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Innovation in times of crisis: the role of orchestration mechanisms and the innovation network in the development of the ELMO Helmet

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Abstract

Purpose: This research aims to investigate the role of orchestration mechanisms and the innovation network in the development of the ELMO helmet as an innovative solution to the effects of COVID-19.

Methodology/approach: This study employed an exploratory and descriptive case study design, incorporating both qualitative and quantitative data collection and analysis techniques. Data were gathered through interviews, observations, technical visits, and document analyses.

Originality/Relevance: This article tackles a topic that has received limited attention in existing literature. It contributes to a deeper understanding of the processes and dynamics of orchestration in innovation networks during periods of crisis while also shedding light on the various roles played by actors involved in these networks.

Main results: The findings highlight the performance and significance of the roles assumed by actors within the ELMO helmet innovation network. Moreover, an informal hierarchical structure was observed among these actors, with certain individuals assuming leadership positions and gaining legitimacy. The results also revealed the dynamism and autonomy of the ELMO helmet innovation network, showcasing the complementary orchestration capabilities demonstrated through knowledge mobility, innovation appropriability, and network stability.

Theoretical/methodological contributions: The study contributes to the field by reaffirming the positive relationship among the integration, betweenness, and orchestration of actors within innovation networks, as well as suggesting new avenues for future research.

Social contributions: The study provides subsidies for government and business managers to understand the dynamics that involve the innovation process and to develop strategies aimed at the effectiveness of an innovation network through orchestration.

Keywords: orchestration of innovation, innovation networks, innovation in times of crisis, COVID-19, ELMO Helmet

INOVAÇÃO EM TEMPOS DE CRISE:O PAPEL DOS MECANISMOS DE ORQUESTRAÇÃO E DA REDE DE INOVAÇÃO NO DESENVOLVIMENTO DO CAPACETE ELMO

Resumo

Objetivo do estudo: Investigar o papel dos mecanismos de orquestração e da rede de inovação no desenvolvimento do capacete elmo como solução inovadora em tempos de crise.

Metodologia/abordagem: Estudo de caso de natureza exploratória, descritiva, abordagem metodológica mista, vez que se utiliza de técnicas de coleta e análise de dados tanto de natureza qualitativa, como quantitativa, propondo um desenho investigativo baseado na coleta de dados por meio de entrevistas, observações, visitas técnicas e análises documentais.

Originalidade/Relevância: o presente artigo aborda temática pouco explorada na literatura, reduz a lacuna científica e amplia o entendimento sobre os processos e a dinâmica da orquestração em redes de inovação em períodos de crises, bem como qualifica os papéis exercidos pelos atores.

Principais resultados: Os resultados destacaram a atuação e relevância dos papeis de atores que compuseram a rede de inovação do capacete elmo, evidenciou também o reconhecimento de uma estrutura hierárquica informal entre os referidos membros, a legitimação da liderança de alguns atores da rede, além de evidenciar a dinamicidade e autonomia da rede de inovação do capacete elmo, através da complementaridade de competências orquestrais percebidas pela mobilidade do conhecimento, apropriabilidade da inovação e estabilidade da rede pelos atores que a compuseram.

Contribuições teóricas/metodológicas: A pesquisa aponta novas avenidas que reforçam a relação positiva entre integração, intermediação e orquestração dos atores em redes de inovação e que podem ser aplicados em estudos semelhantes.

Contribuições sociais: O estudo fornece subsídios para que gestores, públicos e privados, compreendam a dinâmica que envolve o processo de inovação e possam desenvolver estratégias voltadas para a eficácia de uma rede de inovação por meio da orquestração.

Palavras chaves: orquestração de inovação, redes de inovação, inovação em tempos de crises, COVID-19, Capacete ELMO

INNOVACIÓN EN TIEMPOS DE CRISIS: EL PAPEL DE LOS MECANISMOS DE ORQUESTACIÓN Y LA RED DE INNOVACIÓN EN EL DESARROLLO DEL CASCO ELMO

Resumen

Objetivo del estudio: Investigar el papel de los mecanismos de orquestación y la red de innovación en el desarrollo del casco Elmo como solución innovadora en tiempos de crisis.

Metodología/enfoque: Estudio de caso de naturaleza exploratoria y descriptiva, con un enfoque metodológico mixto que utiliza técnicas de recopilación y análisis de datos tanto cualitativos como cuantitativos. Propone un diseño de investigación basado en la recopilación de datos a través de entrevistas, observaciones, visitas técnicas y análisis documentales.

Originalidad/Relevancia: Este artículo aborda un tema poco explorado en la literatura, reduce la brecha científica y amplía la comprensión sobre los procesos y la dinámica de la orquestación en redes de innovación en períodos de crisis, así como califica los roles desempeñados por los actores.

Principales resultados: Los resultados destacaron la actuación y relevancia de los roles de los actores que formaron parte de la red de innovación del casco Elmo. También se evidenció el reconocimiento de una estructura jerárquica informal entre dichos miembros, la legitimación del liderazgo de algunos actores de la red, así como la dinamicidad y autonomía de la red de innovación del casco Elmo, a través de la complementariedad de las competencias orquestales percibidas mediante la movilidad del conocimiento, la apropiabilidad de la innovación y la estabilidad de la red por parte de los actores que la conformaron.

Contribuciones teóricas/metodológicas: La investigación señala nuevas vías que refuerzan la relación positiva entre la integración, intermediación y orquestación de los actores en redes de innovación, y que pueden aplicarse en estudios similares.

Contribuciones sociales: El estudio proporciona información para que los gestores, tanto públicos como privados, comprendan la dinámica que implica el proceso de innovación y puedan desarrollar estrategias orientadas a la eficacia de una red de innovación mediante la orquestación.

Palabras clave: orquestación de innovación, redes de innovación, innovación en tiempos de Crisis, COVID-19, Casco Elmo

Introduction

The literature on the orchestration of innovation networks has extensively developed and adopted several approaches to gain a comprehensive understanding of its meaning. These approaches include a) research on the determinants of different levels of orchestration, b) exploring the relationship between orchestration and absorptive and dynamic capacity, c) examining the elements of network design, d) investigating the role of orchestration in fostering collaborative innovation typologies, and e) describing the characteristics of multiple orchestrators, considering orchestration as an open innovation process (Ritala, Armila, &

Blomqvist, 2009; Reypens, Lievens, & Blazevic, 2021; Linde, 2021; Schepis, Purchase, & Butler, 2021; Andersén & Ljungkvist, 2021). For the purpose of this study, the orchestration of innovation networks refers to a dynamic and complex process that involves coordination and collaboration among various actors.

However, when examining the literature on orchestration and innovation, including the variables that influence the dynamics between these phenomena, a noticeable gap is observed in studies specifically addressing the relationship between crises and the motivation to generate innovation. Although there has been an increase in research works exploring the role of crises as drivers of innovation in the past decade, they typically discuss the innovation process in a general sense without adequately emphasizing the significance of crises in the dynamics of innovative development.

For example, some studies investigate the catalytic role of crises in the emergence of new technological trends (Protasiewicz, 2021); the consequences of information asymmetry resulting from crises and their impact on the innovation process (Phillips, Roehrich, & Kapletia, 2021); the ability of companies to respond to crises by suspending the pursuit of profit (Netz, Reinmoeller, & Axelson, 2022); the increase in the number of patent applications during crises, such as the COVID-19 pandemic (Heinrich & Yang, 2022); and the impact of crises on the efficiency of environmentally friendly technologies (Wei, Liu, & Lin, 2023), among others (Daklhe, Bogner, Becker, Schlaile, Pyka, & Ebesberger, 2021; Bessant, Rush, & Trifilova, 2015).

This scarcity becomes even more significant when considering studies specifically focused on innovation processes driven by crises, analyzing the dynamics of network orchestration involved in the development of innovation during times of crisis (Pan, Cui, & Qian, 2020; Schotter, 2021). Additionally, there is a dearth of studies that aim to analyze the role of organizational variables and mechanisms perceived during collaboration processes among actors

or institutions, which impact the development of innovations in periods of crisis (Geurtes, Geerdink, & Sprenkeling, 2022).

