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2024

Wood 4 Sustainability

Processing, Construction, Products and Design

2024

Főszerkesztő: Dr. Csiha Csilla

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Smart Network: The Role of Meta-Organizational Networks in the Sustainability-Digital Transition

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ABSTRACT
"Without the perspective offered by networks, it is impossible to understand the interconnected and complex world we live in today," stated Albert-László Barabási. The study of network topology, degree distribution, and dynamics has led to the discovery of scale-free networks. Using network science, the potential of efficient connectivity is leveraged in organizational development to analyze both internal organizational structures - internal networks - and inter-organizational, corporate - external - networks. However, examining multi-sided platforms offers an even broader perspective: the meta-organization refers to one of today's central phenomena - the growing importance of collective action at the inter-organizational level, which stems from key issues related to sustainable development and corporate responsibility. Although various business associations have long existed, their numbers have dramatically increased, their forms have significantly diversified, and only recently have they been identified as meta-organizations. Their diversity and heterogeneity raise methodological questions that require novel approaches since the rules governing individual-based organizations do not apply to them. This study, through systematic literature research, explores the role of meta-organizations in the sustainability-digital transition, the methodological challenges in analyzing them, and proposes future research directions related to meta-organizations. The study's key focus lies in dynamics, efficiency, and utility, as well as internal and external interactions.

Keywords: meta-organization, smart network, coopetition, sustainability, Industry, innovation and infrastructure

1. Introduction

Objective: In the modern economy, the sustainability and digital transitions present complex challenges that require innovative organizational models for their resolution. The goal of this research is to demonstrate how the concept of meta-organizational networks can be integrated within the context of sustainability and digitalization. Meta-organizational models offer an opportunity for decentralized, networked organizations to collaborate effectively, thereby supporting sustainable resource utilization and accelerating the adoption of digital solutions.

Background: Over the past decades, network science has become a key domain in understanding complex systems. The theory of scale-free networks developed by Albert-László Barabási and Réka Albert (Barabási & Albert, 1999) highlighted that the structural patterns of complex systems can efficiently facilitate information flow and innovation. Applying these principles in organizational and societal contexts - such as through the formation of meta-organizations - has opened new perspectives in the fields of sustainable development and digitalization (Ahrne & Brunsson, 2005, 2008).
The central question of this research is how meta-organizational networks can support the sustainability and digital transition, and how these organizations contribute to sustainable resource management, accelerating innovation, and integrating digital technologies.

Methodology: This study employs systematic literature research, analyzing nearly 30 relevant scientific sources from diverse fields such as network science, organizational studies, and digital transition. The primary sources include academic journals such as the *Scandinavian Journal of Management* and the *Journal of Public Administration Research and Theory*.
The analysis adopts a qualitative approach, aiming to gain a deeper understanding of the theoretical foundations and practical applications of meta-organizational models.

2. Network Science, Network Management, and Efficient Connectivity

2.1. Topology and Dynamics of Networks

The concept of scale-free networks was introduced in the seminal work of Albert-László Barabási and Réka Albert in 1999, which opened new perspectives on understanding the organizational patterns of complex systems (Barabási & Albert, 1999). Their research revealed that many large-scale networks, such as the Internet, biological systems, and social interactions, are not organized randomly but follow a power-law degree distribution. This means most nodes have relatively few connections, while a small number of nodes - so-called "hubs" or "strong nodes" - have a disproportionately large number of connections, playing a critical role in the network's functionality (Albert & Barabási, 2002). The growth model of scale-free networks is based on two key mechanisms: growth and preferential attachment. The growth mechanism posits that networks expand over time as new nodes are added and connect to existing nodes. Preferential attachment suggests that new nodes are more likely to connect to nodes that already have a higher number of connections. This process follows the "rich-get-richer" principle and fundamentally shapes the network's topological structure (Barabási, 2009). One of the most important characteristics of scale-free networks is their robustness and vulnerability. These networks are highly resilient to random node failures, as the network remains functional even when low-degree nodes are removed. However, such systems are significantly vulnerable to targeted attacks on the "hubs." These attacks can destabilize the entire network, as hubs are central to the system's connectivity patterns (Barabási, 2009; Albert & Barabási, 2002).

From the perspective of information flow and dynamic behavior, scale-free networks exhibit outstanding efficiency. Due to the structure of these networks, information such as data or signals can reach most parts of the network through short paths. This same dynamic characteristic explains why viruses or other infectious processes can spread so effectively in these systems; the "hubs" or "strong nodes" are directly or closely connected to the entire network (Barabási & Albert, 1999). The application of scale-free networks is widespread and observable across various fields. In biological systems, for instance, gene regulatory networks also exhibit scale-free structures, enabling the efficient operation of biological processes (Barabási & Oltvai, 2004). Technological systems, such as the Internet or social media, follow similar network patterns, where the efficient distribution of information is a critical factor. Likewise, social systems, such as supply chains and economic networks, adhere to the same structure, promoting efficient resource management and communication (Newman, 2003). Future research aims to develop new models that account for the heterogeneity and dynamic changes emerging during network evolution (Cohen & Havlin, 2002).

