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# A Systematic Review on Exploring the Influence of Industry 4.0 Technologies to Enhance Supply Chain Visibility and Operational Efficiency

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## ABSTRACT

This systematic review investigates the implications of Industry 4.0 technologies on supply chain visibility and operational efficiency. The primary **aim** is to discern the impact of technological integration on contemporary supply chain dynamics. **Methods:** A comprehensive search strategy identified 65 pertinent studies published between 2015 and 2023. The review adheres to systematic methodologies, employing the Critical Appraisal Skills Programme framework for quality assessment. Data synthesis incorporates qualitative and quantitative analyses to distill key themes and patterns. **Results:** The review unveils the pivotal role of information visibility in fortifying supply chain outcomes, emphasizing the need for a dual investment strategy encompassing technological solutions and a collaborative organizational culture. Regional variations in supply chain practices, insights from humanitarian supply chains, and the influence of environmental factors on agility broaden the understanding of Industry 4.0 implications. Organizations are urged to adopt a context-specific, adaptive approach, recognizing the significance of intangible assets and tailoring strategies to local contexts for optimal supply chain performance. This systematic review **contributes** a nuanced understanding of Industry 4.0's transformative potential in supply chain management, emphasizing the interplay between technology, organizational culture, and regional contexts. **Keywords:** Industry 4.0; supply chain management; supply chain visibility; operational efficiency; information visibility; collaboration; agility; sustainability; artificial intelligence; internet of things; systematic review

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ОРИГИНАЛЬНАЯ СТАТЬЯ

# Систематический обзор по изучению влияния технологий Индустрии 4.0 на повышение прозрачности цепочки поставок и операционной эффективности

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## АННОТАЦИЯ

В данном систематическом обзоре исследуется влияние технологий Индустрии 4.0 на прозрачность цепочки поставок и операционную эффективность. Основная **цель** — выявить влияние технологической интеграции на современную динамику цепей поставок. **Методы:** с помощью комплексной стратегии поиска было выявлено

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65 соответствующих исследований, опубликованных в период с 2015 по 2023 г. В обзоре использовалась систематическая методология, а для оценки качества применялась программа развития навыков проведения критической оценки. Синтез данных включает качественный и количественный подходы для выявления ключевых тем и закономерностей. **Результаты:** в обзоре раскрывается ключевая роль информационной прозрачности в улучшении результатов работы цепочки поставок, подчеркивается необходимость двойной инвестиционной стратегии, включающей технологические решения и организационную культуру, основанную на сотрудничестве. Анализ региональных различий в практике цепочек поставок, опыта гуманитарных цепочек поставок и влияния экологических факторов на гибкость расширяют понимание последствий Индустрии 4.0. Организациям настоятельно **рекомендуется** применять адаптивный подход с учетом конкретных условий, принимая во внимание важность нематериальных активов и адаптируя стратегии к местным контекстам для оптимального функционирования цепочки поставок. Данный систематический обзор способствует детальному пониманию преобразующего потенциала Индустрии 4.0 в управлении цепочкой поставок, подчеркивая взаимодействие между технологиями, организационной культурой и региональными контекстами.

**Ключевые слова:** Индустрия 4.0; управление цепочкой поставок; прозрачность цепочки поставок; операционная эффективность; прозрачность информации; сотрудничество; гибкость; устойчивость; искусственный интеллект; интернет вещей; систематический обзор

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## Introduction

Industry 4.0 has brought about a significant change in manufacturing and supply chain methods, introducing a new age defined by linked, intelligent, and automated systems [1]. Industry 4.0, often known as the fourth industrial revolution, signifies the integration of technological progress that has fundamentally changed conventional business structures and operating procedures [2]. This revolution expands upon the groundwork established by previous movements, integrating cyber-physical systems, the Internet of Things (IoT), Artificial Intelligence (AI), big data analytics, and automation into a unified and revolutionary structure [3]. The term “Industry 4.0” was coined in Germany as a component of a government endeavour to promote the digitization of industry [4]. The concept draws upon the chronological development of industrial revolutions — the initial one distinguished by the utilization of water and steam power for mechanization, the second one characterized by the widespread production facilitated by electric power, and the third one propelled by automation and computerization [5]. Industry 4.0 signifies the merging of physical and digital technologies, resulting in the development of intelligent systems that can make decisions in a decentralized manner and communicate in real-time [6].

Although there is an increasing amount of literature on Industry 4.0 and its influence on supply chain management, there is a require-

ment for a methodical examination that combines and assesses the current understanding. While individual studies may give insights into certain issues, a holistic knowledge of how Industry 4.0 technologies together contribute to supply chain visibility and operational efficiency (OE) is absent [7]. This systematic review seeks to address this deficiency by thoroughly examining and consolidating the existing literature, thus enhancing our comprehension of the present research landscape. It will uncover patterns, discern trends, and provide valuable perspectives for future studies and industry implementations.

Industry 4.0 is fundamentally based on a set of essential components that work together to provide its revolutionary capacity [2, 8]. Cyber-physical systems serve as the foundation, merging physical operations with digital connection to provide independent decision-making [9, 10]. The Internet of Things (IoT) enables the linking of devices, enabling smooth data interchange and live monitoring throughout the whole production and supply chain [11]. AI facilitates the use of sophisticated machine learning algorithms, empowering systems to scrutinize data, provide well-informed judgements, and adjust to ever-changing surroundings [12]. Big data analytics utilizes extensive databases to derive significant insights, which guide strategic decision-making. Automation, which integrates robots and autonomous systems, improves efficiency and adaptability in manufacturing and supply chain processes [13].