The significance of studies on this topic goes beyond examining the role of crises as drivers of innovation. It also involves understanding the impact of the coordination capacity of actors within the innovation network. Thus, the central issue is to comprehend how actors or institutions interact in the orchestration of an innovation network during crises, to discover innovative solutions driven by these crises.

This study examined the role of orchestration mechanisms and the innovation network in developing the ELMO helmet. The ELMO helmet was designed in the Brazilian state of Ceará to assist patients with breathing difficulties and reduce the reliance on intubation during the COVID-19 pandemic. This particular case was selected due to its high social impact, and the results obtained can contribute to narrowing the aforementioned scientific gap. The study illustrates how the pandemic served as a catalyst for the innovation process and explores the underlying mechanisms that facilitated the creation of the helmet. By doing so, it enhances our understanding of the processes and dynamics of orchestration within innovation networks during times of crisis, shedding light on the interactions among various actors and institutions that influenced network orchestration.

This article is divided into five sections, including this introduction that justifies its relevance. The second section presents the theoretical framework, followed by a section that describes the methodology. The fourth section holds the results and discussion, and the fifth section presents the final considerations.

Theoretical Framework

The role of innovation as a driver of economic development is not unidimensional. It goes beyond being a fundamental mechanism for value creation in the production of goods and

services. Innovation also plays a crucial role in uncovering new opportunities and influencing organizational practices that have yet to be explored, thereby revealing previously unknown market prospects (Bell & Pavitt, 1993; 1995; Lall, 1992; Dutrénit, 2000; Chesbrough, 2003; Bell & Figueiredo, 2012; De Vries et al., 2016; Chen, Walker, & Sawhney, 2020).

In this context, institutions, companies, and actors have recognized the importance of mitigating the factors that hinder their capacity to organize and share resources and knowledge. Consequently, they have embraced a new collaborative partnership approach through innovation networks. These networks are characterized by the sharing of assets, the allocation of tasks and responsibilities, collaboration, commitment, and active engagement among the participating actors and institutions to achieve collective benefits. This coordinated effort of task execution is commonly referred to as orchestration. As discussed in the following subsection, authors such as Dhanaraj and Parkhe (2006), Ritala et al. (2009), and Reypens et al. (2021) have extensively studied this phenomenon.

Orchestration within Innovation Networks

The diversity and multiplicity of variables involved in the development of innovations mean that understanding its scope goes beyond solely focusing on the end result. It requires a comprehensive examination of the entire process and the sequential flow of activities promoting value creation through the combination of evolving technological capabilities (Bell & Pavitt, 1993; 1995). This process occurs in a continuous dynamic of addressing challenges and seeking solutions to problems (Meissner & Kotsemir, 2016), where overcoming obstacles in the innovation conception process requires the ability to systematize knowledge and foster its sharing, thereby facilitating the expansion of value networks among heterogeneous, private and institutional partners (Nelson & Winter, 1982; Lundvall, 1992; Grant, 1996; Dyer & Nobeoka, 2000).

Innovation networks emerged as an alternative approach to mitigate the problems and shortcomings of exploring innovation strategies (Tidd et al., 2008). These networks are characterized by their dynamic nature and significant learning potential. They are structured through controls established both in formal and informal authority structures, which may or may not be legitimized by the other members. Additionally, shared beliefs, values, and interests converge to ensure the group's sustainability (Newell & Swan, 2000; Schepis et al., 2018; Raypens, Lievens, & Blazevic, 2019).

Among the various approaches to coordinating and managing innovation networks, orchestration has gained significant attention in the literature. Unlike traditional management models, which often exhibit bureaucratic and controlling characteristics (Ritala, Hurmelinna-Laukkanen, & Nätti, 2012), network orchestration operates through a process where organizational practices are guided without imposing orders or commands. Instead, it relies on the discreet influence between institutions to facilitate value co-creation (Ritala et al., 2012). According to Dhanaraj and Parkhe (2006), orchestration is an effective means of creating and extracting value within a network. It is characterized by three key practices: a) knowledge mobility, which refers to the ease of acquiring knowledge within the network; b) network stability, which allows for the input and output of components within the innovation network; and c) innovation appropriability, which concerns the ability to retain the profits generated by an innovation (Teece, 2000; Dhanaraj & Parkhe, 2006; Schepis, Sharon, & Butler, 2021).

From this perspective, the urgency of demand during crises emerges as a significant factor influencing the orchestration process of innovation networks. Crises often have far-reaching impacts across various sectors of society (economy, environment, health, etc.), compromising the satisfaction of basic human needs (Dahlke et al., 2021) and causing social damage and instability. Bessant et al. (2015) describe this type of innovation, driven by crises, as a radical rethinking of

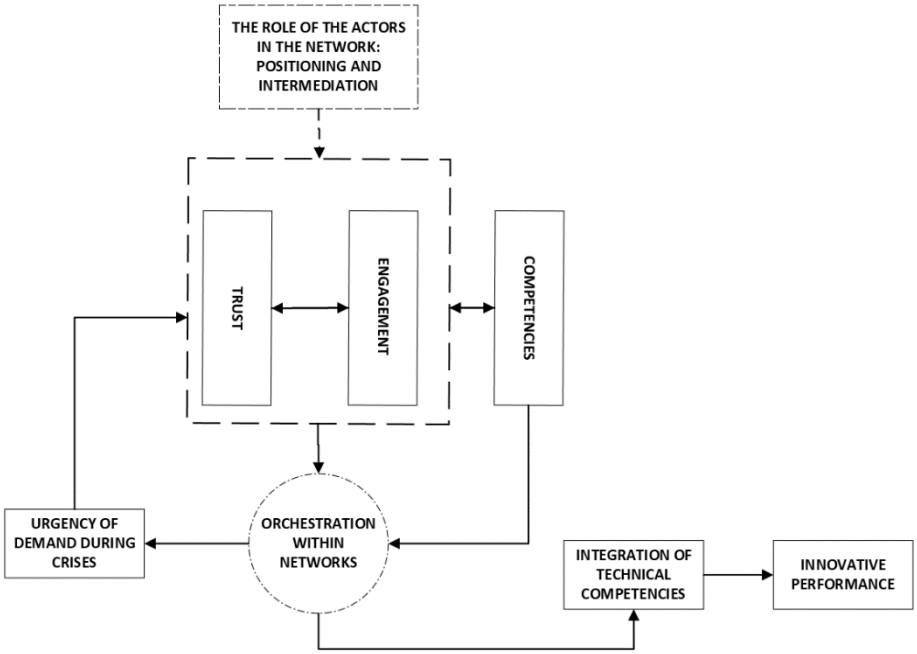
solution approaches. It opens up new pathways for innovation due to the extreme conditions and encourages user participation in shaping these solutions. Rapid prototyping and learning become inseparable features, and there is a swift diffusion of innovations driven by the combination of urgent needs, active user engagement, and resource support from major aid agencies to facilitate widespread adoption.

These aspects reflect a crucial component of the process dynamics, which is characterized by systemic sharing. In this context, value creation and appropriation extend beyond interested stakeholders and encompass the entire innovation ecosystem. Within this ecosystem, skills and relationships intertwine, forming a complex network that can either strengthen or weaken the innovation process (Lievens & Blazevic, 2021; Gregory et al., 2020; Leonidou et al., 2018; Nooteboom, 2004).

This systematization is presented in the framework depicted in Figure 1. It is important to clarify that this article focuses specifically on the orchestration process and its relationship with the performance of actors in the network (Hanneman, 2002). The analysis efforts are centered on understanding how actors position themselves and act as intermediaries, fostering trust and engagement within the network. We present the complete framework in order to provide readers with a comprehensive view of the phenomenon under study. This framework encompasses the orchestration process, proposes the integration of various constructs, and suggests the necessary alignment to generate innovation as a solution to the challenges posed by the crisis (Dahlke et al., 2021; Câmara et al., 2018; Hartley et al., 2020).

Figure 1

Analytical framework proposed for the orchestration of the innovation network opened during crises



Source: Elaborated by the authors

According to Roloff (2008), gaining a comprehensive understanding of the orchestration process requires moving beyond the boundaries of individual firms. The author emphasizes that factors such as diverse partners, public-private interests, shared knowledge, and available technologies can all influence orchestration dynamics. It is essential to comprehend how these elements interact and relate to one another in order to unlock full knowledge and achieve desired value creation. Reypens et al. (2019) further assert the need to analyze cooperation among heterogeneous partners within the network and how this collaboration contributes to overcoming technological, scientific, and organizational deficiencies, ultimately driving knowledge production and innovation (Küppers & Pyka, 2002; Figueiredo, 2003; Figueiredo, 2008; Figueiredo, 2010).

