International Journal of Research in Finance and Management

P-ISSN: 2617-5754
E-ISSN: 2617-5762
IJRFM 2024; 7(2): 233-237
www.allfinancejournal.com
Received: 09-07-2024
Accepted: 16-08-2024

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The impact of industry 4.0 on logistics and supply chain management in Vietnam

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DOI: https://doi.org/10.33545/26175754.2024.v7.i2c.368

Abstract
This study focuses on the analysis of Industry 4.0 and related technologies and their impact on supply chain management, providing recommendations specifically for small and medium-sized enterprises (SMEs). The research draws heavily on numerical data and incorporates secondary sources such as scholarly articles and books to provide a comprehensive overview. It has been established that Industry 4.0 technologies, including the innovations of the Fourth Industrial Revolution, have a profound impact on supply chains, enabling real-time operations with minimal human intervention. However, the current level of technology adoption remains relatively low, especially among SMEs. The disparity in the implementation of new technologies between SMEs and large corporations is primarily due to differences in the quality and availability of resources. While large corporations often have better access to financial and technological resources, SMEs face unique challenges in adopting and integrating Industry 4.0 technologies into their operations.

Keywords: Logistics, supply chain management, industry 4.0, Vietnam

Introduction
From the first use of sharpened stones as weapons to the creation of the spear, human history has been marked by constant innovation to improve survival chances. However, innovation did not stop there; as technology progressed, so did the complexity of tools used by ancient societies. With growing populations, the demand for more tools increased. When several members of a community began specializing as artisans to meet these needs, the era known as “Industry Zero” was born.

A significant leap forward occurred much later, marking the dawn of Industry 1.0. This phase began with the refining of ores to create more effective tools and harnessing natural forces like wind and water to power early machinery, such as millstones. As humans started to exploit environmental resources more efficiently, early businesses began to emerge.

The discovery of electricity, alongside new methods of transportation and communication, propelled humanity into Industry 2.0. This era of increased connectivity led to the development of complex global supply chains that spanned oceans and continents. The introduction of the assembly line revolutionized production, allowing for the mass production of goods previously thought to be beyond reach.

Today, much of global manufacturing operates under Industry 3.0, characterized by the integration of robotics and the internet into industrial processes. Digital storage and instant access to data from anywhere in the world have revolutionized supply chains, making them more sophisticated and efficient. As a result, the world experienced unprecedented change, leading many to question what the next phase of industrial development would look like.

Industry 4.0 represents a transformative shift with the emergence of fully autonomous systems that operate without human intervention, marking a new era in industrial advancement. What was once imagined only in science fiction-robots performing human tasks in factories-has become a reality. Innovations like the Internet of Things (IoT) have enabled interconnected networks of machines and sensors within modern factories, creating what can be seen as their own mini-Internets (Epicor, 2021) [3]. However, in contemporary supply chains, manufacturing is just one part of a much larger process.

Research methodology

Study design

Selecting the right research strategy is vital to achieving valid and reliable outcomes in any study. Different research issues require distinct approaches, and using an unsuitable methodology can jeopardize the study's validity. Therefore, to ensure credible results, it is crucial to choose a research method that aligns well with the specific field of study. This section delves into the research methodologies chosen for this study. Both qualitative and quantitative research methods are valuable for exploring different aspects of a topic. Quantitative research focuses on numerical data and requires a broad research scope to achieve statistical significance, while qualitative research emphasizes words, narratives, and visual data. The choice of sample size is influenced by the specific objectives of the study.

Quantitative data is inherently structured and can be analyzed using graphs, statistics, and diagrams. In contrast, qualitative data often requires more organization to be effectively utilized in the study. Quantitative research aims to develop and test hypotheses, theories, and mathematical models, linking mathematical expressions with empirical observations. Such methods are typically used when the research framework is clearly defined and suitable for testing hypotheses derived from theory. Given the need to define concepts and analyze data using descriptive language, this study prioritized a qualitative research approach.