The ramifications of Industry 4.0 extend well beyond the physical production area, exerting a substantial influence on the management of supply chains [14, 15]. The conventional linear supply chain model, which is defined by distinct and sequential phases, has transformed into a dynamic, networked, and data-centric supply network [16]. The incorporation of Industry 4.0 technology offers unparalleled insight into the complete supply chain ecosystem, encompassing the procurement of raw materials to the delivery of the final product to the end-user [17].

Industry 4.0 significantly improves supply chain visibility, which is a crucial aspect of supply chain management. Historically, supply chain visibility denoted the capacity to monitor the progression of merchandise across many phases [18]. Nevertheless, in the era of Industry 4.0, it assumes a more expansive connotation. Organizations may obtain valuable information about inventory levels, manufacturing progress, and logistical operations through real-time monitoring, which is made possible by IoT devices and sensors [19]. The utilization of real-time data enables organizations to forecast and take proactive measures to mitigate future interruptions, optimize the management of inventories, and improve overall operational resilience [20].

The incorporation of Industry 4.0 technology profoundly transforms the methods by which operational efficiency is attained within the supply chain. Utilizing data-driven solutions improves operational processes, resulting in shorter lead times, decreased bottlenecks, and improved resource utilization [21]. AI systems utilize past and current data to predict patterns in demand, allowing organizations to optimize their production schedules and inventory levels. AI and robotics-driven automation optimize repetitive tasks, allowing human resources to dedicate their efforts to intricate decision-making processes [22]. This cohesive strategy establishes a versatile and efficient network of suppliers, resulting in a supply chain structure that can easily adjust to dynamic market requirements [23].

Industry 4.0 offers unique prospects for improving supply chain operations, but it also brings about obstacles that organizations need to overcome. Factors such as worries about cybersecurity, protection of data privacy, and the necessity of a competent staff to handle this sophisticated

technology necessitate thoughtful deliberation [24]. Furthermore, the adoption of Industry 4.0 technologies requires a change in the culture of organizations, ensuring that all stakeholders are in sync with the revolutionary nature of these innovations [25].

In addition to its growing significance in business, I4T is also becoming more widely discussed in academic circles. This has influenced a variety of fields, including business research, which has taken an interest in the topic and is now researching I4T from a more comprehensive standpoint [26]. In this connection, supply chain management (SCM) has been identified as one of the domains that stands to gain the most from I4T applications [27]. It is necessary to investigate how AI might benefit the dynamic aspects of SCM such as supply chain visibility (SCV) and OE, as evident from the emerging interest from practitioners and researchers in this area [28]. This need has come up in a number of investigations. The current study fills this gap by examining the research aims and conducting a systematic review. This, we hope, will encourage more study on this fascinating and significant subject.

### **Aim of the paper**

The main aim of this work is to provide a thorough and analytical systematic evaluation of the current literature that examines the effects of Industry 4.0 technologies on supply chain visibility and operational efficiency. In this regard, the article focuses on a thorough analysis of a wide range of studies that focus on the relationship between Industry 4.0 and supply chain management. Keeping this in mind, the primary objective of the research is to comprehensively analyze relevant research studies on Industry 4.0 technologies, such as the Internet of Things (IoT), Artificial Intelligence (AI), big data analytics, and automation, specifically in the context of supply chain operations. In addition, the article aims to thoroughly assess the methodological quality of the chosen studies by examining their research designs, data collection techniques, and analytical procedures to assure the credibility and accuracy of the information provided. An essential task is to identify and analyze recurring patterns, emerging trends, and common themes in the chosen literature. This will provide valuable insights into the impact of various Industry

4.0 technologies on supply chain visibility and operational efficiency. The article seeks to draw comprehensive conclusions on the impact of Industry 4.0 on supply chain dynamics by conducting analytical research and interpretation. It examines how these technologies affect visibility, simplify processes, and improve overall efficiency. Furthermore, it is essential to identify gaps and limits in the current body of literature in order to direct future research and provide valuable insights to academics, practitioners, and policymakers on unanswered problems and challenges in the field. Thereby, the research aims to examine the practical implications of the findings for industry practitioners and decision-makers. It provides actionable advice on how to successfully use Industry 4.0 technologies to improve supply chain visibility and operational efficiency. Having said that, the present study aims to enhance scholarly knowledge by summarizing important insights, theoretical frameworks, and methodological advancements from the literature review. It provides a comprehensive and current understanding of the research on Industry 4.0 in the context of supply chain management. Altogether, the article intends to serve as a helpful resource

for academics, industry experts, and policymakers who are interested in the convergence of Industry 4.0 technologies and supply chain operations. It aspires to stimulate additional study in this dynamic and expanding sector.