In this context, theoretical directions suggest that trust, engagement, and competence are critical elements for successful orchestration (Schepis, Purchase, & Butler, 2018; Reypens et al., 2019; Ritvala & Salmi, 2010; Aarikka-Stenroos et al., 2017; Dhanaraj & Parkhe, 2006; Reypens, Lievens, & Blazevic, 2016). These aspects play a vital role in shaping the dynamics of the innovation process by reducing conflicts and fostering the pursuit of collective value. Trust, for instance, ensures harmonious goal definition (Skardon, 2011; Shazi, Gillespie, & Steen, 2015), while engagement unites actors around a common purpose (Hartley et al., 2020; Hunton, Demir, & Eldridge, 2021). Additionally, technical competence indicates the contribution of all actors within the network (Skardon, 2011; Shazi, Gillespie, & Steen, 2013; Hartley et al., 2021; Andersen & Ljungkvist, 2020).

Identifying the factors that constitute the orchestration process and give it a more precise direction is fundamental to the value conception process. When combined with strategies aimed at strengthening orchestration, these factors facilitate the integration of multiple interdependent activities that form the systematicity of network orchestration (Perks et al., 2017; Ritvala & Salmi, 2010; Schepis et al., 2018). By doing so, they promote a balance between the interests of the network members and the collective interests of the network.

Strategic mechanisms of an orchestration

The study employs the mechanisms identified by Dagnino et al. (2016) to define the concept of orchestration. These mechanisms involve the integration of activities performed by actors and are characterized by assigning distinct roles in the processes, with some roles being more prominent than others.

These mechanisms can be categorized into four major themes: i) **Development of objectives**: This involves aligning, predicting, building, framing, and controlling the agenda (Aarikka-Stenroos et al., 2017; Moller & Svahn, 2009; Perks et al., 2017; Reypens et al., 2019;

Ritvala & Salmi, 2010), ii) **Connection and collaboration**: This encompasses co-development, coordination, mobilization, and engagement (Dhanaraj & Parkhe, 2006; Mele & Russo-Spena, 2015; Paquin & Howard Grenville, 2013; Reypens, Lievens, & Blazevic, 2016; Schepis, Ellis, & Purchase, 2018), iii) **Resource development and sharing**: This relates to the management and mobility of resources and knowledge (Aarikka-Stenroos et al., 2017; Dhanaraj & Parkhe, 2006; Mele & Russo-Spena, 2015; Schepis et al., 2018), iv) **Construction of the actor's identity and legitimacy**: This involves the actor's positions that legitimize co-creation, sharing power administration, emphasizing forgotten speeches, and committing to the project's objectives (Mele & Russo-Spena, 2015; Perks et al., 2017; Reypens et al., 2019; Reypens et al., 2016).

By adjusting these mechanisms in the orchestration process, the actors can better comprehend the scope of their relationships. Consequently, these relationships are perceived as inherent to the innovation network, as they are consistently utilized throughout its development stages and over time (Ritvala & Salmi, 2010; Schepis et al., 2018).

An innovative solution during COVID-19: the ELMO helmet

The COVID-19 pandemic has presented numerous challenges to the global community, with the restriction on access to health equipment and supplies being particularly impactful socioeconomically. To address this problem, the industrial sector and the government of the Brazilian state of Ceará collaborated and mobilized actors from various public and private institutions, including the University of Fortaleza (Unifor), Federal University of Ceará (UFC), School of Public Health (ESP), Foundation for Scientific Development (Funcap), Federation of Industries of the State of Ceará (Fiec), and the National Industry Service (SENAI). Together, they formed a network comprising actors with diverse profiles and expertise, pooling their values and knowledge to conceive a solution.

The idea of the ELMO helmet was created from this union. Elmo is an assisted breathing device designed to treat COVID-19 patients with mild or moderate symptoms. It improves breathing capacity, reduces the need for hospitalization in the Intensive Care Unit (ICU) by 60%), is non-invasive, less expensive and safer for health professionals (SUS, 2022). The process around the development of the ELMO helmet, although not linear, took seven months from the original idea to final approval by Anvisa, standing out for having been designed from local materials and resources. After implementing and testing prototypes, the device's final version was adopted in clinical trials and, consequently, approved by public authorities. The first ELMO helmet was officially inthe market in January 2021.

Methodology

This study examines the orchestration and innovation process in the context of the COVID-19 pandemic, focusing on the systematic production of the ELMO helmet, a breathing assistance device developed in the state of Ceará in 2020. Drawing upon the framework presented in Figure 1, we aimed to characterize the underlying dynamics of the network orchestration process. The study highlights the collaboration among actors with diverse expertise and from different institutions who collectively achieved a viable solution in response to the respiratory crisis triggered by COVID-19 in Brazil (Dahlke et al., 2021; Cankurtaran & Beverland, 2020).

The research primarily employs an exploratory and descriptive case study approach (Vergara, 2014). It is exploratory as it aims to enhance the understanding of an innovation network formed during a health crisis, and it is descriptive as it reveals the characteristics of the observed phenomenon (Vergara, 2014). The study utilizes a mixed-methods approach, incorporating both qualitative and quantitative data collection and analysis techniques. The data analysis prioritizes the triangulation strategy (Vergara, 2014; Teixeira, Nascimento, & Carrieri,

2011; Creswell, 2007) to ensure the convergent validation of data obtained from different methodological approaches.

The research was conducted between August 2021 and May 2022. Data were collected through the observation of the network and the developed product, as well as semi-structured interviews with all members. Technical visits to the product development laboratories were also carried out. A total of 20 (twenty) actors were interviewed online using the Google Meet platform, which was necessary due to the social distancing measures implemented during the COVID-19 pandemic. Prior to the interviews, the participants provided their consent through a consent form, and the interviews were recorded and transcribed to capture all aspects of their responses. To ensure confidentiality, the participants were anonymized and identified using numbers. The interviews had an average duration ranging from one to one and a half hours. In addition to interviews, document analysis was conducted, utilizing materials from various sources, including technical documentation produced by the researchers.

Table 1

Methods of data collection

Categories	Quantity	Description
Interviews	20	Institutional managers, physicians, physiotherapists, production engineers, electrical engineers, clinical engineers, civil engineers, designers, production supervisors, laboratory managers, researchers, and patients
Technical visits	03	School of Public Health of the State of Ceará, Laboratories of SENAI (National Service of Industrial Learning), LAPIN – Laboratory of Research and Innovation in Cities of the University of Fortaleza – UNIFOR.
Documents	04	Texts produced from communication between network actors/interviewees through the WhatsApp application, research and development reports and technical manual.

Source: Elaborated by the authors

Operationalization of the variables to measure the levels of network orchestration

The orchestration process was analyzed based on the following mechanisms: developing objectives, promoting connections and collaboration, developing and transforming resources, and building and legitimizing identities. The operationalization of the analysis categories, along with the measurement criteria and theoretical basis used as a reference for the analysis, are summarized in Table 2.

Table 2

Methodological operationalization of the orchestration mechanisms in the network developing the ELMO helmet

Variables	Mechanisms	Definition	Evaluation criteria	References
Orchestration	Developing objectives (DO)	Alignment, prediction, control, and agenda-setting	The orchestration was classified based on the evaluation of the positioning of the network actors/interviewees. We attributed scores from 1 to 3 (low to high) to the intensity of their performance in each of the orchestration mechanisms, supported by empirical evidence.	Aarikka-Stenroos et al., 2017; Huxham & Vangen, 2000; Moller ¨ & Svahn, 2009; Perks et al., 2017; Reypens et al., 2019; Ritvala & Salmi, 2010; Dagnino et al., 2016; Dhanaraj & Parkhe, 2006; Mele & Russo-Spena, 2015; Paquin & Howard Grenville, 2013; Reypens, Lievens, & Blazevic, 2016; Schepis, Ellis, & Purchase, 2018; Schepis et al., 2018; Huxham & Vangen, 2000; Reypens et al., 2016
	Promoting connections and collaboration (CC)	Coordination, mobilization, and engagement of the actors in the network		
	Developing and transforming resources (TR)	Management of resources and management of knowledge mobility		
	Building and legitimizing identities (LI)	Legitimation, enthusiasm, empowerment, commitment with the collectivity		

Source: Elaborated by the authors

During the analysis, the constructs, levels, and dimensions of the orchestration process were evaluated by assigning scores to the actors' roles. These scores were supported by empirical evidence from the interviewees' speeches, document analysis, and technical visits. The assigned scores were then organized in a didactic manner using data display techniques (Miles & Huberman, 2013) to highlight the specific characteristics of the research context. To visualize the innovation network and the interactions among the actors, the data were analyzed using the software tools UCINET 6.740 for data entry and manipulation and NETDRAW 2.179 for the visualization of the network map (Borgatti et al., 2006). The network map allowed for the identification of the network members based on their roles in the orchestration process.

