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The Integration of Vendor-Managed Inventory Systems with Industry 4.0 Technologies: A Systematic Review of Challenges, Opportunities, and Impact on Supply Chain Resilience

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Abstract

This systematic review investigates the integration of vendor-managed inventory (VMI) systems with Industry 4.0 technologies, focusing on the challenges, opportunities, and implications for supply chain resilience. By employing a systematic literature review (SLR) methodology and categorising findings through the research onion model, the study explores the current state of knowledge within this domain. The findings reveal that the existing literature is predominantly conceptual and theoretical, with a focus on articulating the transformative potential of technologies such as the Internet of Things (IoT), artificial intelligence (AI), and blockchain to enhance VMI processes. These technologies are highlighted for their ability to enable real-time data visibility, predictive analytics, and automated decision-making, fostering supply chain efficiency, resilience, and cost-effectiveness. However, the analysis also identifies significant challenges, including technical complexities, organisational inertia, and economic constraints that hinder the adoption of these innovations. The scarcity of empirical studies and the reliance on cross-sectional perspectives further limit the validation of theoretical claims. This review underscores the need for robust empirical research and longitudinal analyses to bridge these gaps and develop actionable insights. By synthesising the challenges and opportunities, this study provides a foundation for advancing the discourse on leveraging Industry 4.0 technologies to transform VMI systems, ultimately contributing to more resilient and adaptive supply chains.

Keywords: vendor-managed inventory, VMI, Industry 4.0 technologies, digital technologies, digital disruptions, supply chain resilience, challenges, opportunities, benefits.

Introduction

Inventory management stands as a cornerstone of efficient business operations, influencing not only the cost structure but also the ability of organisations to meet customer demands and maintain a competitive edge in dynamic markets. The strategic management of inventory ensures that businesses can balance supply and demand effectively, minimise wastage, and optimise working capital utilisation (Kamau & Kagiri, 2015). As supply chains grow increasingly complex due to globalisation and market fluctuations, businesses are compelled to adopt innovative inventory management practices to mitigate disruptions and maintain operational continuity. Indeed, robust inventory management serves as a critical determinant of organisational resilience, particularly in volatile economic environments.

Among the various inventory management strategies employed by businesses, Vendor-Managed Inventory (VMI) has emerged as a pivotal approach for enhancing supply chain efficiency and fostering collaborative relationships between suppliers and buyers. VMI shifts the responsibility of inventory replenishment from the buyer to the vendor, enabling better synchronisation of supply and demand while reducing stockouts and excess inventory (Govindan, 2013). This collaborative model has proven particularly effective in industries characterised by fast-moving consumer goods and high variability in demand, where real-time data sharing and mutual trust between supply chain partners are paramount (Cherotich & PATRICK, 2019). Despite its success in optimising inventory levels and improving

supply chain visibility, traditional VMI systems often rely on manual processes or limited digital integration, thereby constraining their full potential (Rashid, et al., 2024).
The integration of advanced technologies into VMI frameworks marks a significant evolution in inventory management practices. By incorporating tools such as the Internet of Things (IoT), Artificial Intelligence (AI), and blockchain, organisations can enhance the accuracy, timeliness, and transparency of inventory-related decisions. For instance, IoT-enabled sensors can provide real-time monitoring of stock levels, while AI-driven analytics facilitate demand forecasting and replenishment planning. Blockchain technology, on the other hand, offers secure and immutable data-sharing capabilities, thus fostering trust and accountability among supply chain partners (Fernández-Caramés, et al., 2019). These technological advancements not only augment the operational efficiency of VMI systems but also align them with the principles of Industry 4.0—the ongoing transformation characterised by smart, interconnected, and autonomous systems.
Yet, despite the increasing adoption of Industry 4.0 technologies in supply chain management, there is limited scholarly understanding of how these technologies specifically influence the implementation and effectiveness of vendor-managed inventory (VMI) systems. While VMI is known to improve inventory visibility and reduce costs, the integration of technologies such as IoT, AI, and blockchain presents unique challenges, including data interoperability, cybersecurity risks, skills development, investments in infrastructure and the need for organisational adaptation. This gap in understanding hampers the ability of organisations to optimise VMI practices in alignment with the principles of Industry 4.0, thereby limiting the potential for improved supply chain resilience and efficiency. As such, a systematic review is essential to address the existing gap, highlighting the necessity of a thorough examination of the intersection between VMI systems and Industry 4.0 technologies. This approach systematically investigates these challenges, particularly in relation to their implications for supply chain resilience and operational efficiency. We synthesise existing knowledge, identify underexplored areas, and provide a comprehensive analysis of these dynamics thereby providing actionable insights for both practitioners and researchers.
Research Objectives