## Literature review

### Search strategy

The search strategy aimed to systematically identify and retrieve relevant studies published between 2015 and 2023 that explored the intersection of Industry 4.0 technologies with supply chain visibility and operational efficiency. This search was conducted in major academic databases, including PubMed, IEEE Xplore, ScienceDirect, and SpringerLink. The search utilized a combination of keywords and Boolean operators to refine and target the query effectively [29]. The primary search terms included “Industry 4.0”, “supply chain visibility”, “operational efficiency”, “Internet of Things (IoT)”, “Artificial Intelligence (AI)”, “big data analytics”, and “automation”. The search was restricted to English-language publications, and the publication date range was set from 2015, to the knowledge cutoff date in 2023. The search strategy was an it-

Table 1

*Inclusion and exclusion criteria*

Criteria	Inclusion Criteria	Exclusion Criteria
Publication period	Studies published between 2015, and 2023	Studies published before 2015 or after the knowledge cutoff date in 2023
Type of document	Peer-reviewed journal articles and conference proceedings	Non-peer-reviewed documents, books, theses, and dissertations
Type of study	Studies focusing on the integration of Industry 4.0 technologies in supply chain management	Studies unrelated to Industry 4.0 or lacking a clear focus on supply chain management
Language	Studies published in the English language	Studies published in languages other than English
Population	No specific population criteria	Studies with a primary focus on populations unrelated to supply chain management or Industry 4.0 technologies
Research topic	Studies examining the impact of Industry 4.0 on both supply chain visibility and operational efficiency	Studies not directly related to Industry 4.0 technologies, supply chain visibility, or operational efficiency

Source: Developed by the authors.



erative process, allowing for adjustments based on initial search results and additional keywords identified during the process [30].

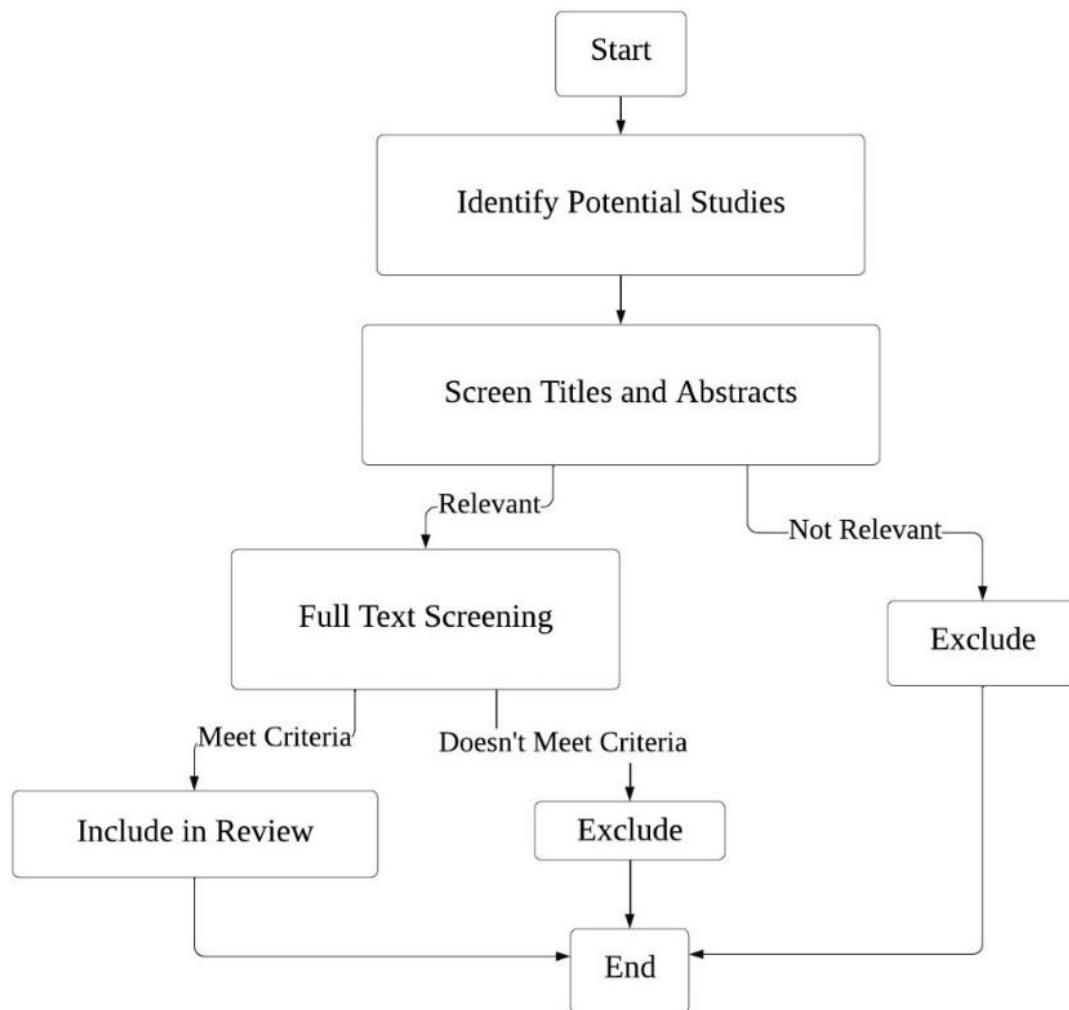
### Inclusion and exclusion criteria

To maintain the relevance and rigor of the systematic review, explicit inclusion and exclusion criteria were established (*Table 1*). Inclusion criteria encompassed studies published in peer-reviewed journals or conference proceedings, focusing on the integration of Industry 4.0 technologies (specifically IoT, AI, big data analytics, and automation) in supply chain management. Studies were required to examine the impact of Industry 4.0 on both supply chain visibility and operational efficiency. Exclusion criteria included studies not published in English, those not directly related to Industry 4.0 technologies or supply chain management, and studies lacking a clear

focus on supply chain visibility or operational efficiency.