Results and discussion

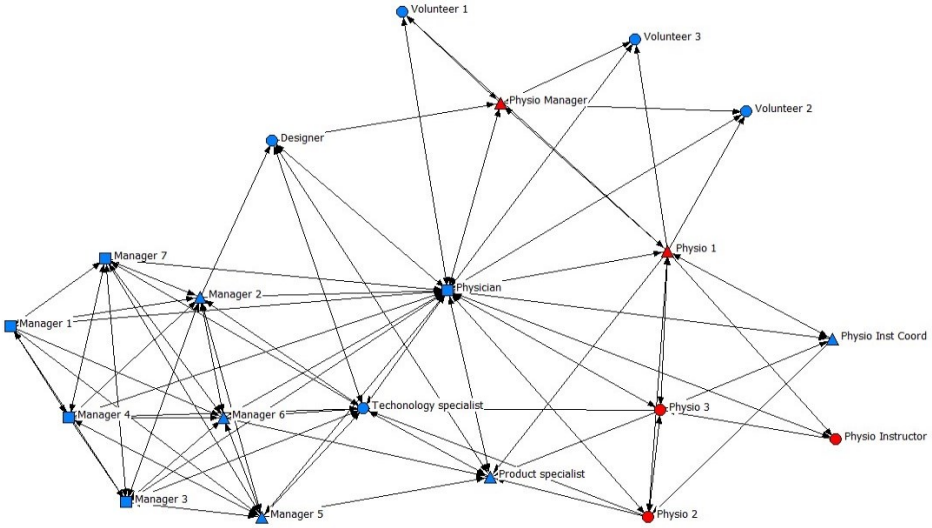
Figure 2 illustrates the graphic representation of the network of actors involved in the orchestration of the ELMO helmet. The actors are represented as nodes in the network. In this representation, male actors are depicted as blue nodes and female actors as red nodes. The nodes are further distinguished based on the type of function they performed. The squares in the figure represent actors who held management roles or represented institutions. Triangles indicate actors who assumed leadership roles, and circles represent those who played technical roles or were patients involved in the process. The connections between the nodes, depicted as edges in the network, indicate the relationships and interactions among the actors. The map highlights stable and strong relationships among the actors, with frequent interactions between the nodes. Importantly, there were no isolated actors, indicating a network where all the components were actively engaged, interacting, and communicating with each other.

Another notable observation is network density, a valuable measure to determine the extent to which a network is maximizing its potential. This metric is calculated by comparing the number of interactions in the network to the total number of possible relationships. The ELMO

helmet orchestration network exhibited a high network density, with a quotient of 0.5973, meaning that the actors effectively utilized approximately 59.73% of the network's potential.

Figure 2

Map of the orchestration network – ELMO helmet



Source: Elaborated by the authors using UCINET

Another crucial variable for comprehending the roles of actors within the network is the degree of centrality among them. This measure represents the total number of interactions an actor (node) has with other actors (output degree), as well as the interactions others have with that specific actor (input degree). Table 3 presents the degree of centrality for each actor in the network.

Table 3

Degree of centrality and betweenness for each actor – ELMO helmet network

ACTOR [as identified in Figure 2]	INSTITUTION	Output degree	Input degree	Betweenness
(1) Manager 1	FUNCAP	72,000	41,000	4,086
(2) Physician	SCHOOL OF PUBLIC HEALTH OF THE STATE OF CEARÁ	**151,000**	**118,000**	**45,152**
(3) Manager 2	SENAI/UNIFOR	111,000	101,000	20,752
(4) Manager 3	SENAI/FIEC	79,000	80,000	2,033
(5) Manager 4	SENAI	79,000	79,000	2,033
(6) Manager 5	TECHNOLOGICAL INSTITUTE OF SENAI	79,000	87,000	1,633
(7) Manager 6	SENAI	78,000	84,000	0,633
(8) Designer	UNIFOR	67,000	83,000	0,633
(9) Manager 7	UFC	45,000	21,000	0,000
(10) Technology specialist	UFC	54,000	63,000	0,633
(11) Product specialist	ESMALTEC	39,000	74,000	2,602
(12) Physiotherapist 1	RESPLAB/UFC	104,000	105,000	23,119
(13) Physiotherapist 2	RESPLAB/UFC	96,000	101,000	23,119
(14) Physiotherapist 3	RESPLAB/UFC	90,000	101,000	23,119
(15) Physiotherapist and Institutional Coordinator	SCHOOL OF PUBLIC HEALTH OF THE STATE OF CEARÁ	32,000	44,000	0,550
(16) Physiotherapist and Instructor	SCHOOL OF PUBLIC HEALTH OF THE STATE OF CEARÁ	26,000	29,000	0,000
(17) Physiotherapist and Manager	MEDICAL COOPERATIVE	61,000	67,000	2,900
(18) Volunteer 1	PATIENT	**30,000**	**25,000**	**0,000**
(19) Volunteer 2	PATIENT	**30,000**	**25,000**	**0,000**
(20) Volunteer 3	PATIENT	**30,000**	**25,000**	**0,000**

Source: Elaborated by the authors using UCINET

Table 3 shows that the actor with the most interactions with the other actors is Med_Inst 1, with an input coefficient of 151,000 and an output coefficient of 118,000. Those who had fewer interactions with the other network participants were the Volunteers.

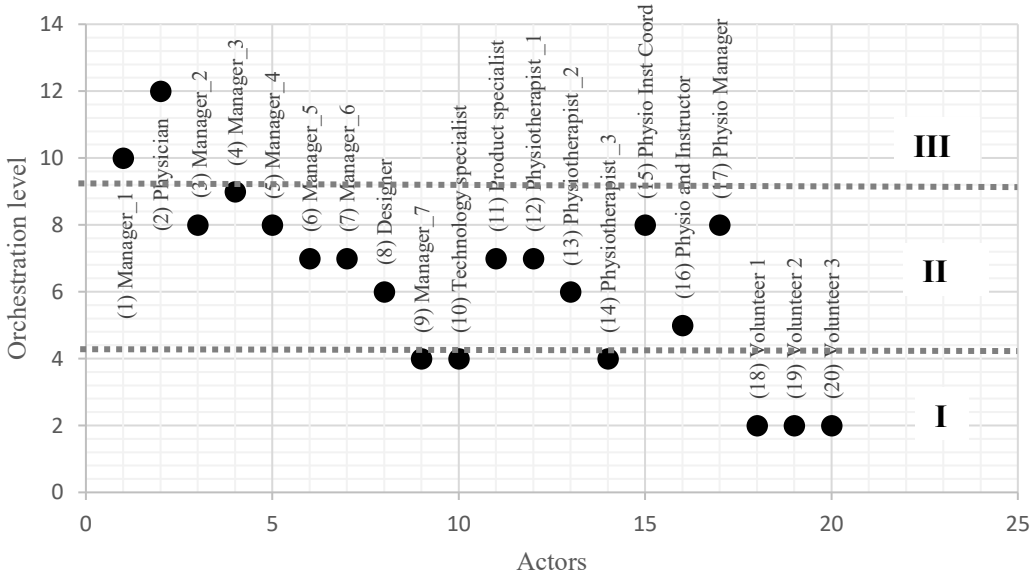
This relationship is further supported by analyzing the data related to the betweenness of actors in the network. This data reveals which nodes are more likely to mediate communication between other nodes, thus highlighting the dynamic nature of the network. Additionally, it was observed that while all actors utilized the network for communication and interaction, certain actors stood out in the process, such as actor 2 (Med_Inst 1).

