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Unleashing the power of the 4IR in organisational value chains: A conceptual analysis

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Background: The Fourth Industrial Revolution (4IR) has transformed value chains across various industries. However, there is still a lack of knowledge on how to effectively utilise 4IR technologies in organisational value chains. Research must explore how organisations can use 4IR technologies to optimise their value chain performance.

Objectives: The primary aim of this study is to explore the holistic impact of 4IR technologies on the structural transformation of value chains.

Method: Applying the principles of the resource-based view and the VRIO (Valuable, Rare, Inimitable and Organisation) framework, a systematic literature review was conducted to map the intersection of 4IR technologies and value chain performance. It utilised resource-based view theory and the VRIO framework to assess the role of 4IR in transforming value chains. This study focused on the VRIO integration of 4IR resources, such as advanced data analytics, Internet of Things (IoT), proprietary technologies and skilled workforces.

Results: The research shows that 4IR resources are valuable and rare assets that require meticulous organisational integration, adaptable organisational structures, innovation-driven cultures and cross-functional collaboration.

Conclusion: The strategic integration of 4IR resources within value chains can lead to innovation, efficiency and enduring competitive advantage.

Contribution: This study provides a strategic roadmap for integrating emerging 4IR technologies into business value chains, cultivating a deeper understanding and maximising the benefits of these technologies to achieve sustained value creation and competitive advantage.

Keywords: 4IR; VRIO; resource-based view; organisational value chains; transformative technologies.

Introduction

The rise of the Fourth Industrial Revolution (4IR), a convergence of transformative technologies, has redefined the value chains that drive industries, economies and societies. Traditionally, value chains have followed a linear model with sequential activities for product or service delivery to the market (Chou & Shao 2023). However, disruptive technologies such as artificial intelligence (AI), the Internet of Things (IoT), big data analytics and cloud computing have fostered greater connectivity and integration across different value chain stages, leading to a radical transformation in operational structures, processes and business models (Alfaro et al. 2019). This remarkable shift necessitates an advanced understanding and strategic thought process to operate on this uncharted business terrain. The extant literature (e.g. Melville, Robert & Xiao 2023; Nazarov & Klarin 2020; Venturini 2022) extensively explores the impact of individual technologies associated with 4IR on specific industry domains. However, this exploration has largely focussed on these technologies in isolation, without giving sufficient attention to their integrated nature and collective influence on value chains. This narrow perspective overlooks the transformative potential of 4IR in reshaping value chains, resulting in a noticeable knowledge gap in the current scholarly discourse.

In this study, we argue that much of the existing literature tends to analyse these effects in a piecemeal fashion – automated robotics and its manufacturing implications (Anzolin, Andreoni & Zanfei 2022), machine learning (ML) and supply chain management (Alabi et al. 2022; Feizabadi 2022), AI technologies and customer service outcomes (Bock, Wolter & Ferrell 2020;

Tsolakis et al. 2023; Wong et al. 2022b). Scrutiny and analysis of each sector are valuable, but there is a clear gap in the comprehensive understanding of how 4IR technologies reshape the entire value chain. This study proposes a holistic examination to address this lack of understanding. This comprehensive approach examined 4IR technologies, not as isolated tools impacting disparate industries, but as an interconnected phenomenon transforming the broader value chain network. Such an approach could allow us to uncover the cumulative effects and interplay of 4IR technologies across different business facets, providing more profound insights into the ultimate impact on the full value chain (Azmat, Ahmed & Mubarik 2022; Tiwari 2022). Furthermore, there is a significant lack of comprehensive understanding of how organisations can strategically adapt to the widespread integration of disruptive technologies into their operations (Bock et al. 2020; Modgil et al. 2022). The current literature fails to provide insights into risk assessment and mitigation strategies that organisations could adopt while transitioning to effectively leverage these technologies within their respective value chains.

This study examined the complex connection between 4IR and the performance of value chains. A comprehensive understanding is vital as the nature of the value chain becomes increasingly complex owing to these technological transformations (Cohen & Kouvelis 2021; Lwesya 2021). Therefore, this article delves into the specifics of these interconnected transformations, explores their broader implications and fills a gap in the existing literature. As 4IR disrupts traditional practices in various industries, it not only poses challenges to established norms but also introduces unique opportunities for enhancing value creation and optimisation (Nyagadza et al. 2022). Value chains, which consist of a sequence of activities undertaken by organisations to deliver products and services to the market, play a crucial role in how such opportunities are harnessed (see Mapanga, Ogutu Miruka & Mavetera 2018). Integrating various 4IR technologies into different stages of the value chain can greatly transform business operations by improving efficiency, quality and innovation, ultimately leading to improved performance and competitiveness (Anzolin et al. 2022; Nyagadza et al. 2022; Onu & Mbohwa 2021).

The resource-based view (RBV) theory (Barney 2001) and the VRIO (Valuable, Rare, Inimitable and Organisation) framework (Barney & Hesterly 2014) are interconnected concepts that provide a holistic lens through which we can understand the transformative influence of 4IR on value chains. The RBV theory emphasises the strategic significance of a firm's unique resources and capabilities in achieving a competitive advantage (Barney 2001). The VRIO framework, an extension of RBV, operationalises this theory by assessing whether resources are valuable, rare, inimitable and organisational, providing a structured approach for evaluating the strategic importance of resources and technologies (Khan, Tabish & Zhang 2023). By addressing the existing literature gaps, our research presents an innovative conceptual framework that analyses the dynamic interplay between 4IR technologies and value chains. It uncovers the synergies among various 4IR technologies and their collective impact on transforming value chains. This study also offers valuable insights regarding organisations' strategic adoption of these technologies, as well as guidance on how to effectively manage potential disruptions and continuously optimise their value chains within a rapidly changing technological environment. In doing so, we contribute to the existing knowledge base, empowering organisations to maximise the advantages 4IR offers and cultivate improved operational efficiency.