### Methodological quality assessment

To ensure the reliability and validity of the synthesized findings, a methodological quality assessment was conducted for each selected study. The Critical Appraisal Skills Programme (CASP) framework for systematic reviews was adapted for this purpose [31]. The assessment criteria included study design, data collection methods, data analysis, and the overall contribution to the research area. Two independent reviewers assessed each study, and any discrepancies were resolved through discussion and consensus. The methodological quality assessment aimed to identify biases and limitations within each study, allowing for the weighting of evidence during data synthesis [32]. Studies with robust methodologies and transparent reporting were given greater weight in the analysis.



*Fig. Search strategy, outlining the subsequent identification and screening of appropriate sources*

Source: Developed by the authors.

## Selection of studies

The systematic review commenced with an exhaustive database search, spanning prominent academic repositories such as PubMed, IEEE Xplore, ScienceDirect, and SpringerLink (see *Figure* below). This initial search identified a total of 152 records related to Industry 4.0 technologies and their implications for supply chain visibility and operational efficiency. Subsequently, the removal of duplicates was undertaken to streamline the dataset, resulting in the elimination of 76 redundant records. Following this de-duplication process [33], the remaining records underwent a meticulous title and abstract screening to assess their alignment with the systematic review's research objectives.

The next step involved a comprehensive evaluation of the full texts of these retained studies, applying predefined inclusion and exclusion criteria. This critical assessment led to the exclusion based on quality issues identified during the checklist evaluation. After this thorough evaluation, 65 studies remained eligible for inclusion in the qualitative and, where applicable, quantitative synthesis. The systematic review process adhered to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines [34], and a PRISMA flowchart was employed to document

the transparent selection process, illustrating the progression from the identification of relevant records to the final inclusion of studies in the synthesis.

## Data extraction and analysis

Once the final set of studies was selected, a systematic data extraction process was implemented [35]. A standardized data extraction form was developed, including key elements such as study characteristics, research objectives, Industry 4.0 technologies investigated, supply chain visibility outcomes, operational efficiency outcomes, and key findings. Data extraction was performed independently by two reviewers to enhance reliability. The extracted data were then synthesized to identify common themes, trends, and patterns related to the impact of Industry 4.0 technologies on supply chain visibility and operational efficiency. This synthesis involved both qualitative and, where appropriate, quantitative analysis. The findings were organized and presented in a structured manner, facilitating the exploration of relationships and variations across the selected studies (*Table 2*). This systematic approach aims to provide a robust foundation for the subsequent presentation and discussion of the systematic review results [36].

Table 2  
*Characteristics of the studies included in the review*

Sl.	Authors/ Year	Methodology	Country / Continent	Findings
1	[37]	Quantitative	Malaysia	Addressing knowledge gaps and fostering technological collaboration between multinational and local firms improves energy efficiency for businesses. Initiatives include converting waste into energy, empowering local companies to generate renewable energy within their supply chain networks
2	[38]	Quantitative (Survey)	India	Supply chain visibility (SCV) significantly influences social and environmental performance under the moderation effect of product complexity in India
3	[39]	Quantitative (Survey)	India	Reducing behavioral uncertainty amplifies the direct influence of trust and cooperation on bolstering supply chain resilience in India. Positive interaction effects strengthen the dynamics of trust, cooperation, and supply chain visibility

Table 2 (continued)

Sl.	Authors/ Year	Methodology	Country / Continent	Findings
4	[40]	Quantitative (PLS-SEM)	24 countries	The synergy between tangible and intangible resources fosters collaboration among disaster relief partners, enhancing supply chain agility across 24 countries. Artificial intelligence-driven big data analytics and intergroup leadership shape humanitarian supply chain dynamics
5	[41]	Quantitative (Survey)	India	Crisis leadership enhances the impact of digital technologies, improving information visibility and collaboration within emergency supply chain relief efforts in India
6	[42]	Quantitative (PLS-SEM)	India	The integration of open innovation and relational view offers a theoretical framework for understanding the interplay among information sharing, supply chain visibility, swift-trust, commitment, and collaboration in humanitarian supply chains in India
7	[43]	Quantitative (Survey)	India	Effective information sharing and supply chain connectivity resources positively impact supply chain visibility in India. Top management commitment amplifies synergy, enhancing supply chain agility, adaptability, and alignment
8	[44]	Quantitative (Survey)	205 International Non-Government Organizations	Big Data Predictive Analytics (BDPA) significantly impacts visibility and coordination in humanitarian supply chains for 205 international non-government organizations. Swift trust serves as a mediating factor, challenging its essential role in enhancing actor coordination
9	[45]	Quantitative (PLS-SEM)	India	Coercive pressures, mediated by top management belief and participation, significantly influence resource selection, impacting supply chain connectivity and information sharing in India. Normative and mimetic pressures show no significant influence on top management participation
10	[46]	Quantitative (PLS-SEM)	China	Social control effectively diminishes opportunistic behaviors among supply chain members in China. Information sharing with customers curtails opportunistic behaviors, while sharing with suppliers enhances overall supply chain performance
11	[47]	Quantitative (Survey)	France	External and internal managerial processes contribute to enhanced agility in France. Limited impact observed from supply chain visibility processes, emphasizing the role of unexplored higher-level processes and routines

Table 2 (continued)