Measuring the orchestration and innovation process of the actors in the network during the pandemic

Considering the evaluations of the orchestration levels of the actors in the network, Figure 3 illustrates that out of the 20 actors, only two achieved a higher level of orchestration, while three actors were at the lowest level. The majority of actors (15) fell within the average range or close to it, indicating a pattern where actors with extreme orchestration profiles (either high or low) had less representation. This observation aligns with the explanation provided by Reypens et al. (2019) regarding the "typical" roles of actors in an orchestration process.

Figure 3

Level of orchestration of actors in the ELMO helmet network



Source: Elaborated by the authors

Although all actors had roles inherent to the orchestration process, what distinguished them from each other was the level of intensity with which they performed these functions within the orchestration. Actors with a high orchestration profile stood out in the network by undertaking crucial actions in the development of the final product and sustaining the alliances formed during the ideation and execution phases. These actions included setting agendas, mobilizing team members, establishing networks with public and private institutions, securing research funding, and overseeing the allocation of resources required for manufacturing and distributing the product. Additionally, they played a key role in obtaining approvals from major federal and state health agencies for the products.

This evidence not only characterizes the orchestration process but also indicates the recognition of a leader in the network who earned respect from others and served as a guide throughout the process. These leaders took on roles that involved greater responsibilities and played a crucial role in the success of the orchestration. They exhibited higher intensity levels in performing their functions than other network members, as shown in Table 4. Their actions were directed towards the overall purpose of the network, going beyond their institutional or technical responsibilities. They aimed to extract and highlight the value that each network component could contribute to the final product and the group itself. By managing internal and external resources that influenced the attainment of the desired outcome, they ensured the effective utilization of resources (Dhanaraj & Parkhe, 2006; Reypens et al., 2019).

At the medium level of orchestration, some actors assumed more technical or organizational roles without taking on extensive responsibilities for overall network management. However, they remained connected and actively involved with all the members. These actors played a significant role in product development and focused on optimizing technical and operational aspects. Their positions were associated with tasks such as defining production

schedules, setting deadlines for prototype manufacturing, collaborating with laboratories on technical operations, ensuring usability, coordinating small teams to facilitate collaboration among other members, providing training, and facilitating the adoption of ELMO helmets in hospitals.

However, categorizing network actors at the medium level of orchestration does not imply a lack of dedication to their tasks. The evaluation considers the intensity with which these actors performed their activities based on the attributes measured in relation to network orchestration. As shown in Table 4, some actors classified at the medium level of orchestration exhibited maximum intensity in certain attributes, while in other attributes, their intensity did not reach the maximum level observed. This balancing of intensities across different attributes resulted in their positioning at a lower level in terms of performing network orchestration roles.

At the lowest level of orchestration, we find actors who obtained the lowest scores in the evaluation of the specified attributes (less than 4). Although only six actors were included in this level, there was greater dispersion among them due to the divergence in their performance of roles within the network. The score reflects the significance of their roles in the orchestration process (Figure 3). It can be observed that the actors at the lowest level (score 2) were perceived as essential to the network, as they contributed to legitimizing the product by volunteering in usability testing (building and legitimizing identities – LI). Other actors at this level, despite not holding prominent positions in the orchestration, fulfilled various roles at moderate to low levels of intensity, but these roles held significant importance in the process by assisting in bureaucratic aspects to obtain approval for the equipment from Brazilian health regulatory agencies.

Table 4

Orchestration – ELMO helmet network

Actor	Orchestration [Developing objectives (DO) + Promoting connections and collaboration (CC) + Developing and transforming resources (TR)+ Building and legitimizing identities (LI)]	Value	Level
1	• Determined the main objectives for other members of the work team (DO=3) • Assisted in the mobilization and engagement of professionals in tasks (CC= level 2) • Acted in the direct organization of the financial transfer and the identification of sectors for production (TR=level 3) • Intended the promotion and satisfaction of common well-being (LI=level 2) 10 High (III)	10	High (III)
2	• Considered a technical manager, he idealized the proposal for the helmet and worked to achieve the goals set by the group (level 3) • Coordinated the technical team and interconnected the other non-medical members and the main leaders (level 3) • Responsible for transferring intellectual resources between network members (level 3) • Responsible for the ideation process, testing and resource development, research and knowledge management (level 3) 12 High (III)	12	High (III)
3	• Responsible for establishing deadlines and command agendas with network actors as a whole (level 1) • Responsible for the link between the medical and physiotherapist teams with the other actors responsible for product development (level 2) • Proceeded with the development and adjustments of the product based on resource management and prototypes updating (level 3) • Perceived the team's motivation as something legitimate and linked to product development (level 2)	8	Medium (II)
4	• Acted directly in the connection between the agendas of the various institutions in the networks making the products (level 2) • Coordinated several SENAI teams and connected them with multidisciplinary teams (level 3) • Proceeded with the organization of SENAI's laboratories through shared management and proceeded with the interconnection of other team members (level 3) • Acted with a focus on providing a product that would help in the process of facilitating treatment and saving lives (level 1)	9	High (III)
5	• Actively worked in determining deadlines and events for the prototypes construction and ideation (level 1) • Established connections and programming with SENAI units to meet the needs of the medical team to create prototypes (level 3) • Acted in the transfer of resources and in granting the use of spaces and laboratories at SENAI (level 3) • Legitimacy arising from the process of co-creation of the final product from the joint action of several institutions (level 1)	8	Medium (II)
6	• Directed the objectives and the team to complete the tasks within the deadline established for the evolution of the tests (level 1) • Responsible for coordinating, with SENAI, the manufacture of helmets and maintenance of ventilators (level 2) • Acted in the readjustment, reuse and reverse engineering of components in the manufacture and maintenance of products (level 2) • Recognized in the commitment with the other members the legitimization of the purpose of the manufactured product (level 2)	7	Medium (II)
7	• Directed the team to complete the tasks within the deadline established for the evolution of the tests (level 1) • Acted as a leader and coordinator of teams in the development of activities and in the exchange of information between actors in the network (level 2) • Assisted in making the helmet and in the search for inputs for the development of initial prototypes (level 2) • Understood the legitimacy of his work from the importance of the product for the population (level 2)	7	Medium (II)

Continued on the next page

8	• Responsible for designing the helmet (level 1) • Coordinated the connection between the product design and the demands required by the multidisciplinary team (level 1) • Acted in the indication and direction to obtain products and inputs necessary for the production of the helmet (level 2) • Legitimacy arising from the process of co-creation of the final product from the joint action of several institutions (level 1)	5	Medium (II)
9	• No elements related to the development of objectives were identified (level 0) • Connected the teams with the resources and interests of the main managers (level 1) • Assistance in transferring and controlling resources for scholarship holders and raising other resources (level 2) • Understood that union and motivation were the most important elements of product construction (level 1)	4	Low (I)
10	• No elements related to the development of objectives were identified (level 0) • Coordinated the test teams and interconnected the laboratories and other test spaces with the other actors in the helmet adjustment process (level 1) • Mobilizer of the knowledge acquired during the process (level 1) • Perceived the team's motivation as something legitimate and linked to product development (level 2)	4	Low (I)
11	• Responsible for the helmet production schedule at the factory (level 1) • Coordinated the helmet manufacturing process and worked in the clean room (level 2) • Acted in the organization of situational leaders and in the collaboration of several companies to meet the demand for production inputs (level 2) • Committed to the development of a product aimed at saving lives (level 2)	7	Medium (II)
12	• Acted directly in the clinical testing of the device with participation in the alignment of care procedures (level 1) • Acted in coordinating the team of physiotherapists in the helmet research and support process (level 2) • Worked on product usability definitions, tests, and research (level 2) • Legitimacy was perceived based on the transfer of knowledge among professionals and acceptance of the product by society (level 2)	7	Medium (II)
13	• No elements related to the development of objectives were identified (level 0) • Responsible for training other teams in other states and organizing studies with teams based on clinical trials (level 2) • Worked on sharing content based on helmet use training in other units and institutions (level 2) • Understood that society's awareness legitimized the helmet (level 2)	6	Medium (II)
14	• No elements related to the development of objectives were identified (level 0) • Worked on adapting usability and clinical tests, in addition to cooperating with bureaucratic aspects for approval by ministerial bodies (level 2) • Acted in training other professionals in the use of helmets (level 1) • Legitimation is perceived as a multidisciplinary element that involves a collective commitment to the pursuit of results (level 1)	4	Low (I)
15	• Institutionalized procedures for instructing health professionals to use ELMO helmets (level 1) • Coordinated the instruction process of the various professionals involved with the use of helmets (level 3) • Participated in the process of developing booklets and notes that institutionalized the protocol of best practices regarding the use of ELMO helmets (level 2) • Perceived legitimacy with the formation of more comprehensive helmet-use instruction networks (level 2)	8	Medium (II)
16	• No elements related to the development of objectives were identified (level 0) • Assisted in coordinating the ELMO helmet use instruction process (level 2)	6	Medium (II)