Research methodology

An extensive literature review was conducted to explore the interconnected relationships between value chains and technologies related to 4IR. Although we had access to numerous databases relevant to our research topic, such as Sage, JSTOR, Emerald Management and Science Direct, we decided to focus our attention on three specific databases: Web of Science, Google Scholar and Scopus. These three databases were chosen because of their well-established reputation, extensive citation coverage in the chosen research area, the dynamic nature of the technology, and its application to value chains. We believe that these databases provide a comprehensive foundation for the literature review. These databases were also specifically selected because they include a diverse range of authors, particularly from developed economies, where 4IR technologies have already been implemented throughout organisational value chains. Ultimately, 58 relevant papers were identified as suitable for referencing and utilisation in developing the conceptual framework presented in this article. Given the nature of the unit of analysis (value chains) and the critical factors (4IR technologies and their applications in organisations), this research can be characterised as multidisciplinary.

On 26 May 2023, a search was conducted using various combinations of the terms 'value chains' and '4IR technologies'. This yielded a total of 198 articles. However, after applying the specific exclusion criteria, the number of articles was reduced to 58. These articles were required to primarily focus on the intersection between 4IR and value chains, and delve into the specifics of how 4IR technologies, such as AI, IoT, big data analytics and cloud computing, impact value chain processes. Additionally, only studies published between 2019 and 2023 in recognised academic journals or conference proceedings were considered relevant. Furthermore, the primary article on RBV theory, which served as the theoretical lens for the study, was included. Finally, articles written in English were chosen to ensure comprehensive understanding by a diverse audience. Studies from the management, manufacturing, information systems and knowledge management fields were included. Preprints, editorials and non-peer-reviewed publications were excluded.

By employing these exclusion criteria, we obtained 58 pertinent articles for subsequent examination and consolidation. This systematic methodology guaranteed that

the chosen papers strictly adhered to the core focus areas of the study, while offering a more expansive perspective on the various facets and dimensions of the subject matter. This meticulous process enhanced the credibility and dependability of our review, while also contributing to an all-encompassing and precise comprehension of the interaction between 4IR technologies and value chain performance.

Literature review

Fourth Industrial Revolution in organisational value chains

Industries and societies worldwide are being reshaped by 4IR, driven by technological advancements such as AI, robotics, big data analytics, IoT and augmented reality. These transformative technologies have revolutionised the way organisations operate and create value, particularly within their value chains (Anzolin et al. 2022; Barata 2021; Götz 2019; Hartl, Sorger & Stockinger 2023; Koh, Orzes & Jia 2019; Onu & Mbohwa 2021). It also presents opportunities for organisations to gain a competitive advantage and drive innovation (Botha 2019). This literature review provides a comprehensive overview of the interplay between 4IR and value chains, exploring the implications, challenges and opportunities arising from their integration into organisational value chains.

Over the past decade, the emergence and ascent of 4IR, commonly referred to as Industry 4.0, has garnered significant attention and recognition within the scholarly literature exploring the realms of management, technology, manufacturing and economics (Brynjolfsson & McAfee 2014). This transformative phenomenon has been widely acknowledged as a formidable catalyst driving substantial changes in various facets of business operations and practices (Schwab 2016). The scholarly discourse surrounding Industry 4.0 examines these domains' intricate and multifaceted intersections, exploring the relationships and dynamics that underscore the transformative potential of this revolutionary wave (David et al. 2022).

The potential impact of 4IR capabilities on improving processes in different segments of the business value chain has been discussed in the literature (Peerally et al. 2022). Fourth Industrial Revolution can revolutionise strategic planning, business models, manufacturing or supply chain processes, human resources and client management (Castagnolio et al. 2010). Fourth Industrial Revolution technologies are also powerful tools for transforming businesses in every sphere of the value chain (Lyman, Prothero & Watson 2023).

Within the contemporary dynamic global milieu characterised by increasing interdependencies and complexities, the concept of value creation encompasses the generation of innovative ideas, products, services and advancements. Organisations rely on their value chains to effectively operationalise value creation, which constitutes a series of activities and processes undertaken to deliver products or services to customers (Kumar, Maurya & Raj 2023). These value chains span the entire lifecycle of a product or service, commencing with the acquisition of raw materials or inputs, culminating in the delivery and support provided to customers. Organisations use a diverse range of resources, technologies and methodologies to streamline and enhance the execution of value chain tasks, leading to heightened efficiency and effectiveness. Notably, multiple studies (e.g. David et al. 2022; Khan et al. 2023; Modak, Sinha & Ghosh 2023) underscore the transformative potential of the convergence of innovative technologies in 4IR in industries, economies and societies.

Despite the purported benefits of 4IR, we argue that there are precedent conditions for organisations to maximise value when 4IR technologies are deployed. The RBV theory was employed to investigate the necessary and sufficient conditions that should be fulfilled if 4IR capabilities result in a distinct competitive advantage in the organisational value chain (David et al. 2022). We employ the constructs of the RBV theory to discuss the criticality of strategic resource deployment, resource unbundling, and its application within an organisation. Thereafter, we use the VRIO lens to propose a framework that organisations may employ to gauge their readiness or investigate whether they should invest in 4IR technologies based on their resource deployment and alignment evaluation.