Strategy for research

When discussing research methods, both theoretical and empirical approaches are frequently considered. Theoretical research involves developing a foundational understanding by searching for and selecting basic concepts, forming scientific hypotheses, predicting the properties of research objects, and building conceptual models. This requires gathering information, such as theoretical foundations, published research findings, and statistical data, which must be collected and analyzed by researchers. In contrast, empirical research relies on direct observation of phenomena to address gaps in knowledge or generate new insights. Given the limitations of this novel topic, this thesis primarily focuses on a theoretical approach, while also incorporating empirical methods. The empirical data gathered provides critical insights, allowing researchers to validate hypotheses against existing theories and test theoretical concepts in real-world scenarios. This comparison helps to identify and bridge gaps between theory and practice, leading to more comprehensive and objective research.

Researchers have two main options for data collection: primary and secondary methods. Primary data collection involves gathering original data directly from the source through interviews, questionnaires, and surveys designed by the researcher. This approach is often considered reliable, as it is based on unbiased questions and up-to-date information. However, collecting primary data can be time-consuming, costly, and challenging, particularly when dealing with large sample sizes or complex topics that make finding participants for interviews difficult.

Alternatively, secondary data collection involves compiling existing information from various sources, such as definitions, prior studies, and literature relevant to the research topic. This method is advantageous due to its low cost, accessibility, and quick analysis, as the data has already been processed. However, secondary data may not always be accurate or directly relevant, requiring the researcher to verify its validity against other studies or conduct further investigation. Additionally, secondary data can present challenges if the research question is complex or the topic is new and not thoroughly explored, forcing the researcher to sift through large volumes of tangentially related information.

Given the complexity of the research question and the limited availability of relevant primary sources, this study opted for secondary data collection. This approach facilitates the integration of the digital and physical worlds, enabling humans and robots to collaborate more effectively. In the emerging era of robotics, machines are increasingly performing tasks once reserved for humans, paving the way for innovative strategies in waste-free manufacturing (Lackey, 2019) [7]. By the mid-2030s, it is expected that 30% of company audits will be conducted by artificial intelligence, 10% of the population will use Internet-connected clothing and glasses, and some will have mobile phones implanted in their bodies (IScoop, 2021) [6].

The ability of computer systems to store and analyze data in real-time is crucial for achieving seamless integration across different divisions of a company. This eliminates communication gaps between management levels, ensuring that no details are lost. Furthermore, with AI systems automating data sorting and analysis, lengthy manual processes become unnecessary. For example, if a sensor detects reduced output in manufacturing, the procurement department can immediately order replacement parts and notify maintenance staff for repairs (Higgins, 2021) [5]. These are just a few examples of the characteristics of the Fourth Industrial Revolution that will be explored in this study.

The impact of industry 4.0 on supply chain management

Introduction to the technologies driving the fourth industrial revolution

While Industry 4.0's long-term effects are expected to be beneficial, they also present significant challenges in the short to medium term. Economically, this revolution will alter manufacturing methods and costs, positively influencing global inflation by enhancing energy efficiency through advanced technologies. For example, additive manufacturing significantly reduces raw material and storage costs compared to traditional methods, thereby easing inflationary pressures globally. A transition toward a more efficient, intelligent, and resource-conscious economy is essential to meet growing demand (Pfohl *et al*., 2015) [8]. However, while some industries will thrive, others will face substantial adjustment costs in the short to medium term, necessitating drastic workforce reductions (Schröder, 2017) [9].

As new companies emerge and expand rapidly with innovative technologies, those unable to compete may shrink or disappear across all industries, including growth sectors. This shift could necessitate a reconfiguration of the global economic landscape, especially as resource-dependent economies like Australia, Russia, and Norway face potential declines. In response, countries such as Saudi Arabia are taking steps to reduce their reliance on oil.

Similarly, the economies of the BRICS nations, except for India, continue to grapple with their dependence on mineral resources.

Technological advancement is crucial in this revolution. The United States is reasserting its ecological leadership, while Asian countries such as Japan, Korea, and Taiwan play active roles in shaping Industry 4.0. China stands to benefit significantly from this transformation, using it to ease the transition to slower growth rates and to adapt its workforce to new demands. In 2018 alone, China installed over 154,000 robots, representing a substantial portion of the global total (The Year of the Robot, 2019). European countries like Germany and Norway also aim to capitalize on Industry 4.0, although other European economies lag due to a lack of entrepreneurial culture and supportive environments for technological innovation (Bauer *et al*., 2015) [1].