2.2. Efficient Connectivity

The efficiency of connectivity plays a crucial role in organizational development, particularly in the era of digital transition and global competitiveness. Both internal and external network operations contribute to the stability and adaptive capacity of organizational structures, determining organizational resilience and innovation potential. To enhance the efficiency of internal networks, integrating digital platforms has become an essential factor. In their study, Li and Lou (2024) demonstrated that the use of digital platforms strengthens relationships between internal and external stakeholders, facilitating information flow and fostering innovation. Such platforms not only increase efficiency but also improve the quality of interactions among diverse stakeholders, such as companies and other groups. In external networks, inter-organizational collaboration also significantly impacts connectivity efficiency. According to the studies of Nasiri, Moradi, and Khodayari (2024), the integration of supply chains through the application of enterprise management systems enables effective coordination between internal and external processes. This approach is particularly critical in the fast-moving consumer goods industry, where process optimization and timely delivery are vital. On a smaller scale, Neronov, Pliekhova, and Kostikova (2024) concluded that the use of distributed computing systems enhances network stability and adaptability. The application of such networks is especially important for processing large volumes of data and ensuring rapid responsiveness. In their study, Vaezi and Aslipour (2024) illustrated, using examples of public institutions and the delivery of essential goods, how institutional capacity affects the efficiency of organizational relationships. The study emphasized that institutional flexibility and the integration of external factors are indispensable for sustainable operation. In summary, to improve connectivity efficiency, organizations must balance the development of internal networks with the optimization of external relationships. The integration of information technologies and innovative solutions can increase the efficiency of organizational processes while supporting sustainable development.

2.3. Digital Transition and Networks: The Impact of Digital Technologies on Connectivity

The rapid development of digital technologies has brought profound changes to the operation of corporate and intercorporate networks, particularly in terms of connectivity efficiency. The digital transition provides opportunities for companies to restructure their internal and external networks, maximizing the speed of information flow and the efficiency of collaboration. Tong and Yang (2024) found in their empirical analysis that fintech innovations enable the automation of corporate financial processes and the optimization of customer relations. Through the integration of digital platforms, financial service networks achieve closer collaboration between providers and customers, thereby increasing the efficiency and profitability of corporate networks. Another area where digital technologies significantly impact connectivity in corporate networks is supply chain management. Ding and colleagues (2024) highlighted that optimizing the charging infrastructure for electric vehicles allows companies to manage energy resources more effectively while maintaining the stability of transportation networks. This approach demonstrates that the digitization of corporate infrastructure not only improves the internal processes of individual companies but also contributes to the more sustainable operation of broader economic networks. Media companies' networks are also undergoing significant transformation through the introduction of digital technologies. Knuth et al. (2024) pointed out that the diversity of relationships between news consumption and media platforms has increased network concentration among companies. Simultaneously, the digital transition has created new opportunities for companies to disseminate information more rapidly and optimize collaboration across platforms. The pharmaceutical and R&D sectors similarly benefit from the opportunities offered by digital networks. Hao and colleagues (2024) showed that the application of digital data processing technologies and artificial intelligence has opened new avenues for research collaborations. Digital networks facilitate the faster sharing of research findings and support innovation processes among companies.

Overall, the digital transition significantly impacts corporate network connectivity on both internal and external levels. New digital solutions allow companies to build more efficient networks, resulting in faster decision-making, higher levels of customer service, and more resilient competitive advantages. However, digitalization also introduces new challenges, such as data protection and infrastructure flexibility, which must be addressed as part of a successful transition.

3. Organizational Structure and Internal Network Analysis

3.1. Applying Network Principles Internally: Contributions to Organizational Efficiency

Organizational structure and internal network analysis are closely related to corporate efficiency, particularly in modern organizations where optimizing complex relational networks is of paramount importance. Applying network principles provides an opportunity to make internal connections more transparent and efficient. Li and Lou (2024) emphasized in their study that during the digital transformation, the restructuring of modern organizational structures significantly enhances institutional efficiency and governance capabilities. Optimizing internal networks plays a particularly important role in supporting innovation activities, as transparent network nodes facilitate the flow of information and reduce resource redundancies. Fathali and Ghiyasi (2024) examined how the network structures of internal production units influence organizational performance. They found that network analysis tools, such as spatial allocation analysis, not only enable more efficient resource utilization but also offer opportunities to reevaluate institutional capacities. Azodi and colleagues (2024) noted that relationships between nodes identified through network analysis have a direct impact on management efficiency. Strong relational nodes support rapid decision-making, while identifying weak points allows for fine-tuning organizational strategies. Examining internal institutional networks thus simultaneously increases operational and strategic efficiency.