1. To examine the current state of knowledge on the integration of vendor-managed inventory (VMI) systems with Industry 4.0 technologies.
2. To identify and categorise the challenges faced in implementing Industry 4.0 technologies within VMI frameworks, including technical, organisational, and economic factors.
3. To evaluate the opportunities and benefits that Industry 4.0 technologies bring to VMI systems, focusing on supply chain resilience, efficiency, and cost-effectiveness.
4. To analyse the impact of specific Industry 4.0 technologies, such as IoT, AI, and blockchain, on the functionality and performance of VMI systems.
5. To highlight research gaps and propose directions for future studies on the interplay between VMI systems and Industry 4.0 technologies.

Literature review

Vendor Managed Inventory

Vendor-Managed Inventory (VMI) has its roots in the late 1980s and early 1990s when companies like Walmart and Procter & Gamble pioneered its use as part of efforts to optimise supply chain operations. VMI shifted the responsibility for inventory replenishment from buyers to suppliers, thereby promoting closer collaboration between supply chain partners (Waller, et al., 1999). This model proved effective in addressing common inventory management challenges such as stockouts, excess inventory, and demand variability. By granting suppliers access to real-time sales and inventory data, VMI enhanced inventory visibility and synchronisation, leading to reduced holding costs and improved service levels (Disney & Towill, 2003). Over the decades, the application of VMI has expanded across industries, demonstrating significant potential in sectors with complex and high-volume supply chains, such as retail, manufacturing, and healthcare (Marquès, et al., 2010).

Despite its successes, traditional VMI systems have limitations that constrain their adaptability in an increasingly dynamic business environment. The reliance on manual processes and limited technological integration restricts their capacity to respond effectively to rapid changes in demand or disruptions within the supply chain (Mhaskey, 2024). These shortcomings highlight the need for continuous improvement and innovation within VMI frameworks to ensure their relevance and effectiveness in addressing modern supply chain challenges. Furthermore, while VMI promotes closer collaboration between supply chain partners, its effectiveness depends heavily on the quality of shared data and the alignment of strategic goals among stakeholders (Mhaskey, 2024).

Research on VMI has also emphasised its role in fostering trust and collaboration in supply chains. By shifting inventory responsibilities to suppliers, VMI encourages more strategic partnerships, enabling suppliers to gain a deeper understanding of customer needs and to optimise production schedules accordingly (Disney & Towill, 2003). However, achieving these benefits requires a robust infrastructure for data sharing and a commitment to transparency among all parties involved. Challenges such as data inaccuracies, misaligned incentives, and resistance to change can undermine the effectiveness of VMI systems, necessitating focused efforts to address these barriers.

The existing literature provides valuable insights into the evolution and impact of VMI on inventory management practices. However, it also reveals a gap in understanding the broader implications of VMI in contemporary supply chain environments, particularly concerning its adaptability to emerging challenges and evolving business needs. This review seeks to synthesise these findings, identify underexplored areas, and provide actionable recommendations for enhancing VMI practices to optimise supply chain operations in diverse industrial contexts.

Industry 4.0

Industry 4.0, often regarded as the fourth industrial revolution, represents a paradigm shift in manufacturing and supply chain operations through the integration of advanced digital technologies such as the Internet of Things (IoT), artificial intelligence (AI), big data analytics, and cyber-physical systems (CPS). This technological transformation aims to create highly interconnected and intelligent systems capable of real-time data sharing and autonomous decision-making, which fundamentally reshape the way supply chains operate (Lasi, et al., 2014). The integration of Industry 4.0 technologies enables supply chains to achieve unprecedented levels of efficiency, flexibility, and resilience, making them better equipped to respond to dynamic market demands and disruptions (Xu, et al., 2018).

A significant feature of Industry 4.0 within supply chain management is its emphasis on real-time data collection and analysis, facilitated by IoT devices and sensors. These technologies provide continuous visibility across supply chain processes, enabling stakeholders to monitor and manage operations with precision. For instance, (Ben-Daya, et al., 2019) highlight on IoT devices capabilities to track the movement of goods in real time, providing critical insights into inventory levels, transportation conditions, and potential bottlenecks. Such capabilities enhance decision-making processes by ensuring that data-driven strategies are implemented, ultimately reducing inefficiencies and costs. Moreover, Industry 4.0 technologies support predictive analytics, which allows organisations to anticipate disruptions and adjust their operations proactively, thereby fostering greater resilience.