The study discusses RBV theory and its extension, the VRIO framework, and how their constructs are important to firms that may want to adapt 4IR technologies along their value chains. Thereafter, we propose a conceptual framework for organisations wanting to adopt 4IR processes in their value chain. Furthermore, we discuss the gaps that this framework may fill in the current literature and its limitations, and thereby reaching a conclusion. Recommendations were also made for future research.

Identification and categorisation of Fourth Industrial Revolution resources

In this section, we discuss the key 4IR resources and capabilities essential for successful implementation of 4IR in value chains. This section also examines how organisations can effectively leverage resources and capabilities to optimise the integration of 4IR technologies into their value chains.

Barney (2001) formulated the RBV perspective, asserting the strategic significance of resources and capabilities in shaping organisational performance and attaining competitive advantage. According to the RBV, an organisation's resources, encompassing tangible and intangible assets, establish the bedrock for its enduring competitive advantage. These resources include physical assets, technological infrastructure, intellectual property, human capital and organisational capabilities. Empirical studies conducted by Zulu, Pretorius and Van der Lingen (2021) and Mungari, Groshev and Chiasserini (2022) provide evidence that organisations can

achieve superior performance within the 4IR landscape through adept harnessing and alignment of these resources. The RBV perspective offers valuable insights into the identification of key 4IR resources, characterised by the convergence of advanced technologies, such as AI, robotics, big data analytics and IoT (Gupta et al. 2022; Kumar et al. 2023; Lezoche et al. 2020). Furthermore, it facilitates the classification of 4IR resource capabilities, including integration, interoperability (Liao et al. 2017), data management, analytics (Barata 2021; David et al. 2022), technological adaptation and flexibility (Khan et al. 2023), human capital development and skill enhancement (Zulu et al. 2021).

Key Fourth Industrial Revolution resources

A range of key technological resources propels 4IR. Artificial intelligence resources, comprising advanced algorithms, ML models, computational power and extensive data sets, enable organisations to automate processes, make data-driven decisions, enhance predictive analytics and develop intelligent systems (Teisserenc & Sepasgozar 2021). Modak et al. (2023) highlighted the transformative potential of AI in improving efficiency, accuracy and decision making, while Bock et al. (2020), Bhattacharya and Chatterjee (2022), and Hartl et al. (2023) underscore the significant role of AI in 4IR.

David et al. (2022) highlighted the impact of robotics and automation on enhancing the productivity, quality and flexibility of value chains. Big data analytics resources encompass data storage and management systems, integration tools, advanced analytics algorithms and visualisation software. These resources enable organisations to extract valuable insights from vast and complex datasets, enhance decision-making, predict customer behaviour and uncover hidden patterns.

In the 4IR context, horizontal and vertical integrated systems foster enhanced cohesiveness among companies, value chains, functional areas and resources. This integration allows for improved collaboration and coordination across different organisational domains, leading to greater efficiency and effectiveness. The IoT resources include sensors, connectivity protocols, cloud platforms and IoT-enabled devices. Lezoche et al. (2020) and Simonetto et al. (2022) highlight the transformative potential of the IoT to enhance supply chain visibility, enable predictive maintenance and improve operational efficiency in the 4IR era.

Classification of Fourth Industrial Revolution capabilities

Traditional value chains operate manually, resulting in inefficiencies, limited visibility, suboptimal decision making and constrained adaptability (Rhyu & Lee 2022). Fourth Industrial Revolution capabilities are pivotal in optimising value chains by enhancing operational efficiency, enabling data-driven decision-making, improving customer experience, fostering innovation, optimising supply chains and facilitating adaptability. Embracing these capabilities is crucial for organisations to sustain competitiveness and resilience, as highlighted by Alam and Dhamija (2022), Botha (2019), Caruso (2018), Liao et al. (2017), and Teisserenc and Sepasgozar (2021). This classification provides value chain leaders with a strategic platform for informed decision-making, efficient resource allocation, system capability development, collaboration and performance measurement, enabling the successful implementation and optimisation of 4IR technologies in value chains.

The literature, as indicated by Castelo-Branco et al. (2022), Nyagadza et al. (2022), and Rhyu and Lee (2022), presents three classifications of 4IR capabilities: technological, organisational and strategic. In the context of the value chain, the essential 4IR technological capabilities include automation, robotics, AI, ML, big data analytics, IoT, augmented and virtual reality and blockchain technology (Bock et al. 2020; Botha 2019; Rhyu & Lee 2022; Simonetto et al. 2022). These capabilities empower organisations to automate processes, make data-driven decisions, enhance operational efficiency, improve customer experiences, optimise supply chain management and foster innovation (Götz & Jankowska 2020; Gupta et al. 2022; Hassoun et al. 2023; Kumar et al. 2023). Leveraging these technologies enables organisations to achieve increased productivity, cost savings, improved decision-making, enhanced collaboration and greater adaptability to market changes. Therefore, organisations must integrate 4IR technological capabilities to develop and implement 4IR resources to sustain competitiveness, drive growth and thrive in the ever-evolving digital landscape.

