complexities of coopetition, fostering environments that support sustained innovation, resilience, and collective prosperity [9].

Drawing upon S-D logic foundations, systemic constructs for technology-driven coopetition networks can be delineated. These constructs focus on the roles of institutionalization, coordination, and technology in shaping coopetition networks, highlighting the interplay between competing and collaborating entities within service ecosystems.

Construct #1 (systemic and institutional coopetition networks): Underscoring the systemic and dynamic interplay among actors, this construct institutionalizes technology-driven coopetition networks organically from micro-level interactions to broader mezzo-level norms and rules [68]. Coopetition practices, when initiated at the micro-level by individual actors, serve as catalysts for the emergence of new institutions. These emergent institutions facilitate enhanced value creation, setting the foundation for integrated coopetition strategies in technology-driven networks.

Construct#2 (coopetition networks coordination): Anchoring the micro-level where actors engage in complex interactions to co-create value, this construct highlights the shared motivation to optimize these interactions through effective coordination of resource exchanges [31]. The coordination is intricately managed through both specific, actor-generated rules and broader institutional frameworks, ensuring that the outcomes of coopetition align with the collective objectives [57]. Technology-driven coopetition networks coordinate the interactions through strict protocols (actor-generated rules) and regulatory guidelines (institutional frameworks), ensuring competitive advantage and public safety.

Construct#3 (the role of technology in coopetition networks): Acknowledging the technology's dual role, this construct addresses technology as an enabler (operand resource) and initiator (operant resource) of coopetition actions. This dual role of the technology enables novel ways of integrating and utilizing other resources within technology-driven coopetition networks, enhancing innovation and value co-creation [69]. This construct positions technology as a systemic and institutional resource, reshaping the patterns of resource integration and competition dynamics.

The synthesis of these constructs results in a nuanced understanding of the mechanisms, thus driving coopetition within service ecosystems. The institutionalization construct (construct#1) reminds us of the importance of organic, bottom-up processes in shaping the ecosystem's rules and norms in coopetition networks. The coordination construct (construct#2) underscores the necessity for clear, shared protocols for managing complex interactions in coopetition networks. Lastly, construct#3 highlights the crucial role of technology in enabling and propelling coopetition in networks. For practitioners, these constructs offer a roadmap for navigating the complexities of coopetition networks. By understanding and applying these constructs, firms can better position themselves to leverage the benefits of coopetition, from enhanced innovation to access to new markets and resources. The future of competitive advantage lies in mastering these dynamics, where the ability to collaborate strategically with competitors will define success in the rapidly evolving.

5. Experimental Technology-Driven Coopetition Network and Hypothesis Testing

Systemic building blocks form the foundation for developing an effective technology-driven coopetition network, as they encapsulate the essential elements for facilitating value co-creation in service ecosystems. Drawing from constructs, building blocks illustrate how coopetition unfolds strategically, engaging various actors in a dance of collaboration and competition that enriches the service ecosystem.

Figure 1, adapted from [49], succinctly captures the systemic building blocks essential for forming technology-enabled cooperation networks, demonstrating their interconnected roles in facilitating their growth.

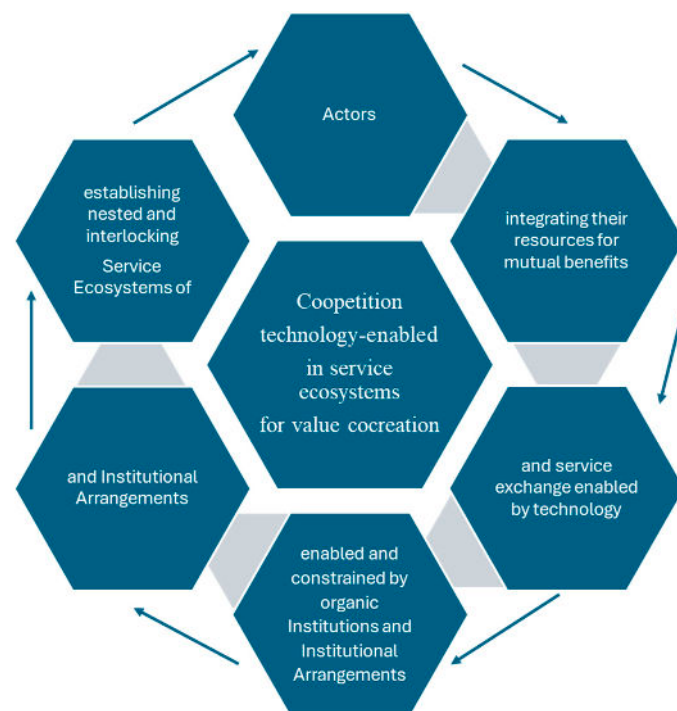


Figure 1. Building blocks for coopetition networks; adapted from Vargo & Lusch (2016).