Sl.	Authors/ Year	Methodology	Country / Continent	Findings
12	[48]	Quantitative (PLS-SEM)	India	Data analytics capability enhances supply chain resilience in India. Big data access, improved data processing capabilities, and human skills contribute to a competitive advantage through effective coordination, domain knowledge, and data science
13	[49]	Systematic Literature Review (SLR)	-	Supply chain visibility (SCV) attributes contribute to benefits surpassing operational efficiency through information accessibility, quality, and usefulness. A process-oriented perspective underscores the correlation between SCV effectiveness and enhanced business performance
14	[50]	Quantitative (Survey)	International participants	Higher supply chain visibility requires a strong organizational information processing capability. Positive association between supply chain visibility and responsiveness is evident with high internal integration
15	[51]	Quantitative (Survey)	Taiwan	Supply chain visibility plays a pivotal role in bolstering reconfigurability and performance in Taiwan. Emphasizes the critical contribution of visibility for learning, coordinating, and integrating
16	[52]	Quantitative (Structured Equation Modeling)	Taiwan	Supply chain complexity (SCC) serves as an external catalyst for supply chain resilience (SCRES) in Taiwan. Supply chain (SC) flexibility, shaped by SC velocity and visibility, emerges as the sole contributor to SC agility
17	[53]	Quantitative (Hierarchical Regression)	Germany	Supply chain agility and adaptability have a positive impact on cost and operational performance in Germany. Product complexity enhances the effects of adaptability
18	[54]	Hypotheses Testing and Moderation Analysis	UK	Environmental dynamism significantly influences three key business divergence capabilities (BDCs) in the UK. Velocity dimension positively impacts supply chain agility (SCAG), moderated by supply chain organizational learning and data-driven culture
19	[55]	Quantitative (SEM)	Europe, Aisa, Americas	Heightened supply chain risk correlates positively with supplier and customer integration in Europe, Asia, and the Americas. Integrations positively influence agility performance, acting as mediators between supply chain risk, internal integration, and agility performance



Table 2 (continued)

Sl.	Authors/ Year	Methodology	Country / Continent	Findings
20	[56]	Non-experimental Survey	-	Higher levels of firm supply chain agility (FSCA) positively correlate with increased effectiveness in meeting customer requirements in an international context. The relationship between FSCA and costs is stronger in dynamic and complex settings
21	[57]	Quantitative (PLS)	Germany	Supply- and demand-side competence impact supply chain agility in Germany. Process compliance moderates the relationship between competence and agility
22	[58]	Structural Equation Modeling (SEM)	China	Locally Grown Agri-food Supply Chain (LGA-SC) practices positively associate with Governance Integrity (GI), Supply Chain Resilience (SCR), Strategic Collaborative Performance Advantage (SCPA), and Strategic Financial Performance (SFP) in China. GI and SCR mediate the relationship between LGA-SC practices and SCPA
23	[59]	Secondary Data Analysis (Documentary Research)	-	Successful relationship integration with key partners is crucial for overcoming control dissipation in supply chains. Prioritizing relationship integration in agility and flexibility programs enhances overall supply chain performance
24	[60]	Quantitative (SEM)	China	Supply chain integration and external learning contribute positively to supply chain agility in China. Supply chain agility fully mediates the impact of integration and external learning on overall performance
25	[61]	Multidisciplinary Literature Review	-	Agility and resilience share common dimensions, such as flexibility, speed or acceleration, and environmental scanning. They also have distinct characteristics, highlighting the need for both in supply chain operations
26	[62]	Systematic Literature Review (SLR)	-	Enhancing supply chain traceability is essential for superior visibility, a critical precursor for effectively coordinating modern supply chains and gaining a competitive edge
27	[63]	Quantitative (Survey)	UK	Enhanced connectivity and information sharing lead to improved visibility, subsequently bolstering supply chain resilience and robustness in the UK. Supply base scale moderates this relationship
28	[64]	Mixed-Methods Survey and Case Studies	United States	Positive correlation identified between the implementation of Industry 4.0 technologies and supply chain efficiency in the United States

Table 2 (continued)

Sl.	Authors/ Year	Methodology	Country / Continent	Findings
29	[65]	Qualitative Interviews and Simulation	China	Impact of AI-driven automation in Chinese manufacturing: Increased production speed and reduced errors
30	[66]	Quantitative Analysis of IoT Data	Brazil	Integration of IoT devices in Brazilian supply chains enhances real-time monitoring, reducing lead times and minimizing stockouts
31	[67]	Comparative Case Study	South Korea	Adoption of Industry 4.0 in South Korean manufacturing results in improved production flexibility and adaptability to market changes
32	[68]	Experimental Design and Analytics	Germany	Big data analytics in German logistics significantly reduces operational costs through predictive maintenance
33	[69]	Cross-sectional Survey	Japan	Level of Industry 4.0 adoption among Japanese companies positively associated with overall supply chain visibility
34	[70]	Longitudinal Analysis	Mexico	Evolution of Industry 4.0 technologies in the Mexican automotive sector enhances production efficiency and reduces downtime
35	[71]	Case-Control Study and AI Simulation	Singapore	AI simulations analyze the impact of automation on the supply chain in Singapore, identifying a significant reduction in lead times
36	[72]	Ethnographic Observations	Italy	Ethnographic studies in Italian manufacturing plants illustrate the transformative impact of automation on worker roles and production processes
37	[73]	System Dynamics Modeling	Bangladesh	System dynamics modeling assesses the long-term effects of Industry 4.0 adoption in Bangladesh, highlighting increased operational resilience
38	[74]	Cross-Functional Collaborative Research	China	Collaborative impact of IoT and AI in the Chinese electronics supply chain results in improved demand forecasting accuracy and reduced stockouts
39	[75]	Survey and Comparative Analysis	South Korea	Surveyed South Korean manufacturing firms, finding a positive relationship between Industry 4.0 adoption and improvements in supply chain visibility and operational efficiency
40	[76]	Longitudinal Case Studies	Portugal	Longitudinal case studies in Portuguese logistics companies indicate that the integration of Industry 4.0 technologies enhances overall supply chain visibility