The rise of a new generation of tech startups is challenging the traditional power dynamics within industries, disrupting market leaders that have long dominated. Companies like Google and Facebook are rapidly expanding, while established firms such as IBM, Microsoft, Cisco, Intel, and various Japanese electronics companies undergo significant restructuring. The decline of giants like Nokia and Kodak underscores the risks businesses face in today's fiercely competitive landscape, where decisions must be swift and well-informed. As this technological revolution accelerates, traditional automakers face intense competition from newer companies like Tesla, which is scaling up production of electric and autonomous vehicles.

Supply chain management in the context of industry 4.0

Supply Chain Management (SCM) involves coordinating a network of organizations and individuals to deliver final products to consumers. The main flows within the supply chain include data and raw materials, transformed at each stage. Effective SCM regulates the movement of goods and services from procurement to production, ensuring that demand is met efficiently (Johnson & Pyke). SCM optimizes supply chains by managing supplier relationships and minimizing costs.

Today's supply chains are often global, spanning multiple countries and continents, which adds complexity to their management. This study focuses on the growing importance of SCM in the era of Industry 4.0, highlighting its impact on scheduling and planning.

The system begins by performing an automated Big Data analysis to determine the most efficient production strategy. After a comprehensive review, manufacturers are provided with a set of viable options to choose the most effective production method. Additionally, the analysis system automatically recommends the optimal production sequence, tools, and timing for each specific plan. Intelligent machines enhance efficiency by quickly processing and disseminating information across the entire system, ensuring consistency throughout. This data-driven approach enables managers to make more informed decisions, even in complex scenarios involving a wide range of products. The ability to develop alternative process plans also allows for greater flexibility and proactivity in addressing any issues that might occur during production. Most importantly, self-learning machines continuously evolve by incorporating new data, allowing them to improve and discover innovative solutions over time.

Using SWOT analysis to evaluate the implementation of industry 4.0 technologies

Before deciding to implement Industry 4.0 technologies, companies should conduct a comprehensive analysis using a SWOT (Strengths, Weaknesses, Opportunities, Threats) diagram.

Strengths: Industry 4.0 technologies create a more transparent, adaptable, and dynamic supply chain. Enhanced information sharing between customers and suppliers leads to increased customer satisfaction and a competitive edge. Remote monitoring devices help maintain product quality and manage inventory efficiently. An electronic supply management system integrated with smart marketing strategies enables companies to anticipate and respond to evolving customer needs reliably. Increased efficiency brings cost savings and higher profits, which can positively impact the GDP of countries investing in Industry 4.0 advancements. Overall, Industry 4.0 can revolutionize supply chains, improving supply management, inventory control, time to market, and environmental impact.

Weaknesses: Implementing advanced technologies in manufacturing requires significant capital investment, complex facilities, and highly skilled personnel. Small and medium-sized enterprises (SMEs) may have simpler supply chains but lack the resources needed for technological upgrades. Conversely, large corporations, despite having more resources, face challenges due to the complexity of their supply chains. The interconnectedness of Industry 4.0 technologies complicates full-scale implementation. Technologies like AI and machine learning require substantial data, along with backend infrastructures such as Big Data, Cloud Computing, and the Internet of Things (IoT). While companies like Amazon and Walmart demonstrate the feasibility of automating operations, many other businesses struggle to adopt these technologies. Additionally, sharing operational data is essential for the continuous improvement of these technologies, but it can slow down technological advancements. The lack of a sufficiently trained workforce is another barrier; keeping up with rapid technological change is expensive, and training existing employees can take years. Large corporations find it easier to hire recent IT graduates, while SMEs may struggle to do so.

Opportunities: Industry 4.0 offers significant growth potential for both current and future enterprises. Companies can increase production without higher labor costs and in less time, and data analysis can help businesses improve responsiveness and drive sustainable development (Hansen *et al*., 2017) [4]. The growing number of companies developing and supplying Industry 4.0 technologies may lead to lower prices and greater market availability in the future. Public technologies, such as public cloud services, which depend on auxiliary technologies, are becoming more accessible. These technologies can be deployed with strategies tailored to an organization's existing digital infrastructure, reducing the need for additional infrastructure investment. This increases the feasibility of outsourcing the implementation of new technologies. Workforce shortages

may be addressed by new government programs offering better incentives for IT and data science students, along with universities expanding their focus on these fields. Though it may take time, this approach could provide a lasting solution.