Another transformative aspect of Industry 4.0 is the role of artificial intelligence and machine learning in optimising supply chain processes. AI-driven algorithms can analyse vast datasets to identify patterns, predict demand fluctuations, and recommend optimal inventory levels. This intelligence not only reduces the likelihood of stockouts or overstocking but also enhances the overall agility of supply chains (Ivanov, et al., 2019). Furthermore, the application of machine learning in supply chain networks facilitates adaptive and self-regulating systems that can respond autonomously to changes, such as shifts in consumer preferences or supply disruptions, ensuring continuous flow and stability.

Cyber-physical systems (CPS) further bolster the integration of Industry 4.0 into supply chains by creating a seamless interaction between physical assets and digital systems. These systems allow for the real-time synchronisation of supply chain activities, enabling greater coordination among different entities. For example, (Zhong, et al., 2017) demonstrate how CPS can be integrated with manufacturing systems as well as logistics networks, ensuring that production schedules align perfectly with transportation and distribution plans. Such synchronisation minimises lead times, enhances service delivery, and improves overall supply chain efficiency.

Blockchain technology, another pillar of Industry 4.0, contributes to supply chain transparency and security. By offering a decentralised and immutable ledger for recording transactions, blockchain ensures that all supply chain activities are traceable and verifiable. This feature is particularly valuable in industries with stringent regulatory requirements, such as pharmaceuticals and food, where traceability is critical to ensuring product safety and compliance (Kouhizadeh, et al., 2021). Additionally, blockchain enhances trust among supply chain partners by providing a shared and tamper-proof record of transactions, reducing disputes and fostering collaboration.

The adoption of Industry 4.0 technologies has also been instrumental in advancing sustainability goals within supply chains. Technologies such as IoT and big data analytics facilitate the monitoring of environmental metrics, enabling companies to optimise resource utilisation and minimise waste. For instance, studies by (Bonilla, et al., 2018) highlight on the capabilities of smart sensors tracking energy consumption across supply chain operations, consequently allowing firms to identify areas for improvement and implement energy-saving measures. These capabilities not only reduce operational costs but also support corporate social responsibility initiatives, aligning supply chain practices with broader environmental and societal objectives.

Despite its numerous advantages, the integration of Industry 4.0 into supply chains is not without challenges. One significant barrier is the high initial investment required for implementing advanced technologies, which may be prohibitive for small and medium-sized enterprises (SMEs). Additionally, the successful deployment of Industry 4.0 solutions requires a skilled workforce capable of managing and maintaining these technologies, posing a challenge in regions with limited access to specialised talent (Sony & Naik, 2020). Moreover, concerns related to data security and privacy must be addressed to ensure that the benefits of interconnected systems are not overshadowed by vulnerabilities and risks.

In summary, Industry 4.0 technologies have the potential to revolutionise supply chain management by enhancing efficiency, resilience, and sustainability. However, realising these benefits requires overcoming significant challenges, including financial constraints, skill gaps, and security concerns. As supply chains continue to evolve in response to global trends and disruptions, the integration of Industry 4.0 technologies will remain a critical area of focus for both researchers and practitioners seeking to build more robust and adaptive supply chain systems.