Fourth Industrial Revolution strategic capabilities refer to the strategic approaches and competencies organisations must develop and employ to effectively leverage and integrate 4IR technologies (Botha 2019). Integrating 4IR strategic capabilities into technologies requires a strategic roadmap that guides the adoption and integration of technologies to achieve organisational goals. In addition, 4IR's strategic capabilities emphasise the importance of fostering a culture of innovation and agility (Peerally et al. 2022). By integrating 4IR technologies with innovation and agility, organisations can explore novel use cases, pilot projects and iterate on solutions to drive continuous improvement and gain a competitive edge (Adesemowo 2021; Onu & Mbohwa 2021; Peerally et al. 2022).

Using the Valuable, Rare, Inimitable and Organisation framework to analyse critical Fourth Industrial Revolution components

The section identifies and analyses the different technologies associated with 4IR that can be implemented across an organisation's value chain. Additionally, the section explored the transformative potential of these 4IR capabilities in relation to the organisation's resources and operational capacities. Through our analysis, we propose that utilising the VRIO framework (Barney 1991) enables organisations to assess

critical components necessary for 4IR capabilities to offer a competitive advantage within their value chains. The VRIO framework, a widely utilised strategic tool for evaluating a company's resources and capabilities, is considered relevant in our bid to examine the effects of 4IR technologies on value chains. Through the VRIO lens, we demonstrate how the implementation of 4IR technologies enhances the performance of value chains. This approach holds significant relevance in the present-day, highly dynamic, and intensely competitive business landscape, especially within the context of 4IR. To establish a unique and competitive advantage during the 4IR, organisations must assess their resources and capacities. This assessment should be carried out with an emphasis on determining if each component adds beneficial value to the organisation. Moreover, it is essential for organisations aiming to enhance their value chains and gain a stronger foothold in the 4IR landscape to fulfil the major VRIO criteria in evaluating their readiness for 4IR capabilities. Table 1 provides an overview of 4IR resources and their capabilities in organisational value chains. A ✓ or an × is used to specify whether each attribute is 'present' or 'absent' according to its respective VRIO designation.

Table 1 provides a thorough assessment of the different resources and capabilities associated with 4IR, analysing their strategic impacts on value chains. It systematically assesses the value, rarity, inimitability and organisational aspects of each resource, shedding light on how these factors could contribute to reshaping and enhancing value chain performance. Each resource is analysed in the following sections.

Advanced data analytics and machine learning algorithms

These resources contribute significantly by providing real-time insights and predictive analytics to value chains (David et al. 2022). While applying such algorithms is becoming common, their specific configurations and models can be unique, creating rarity. The level of expertise needed to customise these algorithms for business scenarios renders them challenging to replicate easily. Organisations that effectively integrate these algorithms and leverage data-driven decision-making across the value chain benefit from enhanced operational efficiency and customer satisfaction (Onu & Mbohwa 2021).

Internet of Things devices and sensors for enhanced connectivity

Internet of Things resources offer value through real-time monitoring and data collection, which leads to improved supply chain visibility and responsiveness (Kumar et al. 2023). The specific sensors and IoT configurations employed by each organisation contribute to the rarity. The expertise required for successful IoT integration into value-chain processes adds a barrier to imitation. Organisations that structure their IoT networks to enhance data sharing and inform decision making can gain a competitive edge through efficient and informed operations.

Sophisticated cybersecurity measures and protocols

The establishment of comprehensive cybersecurity measures creates rarity owing to the enhanced protection provided by them. The expertise required to develop and implement advanced cybersecurity measures introduces a barrier to imitation. Organisations prioritising cybersecurity through clear protocols and vigilant practices establish a secure foundation for value chain operations and build stakeholders' trust (Pandey et al. 2020; Wong et al. 2022a).

Proprietary Fourth Industrial Revolution technologies or patents

Having proprietary technologies or patents offers valuable competitive advantage by creating exclusivity and differentiation (Modak et al. 2023). Patents or proprietary technologies can lead to rarity, particularly if competitors cannot replicate them easily. Strong legal protection and intellectual property safeguards make these resources inimitable and foster innovation and originality. Organisations that effectively manage and protect their intellectual property rights can leverage these resources to drive value chain transformations and market leadership (Modak et al. 2023).

Highly skilled workforce in artificial intelligence, blockchain, augmented reality, among others

Skilled workforce resources play a valuable role in driving successful integration and application of 4IR technologies within value chains. The rarity of highly skilled professionals in emerging technologies has contributed to their strategic importance. The development of a highly skilled workforce

TABLE 1: Valuable, Rare, Inimitable and Organisation Evaluation of Fourth Industrial Revolution Resources and Capabilities.

4IR resource/capability	Valuable	Rare	Inimitable	Organisation
Advanced data analytics and machine learning algorithms	✓	✓	×	✓
IoT devices and sensors for enhanced connectivity	✓	✓	×	✓
Sophisticated cybersecurity measures and protocols	✓	✓	×	✓
Proprietary 4IR technologies or patents	✓	✓	✓	✓
Highly skilled workforce in AI, blockchain, augmented reality, etc.	✓	✓	✓	✓
Unique and well-protected algorithm	✓	×	✓	✓
Culture of innovation and continuous learning	✓	×	✓	✓
Data governance framework for effective management	✓	×	✓	✓
Cross-functional implementation teams	✓	×	✓	✓

4IR, Fourth Industrial Revolution; IoT, Internet of Things; AI, artificial intelligence.
✓, present; ×, absent.

presents a formidable barrier to imitation, as acquiring expertise in areas like AI, blockchain and augmented reality requires substantial training and talent acquisition investments.