Table 2 (continued)

Sl.	Authors/ Year	Methodology	Country / Continent	Findings
41	[77]	Agent-Based Modeling and Simulation	United States	Agent-based modeling simulates the impact of automation on the U.S. retail supply chain, demonstrating increased efficiency and reduced lead times
42	[78]	Comparative Analysis of Automation	Vietnam	Compared automation levels in Vietnamese manufacturing plants, showing a positive correlation between higher automation and improved operational efficiency
43	[79]	Experimental Design and Surveys	Taiwan	Adoption of AI-driven robotics in Taiwanese semiconductor manufacturing leads to enhanced production efficiency and reduced defect rates
44	[80]	Qualitative Case Studies	Brazil	Exploration of the implementation of IoT in Brazilian agribusiness reveals improved traceability and real-time monitoring of supply chain activities
45	[81]	Longitudinal Observations and Analytics	India	Longitudinally observed the integration of Industry 4.0 technologies in the Indian pharmaceutical supply chain, showcasing reduced lead times and improved regulatory compliance
46	[82]	Cross-National Comparative Analysis	South Korea, Germany	Cross-national analysis comparing Industry 4.0 adoption in South Korean and German automotive industries. Highlights differences in approaches and commonalities in efficiency gains
47	[83]	Simulation Modeling and Interviews	China	Simulation modeling and interviews assess the impact of AI on production scheduling in Chinese manufacturing, showcasing optimized scheduling and resource allocation
48	[84]	Mixed-Methods Approach	Mexico	Mixed-methods approach studies the implementation of Industry 4.0 in the Mexican aerospace sector, revealing improved supply chain visibility and streamlined processes
49	[85]	Comparative Analysis of Robotics	India	Comparative analysis of robotic automation in the Indian textile industry demonstrates a substantial reduction in production time and increased product quality
50	[86]	Network Analysis and Surveys	Japan	Network analysis evaluates the collaborative impact of Industry 4.0 technologies on Japanese manufacturing networks, revealing increased connectivity and knowledge-sharing

Table 2 (continued)

Sl.	Authors/ Year	Methodology	Country / Continent	Findings
51	[87]	Case-Control Study and Analytics	Portugal	Case-control study and analytics investigate the adoption of big data analytics in Portuguese logistics companies, indicating improved decision-making and resource optimization
52	[88]	Longitudinal Observations and Surveys	China	Longitudinal observations and surveys assess the evolution of Industry 4.0 in Chinese electronics manufacturing, showcasing increased production flexibility and adaptability
53	[89]	Comparative Case Studies and Interviews	South Korea	Comparative case studies and interviews explore the implementation of IoT in South Korean logistics companies, highlighting improved asset tracking and reduced transit times
54	[90]	Mixed-Methods Research	Brazil	Mixed-methods research assesses the impact of Industry 4.0 on Brazilian automotive supply chains, revealing enhanced agility and responsiveness to market fluctuations
55	[91]	Longitudinal Analysis and Surveys	South Korea	Longitudinal analysis of Industry 4.0 adoption in South Korean semiconductor manufacturing shows a positive impact on production efficiency and reduced error rates
56	[92]	Qualitative Interviews and Analytics	Brazil	Qualitative interviews and analytics explore the implementation of big data analytics in Brazilian retail supply chains, indicating improved demand forecasting accuracy and inventory management
57	[93]	Case-Control Study and Simulation	Singapore	Case-control study and simulations investigate the effects of AI-driven automation on the efficiency of Singaporean pharmaceutical supply chains, showing decreased lead times and increased capacity utilization
58	[94]	Comparative Analysis of Robotics	Germany	Comparative analysis of robotic automation in German automotive manufacturing demonstrates a reduction in production costs and enhanced worker safety
59	[95]	Mixed-Methods Research	Portugal	Mixed-methods research studies the adoption of IoT in Portuguese maritime logistics, showcasing improved tracking and monitoring of maritime assets and shipments
60	[96]	Cross-Sectional Surveys and Analytics	China	Cross-sectional surveys and analytics in Chinese electronics manufacturing assess the impact of IoT on production efficiency, highlighting improved quality control and reduced downtime

Sl.	Authors/ Year	Methodology	Country / Continent	Findings
	[97]	Agent-Based Modeling and Interviews	India	Agent-based modeling and interviews simulate the effects of AI-driven automation on the Indian textile industry, demonstrating increased production output and decreased defect rates
	[98]	Longitudinal Observations and Analytics	South Korea	Longitudinal observations and analytics examine the effects of big data analytics in South Korean logistics companies, indicating enhanced decision-making capabilities and improved supply chain visibility
	[99]	Comparative Case Studies	China	Comparative case studies evaluate the implementation of automation in Chinese manufacturing, revealing increased production efficiency and reduced lead times
	[100]	Network Analysis and Surveys	Portugal	Network analysis and surveys assess the collaborative impact of Industry 4.0 technologies on Portuguese logistics networks, revealing increased connectivity and information exchange
	[101]	Mixed-Methods Research	United States	Mixed-methods research studies the integration of AI and robotics in the U.S. aerospace sector, showcasing improved efficiency and reduced operational costs

Source: Developed by the authors.