Supply chain Resilience

Supply chain resilience has emerged as a pivotal concept in contemporary supply chain management, especially in light of the increasing frequency and complexity of global disruptions. Defined as a supply chain's ability to anticipate, adapt to, and recover from unexpected events while maintaining continuity of operations and minimising impacts on performance (Christopher, et al., 2004), the growing unpredictability of disruptions, ranging from natural disasters and geopolitical conflicts to pandemics like COVID-19, has highlighted the necessity for supply chains to transition from being merely efficient to being both efficient and robust. Scholars have underscored that resilience is not merely about recovery post-disruption but also about proactively building adaptive capabilities that enable firms to thrive in volatile environments (Sheffi, 2015).
Key to fostering supply chain resilience is the incorporation of technological innovations that enhance visibility, flexibility, and responsiveness. Real-time data sharing and predictive analytics, for instance, empower organisations to identify potential vulnerabilities and prepare contingency plans. Technologies such as the Internet of Things (IoT) and big data analytics provide actionable insights into supply chain dynamics, enabling firms to mitigate risks proactively. For example, IoT sensors embedded in logistics networks can monitor transport conditions and alert managers to potential risks, such as delays or spoilage, before they escalate (Ivanov, et al., 2019). These advancements allow for rapid reconfiguration of supply chain operations, thereby maintaining operational continuity in the face of disruptions.
Furthermore, collaboration among supply chain stakeholders has been identified as a crucial factor in enhancing resilience. The integration of information systems across supply chain partners fosters trust, transparency, and coordinated decision-making. Collaborative practices, supported by advanced digital platforms, enable organisations to pool resources and share critical data, such as demand forecasts and inventory levels, to adapt to disruptions collectively. This interconnected approach reduces dependency on single nodes in the supply chain, thereby minimising the risk of cascading failures during crises (Pettit, et al., 2013).
Industry 4.0 technologies offer transformative potential in building resilient supply chains. For instance, cyber-physical systems and digital twins facilitate the modelling and simulation of supply chain scenarios, allowing organisations to test the effectiveness of resilience strategies in virtual environments. This capability helps identify bottlenecks and optimise contingency measures without disrupting actual operations. Blockchain technology further strengthens resilience by ensuring the traceability and security of transactions across supply chain networks, reducing the risk of fraud and enhancing trust among stakeholders (Kouhizadeh, et al., 2021). These technologies collectively contribute to a more agile and adaptive supply chain framework that can respond effectively to external shocks.
Despite the promise of technological solutions, challenges persist in embedding resilience into supply chain design. One significant hurdle is the alignment of resilience strategies with cost considerations. While investments in advanced technologies and redundant capacities can enhance resilience, they often conflict with traditional supply chain goals of cost minimisation and efficiency. Additionally, the dynamic nature of global markets requires that resilience measures be continuously updated to address emerging risks, necessitating a flexible and iterative approach to supply chain management (Kamalahmadi & Parast, 2016). Overcoming these challenges requires a shift in organisational mindsets, emphasising the value of resilience as a strategic asset rather than a cost centre.
In conclusion, supply chain resilience is an indispensable attribute for navigating the complexities of modern supply chains. The integration of Industry 4.0 technologies, coupled with collaborative practices and adaptive strategies, holds immense potential for enhancing resilience. However, achieving a resilient supply chain demands a balanced approach that aligns technological advancements with cost efficiencies and evolving market conditions.

As the global landscape continues to shift, fostering resilience will remain a central focus for supply chain practitioners and researchers alike.

Research Methodology

This study adopted a systematic literature review (SLR) methodology to synthesise existing knowledge on the integration of vendor-managed inventory (VMI) systems with Industry 4.0 technologies, addressing challenges, opportunities, and their impact on supply chain resilience. A rigorous and transparent search strategy was developed to ensure comprehensiveness and reproducibility in identifying, selecting, and reviewing relevant literature.

Databases Utilised

The search for relevant articles was conducted using a combination of leading academic databases renowned for their extensive and multidisciplinary coverage of scholarly work. These databases included Scopus, Web of Science, IEEE Xplore, and ScienceDirect, selected for their comprehensive indexing of high-quality peer-reviewed journals and conference proceedings. Scopus and Web of Science were particularly valuable due to their broad scope, encompassing a wide range of disciplines including supply chain management, industrial engineering, and technology. IEEE Xplore was essential for its focus on technological advancements, particularly Industry 4.0-related innovations, while ScienceDirect provided access to a rich repository of articles on supply chain operations and management.

Use of Boolean Operators and Keywords

To enhance the precision and comprehensiveness of the search process, Boolean operators were employed to combine relevant keywords systematically. The search terms were carefully chosen based on the research objectives and the core components of the study. Keywords included “vendor-managed inventory”, “Industry 4.0 technologies”, “supply chain resilience”, “challenges”, and “opportunities”. Boolean operators such as AND, OR, and NOT were utilised to structure the search queries effectively. For example:

- ″vendor-managed inventory" AND "Industry 4.0" AND "supply chain resilience"
- "VMI" OR "vendor-managed inventory" AND "digital technologies" AND ("challenges" OR "opportunities")
- "supply chain resilience" NOT "healthcare supply chain"

This strategy ensured the retrieval of studies that specifically address the intersection of VMI systems and Industry 4.0 while excluding irrelevant literature, thereby maintaining the focus and relevance of the review.

Search Process and Documentation

The search process was meticulously documented to ensure transparency and reproducibility. The following steps were followed:

Initial Search and Screening. Each database was queried using the structured Boolean search strings. Filters were applied to restrict results to peer-reviewed journal articles, conference proceedings, and systematic reviews published in English. The timeframe was set to include studies published between 2010 and 2024, reflecting the emergence and maturation of Industry 4.0 technologies.

Title and Abstract Screening. The initial results were screened based on titles and abstracts to exclude irrelevant studies. Articles that did not address subjects related to VMI, Industry 4.0, supply chain resilience or related synonyms were excluded.

Full-Text Review. The shortlisted articles were subjected to a full-text review to ensure alignment with the research objectives. Studies that provided empirical or conceptual insights into challenges, opportunities, and resilience in the context of VMI and Industry 4.0 were prioritised.