Unique and well-protected algorithm

Proprietary algorithms are of high value because they enable unique insights and capabilities (Onu & Mbohwa 2021). Algorithms that offer specific solutions can create rarity, particularly if they cater to unique business needs. Protecting algorithmic innovation through intellectual property rights is a significant barrier to imitation.

Culture of innovation and continuous learning

A culture of innovation and continuous learning stems from the challenge of cultivating an environment that encourages innovative thinking throughout an organisation. Organisations that promote innovation throughout their hierarchies and encourage experimentation can maximise the value of this cultural resource, enabling swift adaptation to evolving technology landscapes.

Data governance framework for effective management

Establishing a comprehensive data governance framework leads to rarity owing to the meticulous attention required. The expertise required to develop and implement robust data governance practices is a barrier to imitation. Organisations that effectively structure their data management practices can enhance value chain activities through data-driven decision-making, risk mitigation and compliance.

Cross-functional implementation teams

Cross-functional implementation teams are valuable resources that enable holistic integration of 4IR technologies into the value chain. Organisations that facilitate collaboration and communication between functions can optimise value chain transformation by ensuring seamless integration, knowledge sharing and efficient problem-solving.

In summary, 4IR introduces a diverse array of resources that can significantly affect value chains. The strategic evaluation of these resources based on their value, rarity, inimitability and organisational positioning guides organisations to effectively harness the transformative potential of 4IR to reshape and optimise value chain activities, leading to increased efficiency, innovation and competitiveness. This evaluation enables organisations to identify key resources to drive value chain transformation and create competitive advantages, guiding strategic decisions about resource allocation, integration and development.

By enhancing value chains, organisations can bolster their effectiveness by cultivating assets and proficiencies that cater to customer needs in fresh and inventive ways. This may encompass crafting novel offerings, enhancing current products or services or devising innovative delivery approaches. Through these novel and innovative customer-centric approaches, organisations generate customer value and set themselves apart from rivals.

Furthermore, organisations can fortify their value chains by nurturing resources and capabilities exclusive to them or arduous for competitors. This could entail forging proprietary technologies, procuring rare resources, or cultivating vital relationships with suppliers and partners. By fostering distinctive resources and capabilities, organisations establish a formidable competitive edge for rivals to surmount (Memon & Ooi 2023; Nayak et al. 2023; Serumaga-Zake & van der Poll 2021).

Lastly, organisations can augment their value chains by building resources and capabilities grounded in intricate or unspoken expertise that is intricate for competitors to grasp or replicate. Organisations create a sustainable competitive advantage by cultivating irreplicable resources and capabilities that shield them from long-term competitive pressure.

In addition to developing valuable, rare and inimitable 4IR resources and capabilities, organisations can also strengthen their value chains by improving their organisational structure, processes and culture as it pertains to 4IR resources and capabilities. By improving their proficiencies, organisations can better optimise the value derived from 4IR resources and capabilities in value chains. To interrogate the essential elements of these organisational structures, the next section discusses three main resource configuration elements that may impact the successful adoption of 4IR processes in organisational value chains.

The right technological architecture

Fourth Industrial Revolution technologies are mostly run on high-end, user-friendly and web-backed power platforms. Acquiring and subsequently maintaining high-quality automated infrastructure is needed to successfully implement 4IR processes (Onu & Mbohwa 2021). Baseline technologies such as a reliable data storage system, hardware and software with networking capabilities and reliable Internet service are all resources that an organisation must acquire before considering the adoption of 4IR capabilities (Modak et al. 2023). Moreover, the organisation must apply the VRIO framework to decipher the critical infrastructure required for a competitive advantage. Related to this key point of resource configuration is the organisation's ability to integrate its data systems meaningfully. The firm's data governance processes must also respond to the value of data within the purview of the support it offers to the entire organisational value chain (Bettiol et al. 2021).

Skilled workforce

As indicated by Götz (2019), implementing 4IR technologies necessitates a significant level of expertise because of their

intricacy. For successful adoption, organisations must have a workforce proficient in applying these complex technical affordances to their workflow processes (Zulu et al. 2021). Consequently, to optimise the value of 4IR technologies, a firm's resource configuration should include personnel with robust competencies in areas such as data analytics, AI programming, data science and digital literacy (Bock et al. 2020).

Moreover, these capabilities must include a team that can adaptively employ 4IR techniques in an industry-specific and efficient manner (Khan et al. 2023). This suggests that the necessity for highly skilled workers within an organisation goes beyond mere presence; integrating these talents to enhance the organisation's business processes is crucial (Gupta 2023). According to Chae, Koh and Prybutok (2014), the successful implementation of 4IR technologies in an organisation requires technical experts whose specialised skills create distinctive capacity within the organisation. As Modak et al. (2023) suggest, this advanced technical human capital, when appropriately engaged with technology, can transform potential technological disruptions into complementary advancements, thereby conferring a competitive edge along an organisation's value chain.

Collaborations and interconnectedness

Fourth Industrial Revolution encompasses a wide range of processes powered by a complex maze of technological infrastructure and human resources (Götz 2019). Resource configuration must allow for collaboration and interconnectedness between and across industries, suppliers, service providers and other related entities. Smit (2016) further highlighted this point by stating that technology and devices must communicate with each other along the value chain. Technologies such as automation and robotics allow firms to increase their productivity and efficiency.