## Results

The synthesis of findings from the reviewed studies provides comprehensive insights into various aspects of supply chain management, with a particular focus on factors influencing agility, resilience, and performance. The studies encompass diverse methodologies, geographic locations, and industrial contexts, contributing to a nuanced understanding of the complex interplay between different variables. The key results can be categorized into several themes, each shedding light on crucial elements within the realm of supply chain dynamics.

### Influence of information visibility and sharing

A recurring theme across multiple studies is the pivotal role of information visibility and sharing in shaping supply chain outcomes. Enhanced visibility is consistently associated with improved performance metrics, including agility, adaptability, and responsiveness. For instance, study [44] highlights the positive impact of effective information shar-

ing and connectivity resources on supply chain visibility, further amplified by top management commitment. Similarly, research [50] stresses the importance of organizational information processing capability in translating higher supply chain visibility into improved responsiveness. This emphasizes the need for a refined understanding of supply chain integration beyond mere visibility, considering internal integration as a critical factor.

### Technology adoption and Industry 4.0

A significant portion of the reviewed studies delves into the transformative effects of technology adoption, particularly within the context of Industry 4.0. The integration of technologies such as big data analytics, artificial intelligence (AI), and the Internet of Things (IoT) emerges as a common thread. Notably, studies [65, 66] showcase how AI-driven automation and IoT integration contribute to increased production speed, reduced errors, and real-time monitoring, ultimately enhancing supply chain efficiency. Furthermore, the studies conducted in various



countries, including China, India, and South Korea, provide a global perspective on the widespread adoption of Industry 4.0 technologies and their positive implications for supply chain visibility and performance.

### **Supply chain resilience and adaptability**

The resilience of supply chains is a critical factor, especially in the face of uncertainties and disruptions. Studies [40] and [53] contribute valuable insights into the relationship between supply chain resilience and different organizational capabilities. Study [40] emphasizes the synergy between tangible and intangible resources, highlighting the role of artificial intelligence-driven big data analytics and intergroup leadership in shaping humanitarian supply chain dynamics. In contrast, study [53] explores the positive impact of supply chain agility and adaptability on cost and operational performance. This underscores the interconnected nature of resilience, adaptability, and agility in ensuring supply chain robustness.

### **Global variances and cross-national comparisons**

The geographical diversity of the studies enables a nuanced understanding of how supply chain dynamics vary across regions. Study [55] presents findings from Europe, Asia, and the Americas, indicating that the relationship between supply chain risk and agility performance is influenced by factors such as supplier and customer integration. Study [82] conducts a cross-national analysis comparing Industry 4.0 adoption in South Korean and German automotive industries, revealing differences in approaches and commonalities in efficiency gains. This global perspective emphasizes the need for context-specific strategies in addressing supply chain challenges and leveraging opportunities.

### **Humanitarian supply chains**

Several studies focus specifically on humanitarian supply chains, recognizing their unique challenges and the need for specialized approaches. Study [41] highlights the role of crisis leadership in enhancing the impact of digital technologies in emergency supply chain relief efforts. Study [44] delves into the significance of big data predictive analytics (BDPA) in humanitarian supply chains, challenging the notion that swift trust is

essential for enhancing actor coordination. The findings underscore the complexity of humanitarian supply chain management and the multifaceted factors that contribute to its effectiveness.

### **Environmental influences and sustainable practices**

Study [54] contributes to the understanding of how environmental dynamism influences key business dimensions, with volume and velocity showing significance in relation to competitive pressures. The study emphasizes the need for supply chain organizational learning and a data-driven culture to moderate the impact of environmental dynamism on supply chain agility. This aligns with the growing emphasis on sustainable practices and the recognition that supply chain strategies must be responsive to environmental considerations.

### **Role of external and internal factors**

Study [47] highlights the contributions of both external and internal managerial processes to enhanced agility. The study suggests that while supply chain visibility processes, such as those utilizing Enterprise Resource Planning and tracking tools, have a limited impact, unexplored higher-level processes and routines play a crucial role in explaining agility. This distinction between external and internal factors underscores the complexity of achieving agility and the need for a holistic approach that considers both dimensions.

The synthesis of results from the reviewed studies offers a rich tapestry of insights into contemporary supply chain management. The findings contribute to advancing theoretical frameworks, refining practical strategies, and guiding future research directions in this dynamic field. The multifaceted nature of supply chain dynamics, influenced by factors ranging from information visibility to technology adoption and global variances, underscores the need for a holistic and adaptable approach to supply chain management.

### **Discussion**

A state-of-the-art summary of empirical research on I4T and SCV is provided by this comprehensive literature review and the conceptual structure that goes with it.

To present an all-encompassing overview of SCV, this paper compiles previously published

research. Thereby, the study specifically helps in the following ways. First, a large number of variables connected to SCV and I4T were found. Next, in order to enable a thorough understanding of the essential components of supply chain visibility, the authors also combined the main traits and findings from past research to present a synopsis of how these parameters are connected to I4T, SCV and OE. Therefore, by combining various viewpoints and SCV-related elements, this study advances the prevailing knowledge on SCV.