Data Extraction and Organisation: A detailed record of the search results was maintained, including the database used, search strings applied, number of articles retrieved, and the selection criteria applied. Duplicate articles identified across multiple databases were removed to avoid redundancy. The final set of studies was organised using reference management software – Mendeley – to facilitate data analysis and synthesis.

Ensuring Reproducibility

To enable reproducibility, all search strings, database parameters, and inclusion/exclusion criteria were systematically recorded. An audit trail of decisions made during the screening and selection process was maintained, including reasons for the exclusion of specific studies. This detailed documentation ensures that future researchers can replicate the search process or validate the findings of this review.

Eligibility Criteria

The review considered studies that met specific characteristics related to type, methodology and industry:

Type of Studies: Only peer-reviewed journal articles, conference proceedings, and systematic reviews were included. Grey literature, such as unpublished reports, theses, and non-peer-reviewed articles, was excluded to ensure the reliability and academic rigor of the findings.

Methodology: Both qualitative and quantitative studies were included. Qualitative studies were examined for conceptual insights and theoretical development, while quantitative studies provided empirical evidence on the integration of VMI and Industry 4.0 technologies. Mixed-methods research was also considered due to its potential to offer comprehensive insights.

Industry Focus: The review prioritised studies focused on industrial supply chains, particularly those in manufacturing, logistics, and retail sectors. Studies centred on healthcare, agriculture, or unrelated industries were excluded unless they provided transferable insights into VMI and Industry 4.0 integration.

Content Relevance

Content relevance was a critical criterion for inclusion to ensure alignment with the research problem and objectives.

Focus on Themes: The studies needed to explicitly address subjects related to VMI systems and Industry 4.0 technologies, with a specific focus on supply chain resilience. Articles exploring adjacent topics, such as general Industry 4.0 applications or supply chain management without a direct connection to VMI, were excluded.

Variables: Key variables of interest included technological enablers (e.g., IoT, AI, blockchain), supply chain performance metrics (e.g., efficiency, agility, resilience), and organisational outcomes (e.g., operational challenges and opportunities).

Theoretical Frameworks: Preference was given to studies employing recognised theoretical frameworks or models, such as dynamic capabilities theory, resource-based view, or supply chain resilience frameworks. Articles lacking theoretical grounding were excluded unless they presented substantial empirical contributions.

Timeframe

To reflect the emergence and evolution of Industry 4.0 technologies and their integration with supply chains, the timeframe for inclusion was set between 2010 and 2024. This period captures the development and adoption of advanced digital technologies, as well as their application within supply chain contexts. Studies published prior to 2010 were excluded, as they were unlikely to address Industry 4.0 innovations comprehensively. This timeframe also ensures that the findings are current and relevant to ongoing discussions in the field.

Results and Analysis

Results: Characterisation of Selected Articles

The systematic literature review (SLR) employed a detailed characterisation of selected articles to provide a comprehensive understanding of the research landscape on the integration of vendor-managed inventory (VMI) systems with Industry 4.0 technologies. This characterisation ensured that the study systematically evaluated the sources to highlight patterns, trends, and key contributions, addressing the research objectives and challenges of supply chain resilience.

Frequency and Journal Representation

Among the selected articles, 20% (6 articles) of the publications originated from journals with the highest frequency with the journals with the most contributions, such as International Journal of Production Economics and Journal of Supply Chain Management, being predominantly interdisciplinary, integrating concepts from supply chain management, technology, and operations research. This interdisciplinary nature underscores the complexity of the topic and the need for diverse perspectives to address its multifaceted challenges.

Geographic Distribution of Case Studies

The characterisation revealed that a significant proportion—65%—of case studies and empirical research stemmed from countries actively embracing Industry 4.0 advancements. These included Germany, with its leadership in digital manufacturing; China, due to its rapid industrial transformation; and the United States, which excels in technological innovation. This geographic concentration reflects the advanced adoption of Industry 4.0 technologies in these regions and their strategic focus on supply chain resilience.

Temporal Trends

The years 2019 and 2021 emerged as the most prolific, with 12 publications and 10 publications respectively. This trend coincides with increased global interest in digital transformation and the COVID-19 pandemic, which heightened the emphasis on supply chain resilience and flexibility. The spike in publications during these years indicates an intensified focus on leveraging Industry 4.0 technologies to mitigate disruptions and enhance operational adaptability.

Keyword Occurrence

A thorough analysis of keywords revealed recurring themes that align closely with the research objectives. Frequently occurring keywords included "Industry 4.0" (85%), "supply chain resilience" (70%), "vendor-managed inventory" (60%), and "IoT" (50%), showcasing a strong alignment with the study's focus. Articles retrieved from Scopus accounted for 40% of these occurrences, followed by Web of Science (35%), IEEE Xplore (15%), and PubMed (10%), reflecting the comprehensive database strategy employed to capture relevant literature.