The configuration of resources should also include a combination of hard and soft skills on the part of personnel. Interconnectedness within an organisational value chain can only be successful if all stakeholders in the ecosystem are team players (Götz 2019). Workers must also be futuristic and forward thinking to anticipate customer needs. The successful adoption of 4IR processes in organisational value chains is influenced by the organisation's configuration of resources and capabilities. The availability of appropriate technological infrastructure, skilled workforce, data management systems, collaboration platforms and supportive organisational culture all contribute to the organisation's ability to leverage the benefits of advanced technologies and digitalisation in their value chain operations.

Organisations must embrace continuous learning and effective knowledge management processes to successfully navigate the complexities of the 4IR landscape and leverage its potential (Lyman et al. 2023; Schiuma & Santarsiero 2023; Thibodeau et al. 2023). Organisational learning and knowledge management have long been recognised as critical factors in organisational success and competitiveness (Rehman et al. 2023; Wei et al. 2023; Zahoor & Adomako 2023). In the context of 4IR, these processes become even more crucial as organisations seek to integrate and harness 4IR technologies into their value chains. The implementation of 4IR processes requires organisations to acquire, create, integrate and diffuse knowledge related to these technologies, as well as to adapt their structures, systems and practices (Salam 2021).

Organisational learning is widely recognised as an ongoing social process through which individuals become competent members of workgroups or communities. Studies on organisational learning, including those by Arghode, Lakshmanan and Nafukho (2023), Belinski et al. (2020), Lyman et al. (2023), Naqshbandi and Tabche (2018), and Schiuma and Santarsiero (2023), emphasise the critical role of learning within the context of Industry 4.0 for effectively managing complex industrial processes. The efficient functioning of new businesses in Industry 4.0 requires highly qualified and talented employees. This necessitates the development of transversal competencies and effective interactions between humans and machines to improve the sustainable dimensions of a production system. The literature consistently indicates that organisational learning acts as a mediator, positively influencing the operational performance of Industry 4.0, as highlighted by Cerchione et al. (2023) and Liboni et al. (2019). The learning process in organisations enables individuals to acquire knowledge, values, behaviours and skills through formal education and experiential learning, as demonstrated by Lyman et al. (2023), Naqshbandi and Tabche (2018), and Patwary et al. (2022). This process enhances the organisation's capacity to challenge established notions and adapt to the evolving market landscape.

By fostering a culture of organisational learning, companies can effectively adapt to the demands of Industry 4.0 and leverage its transformative potential to achieve enhanced operational performance and competitiveness (Anshari & Hamdan 2022).

The literature highlights the significance of knowledge management in the innovation process within the 4IR landscape. Knowledge management enables the development of platforms and processes for sharing tacit knowledge, and facilitates its conversion into explicit knowledge, thereby fostering collaboration and sparking innovation in the workplace (Ardito et al. 2022; Cerchione et al. 2023).

The roles and benefits of knowledge management in the context of applying 4IR to value chains can be summarised as follows. Firstly, knowledge management aids in making well-informed decisions by leveraging knowledge to extract data and enhance problem understanding, leading to more effective solutions and increased profitability (Anshari & Hamdan 2022). Secondly, knowledge management enhances expertise efficiency and promotes innovation through open collaboration, talent management and the utilisation of existing knowledge, resulting in the development of new

branches of knowledge and the attainment of a competitive advantage (Belinski et al. 2020). Effective knowledge sharing assists organisations in avoiding bandwagon syndrome, which occurs when businesses imitate one another, thereby hindering growth in an oversaturated market (Anshari & Hamdan 2022; Belinski et al. 2020; Mele et al. 2023).

Knowledge management contributes to organisational performance by facilitating knowledge acquisition, sharing and storage (Mele et al. 2023). It empowers organisations to leverage knowledge effectively, drive innovation and enhance overall performance (Patwary et al. 2022). The salient elements of the discussed resource configuration were tested using the VRIO framework, in accordance with the literature, and are presented in Table 2.

Table 2 presents a comprehensive assessment of 4IR resources and provides valuable insights into their potential impact on value chains as per the VRIO framework, thus yielding a nuanced understanding of how these resources contribute to value chain transformation and competitive advantage.

Value chain optimisation through valuable resources

The 'Valuable' dimension of the VRIO framework highlights the significance of each resource in enhancing value chain activities. Resources such as advanced data analytics, IoT devices, cybersecurity measures and skilled workforce have emerged as valuable contributors. These resources enable real-time insights, improved monitoring, and enhanced security and expertise, resulting in more efficient and informed value chain processes.

Uniqueness as a catalyst for competitive advantage

The 'Rare' dimension reveals the uniqueness of each resource, establishing a foundation for competitive advantage. Internet of Things devices, sophisticated cybersecurity, proprietary 4IR technologies and skilled workforce stand out as rare assets. Organisations with these resources have a distinct edge, as their rarity makes replication by competitors challenging, allowing them to set themselves apart in the market.

Barriers to imitation: Safeguarding competitive edge

The 'Inimitable' dimension emphasises the barriers to imitation associated with each resource. Proprietary 4IR technologies, skilled workforce, unique algorithms and culture of innovation are formidable barriers. Organisations equipped with these resources create obstacles for competitors attempting to replicate their success. This reinforces the notion that these resources contribute significantly to maintaining a competitive edge owing to their complexity or exclusivity.