Building block#1 (Coopetition Actors): Identified as the cornerstone of value co-creation, competition actors include firms, customers, and other stakeholders. These actors adeptly navigate the dual roles of collaboration and competition, embodying the dynamic essence of the technology-driven coopetition network.

Building block#2 (Resource Integration): This represents the collaborative efforts among actors to merge diverse resources, capabilities, and competencies. The goal is to fortify the ecosystem's collective value proposition, showcasing the synergy of shared endeavours in the technology-driven coopetition network.

Building block#3 (Service Exchange): Acting as the conduit for offering and utilizing integrated resources within the technology-driven coopetition network. This mechanism fosters mutual benefits and amplifies value co-creation among participants, highlighting the reciprocal nature of coopetition networks.

Building block#4 (Institutions and Institutional Arrangements): The endogenously generated rules, norms, and cultural-cognitive elements both enable and constrain cooperation actions. This guides the governance and operational dynamics of technology-driven coopetition networks, ensuring a balanced interplay between competition and collaboration.

Building block#5 (Nested Service Ecosystems): Reflects the broader context in which resource integration and service exchange unfold. Characterized by multiple interconnected layers of cooperation and collaboration, it underscores the complexity and richness of the technology-driven coopetition network.

Building block#6 (Operand Technology): Technologies enabling coopetition actions provide resource integration and service exchange tools. These technologies facilitate the operational aspects of coopetition, ensuring actors can engage effectively in the technology-driven coopetition network.

Building block#7 (Operant Technology): The technologies that trigger coopetition actions, spearheading innovation, and strategic reconfigurations within the technology-driven coopetition network. They offer advanced capabilities and insights as catalysts for transformation and growth.

Integrating these building blocks for this research purpose, an experimental technology-driven coopetition network has been implemented, underscoring the critical role of institutional constructs in orchestrating the interactions among coopetition actors, facilitating the integration of resources, and enabling the exchange of services.

5.1. Implementation of the Experimental Technology-Driven Coopetition Network

The experimental network was implemented within the Portuguese ornamental stone sector to evaluate whether transitioning to technology-driven coopetition networks enhances value co-creation.

This sector, integral to Portugal's cultural heritage, has significantly contributed to iconic stone monuments worldwide since the 15th century [70]. Recent reports from the Portuguese Stone Federation highlight its economic importance: the sector exports to 116 countries, ranks ninth globally in the International Stone Trade, and is second in international trade per capita [71]. Predominantly composed of SMEs, the sector's exports surpassed imports by 660%, with a significant portion destined for markets beyond Europe. In 2021, this sector generated a turnover of €1.230 billion, supporting over 16,600 direct jobs, particularly in inland regions [72].

The selection of stone SMEs was based on convenience, with direct invitations sent directly to twenty-two companies identified as having the technological capabilities that reflect the state of the art in the sector. However, due to the costs involved and potential disruptions to their operations, only three companies accepted the invitation to participate in the experimental network.

These companies, representing state-of-the-art practices in the Portuguese stone industry, integrated their machinery with the Building Information Modeling (BIM) systems used by architects, thereby showcasing the sector's advanced technology.

To operationalize the experimental technology-driven coopetition network and test the hypothesis, a secure IoT software application (Figure 2), named Cockpit4.0 V1.0, was developed to connect the shop floors of the participating SMEs.

This integration facilitated the strategic connection of the three SMEs, enabling an evaluation of how coopetition-driven networks can enhance value co-creation.

A comprehensive confidentiality agreement was established with the three companies to safeguard sensitive information related to their operations, clientele, employees, resources, and competitive positioning. This agreement ensured all parties could

collaborate within the coopetition framework without risking their proprietary data or competitive advantage.