Wen et al. (2024) highlighted that optimizing internal networks plays a crucial role in ensuring sustainable development in economic institutions. According to their analysis, the application of network principles clearly improves the quality of internal connections and supports organizational knowledge management, which is essential for innovation.

3.2 Case Studies: The Relationship Between Organizational Structure and Product-Service Systems

The transformation and networking of organizations, along with the integration of product-service systems (PSS), have been the focus of numerous studies in recent years. These studies highlight how changes in organizational structures contribute to the success of PSS, emphasizing the fundamental role of network building and collaboration. Reim, Parida, and Örtqvist (2015) reviewed business models of product-service systems, noting that their implementation often depends on collaboration between companies and their network partners. Their findings reveal that successful PSS implementation requires the adaptation of organizational processes and the establishment of flexible structures. Such systems facilitate more efficient resource utilization, supporting sustainability goals. Martinez et al. (2010) examined the challenges of manufacturing organizations transitioning into product-service (PS) providers. They found that rigid organizational structures can hinder changes, whereas more flexible models enable rapid adaptation and the exploitation of new market opportunities.

Developing internal capacities and strengthening partnerships are essential for successful transformation. Clegg et al. (2017) presented a case study of a small and medium-sized enterprise (SME) that became a PSS provider encompassing multiple organizations. Their analysis emphasized that the success of such transformations lies in strengthening supplier and customer relationships while also adapting internal organizational processes to the new business model. Raddats and Burton (2011) explored how service-oriented strategies modify the structures of product-focused companies. They found that new strategies increase organizational complexity but also create opportunities for more efficient resource allocation and improved competitiveness. Matschewsky and Kambanou (2018) noted that designing PSS often requires companies to manage network relationships and adapt business models. According to their results, successful implementation depends on enhancing collaboration with network partners. Lerch and Gotsch (2015) investigated the role of digital PSS, which allows manufacturing companies to forge closer connections with their customers. They found that integrating digital solutions improves servi-ce quality but also demands significant organizational changes. Vendrell-Herrero and Bustinza (2021) highlighted the role of information technologies in PSS innovation. They concluded that IT tools not only enhance data management but also support the development of decentralized organizational structures, promoting agility. Finally, Gaiardelli et al. (2021) examined the impact of Industry 4.0 on the evolution of PSS. Their findings showed that digitalization and smart technologies enable the efficient operation of complex product-service systems, while organizational and network structures undergo significant transformation.

4. Corporate Networks, Inter-Organizational Network Analysis, and Multi-Sided Platforms

Multi-sided platforms play a pivotal role in the modern economy, but managing interactions among diverse stakeholder groups remains a challenge. Platforms like Uber, Airbnb, and similar digital ecosystems have fundamentally reshaped the dynamics of economic operation and stakeholder collaboration. These innovative business models connect various groups within a single technological framework, facilitating value creation and efficient resource allocation. Below, the topic is explored from three main perspectives.

4.1. Role of Multi-Sided Platforms: Examples from Uber, Airbnb, and Other Digital Ecosystems

Multi-sided platforms create value by connecting diverse groups - such as users, service providers, and external partners - within a single digital space. For example, Uber has revolutionized the transportation sector by simplifying the connection between demand and supply through a centralized technological system. Airbnb has made it easier for property owners and renters to connect, leveraging existing real estate capacity. These ecosystems reduce transaction costs and offer more flexible business models. Their value lies largely in data processing and analysis, enabling the identification of demand patterns, service optimization, and enhanced customer experiences. For instance, Uber uses real-time data to optimize routes, while Airbnb improves service quality through user feedback.

4.2. Connection to Sustainability: The Role of Digital Platforms in Promoting Sustainable Development

Multi-sided platforms contribute to sustainable development by enabling more efficient resource use. Uber and Airbnb illustrate how underutilized assets can be leveraged. Uber increases car utilization, reducing the number of vehicles on the road and mitigating environmental impact. Airbnb allows existing residential properties to be utilized without the need for new hotel construction, alleviating urban pressure. Moreover, platforms can promote circular economy principles, prioritizing resource recycling and reuse. For example, platforms like Poshmark and Vinted enable the resale of used clothing and goods, supporting sustainable consumption patterns. Data-driven operations help measure environmental impacts and develop strategies for their reduction.