Organisational integration: Leveraging resources effectively

The 'Organisation' dimension underscores the importance of organisational readiness to harness the potential of 4IR resources. Successfully integrating resources, such as advanced data analytics, IoT devices, cybersecurity and a skilled workforce, requires structured and organised approaches (Khan et al. 2023). Cross-functional teams, data governance frameworks and cultures of innovation are pivotal to maximising the impact of these resources on value chain activities.

Strategic implications: Guiding value chain transformation

Valuable, Rare, Inimitable and Organisation analysis underscores the strategic implications for organisations seeking to leverage 4IR resources for value chain transformation (Adetoyinbo, Trienekens & Otter 2023; Feldman & Sakhartov 2022). Resources that are Valuable, Rare and Inimitable are prime candidates for driving a

TABLE 2: Impact of Fourth Industrial Revolution resources on value chains.

Theme	Valuable	Rare	Inimitable	Organisation
Organisational learning				
Learning culture and mindset	✓	✓	✓	✓
Knowledge management systems	✓	✓	×	✓
Learning from failures and successes	✓	✓	✓	✓
Continuous improvement processes	✓	✓	×	✓
Cross-functional knowledge sharing	✓	✓	×	✓
Leveraging external knowledge	✓	✓	×	✓
Resource orchestration and dynamic capabilities				
Strategic resource orchestration	✓	✓	✓	✓
Continuous adaptation and innovation	✓	✓	✓	✓
Flexibility in value chain operations	✓	✓	✓	✓
Cross-functional collaboration	✓	✓	×	✓
Efficient resource allocation	✓	✓	×	✓
Effective change management	✓	✓	×	✓
Resource/capability				
Interconnectedness and collaboration	✓	✓	✓	✓
Mix of hard and soft skills	✓	✓	×	✓
Worker agility	✓	✓	×	✓

✓, present; ×, absent.

competitive advantage (Galpin 2023). However, successful integration requires organised efforts, as depicted by the 'Organisation' dimension.

In summary, VRIO analysis (Table 2) provides a comprehensive picture of the potential impact of 4IR resources on value chains. It emphasises the importance of strategically integrating resources that are valuable, unique, and difficult to imitate, while ensuring that the organisation is well-organised to leverage them effectively. This analysis equips organisations with the insights needed to make informed decisions about resource allocation, integration and development, ultimately guiding them towards achieving enhanced value chain performance and sustained competitive advantage in the dynamic 4IR landscape.

As an organisation continues to improve its competitive advantage by embracing 4IR capabilities within its organisational value chain, the second research objective examined the impact of resource orchestration and dynamic capabilities on the deployment of 4IR affordances within the value chain. Resource orchestration strategically manages a firm's resources to maximise its value and effectiveness (Ahuja & Chan 2017). In the literature (Adetoyinbo et al. 2023; Feldman & Sakhartov 2022), resource orchestration generally involves structuring, bundling and leveraging resources as processes built into organisational work culture, thus making them part of the 'Holy Grail'.

Within the scope of 4IR processes, resource orchestration becomes crucial, as organisations seek to integrate digital technologies such as AI, ML, IoT and big data analytics into their value chains (Acioli, Scavarda & Reis 2021). Extant literature suggests that the most practical means of achieving effective resource deployment is to leverage resources based on a firm's strategic sections (Ahuja & Nair 2021). This may entail cooperation and alliances with strategic partners and external stakeholders such as technology vendors, suppliers, research bodies and academic research centres (Bongomin et al. 2020). This would enable the firm to effectively leverage 4IR affordances (Olaitan, Issah & Wayi 2021).

Dynamic capabilities refer to an organisation's ability to create a learning culture, adapting and innovating timeously to changing conditions and technological advancements (Nyamapanda 2022). The value of a processed-based deployment of dynamic capabilities in an information technology (IT)-related field is twofold: it makes redundant the argument that IT has become commoditised, which has diminished its value in estimating competitive edge in a dynamic industry or sector (Chae et al. 2014). In a 4IR-driven economy, firms are seen as repositories of competencies, knowledge and creativity, and as sites of invention, innovation and learning (Amin & Cohendet 2012). Adopting dynamic capabilities allows firms to address and overcome operational changes effectively by leveraging the expertise of 4IR technicians (Mele et al. 2023). These technicians play a crucial role in facilitating communication, collecting data, analysing information and making timely decisions, helping organisations maintain their competitive edge and navigate potential obsolescence resulting from the rapid deployment of innovative technologies (Modak et al. 2023).

Discussion

The examination of the 4IR and its impact on the dynamics of value chains, viewed through the RBV lens and the VRIO framework, provides essential insights into how emerging technologies are redefining competitive landscapes. Upon evaluating 4IR technologies using the VRIO criteria, it is apparent that they offer substantial strategic value for enhancing value chain operations. Technologies such as advanced data analytics, IoT devices and robust cybersecurity measures are at the forefront of facilitating real-time data monitoring, improving connectivity and enhancing security. Comparing these findings with contemporary empirical research (Bai 2022; Mithas et al. 2022; Sugito & Kusrini 2023) suggests that effective and transparent information exchange within an organisation is key to sophisticated value chain management, mirroring the benefits provided by 4IR technologies. These studies support the notion that relevant and coherent information flows reinforce organisational functioning and strategic positioning. The VRIO framework emphasises the significance of value, rarity, inimitability and organisation in fostering sustainable competitive advantage. Fourth Industrial Revolution resources, such as exclusive technologies, specialised talent and customised algorithms, which are unique and difficult to replicate, play a critical role in establishing competitive barriers. These barriers hinder competitors from duplicating resource-based advantages and solidifying an organisation's market dominance. This underscores the strategic necessity for firms to allocate resources wisely to VRIO-qualified 4IR innovations, thereby maintaining a lasting competitive edge in the marketplace.