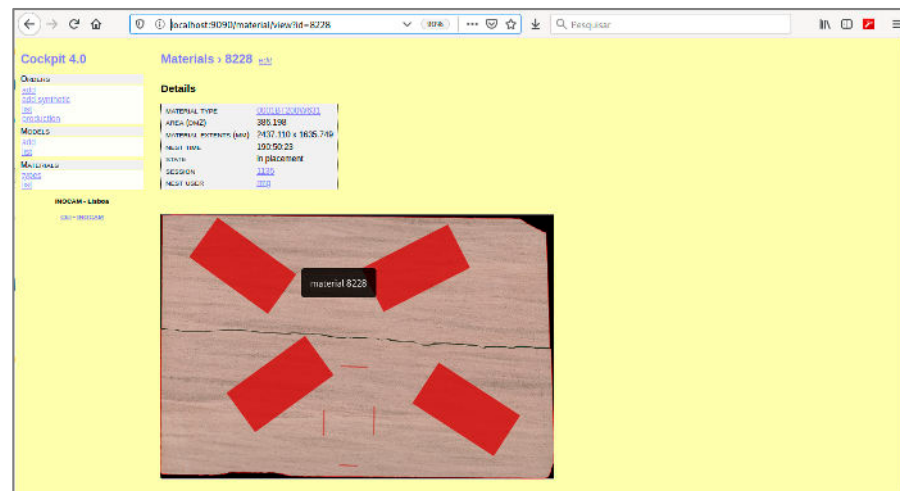


Figure 2. IoT software interface.

5.2. Evaluation Metrics

BIM plays a crucial role in achieving zero waste in construction projects by seamlessly integrating financial data with every component of the digital model [73]. This integration transforms budgeting into a dynamic, detail-oriented process that offers real-time visibility and continuous updates on the financial implications of design decisions and manufacturing changes throughout the project's lifecycle [74]. To meet the stringent requirements of BIM, stone manufacturers must minimize waste and align closely with industry standards. Consequently, the “first time through KPI” (KPI_{FTT}) was selected as a critical performance indicator for this study [75].

KPI_{FTT} measures the percentage of products or services that meet quality and compliance standards without necessitating rework or adjustments. By reflecting operational efficiency, KPI_{FTT} directly contributes to value creation by reducing waste, conserving time, and minimizing the need for additional resources. High KPI_{FTT} rates indicate processes that are efficient and effective in meeting quality standards on the first attempt, thereby significantly enhancing overall operational performance and value generation (Equation (1)).

$$KPI_{FTT}(\%) = \sum_{i=1}^n \left(\frac{\sum \text{parts produced}_{(\text{daily})} - \text{defective parts}_{(\text{daily})}}{\sum \text{parts produced}_{(\text{daily})}} \right) \times 100\% \quad (1)$$

where parts produced means the total number of parts produced daily, defective parts means the total number of parts produced each day that are identified as defective and require rework or cannot be used, and n represents the number of days over which the observation is made.

A data collection strategy was implemented over two fifty-four-day intervals to assess how the technology-driven coopetition network influences the KPI_{FTT} . This approach allowed for a comparative analysis of first time through (FTT) outcomes when transitioning stone SMEs to a technology-driven coopetition network to enhance value co-creation.

5.3. Data Collection, Results, and Discussion

The first 54-day period, conducted in May and June 2023, was focused on capturing state-of-the-art practices (SoAP) at the anonymized companies. This baseline phase documented each company's reliance on internal resources for production and delivery, providing essential reference data for subsequent comparisons.

The second 54-day period, concluding in November and December 2023, assessed the effects of integrating the same three stone firms into the technology-driven cooperation network practices (CTdNP). During this period, the selected stone companies were strategically connected by the IoT system (Figure 3), sharing real-time information about the availability of manufacturing resources and raw material stocks. Table 1 presents a summary of the average data collected.