Continued on the next

	• Participated in the process of developing booklets and notes that institutionalized the protocol of best practices regarding the use of ELMO helmets (level 2) • Perceived legitimacy with the formation of more comprehensive helmet-use instruction networks (level 2)		
17	• Promoted the insertion of ELMO helmets with the private sector and established control agendas over the learning and healing curve of patients (level 1) • Coordinated the implementation of the helmet with the private sector and carried out training and awareness of professionals regarding its effectiveness (level 3) • Passed on to the helmet development network technical aspects and adjustments arising from clinical experimentation (level 2) • Acted for the recognition and acceptance of the helmet with the private institution and other professionals (level 2)	8	Medium (II)
18	• No elements related to the development of objectives were identified (level 0) • No elements related to promoting connections and collaboration were identified (level 0) • No elements related to the development and transfer of resources were identified (level 0) • • Was a volunteer in the use of the helmet, legitimizing the collective action in the search for positive results (level 2)	2	Low (I)
19	• No elements related to the development of objectives were identified (level 0) • No elements related to promoting connections and collaboration were identified (level 0) • No elements related to the development and transfer of resources were identified (level 0) • Was a volunteer in the use of the helmet, legitimizing the collective action in the search for positive results (level 2)	2	Low (I)
20	• No elements related to the development of objectives were identified (level 0) • No elements related to promoting connections and collaboration were identified (level 0) • No elements related to the development and transfer of resources were identified (level 0) • Was a volunteer in the use of the helmet, legitimizing the collective action in the search for positive results (level 2)	2	Low (I)

Source: Elaborated by the authors based on Schepis et al. (2021)

The data display, prepared based on the actors' behavior in the orchestration process (Miles & Huberman, 2013; Schelpis et al., 2021), allowed us to establish connections between the actions performed and the required skills that actors needed to demonstrate. It was observed that the competency of building and legitimizing identities (LI) was more frequent, indicating a greater presence and consistent commitment, effort, and collective empowerment (Huxham & Vangen, 2000; Mele & Russo-Spena, 2015; Perks et al., 2017; Reypens et al., 2019; Reypens et al., 2016). On the other hand, the competency of developing objectives (DO) had the lowest frequency. This is because this category is associated with goal alignment, agenda setting, and design, which are typically attributed to those with institutional powers (Aarikka-Stenroos et al., 2017; Huxham & Vangen, 2000; Moller & Svahn, 2009; Perks et al., 2017; Reypens et al., 2019; Ritvala & Salmi, 2010).

Table 5 illustrates the relationship between the frequency of orchestration mechanisms and the actors, revealing that 30% of the actors had a low relevance in the orchestration process, 55% had a medium relevance in the process, and only 15% had a high relevance in the role of network orchestration. These actors assumed specific functions that significantly impacted the entire network.

Table 5

Data display of competencies in the orchestration process of actors in the network – ELMO Helmet

ACTOR [as identified in Figure 2]	Orchestration				Relevance
	DO	CC	TR	LI	
(1) Manager 1	HIGH	MEDIUM	HIGH	MEDIUM	HIGH
(2) Physician	HIGH	HIGH	HIGH	HIGH	HIGH
(3) Manager 2	LOW	MEDIUM	HIGH	MEDIUM	MEDIUM
(4) Manager 3	MEDIUM	HIGH	HIGH	LOW	HIGH
(5) Manager 4	LOW	HIGH	HIGH	LOW	MEDIUM
(6) Manager 5	LOW	MEDIUM	MEDIUM	MEDIUM	MEDIUM
(7) Manager 6	LOW	MEDIUM	MEDIUM	MEDIUM	MEDIO
(8) Designer	LOW	LOW	MEDIUM	LOW	MEDIUM
(9) Manager 7	NOT IDENT.	LOW	MEDIUM	LOW	LOW
(10) Technology specialist	NOT IDENT.	LOW	LOW	MEDIUM	LOW
(11) Product specialist	LOW	MEDIUM	MEDIUM	MEDIUM	MEDIUM
(12) Physiotherapist 1	LOW	MEDIUM	MEDIUM	MEDIUM	MEDIUM
(13) Physiotherapist 2	NOT IDENT.	MEDIUM	MEDIUM	MEDIUM	MEDIUM
(14) Physiotherapist 3	NOT IDENT.	MEDIUM	LOW	LOW	LOW
(15) Physiotherapist and Institutional Coordinator	LOW	HIGH	MEDIUM	MEDIUM	MEDIUM
(16) Physiotherapist and Instructor	NOT IDENT.	MEDIUM	MEDIUM	MEDIUM	MEDIO
(17) Physiotherapist and Manager	LOW	HIGH	MEDIUM	MEDIUM	MEDIO
(18) Volunteer 1	NOT IDENT.	NOT IDENT.	NOT IDENT.	MEDIUM	LOW
(19) Volunteer 2	NOT IDENT.	NOT IDENT.	NOT IDENT.	MEDIUM	LOW
(20) Volunteer 3	NOT IDENT.	NOT IDENT.	NOT IDENT.	MEDIUM	LOW

Source: Elaborated by the authors

Orchestration and the actors' positioning in the network

The findings indicate that although the actors possessed skills that aided in the process of network integration, their levels of orchestration varied. Some actors excelled in the orchestration process, while others had a more limited involvement.

A similar pattern can be observed in the socialization process of the network, as reflected in the degrees of interaction and integration among actors. It is notable that the actors who excelled in orchestration did not always have high levels of interaction and/or integration. This can be attributed to the fact that these actors did not necessarily need to establish direct connections with every other network member for their role in the

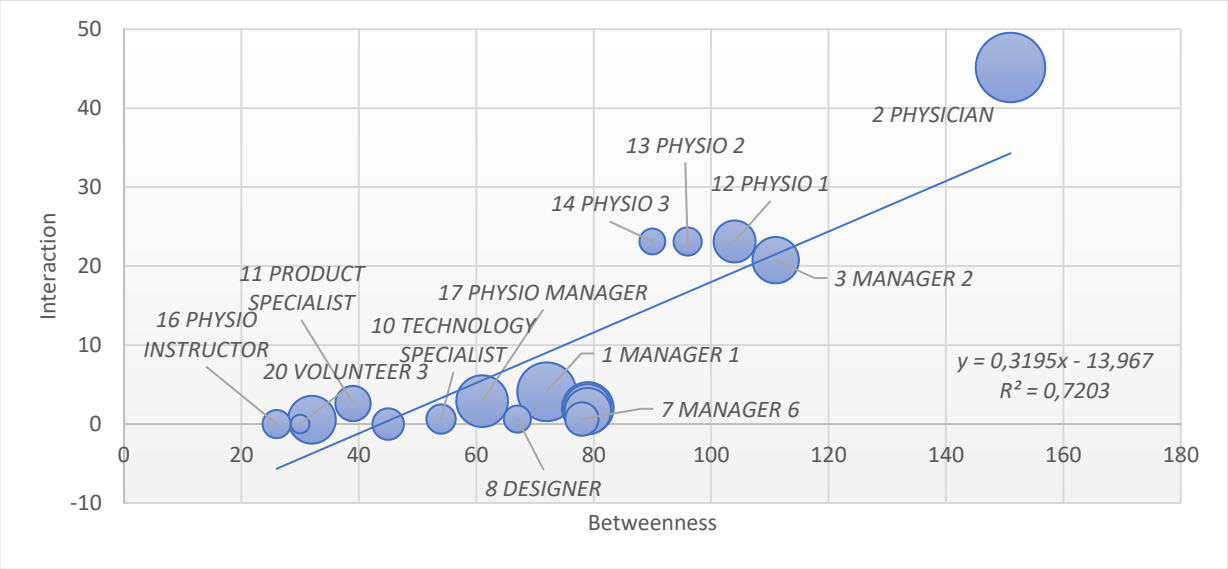
orchestration to be considered significant. Instead, they relied on other actors who held more central positions in the process to act as intermediaries and facilitate connections. An example of such a central actor who played a facilitator role on multiple fronts is actor (2) Physician, who demonstrated high interaction, integration, and orchestration rates.