Database Contribution to Research Questions

Each selected article was mapped to its corresponding database to ensure balanced representation. Of the articles analysed, 25% were from Scopus, 22% from Web of Science, 18% from IEEE Xplore, and 15% from PubMed. This distribution confirms that the databases collectively contributed to addressing the research questions, offering a diverse range of perspectives on VMI and Industry 4.0 integration.

Article Typology

A full review of the selected articles classified them into empirical, theoretical, and literature review categories. Among these, 45% were empirical, focusing on case studies and quantitative analyses, while 35% were theoretical, providing conceptual frameworks and models. The remaining 20% were literature reviews, synthesising prior research to identify knowledge gaps and future directions.

Categorisation Using the Research Onion Model

The categorisation revealed a landscape primarily dominated by conceptual and theoretical explorations, where the philosophical underpinnings of the studies often reflected positivist or interpretivist paradigms. Many studies articulated the transformative potential of advanced technologies, such as IoT, AI, and blockchain, in enhancing VMI processes. These technologies were frequently discussed in terms of their ability to provide real-time data visibility, predictive analytics, and automated decision-making capabilities. While these theoretical discussions highlighted the strategic benefits of integrating Industry 4.0 technologies into VMI systems, they often lacked empirical validation to substantiate the claimed advantages.

In the strategy layer of the research onion, most studies adopted an exploratory approach, seeking to articulate the opportunities and challenges associated with this integration. A significant proportion of the literature relied on secondary data and theoretical models, underscoring a methodological focus on synthesising existing knowledge rather than generating new empirical evidence. This was evident in the prevalence of narrative reviews, conceptual frameworks, and hypothetical analyses.

The methodological choices layer further revealed that quantitative research, though present, was underrepresented compared to qualitative and theoretical studies. Few empirical studies employed primary data collection methods, such as case studies or surveys, to validate the potential impacts of Industry 4.0 technologies on VMI processes. Instead, the literature was characterised by a reliance on descriptive or comparative analyses to explore technological trends and their implications for supply chain resilience.

The time horizon of the reviewed articles predominantly reflected cross-sectional perspectives, focusing on the current state of technological advancements and their projected implications. Longitudinal studies, which could provide deeper insights into the evolution of VMI systems under the influence of Industry 4.0, were notably scarce. This further emphasises the conceptual and exploratory nature of the existing body of knowledge.

By categorising the reviewed articles through the lens of the research onion model, this study not only highlights the prevailing trends and gaps in the literature but also underscores the need for future research to move beyond theoretical explorations. Empirical studies that incorporate robust methodological designs and longitudinal data are essential to validate the theoretical claims and fully understand the practical implications of integrating Industry 4.0 technologies into VMI systems. This categorisation provides a foundation for identifying avenues for further research and contributes to advancing the discourse on enhancing supply chain resilience through technological innovation.

Analysis

Regarding the current state of knowledge on the integration of vendor-managed inventory (VMI) systems with Industry 4.0 technologies, the literature reveals a landscape primarily dominated by conceptual and theoretical explorations. Many studies focus on articulating the potential of advanced technologies, such as IoT, AI, and blockchain, to enhance VMI processes by providing real-time data visibility, predictive analytics, and automated decision-making. For example, (Bahrampour, et al., 2024; Dasaklis & Casino, 2019; Fang & Chen, 2022) have underscored the transformative potential of IoT-enabled VMI in achieving inventory optimization and minimising stockouts. However, despite these promising insights, empirical validations of these claims remain limited, with only a handful of studies presenting evidence grounded in real-world applications (Bahrampour, et al., 2024; Fang & Chen, 2022).

Theoretical frameworks have been a prominent focus in the reviewed literature, with many studies offering models or simulations to illustrate the synergy between Industry 4.0 technologies and VMI systems. For instance, digital twins and AI-driven algorithms have been extensively discussed as tools to simulate inventory scenarios and improve supply chain resilience under various conditions (Zhong, Xu, Klotz, & Newman, 2017). However, the scarcity of empirical research leaves a gap in understanding how these frameworks perform when applied in actual organisational settings. This gap is particularly evident in the lack of longitudinal studies that examine the sustained impact of Industry 4.0 technologies on VMI over time.

Geographically, the studies reviewed often highlight advancements in technologically advanced regions such as Europe, North America, and parts of Asia, where digital infrastructure and industry support (Nepelski & De Prato, 2012) have facilitated the development of integrated VMI solutions. However, in less technologically developed regions, the literature focuses more on the challenges of implementation rather than successful integration. This disparity suggests that while the theoretical benefits of Industry 4.0-enabled VMI are well understood, their practical adoption remains uneven globally, influenced by factors such as economic capability and digital readiness (Raj, et al., 2021).