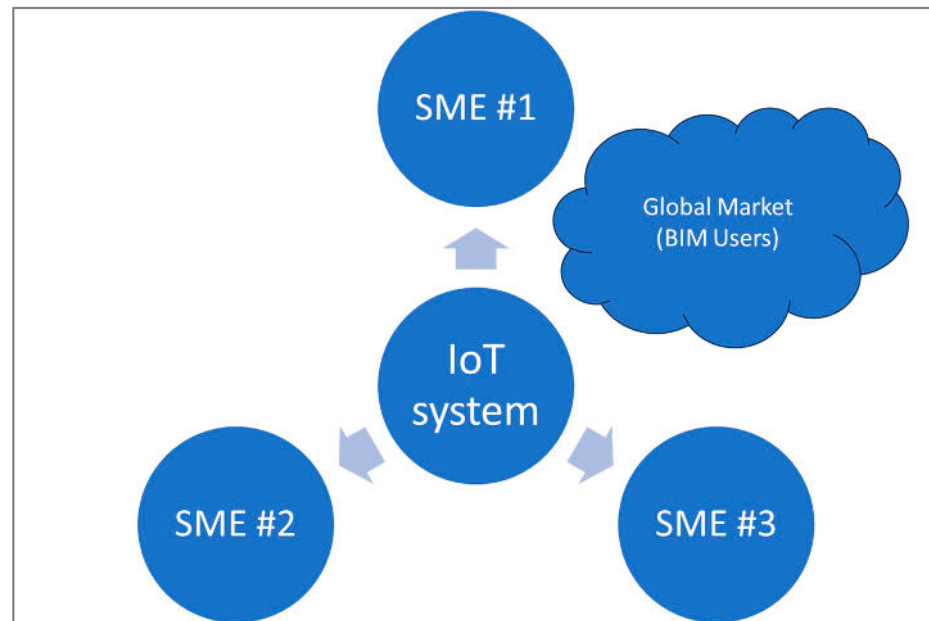


Figure 3. Implementation of the experimental technology-driven cooperation network.

Table 1. Summary of average data collected and KPIFTT assessment.

Data ID	Description	SoAP	CTdNP
Data 1	Parts Produced	369.9	454.3
Data 2	Defective Parts	37.3	38.5
KPI _{FTT}	(%)	90.9%	91.4%

Throughout the study, data management and privacy were maintained in compliance with confidentiality agreements. All data were anonymized and referred to only by company labels. Data collection, recording, and exportation procedures were strictly followed, with results exported to Excel files as detailed in the methodology section. This ensured a secure and consistent approach to data handling, enabling detailed analysis while safeguarding the privacy and proprietary information of the participating companies.

The collected data were used to assess the KPI_{FTT} under both SoAP and CTdNP, as shown in Table 1 and daily illustrated in Figure 4. The comparison provided insights into how the technology-driven cooperation network could improve value co-creation in the Portuguese ornamental stone sector.

Despite a slight increase in KPI_{FTT}, from 90.9% to 91.4%, the analysis reveals a significant rise in total production. Under CTdNP, the total parts produced increased by 22.7% (from 370 to 454), demonstrating an enhanced production capacity within the cooperation network. The marginal improvement in KPI_{FTT} and the increase in output suggest that cooperation practices facilitate better overall efficiency and capacity utilization.

The positive slope (0.0007) in the trend line indicates that, over time, KPI_{FTT} tends to increase under cooperation practices. Although the immediate quantitative improvement in KPI_{FTT} appears small, the consistent upward trend highlights the potential for long-term efficiency gains under CTdNP. The econometric analysis of the trend line suggests a gradual improvement in operational efficiency within the cooperation network over

time. The moderate R^2 value indicates that while time improves KPI_{FTT} , other factors may influence this performance metric.

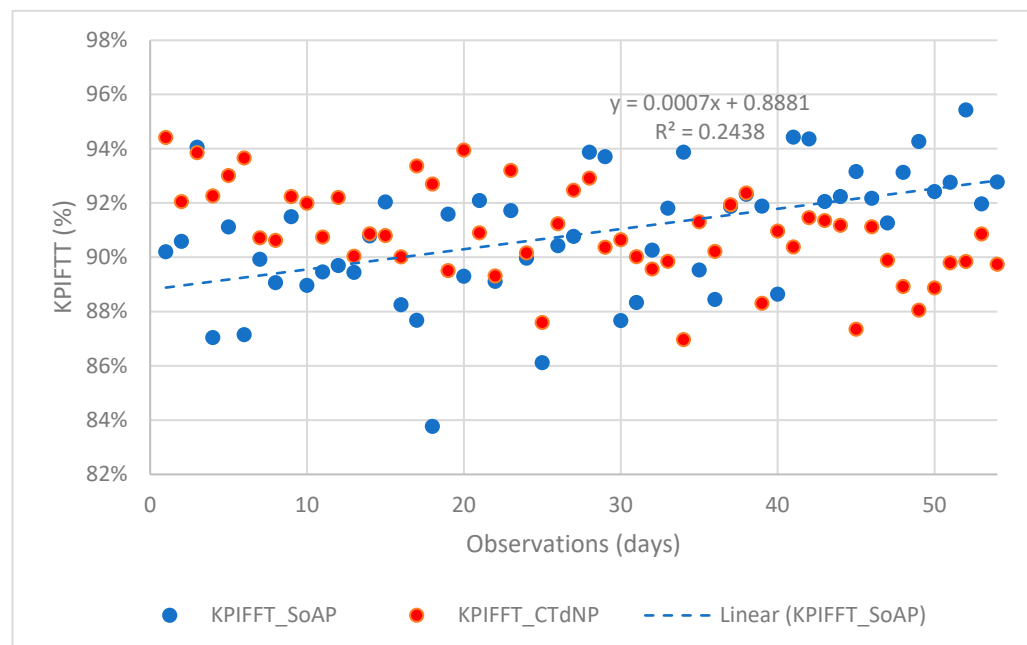


Figure 4. Daily average trend of first time through KPI (KPI_{FTT}).