The actors who did not receive as much recognition in terms of orchestration, such as technicians, for instance, but showed higher prominence in the analysis of the network's socialization, did so because of their active engagement in interacting with other members to find suitable solutions to their problems. This dynamic highlights the flow of the innovation network and sheds light on elements that contribute to the characterization of orchestration.

In this regard, Figure 4 illustrates the relationship between three variables: interaction, betweenness, and orchestration in the network. The figure demonstrates a positive correlation between interaction and integration within the network, leading to actors who exhibit high levels of orchestration (represented by the size of the circles).

Figure 4

Relationship between interaction, betweenness, and orchestration of actors in the ELMO helmet network



Source: Elaborated by the authors

However, despite this positive relationship, certain actors exhibited high levels of orchestration but lower levels of interaction and betweenness. These actors played strategic roles, focusing on centralized actions, commands, and directions, rather than direct socialization. They delegated tasks and responsibilities to other actors who took on more interactive roles within the network. This is exemplified by actors (1) Manager 1 and (2) Physician, who, despite their significant orchestration levels, demonstrated distinct levels of interaction and betweenness, as depicted in Figure 4.

Therefore, the high rates of centralization, betweenness, and interaction in the network can be considered driving factors for network orchestration. The positioning of these actors can influence the dynamics of the innovation network orchestration process.

Final considerations

Based on the analyzed data, it can be concluded that the orchestration process was a systematic and collaborative experience, involving active participation from all members in the product development, albeit to varying degrees. This collaborative effort led to the optimization of dynamics throughout the process, making decision-making easier and enabling the establishment of objectives and goals by institutional managers. Although communication between actors was not unlimited, information was effectively transmitted and reached everyone in a timely manner, even considering the constraints imposed by the COVID-19 pandemic.

It was observed that while there was no formally established hierarchy within the network, the actors recognized the existence of strategic levels of action. They attributed legitimacy to these levels and sought support for their actions accordingly. Institutional managers, who set the agenda of objectives, were perceived as occupying higher levels of authority. The roles performed by these managers were crucial in providing financial, technical, material, logistical, and legal support to the network.

Regarding leadership within the process, one actor emerged as a standout, demonstrating high levels of orchestration in all measured mechanisms. This actor assumed the role of coordinator and supervisor, gaining authority and influence over the other members. Notably, the network's success was not solely dependent on all actors being highly involved in the orchestration process. Despite variations in individual levels of relevance, the presence of trust and engagement among the actors played a significant role in minimizing conflicts of interest and multisectoral conflicts. As a result, the process was able to proceed smoothly.

As a theoretical contribution, this study provides a framework for understanding the dynamics of network orchestration, particularly in crises. The identified elements in Figure 1 shed light on the factors influencing the orchestration process within an innovation network. Additionally, this research contributes to the existing literature by reinforcing the positive relationship between integration, betweenness, and orchestration of actors within innovation networks.

From a managerial perspective, this study offers insights for managers involved in similar networks. It emphasizes the importance of employing management techniques that foster the engagement of multi-distributed leaders within the network. This can be achieved through building trust in the skills and roles of each participant, ultimately promoting effective orchestration.

This research acknowledges certain limitations that need to be considered when interpreting its findings. The scope and generalizability of the findings are limited to the specific case of orchestration analyzed, which is influenced by the research context and specific objectives. Thus, future studies could explore network orchestration processes in different social and economic contexts that are not specifically related to crises. Additionally, conducting a comprehensive analysis of the orchestration process, including the variables that

shape it and its impact as public policy drivers, would provide valuable insights for future research.

AUTHORS' CONTRIBUTIONS

Contribution	Torres Jr., P.	Câmara, S. F.	Mota, T. L. N.
Contextualization	X	X	X
Methodology	X	X	X
Software	----	----	----
Validation	X	X	X
Formal analysis	X	X	X
Investigation	X	X	X
Resources	----	----	----
Data curation	X	X	X
Original	X	----	----
Revision and editing	X	X	X
Viewing	X	X	X
Supervision	----	X	----
Project management	----	X	X
Obtaining funding	----	----	----

REFERENCES

Andersén, J., & Ljungkvist, T. (2021). Resource orchestration for team-based innovation: a case study of the interplay between teams, customers, and top management. *R and D Management, 51(1),* 147–160. https://doi.org/10.1111/radm.12442

Aarikka-Stenroos, L., Jaakkola, E., Harrison, D., & Mäkitalo-Keinonen, T. (2017). How to manage innovation processes in extensive networks: A longitudinal study. **I***ndustrial Marketing Management,* 67, 88–105. https://doi.org/10.1016/j.indmarman.2017.09.014

Bell, Martin; Pavitt, Keith. (1993).Technological accumulation and industrial growth: contrast between developed and developing countries. *Industrial and Corporate Change,* v. 2, n. 1, p. 157-210. https://doi.org/10.1093/icc/2.2.157

Bell, Martin; Pavitt, Keith. (1995). The development of technological capabilities. *In: Haque,*

Irfan et al. (Coord.). Trade, technology and international competitiveness. Washington: The World Bank.

Borgatti, S.P., Cross, R. (2003). A relational view of information seeking and learning in social networks. *Manag. Sci*. 49, 432–445.

Brasil, Sistema Único de Saúde - SUS. (2022). Disponível em: https://sus.ce.gov.br/elmo/o-que-e/ Acesso em 16/07/22.

Câmara, S. F., & Brasil, A. (2015). A coevolução entre políticas públicas/instituições e o desenvolvimento tecnológico: o caso da Petrobras Biocombustível. *Revista de Administração Pública, 49*(6), 1453–1478. https://doi.org/10.1590/0034-7612136192

Cankurtaran, P., & Beverland, M. B. (2020). Using design thinking to respond to crises: B2B lessons from the 2020 COVID-19 pandemic. *Industrial Marketing Management, 88*(June), 255–260. https://doi.org/10.1016/j.indmarman.2020.05.030

Creswell, J. W., (2007). Projeto de pesquisa: método qualitativo, quantitativo e misto. tradução de Luciana de Oliveira Rocha. 2ª ed. Porto Alegre: Artmed.

Dagnino, G. B., Levanti, G., & Mocciaro Li Destri, A. (2016). Structural dynamics and intentional governance in strategic interorganizational network evolution: A multilevel approach. *Organization Studies,* 37(3), 349–373. https://doi.org/10.1177/0170840615625706

Dhanaraj, C., & Parkhe, A. (2006). Orchestrating innovation networks. **A***cademy of Management Review***,** 31, 659–669. http://www.jstor.org/stable/20159234

Dahlke, J., Bogner, K., Becker, M., Schlaile, M. P., Pyka, A., & Ebersberger, B. (2021). Crisis-driven innovation and fundamental human needs: A typological framework of rapid-response COVID-19 innovations. *Technological Forecasting and Social Change, 169*, 120799. https://doi.org/10.1016/j.techfore.2021.120799

Figueiredo, PN. N. (2003). Learning, capability accumulation and firms differences: evidence

from latecomer steel. *Industrial and Corporate Change*, v. 12, n. 3, p. 607-643. http://hdl.handle.net/10438/23035

Figueiredo, Paulo N. (2010). Discontinuous innovation capability accumulation in latecomer natural resource-processing firms. *Technological Forecasting and Social Change,* v. 77, n. 7, p. 1090-1108. https://doi.org/10.1016/j.techfore.2010.02.004

Figueiredo, Paulo N. (2008). Industrial policy changes and firm-level technological capability development: evidence from Northern Brazil. *World Development*, v. 36, n. 1, p. 55-88. https://doi.org/10.1016/j.worlddev.2007.02.009