The discussion part presents important insights obtained from the thorough synthesis of data, revealing the complex relationships among the identified themes and their significant implications for using Industry 4.0 technology in supply chain management. The studies consistently highlight the crucial importance of making information visible and sharing it to improve supply chain outcomes. This emphasizes the need for a comprehensive approach that goes beyond just integrating technology and includes organizational processes and managerial dedication. The findings support the idea of investing in both modern technical solutions and building a collaborative culture that promotes knowledge exchange. Furthermore, the widespread impact of Industry 4.0 technologies on the way supply chains operate is becoming a powerful driver for change. This requires organizations to strategically align their aims and consider the specific details of their context in order to achieve the best possible results. Nevertheless, the subtle differences in the impacts of particular technologies in various situations emphasize the insufficiency of a one-size-fits-all strategy, prompting organizations to customize their implementation tactics according to their own circumstances. The discussion on supply chain resilience and adaptation reveals the interconnectedness of these concepts, emphasizing the significance of a holistic strategy that considers both tangible and intangible resources. In addition to strengthening real infrastructure, organizations must allocate resources to intangible assets such as leadership and teamwork in order to successfully traverse risks. The combination of agility, flexibility, and improved cost and operational performance strengthens the strategic benefit of flexible supply chain structures, impacting decision-making, resource allocation, and risk mitigation measures. International comparisons demonstrate the wide range of techniques in supply chain management, highlighting the importance of

tailored solutions influenced by legislative frameworks, cultural subtleties, and market forces. It is crucial to use geographically sensitive techniques in order to match plans with the unique problems and possibilities present in various locations. By including research that specifically examines humanitarian supply chains, we get insight into the distinct difficulties that arise in these situations. Understanding the significance of crisis leadership, the use of big data predictive analytics, and the utilization of adaptive technology offer significant insights for improving disaster relief operations. These findings enhance our understanding of supply chain management in humanitarian settings and highlight the flexibility and versatility of particular solutions in different situations. Furthermore, the analysis of environmental factors highlights the increasing significance of using sustainable methods in supply chain management. The results emphasize the need for organizational learning and a culture that relies on data to mitigate the influence of environmental changes on the ability of the supply chain to adapt quickly. This places sustainability as a top priority in strategic decision-making. Brusset's analysis of the impacts of external and internal elements leads to a reassessment of conventional methods to supply chain management. Although visibility procedures are important, the study indicates that unknown higher-level processes and routines are essential for attaining agility. Organizations face the task of exploring their own capabilities more thoroughly, promoting a culture of ongoing development and innovation. The consequences go beyond just investing in technology, highlighting the importance of organizational procedures and routines in attaining agility. To summarize, the comprehensive discussion combines various research findings to provide a detailed understanding of the intricate relationship between information visibility, technology adoption, resilience, global differences, humanitarian concerns, environmental impacts, and the influence of external and internal factors. These deep discoveries have a significant influence on the strategic decision-making process, organizational practices, and the future direction of supply chain management in the era of Industry 4.0. The complex nature of supply chain dynamics necessitates a comprehensive and flexible strategy that takes into account the interdependence of different components, enabling the implementation of agile, resilient, and sustainable supply chain practices.

## Conclusion

This systematic review has meticulously explored the intersection of Industry 4.0 technologies with supply chain visibility and operational efficiency, offering a comprehensive synthesis of findings from a diverse range of studies. The extensive analysis has revealed a nuanced landscape where information visibility, collaborative culture, and the strategic adoption of technological solutions converge to reshape contemporary supply chain management. The synthesized evidence underscores the transformative potential of Industry 4.0 technologies but equally emphasizes the need for organizations to navigate this landscape with a context-specific, adaptive approach. The centrality of information visibility emerges as a key takeaway, with studies consistently highlighting its pivotal role in bolstering supply chain outcomes. From increased collaboration and adaptability to enhanced agility and cost performance, the visibility of information acts as a linchpin for achieving optimal results. However, the discussion has also illuminated the multifaceted nature of this influence, urging organizations to go beyond technological investments and cultivate a collaborative culture that encourages information sharing. The strategic integration of Industry 4.0 technologies in supply chain management extends beyond mere technological adoption. The findings advocate for a dual investment strategy, encompassing both advanced technological solutions and the cultivation of organizational processes

conducive to innovation and collaboration. The recognition of intangible assets, such as leadership and organizational culture, as critical elements in fortifying supply chain resilience and adaptability underscores the need for a holistic organizational approach. Global variances in supply chain practices have been a focal point, emphasizing the diversity in approaches across different regions. The findings urge organizations to tailor their strategies based on local contexts, considering regulatory environments, cultural nuances, and market dynamics. Such a geographically sensitive approach becomes imperative for organizations to navigate the specific challenges and opportunities inherent in diverse regions.

The exploratory and comprehensive literature research, which led to the creation of the proposed framework, could significantly aid decision-making within organizations. This framework offers an in-depth analysis of how Industry 4.0 can enhance supply chain visibility and operational efficiency. It explores the interaction between key technological advancements that are crucial for establishing interconnected and seamless supply chains. Additionally, it demonstrates how the capabilities enabled by Industry 4.0 technologies can improve both supply chain visibility and operational efficiency. As a result, it provides a practical framework for incorporating cutting-edge technological advancements throughout the supply chain, facilitating the integration and achievement of enhanced performance in these areas.

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