The increase in daily production under CTdNP, despite a similar KPI_{FTT} being maintained, reflects improved resource utilization and process efficiency. The ability to produce more parts without a proportional increase in defects underscores the benefits of cooperation in leveraging collective capabilities and resources.

The positive trend in KPI_{FTT} over time under CTdNP indicates that cooperation practices can lead to cumulative improvements in operational performance. As companies within the cooperation network continue to refine their processes and leverage shared knowledge and technology, their efficiency in producing defect-free parts on the first attempt improves.

To evaluate whether CTdNP makes a significant difference compared to SoAP, a statistical test was conducted. A paired t -test was used to compare means from two related groups. The t -test produced a p -value of 19.81×10^{-18} , indicating that the observed mean differences are highly unlikely to have occurred by chance. This low p -value suggests a statistically significant improvement in on-time delivery performance under CTdNP compared to SoAP.

Under SoAP, the regression model is statistically significant (significance $f = 0.001501$), indicating a meaningful relationship between non-defective parts and KPI_{FTT} . In contrast, under CTdNP, the regression model is not statistically significant (significance $f = 0.712023$), suggesting that the relationship between non-defective parts and KPI_{FTT} under cooperation practices is not as impactful. This finding indicates that the performance of KPI_{FTT} under CTdNP requires ongoing monitoring, with necessary adjustments to ensure that the shift from current best practices results in actual performance improvements. To fully realize the potential benefits of technology-driven cooperation, it may be necessary to revisit and refine network practices by enhancing communication, setting more precise goals, and offering better incentives for cooperation.

These results support the hypothesis that transitioning to Cooperation-driven Networks potentially enhances value co-creation in the Portuguese ornamental stone sector. By sharing resources and expertise, companies can improve their first time through results, leading to sustained improvements in quality and efficiency.

While the R^2 value of 0.2438 suggests that time explains a moderate portion of the variation in KPI_{FTT} , it also implies that other variables contribute to performance improvements. Future research could explore these variables, such as specific technological integrations or collaborative strategies within the network.

This empirical evaluation demonstrates that coopetition networks, enhanced by IoT, can boost value creation while maintaining or slightly improving operational efficiency as measured by KPI_{FTT} . The upward trend in KPI_{FTT} indicates potential long-term gains in operational performance, supporting the adoption of coopetition as a strategic approach for SMEs in the ornamental stone sector. Further analysis into other influencing factors could provide deeper insights into maximizing the benefits of such networks.

6. Conclusions

This study aimed to explore the role of technology in coopetition by examining it through the lens of S-D Logic. The objective was to identify the foundational elements necessary for effective technology-driven coopetition networks. The research was designed to identify key constructs and building blocks, hypothesizing that transitioning to a technology-driven coopetition network enhances value co-creation.

To test this hypothesis, the research critically evaluated mainstream approaches to coopetition, identifying existing gaps—particularly in value creation mechanisms—and the role of technology in framing technology-driven coopetition networks. The study then experimented with IoT technology as a catalyst for value creation within an experimental technology-driven coopetition network, focusing on ornamental stone SMEs, a key sector in the Portuguese economy.

The findings confirm that technology-driven coopetition networks can indeed enhance value co-creation among stone SMEs. By integrating their resources and capabilities within a cooperative framework, the participating companies improved their first time through rates and overall output.

However, the study also revealed some limitations. The relationship between non-defective parts and KPI_{FTT} under the experimental technology-driven coopetition network was not as strong as under traditional practices. This suggests that while coopetition can enhance value co-creation, its effectiveness may be contingent upon continuous monitoring and refinement. To fully harness the potential benefits of these networks, it is crucial to enhance communication, set clear goals, and provide strong incentives for cooperation.

Moreover, while the findings indicate that time positively influences KPI_{FTT} , other variables also contribute to performance improvements. Future research should explore these additional variables, particularly examining specific technological integrations and collaborative strategies within coopetition networks. Such studies could provide deeper insights into maximizing the benefits of technology-driven coopetition and offer broader applications in other sectors.

In conclusion, this study supports the hypothesis that transitioning to coopetition technology-driven networks enhances value co-creation in stone SMEs. The findings advocate adopting coopetition as a strategic approach, particularly in sectors where technology integration and resource sharing can lead to significant competitive advantages. However, the study's limitations underscore the need for ongoing research to optimize these networks and fully realize their potential.

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