Geurts, A., Geerdink, T., & Sprenkeling, M. (2022). Accelerated innovation in crises: The role of collaboration in the development of alternative ventilators during the COVID-19 pandemic. *Technology in Society*, *68*(December 2020), 101923. https://doi.org/10.1016/j.techsoc.2022.101923

Hanneman, R. A. Propiedades básicas de las redes y de los actores. In: Hanneman, R. A. *Introducción a los métodos del análisis de redes sociales*. Departamento de Sociología de la Universidad de California Riverside, 2002b

Hartley, D. M., Keck, C., Havens, M., Margolis, P. A., & Seid, M. (2021). Measuring engagement in a collaborative learning health system: The case of ImproveCareNow. *Learning Health Systems, 5*(2), 1–9. https://doi.org/10.1002/lrh2.10225

Heinrich, T., & Yang, J. (2022). Innovation in times of Covid-19. arXiv preprint arXiv:2212.14159.(Zhang, 2019). https://doi.org/10.48550/arXiv.2212.14159

Huxham, C., & Vangen, S. (2000). Leadership in the shaping and implementation of collaboration agendas: How things happen in a (not quite) joined-up world. *Academy of Management Journal,* 43, 1159–1175. https://doi.org/10.2307/1556343

Lievens, A., & Blažević, V. (2021). A service design perspective on the stakeholder engagement journey during B2B innovation: Challenges and future research agenda.

Industrial Marketing Management, *95*(October 2020), 128–141. https://doi.org/10.1016/j.indmarman.2021.04.007

Linde, Lina et al. (2021). Dynamic capabilities for ecosystem orchestration A capability-based framework for smart city innovation initiatives. *Technological Forecasting and Social Change,* v. 166, p. 120614. https://doi.org/10.1016/j.techfore.2021.120614

Meissner, Dirk; Kotsemir, Maxim. (2016). Conceptualizing the innovation process towards the 'active innovation paradigm'—trends and outlook. *Journal of Innovation and Entrepreneurship*, v. 5, n. 1, p. 1-18. https://doi.org/10.1186/s13731-016-0042-z

Mele, C., & Russo-Spena, T. (2015). Innomediary agency and practices in shaping market innovation. *Industrial Marketing Management,* 44, 42–53. https://doi.org/10.1016/j.indmarman.2014.10.006

Miles, M. B.; Huberman, A. Michael. (2013). *Qualitative data analysis: An expanded sourcebook*. 3 ed. sage.

Moller, ¨ K., & Svahn, S. (2009). How to influence the birth of new business fields—Network perspective. *Industrial Marketing Management*, 38(4), 450–458. https://doi.org/10.1016/j.indmarman.2008.02.009

Netz, J., Reinmoeller, P., & Axelson, M. (2022). Crisis-driven innovation of products new to firms: the sensitization response to COVID-19. *R and D Management*, *52*(2), 407–426. https://doi.org/10.1111/radm.12522

Oliveira, M. M de. (2010). *Como fazer pesquisa qualitativa.* 6. ed. Petrópolis, RJ: Vozes

Pan, Shan L.; Cui, Miao; Qian, Jinfang. (2020). Information resource orchestration during the COVID-19 pandemic: A study of community lockdowns in China. *International journal of information management,* v. 54, p. 102143. https://doi.org/10.1016/j.ijinfomgt.2020.102143

Paquin, R. L., & Howard-Grenville, J. (2013). Blind dates and arranged marriages:

Longitudinal processes of network orchestration. *Organization Studies*, 34(11), 1623–1653. https://doi.org/10.1177/0170840612470230

Perks, H., Kowalkowski, C., Witell, L., & Gustafsson, A. (2017). Network orchestration for value platform development. *Industrial Marketing Management*, 67, 106–121. https://doi.org/10.1016/j.indmarman.2017.08.002

Phillips, W., Roehrich, J. K., & Kapletia, D. (2023). Responding to information asymmetry in crisis situations: innovation in the time of the COVID-19 pandemic. *Public Management Review*, *25*(1), 175–198. https://doi.org/10.1080/14719037.2021.1960737

Protasiewicz, A. (2021). Implications of the COVID-19 Crisis on the Creation of Innovations-Assessment Attempt. *Studies in Logic, Grammar and Rhetoric*, *66*(4), 483–495. https://doi.org/10.2478/slgr-2021-0027

Pyka. A & G. Kuppers (2002). *Innovation Networks: Theory and practice.* Edward Elgar, Cheltenham.

Reypens, C., Lievens, A., & Blazevic, V. (2016). Leveraging value in multi-stakeholder innovation networks: A process framework for value co-creation and capture. *Industrial Marketing Management,* 56, 40–50. https://doi.org/10.1016/j.indmarman.2016.03.005

Ritala, P., Armila, L., & Blomqvist, K. (2009). Innovation orchestration capability - Defining the organizational and individual level determinants. *International Journal of Innovation Management, 13*(4), 569–591. https://doi.org/10.1142/S136391960900242X

Reypens, C; Lievens, A; Blazevic, V. (2021). Hybrid Orchestration in Multi-stakeholder Innovation Networks: Practices of mobilizing multiple, diverse stakeholders across organizational boundaries. *Organization Studies*, v. 42, n. 1, p. 61-83.

https://doi.org/10.1177/0170840619868268

Ritala, P; Armila, L; Blomqvist, K. (2009). Innovation orchestration capability—Defining the organizational and individual level determinants. *International Journal of Innovation Management*, v. 13, n. 04, p. 569-591. http://dx.doi.org/10.1142/S136391960900242X

Ritvala, T., & Salmi, A. (2010). Value-based network mobilization: A case study of modern environmental networkers. *Industrial Marketing Management,* 39(6), 898–907. https://doi.org/10.1016/j.indmarman.2010.06.009

Roloff, J. (2008). Learning from multi-stakeholder networks: Issue-focussed stakeholder management. *Journal of Business Ethics*, 82, 233–250. https://doi.org/10.1007/s10551-007-9573-3

Schepis, D., Ellis, N., & Purchase, S. (2018). Exploring strategies and dynamic capabilities for net formation and management. *Industrial Marketing Management,* 74, 115–125. https://doi.org/10.1016/j.indmarman.2017.09.023

Schepis, D., Purchase, S., & Butler, B. (2021). Facilitating open innovation processes through network orchestration mechanisms. *Industrial Marketing Management, 93*(July 2019), 270–280. https://doi.org/10.1016/j.indmarman.2021.01.015

Schotter, A. (2021). Resilient or not: boundary-spanning in innovation focused MNEs during global crises. *critical perspectives on international business.* https://doi.org/10.1108/cpoib-05-2020-0037

Shazi, R., Gillespie, N., & Steen, J. (2015). Trust as a predictor of innovation network ties in project teams. *International Journal of Project Management***,** *33*(1), 81–91. https://doi.org/10.1016/j.ijproman.2014.06.001

Skardon, J. (2011). The role of trust in innovation networks. *Procedia - Social and Behavioral Sciences***,** *26*, 85–93. https://doi.org/10.1016/j.sbspro.2011.10.565

Teece, D. J. (2000). Managing intellectual capital: Organizational, strategic, and policy dimensions. London: Oxford University Press

Teixeira, J. C., Nascimento, M. C. R., & Carrieri, A. de P. (2012). Triangulação entre meátodos na administração: Gerando conversações paradigmaáticas ou meras validações "convergentes"? *Revista de Administracao Publica*, *46*(1), 191–220.

Tidd, J., Bessant, J., Pavitt, K. (2008). *Gestão da inovação*. 3. Ed. Porto Alegre: Bookman.

Wei, X., Liu, R., & Lin, Z. (2023). "Crisis" or "opportunity"? COVID-19 pandemic's impact on environmentally sound invention efficiency in China. *Frontiers in Public Health*, *10*(2). https://doi.org/10.3389/fpubh.2022.1102680

Vergara, S. C. (2014). Projetos e Relatórios de Pesquisa em Administração. São Paulo: Atlas.

Zhang, S. (2019). Public participation in the Geoweb era: Defining a typology for geo-participation in local governments. *Cities*, *85*, 38–50. https://doi.org/10.1016/j.cities.2018.12.004