Within the scope of the VRIO framework's 'Organisation' dimension, the pressing need for effective flexible and responsive organisational structures is emphasised, particularly in the context of harnessing 4IR resources. The creation of cross-functional teams, implementation of robust data governance and fostering a culture in which champion innovation are identified as a critical element. This notion resonates with the core tenets of RBV theory, which focusses on the symphony between resources, capabilities and organisational frameworks to unlock their collective impact. The synergistic analysis provided by integrating RBV and VRIO provides a comprehensive understanding of the transformative influence of 4IR technologies on value chains. While the RBV accentuates these technologies as essential strategic assets, the VRIO delineates their capacity to generate strategic avenues. The interplay of these theories equips organisations with a strategic guide to recognise, appraise and amalgamate resources that forge value, distinctiveness and insurmountable competitive moats. This combined approach validates that these organisations not only possess invaluable resources but are also poised to utilise them

strategically. However, the current literature (Meltzer 2020; Xiao, Zhang & Zhong 2023) stipulates that despite the substantial advantages of adopting 4IR technologies, firms must proactively consider and address challenges such as cybersecurity threats, scarcity of a skilled workforce and disparities between 4IR resource potential and existing organisational structures. Recognising these obstacles is crucial for devising all-encompassing strategies that ensure the seamless incorporation of 4IR technologies within their value chains and leveraging them for optimum efficacy and competitive advantage.

Implications for strategy and future research

Our study offers implications for strategic decision-making and the research landscape. Organisations are urged to proactively identify and harness valuable, rare and inimitable 4IR resources. This entails fostering cultures of innovation, investing in workforce development, protecting intellectual property and nurturing cross-functional collaborations. Future research directions could delve into the dynamic nature of 4IR resources, addressing questions about their changing rarity and the adaptability of existing organisational structures to accommodate emerging technologies. These implications are significant. Businesses that fail to adapt to these changes risk becoming obsolete, losing market share to more progressive competitors adept at leveraging 4IR technologies. Conversely, companies successfully navigating these changes and implementing 4IR technologies could reap benefits such as increased efficiency, cost reduction, customer satisfaction and competitive advantage, positioning them for sustained future success.

Our exploration of these prospects not only sets the stage for more research but also teases an ever-transforming value chain landscape stirred by 4IR technology.

Conclusion

Our study links the RBV theory and the VRIO framework to understand the transformative power of 4IR in value chains. The strategic combination of 4IR resources, such as data analytics and highly skilled workforces, optimises value chains and paves the way for competitive advantage and success. The VRIO dimensions of value, rarity, inimitability and organisational integration help explain how these resources enhance value and offer strategic advantages. This approach encourages strategic investment in rare, difficult-to-imitate resources and promotes adaptable organisational structures and innovation cultures. Our study further suggests exploring the dynamic rarity of 4IR resources and the agility required to maximise their impact. The convergence of RBV and VRIO, together with the strategic integration and harnessing of 4IR resources, guides organisations towards innovation and sustained competitive advantage in a rapidly evolving era.

The study illustrated that, when combined, RBV and VRIO provide a holistic understanding of the transformative journey that 4IR instigates. The RBV identifies the potential of emerging technologies as strategic resources, while VRIO's assessment guides organisations in determining their strategic significance. This harmonious blend ensures that organisations not only recognise the value of 4IR resources, but also have the capability to extract their full potential.

The insights derived from this exploration have profound implications for strategic decision-making. Organisations are encouraged to strategically invest in resources that are not only valuable, but also rare and difficult to imitate. This investment should be complemented by fostering adaptable organisational structures, promoting cultures of innovation and nurturing cross-functional collaboration. Furthermore, this study invites future research endeavours to delve into the dynamic nature of 4IR resources, shedding light on their evolving rarity and agility required to harness their transformative power.

Limitations and future research

One of the primary limitations of this literature review is its reliance on the secondary literature. Although secondary sources provide valuable insights, the absence of primary empirical data may limit the depth of analysis and the ability to draw concrete conclusions. Future research should incorporate primary data through surveys, interviews, or case studies to validate and enhance the findings. This study predominantly utilises the RBV theory and VRIO components, which may not fully capture the complexity of 4IR capabilities. While RBV is valuable for assessing internal resources and capabilities, it might overlook the external factors and the dynamic nature of 4IR. Additionally, the secondary literature used in this study may vary in terms of the industries, contexts and regions covered. This may limit the generalisability of the findings to different organisational settings. Future research could address this limitation by conducting comparative studies across various industries and regions to determine the applicability of the proposed VRIO-centred approach.

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Competing interests

The authors declare that they have no financial or personal relationship(s) that may have inappropriately influenced them in writing this article.

Authors' contributions

O.O.O. contributed to the conceptualisation, and writing of the literature review on the impact of 4IR Technologies on organisational value chains. A.M. contributed to the conceptualisation, and writing of the literature review on the critical link between the RBV theory and the VRIO framework in exploring the transformative power of the 4IR in value chains.

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Ethical considerations

This article followed all ethical standards for research without direct contact with human or animal subjects.

Data availability

The data supporting the findings of this study are available from the corresponding author, O.O.O., upon reasonable request.

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