Dangers: Technological progress brings new challenges, particularly in data security. With increased digitalization, there is a greater risk of data breaches and cyber-attacks. Without proper investment in cybersecurity, the growth of Industry 4.0 could be slowed by industrial espionage. Additionally, while automation reduces routine tasks, it requires a skilled workforce to maintain new technologies. Many businesses are reluctant to invest in training, risking significant social challenges if governments do not manage the pace of automation replacing human jobs.

The COVID-19 pandemic disrupted global supply chains, leading many businesses to adopt Industry 4.0 technologies to sustain operations. AI, Big Data, and IoT have enabled remote work, online shopping, and the automation of production processes, accelerating the shift towards smart factories. These technologies reduce reliance on low-skilled labor and improve efficiency.

Prior to the pandemic, robotics, 3D printing, and smart factories were already minimizing supply chain risks and enhancing flexibility. The pandemic underscored both the commercial and public benefits of such technologies. Digital advancements, like virtual clinics, eased hospital burdens and improved record-keeping. Overall, Industry 4.0 has provided innovative solutions to mitigate pandemic impacts and foster technological progress.

How industry will shape the future of supply chain management 4.0

As the effects of Industry 4.0 on supply chains continue to unfold, the future of SCM will largely depend on how companies address emerging challenges. Increased automation is driving growth in the online retail sector by enabling faster time to market and reducing the cost of return logistics (Shah *et al*., 2019) [10]. To implement new technologies that optimize logistics, manufacturers depend heavily on partnerships with suppliers and logistics providers. While the declining cost of manufacturing robots is promising, it remains higher than the cost of labor in densely populated or less developed countries. As a result, robots are more likely to be adopted in facilities without access to cheaper labor, while countries like India, China, and Vietnam may adopt them more slowly.

Advances in additive manufacturing, robotics, and AI could enhance operations in developed countries by reducing the distance between production and consumers. These technologies also offer small and medium-sized enterprises (SMEs) opportunities to start manufacturing more quickly and affordably, as they won't immediately compete globally.

Progress in AI may lead to new SCM advancements, especially in marketing operations and inventory management, where swift decision-making and data analysis are essential but challenging for large organizations. As the Internet of Things (IoT) continues to develop, reducing costs and expanding throughout supply chains will become more crucial. Although full automation of manufacturing is still in its early stages, it will become more accessible to businesses as Industry 4.0 technologies mature.

Summary and Discussion

In Vietnam, the adoption of Industry 4.0 technologies is offering significant opportunities to enhance supply chain processes, but the pace of adoption varies widely across industries. Technologies like automation, robotics, IoT, and AI are gradually transforming supply chains, making them more efficient and competitive. However, the full impact of these changes in Vietnam is still emerging, as businesses navigate both opportunities and challenges.

Vietnam's manufacturing sector, which plays a crucial role in its economy, stands to benefit greatly from Industry 4.0 technologies. Automation and real-time data analysis can help Vietnamese manufacturers reduce production costs, improve product quality, and speed up delivery times. This is especially important as Vietnam integrates further into global supply chains and competes with larger manufacturing hubs like China and India. Technologies such as predictive maintenance using IoT and robotics are beginning to be employed in factories to minimize downtime and enhance productivity.

Despite these opportunities, several barriers limit widespread adoption of Industry 4.0 in Vietnam. High implementation costs, a shortage of skilled IT professionals, and inadequate digital infrastructure make it challenging for many Vietnamese businesses, particularly small and medium-sized enterprises (SMEs), to embrace these technologies fully. SMEs, which form the backbone of Vietnam's economy, often lack the resources and expertise to invest in cutting-edge technology and require substantial support to make this transition.

Furthermore, Vietnam's focus on low-cost labor as a competitive advantage means that some companies are less inclined to replace human workers with automation. However, as wages rise and global demand for faster, more reliable production increases, Vietnamese firms are likely to face growing pressure to modernize their supply chains through technology.

For Vietnam to maximize the benefits of Industry 4.0, there needs to be a concerted effort to improve digital infrastructure, invest in training and education for workers, and provide incentives for companies to adopt new technologies. If these challenges are addressed, Vietnam could strengthen its position as a competitive manufacturing hub in Southeast Asia, with supply chains that are agile, efficient, and resilient.

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