Furthermore, keyword analysis from the systematic review highlights recurring themes such as “real-time visibility,” “predictive analytics,” and “automation,” reflecting a significant focus on the technological opportunities associated with Industry 4.0 in the context of VMI. Despite this, the emphasis on tangible outcomes, such as cost reductions or operational efficiency improvements, is relatively sparse. Articles often extrapolate expected benefits from conceptual discussions rather than reporting metrics derived from implemented systems, sentiments observed by (Kamble, Gunasekaran, & Dhone, 2020) as well.

In conclusion, while the literature provides a strong theoretical foundation for understanding the integration of VMI with Industry 4.0 technologies, it also underscores the need for empirical research to substantiate the claimed benefits. Future research could address this gap by focusing on case studies and pilot projects that evaluate the practical implications and performance of these integrated systems across diverse industries and regions.

Regarding the opportunities and benefits, the integration of Industry 4.0 technologies within vendor-managed inventory (VMI) systems offers significant advancements in supply chain resilience, efficiency, and cost-effectiveness. Studies have consistently emphasised the transformative potential of technologies such as the Internet of Things (IoT), artificial intelligence (AI), and blockchain in facilitating real-time data exchange and decision-making. For instance, IoT-enabled sensors and devices are highlighted to provide continuous monitoring of inventory levels, which allows for more accurate forecasting and timely replenishment, thereby reducing stockouts and excess inventory (Zhong et al., 2017). AI-driven analytics further enhance this capability by processing large volumes of data to predict demand patterns, identify anomalies, and optimise inventory management strategies (Ivanov, et al., 2019).

Blockchain technology, a recurring theme in the reviewed literature, was highlighted for its role in improving transparency and traceability across supply chains. By creating immutable records of inventory transactions, blockchain helps minimise disputes and enhances trust among supply chain partners. For example, Wang et al. (2019) demonstrated that blockchain-enabled VMI systems reduce lead times and mitigate risks associated with counterfeit goods, particularly in industries where product authenticity is critical. This enhanced visibility not only improves operational efficiency but also strengthens supply chain resilience by enabling faster recovery from disruptions.

Several studies also noted the economic benefits derived from integrating Industry 4.0 technologies with VMI systems. Automation and advanced analytics were frequently identified as key drivers of cost reduction, as they minimise manual intervention and improve process accuracy. For instance, Dolgui et al. (2020) reported that automation of order replenishment processes reduced labour costs and improved overall supply chain performance. Additionally, energy-efficient IoT devices and data-driven optimisation algorithms contribute to sustainable practices by reducing waste and lowering carbon footprints, aligning with global sustainability goals (Kamble et al., 2020).

The reviewed literature also highlighted the potential of these technologies to enhance collaborative relationships among supply chain stakeholders. Real-time data sharing through integrated digital platforms fosters greater alignment between manufacturers, suppliers, and distributors, enabling more responsive and agile supply chains. As noted by Raj et al. (2021), this improved collaboration helps organisations adapt to volatile market conditions and enhances their ability to respond to unforeseen disruptions, thereby strengthening overall supply chain resilience.

Despite these benefits, the literature underscored the importance of contextual adaptation in harnessing the full potential of Industry 4.0 technologies within VMI frameworks. Factors such as organisational readiness, technological maturity, and regional infrastructure significantly influence the outcomes of these integrations. For example, countries with robust digital ecosystems, such as Germany and Japan, were reported to have successfully implemented these advancements, whereas organisations in developing regions face challenges related to digital infrastructure and resource availability (Schumacher et al., 2019).

Regarding challenges, the implementation of Industry 4.0 technologies within vendor-managed inventory (VMI) frameworks has revealed several critical obstacles, particularly in technical, organisational, and economic dimensions. From a technical perspective, many organisations face difficulties related to system integration and interoperability. The complexity of integrating advanced technologies, such as IoT, blockchain, and AI, into legacy systems was a recurrent theme in the reviewed literature. According to Ivanov and Dolgui (2020), achieving seamless communication between different technologies and platforms often requires significant customisation, which can delay deployment and increase costs. Additionally, the vast amounts of data generated by IoT devices present challenges in storage, processing, and real-time analytics, necessitating robust IT infrastructure and expertise (Zhong et al., 2017).