4.3. Challenges and Opportunities: Managing Interactions Among Diverse Stakeholder Groups

The primary challenge of multi-sided platforms is managing interactions among stakeholder groups. For instance, Uber must balance the expectations of drivers, passengers, and regulatory authorities. Platforms often encounter difficulties reconciling diverse interests, particularly regarding the equitable distribution of resources and revenue. Building trust is crucial for the success of these platforms. Airbnb, for example, has invested heavily in implementing a user review system to enhance transparency and reduce risks. However, regulatory issues such as taxation and labor compliance remain significant challenges. Opportunities include strengthening stakeholder collaboration and advancing technological solutions. AI-based systems, for example, can help maintain balance among stakeholder groups by using real-time data to support decision-making. Initiatives like Uber Green, which encourages the use of electric vehicles, showcase how platforms can become leaders in sustainability.

5. The Meta-Organizational Model

The meta-organizational model has become increasingly significant in organizational research over the past two decades, particularly in understanding networked operations and decentralized organizational forms. This approach uncovers new dimensions of organizational efficiency and interactions that transcend traditional hierarchical structures.

5.1. Definition and Background: The Emergence of the Meta-Organization Concept

The concept of meta-organizations was introduced by Ahrne and Brunsson (2005, 2008) and refers to organizational structures that integrate other organizations rather than relying on individuals or workgroups. These organizations operate not through hierarchy but by fostering collaboration and regulation. Examples include industrial associations, standardization bodies, and networked platforms like ISO or Fair Trade organizations. According to the theory developed by the authors, the purpose of meta-organizations is to facilitate cooperation among their members (other organizations) while preserving their autonomy. Meta-organizations establish rules, standardize processes, and ensure coordinated use of resources without exerting direct control over their members.

5.2. Methodological Challenges: Differences from Individual-Based Organizational Analysis

Research on meta-organizations fundamentally differs from studies of individual-based organizations, as the focus shifts from individual relationships to inter-organizational interactions. This presents methodological challenges, particularly in data collection and analysis for inter-organizational networks. The study of meta-organizations requires careful attention to the balance between member autonomy and central coordination. Analyses must consider the individual goals of the member organizations as well as the collective benefits generated by the meta-organization. Network analysis methods and qualitative approaches are frequently used to explore collaboration dynamics (Provan & Kenis, 2008).

Additionally, meta-organizational research integrates institutional theories and findings from network studies to understand how standards emerge and consensus is achieved among members. A key challenge in these analyses lies in managing data complexity and the multilayered nature of interactions.

6. Summary and Future Research Directions

6.1. Coopetition and the Strength of Networked Organizational Models

The research highlights the significant potential of meta-organizational models in achieving sustainability and digital transitions. These models enable diverse organizations to collaborate effectively towards shared goals while maintaining their autonomy. The decentralized, networked operation of meta-organizations facilitates more sustainable resource management, accelerates innovation, and promotes the broader adoption of digital technologies. Real-to-Virtual / Virtual-to-Real (R2V) platforms exemplify how meta-organizational models support sustainability and the circular economy. These platforms enable seamless interaction between virtual and physical dimensions, allowing for tracking, recycling, and optimized resource use. By fostering collaboration among various organizations, R2V systems enhance material recycling and improve transparency in value chain operations. Such systems play a vital role in reducing waste and maximizing resource efficiency. Meta-organizational networks also integrate digital technologies, such as IoT and AI, which serve as the foundation for data-driven decision-making. These systems ensure that collaborating organizations can respond more quickly to changing market and environmental conditions, such as optimizing energy use, reducing the carbon footprint of operations and logistics, and improving the local distribution of resources. A critical component of meta-organizational models is coopetition, the balance of competitive and cooperative organizational behavior. This approach is particularly effective in digital platforms and sustainability innovations, where organizations can share resources and technologies without compromising their market positions. This enables the development of closed-loop economic models, where waste is minimized and transformed into valuable resources for other organizations. The findings also suggest that meta-organizational models hold further innovation potential, especially in emerging areas such as renewable energy, green technologies, and sustainable urban development. Networked collaborations integrate expertise and resources from various disciplines, forming the basis for multidisciplinary approaches.

6.2. Future Research: Examining Dynamics, Efficiency, and Internal-External Interactions

Future research should develop methodologies to support the practical implementation of meta-organizational models. Special attention should be given to building trust and enhancing digital infrastructure to facilitate information flow and collaboration. Advancing network analysis methods, such as modeling interaction dynamics and monitoring preferential attachments, can provide valuable tools for optimizing stakeholder relationships.

Research should also focus on mechanisms that drive innovation, particularly in industries aligned with sustainability goals, such as renewable energy and the circular economy.

Introducing AI-based systems and automated decision-making processes is another promising area, which could enhance the efficiency of meta-organizational operations. Lastly, future studies should adopt an interdisciplinary approach that combines insights from network science, institutional theory, and technological innovation.

This will enable a deeper understanding of meta-organizational models and contribute to their effective application in the realms of sustainability and digital transitions.

Author statement

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