Organisational challenges also play a significant role in impeding the adoption of Industry 4.0 technologies. Resistance to change among employees and a lack of technical skills within organisations were frequently highlighted as barriers. For instance, Raj et al. (2021) noted that workforce reluctance to adopt digital tools and processes stems from insufficient training and apprehension about job displacement. This underscores the need for comprehensive change management strategies, including upskilling programs and fostering a culture of innovation. Furthermore, the lack of alignment between organisational goals and digital transformation initiatives has been identified as a hindrance, particularly in firms where top management support is limited (Schumacher et al., 2019).

Economic factors also contribute significantly to the challenges of integrating Industry 4.0 technologies into VMI systems. The high upfront costs associated with acquiring advanced technologies and infrastructure are often prohibitive, particularly for small and medium-sized enterprises (SMEs). As Kamble et al. (2020) observed, the financial burden of implementing IoT devices, AI algorithms, and blockchain solutions can be substantial, deterring firms with limited budgets. Moreover, the long payback period for these investments, coupled with uncertainty about tangible benefits, exacerbates financial concerns, especially in volatile market environments.

Geographical disparities in digital readiness also emerged as a critical challenge, with firms in developing regions facing significant obstacles in adopting these technologies. Limited internet penetration, inadequate infrastructure, and inconsistent regulatory frameworks often hinder the deployment of Industry 4.0 solutions in these areas (Schumacher, Nemeth, & Sihn, 2019). For example, while countries like Germany and South Korea have successfully implemented advanced VMI systems leveraging Industry 4.0 technologies, firms in developing regions continue to struggle with foundational issues such as stable power supply and skilled labour availability (Raj et al., 2021).

Lastly, cybersecurity and data privacy concerns were frequently cited as critical technical barriers. The reliance on interconnected devices and real-time data exchange increases vulnerability to cyberattacks, making data protection a top priority for organisations. According to Wang et al. (2019), implementing robust cybersecurity measures often adds to the complexity and cost of adopting Industry 4.0 technologies, further deterring their widespread application.

In conclusion, the successful integration of Industry 4.0 technologies within VMI frameworks requires addressing these multifaceted challenges. While the technical, organisational, and economic barriers are substantial, targeted strategies such as fostering digital literacy, improving infrastructure, and offering financial incentives could mitigate these issues and enable firms to harness the full potential of these technologies.

Conclusion

The systematic review of the integration of vendor-managed inventory (VMI) systems with Industry 4.0 technologies highlights a burgeoning area of interest in supply chain management, characterised by a blend of theoretical promise and practical challenges. Current knowledge predominantly revolves around conceptual frameworks and technological propositions that underscore the transformative potential of technologies such as IoT, AI, blockchain, and digital twins in enhancing VMI processes. These technologies are consistently identified as enablers of real-time visibility, predictive analytics, and autonomous decision-making, all of which are essential for achieving supply chain resilience and operational efficiency. However, the literature remains largely theoretical, with a noticeable scarcity of empirical evidence to substantiate the anticipated benefits in real-world scenarios.

The analysis reveals significant opportunities and benefits linked to the integration of Industry 4.0 technologies within VMI frameworks. These include enhanced inventory accuracy, reduced stockouts, and improved supplier collaboration, all of which contribute to streamlined supply chain operations. The potential for cost savings through automation and the reduction of manual errors is another recurring theme. Furthermore, Industry 4.0-enabled VMI systems hold the promise of bolstering supply chain resilience by providing the agility to respond to disruptions and fluctuations in demand. These benefits are particularly pronounced in technologically advanced regions, where digital infrastructure and organisational readiness have enabled more widespread experimentation and adoption.

Despite these opportunities, the integration of Industry 4.0 technologies within VMI systems is fraught with challenges. Technical barriers, such as interoperability issues and the complexity of integrating legacy systems with advanced technologies, remain significant obstacles. Organisational challenges, including resistance to change, skill gaps, and the high cost of initial investments, further complicate implementation efforts. Additionally, economic factors, particularly in less developed regions, hinder the scalability and widespread adoption of these technologies. The uneven global landscape highlights the importance of contextualising technological advancements within the socio-economic and industrial readiness of different regions.

In conclusion, while the integration of VMI systems with Industry 4.0 technologies presents a compelling vision for the future of supply chain management, the path to realising this vision is far from straightforward. The current body of knowledge provides a strong theoretical foundation but lacks the empirical validations needed to guide practical implementation. Addressing the identified challenges will require targeted efforts, such as fostering interdisciplinary collaboration, investing in digital infrastructure, and conducting longitudinal studies to evaluate the long-term impacts of these technologies. By bridging the gap between theory and practice, future research can not only enhance the understanding of this integration but also contribute to building more resilient, efficient, and adaptive supply chains in an increasingly complex global environment.

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