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Supply Chain 5.0: A Comprehensive Literature Review on Implications, Applications and Challenges

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Abstract:- Supply Chain 5.0 represents a paradigm shift in logistics and operations, integrating advanced digital technologies such as artificial intelligence, Internet of Things (IoT), blockchain, and analytics. This paper explores the transformative potential of Supply Chain 5.0 in optimizing efficiency, flexibility, and responsiveness within supply chain management practices. Through an analysis of current literature and industry trends, we elucidate how Supply Chain 5.0 enables real-time data insights, predictive analytics, and automated decision-making to revolutionize traditional supply chain models. However, challenges including data security, interoperability issues, and workforce training remain significant barriers to adoption. This study underscores the importance of addressing these challenges to fully realize the benefits of Supply Chain 5.0 in driving competitiveness, resilience, and sustainability in the global marketplace.

Keywords:- *Industry 5.0 · Supply Chain 5.0, Supply Chain 4.0· Supply Chain Resilience (SCR) Supply Chainsustainability (SCS) · Human-Centric Supply Chain (HCSC).*

I. INTRODUCTION

In today's rapidly evolving industrial landscape, the concept of Supply Chain 5.0 has emerged as a beacon of innovation, promising to revolutionize the way businesses manage their operations and logistics. Building upon the foundations laid by previous industrial revolutions, Supply Chain 5.0 represents a transformative era characterized by the seamless integration of advanced digital technologies and strategic reconfigurations of supply chain processes.

As industries transition towards this new paradigm, marked by heightened digitalization, connectivity, and automation, it becomes imperative to understand the multifaceted dimensions of Supply Chain 5.0. This entails exploring not only its potential benefits and applications but also the challenges and implications associated with its adoption.

At its core, Supply Chain 5.0 embodies a vision of interconnectedness, agility, and intelligence, enabled by a fusion of cutting-edge technologies such as artificial intelligence (AI), the Internet of Things (IoT), blockchain, and big data analytics. These technologies empower organizations to achieve unprecedented levels of efficiency, flexibility, and responsiveness in their supply chain operations, thereby gaining a competitive edge in today's dynamic marketplace.

However, amidst the promises of enhanced productivity, cost savings, and innovation, the transition to Supply Chain 5.0 is not without its hurdles. Concerns regarding data security, privacy, interoperability, and ethical considerations loom large, while the potential for workforce displacement raises questions about the socio-economic implications of this technological revolution.

In light of these complexities, this comprehensive literature review aims to delve deep into the implications, applications, and challenges of Supply Chain 5.0. By synthesizing existing research, industry insights, and emerging trends, we seek to provide a nuanced understanding of how Supply Chain 5.0 is reshaping the future of logistics and operations management.

Through a critical examination of the opportunities and limitations posed by Supply Chain 5.0, this study aims to inform stakeholders, policymakers, and practitioners about the strategic considerations involved in embracing this new era of supply chain management. By identifying key research gaps and avenues for future exploration, we aspire to contribute to the ongoing discourse surrounding Supply Chain 5.0 and pave the way for its successful implementation and optimization in diverse industrial contexts.

Our study is structured into five main sections to comprehensively address the transition to Supply Chain 5.0. Beginning with the Evolution of Supply Chain 5.0, we trace its developmental trajectory. Moving to From Supply Chain 4.0 to Supply Chain 5.0, we examine the defining features of this transition. Key Technologies in Supply Chain 5.0 explores the pivotal role of technology, while Supply Chain 5.0 Constructs delves into its core principles. Finally, Challenges in Supply Chain 5.0 highlights the complexities of adoption. Through these sections, we aim to offer a holistic understanding of the transition towards Supply Chain 5.0 and its implications.

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A. Evolution of Supply Chain 5.0

Supply Chain 1.0 had a primary focus on internal optimization. The aim was to automate manufacturing processes using the principles of scientific management such as time and motion study. Supply Chain 2.0 came about with the improvement of globalization and the internet. Companies established virtual supply chain networks where they outsourced production and moved to high levels of customization [1] . The focus of Supply Chain 3.0 is the realization that complete supply chain integration is essential. Members now collaborate but they also look to have network transparency, which allows them to see each other's internal processes. Throughout any changes to the supply chain, the aim is to capture financial data. The vision of Supply Chain 4.0 is to apply the Industry 4.0 perspective, which is derived from the broader concept of the fourth industrial revolution. [2] This is represented by the recent trend to automate the manufacturing process using technologies such as Cyber-Physical Systems (CPS), Internet of Things (IoT), Industrial Internet of Things (IIOT), advanced robotics, big data analytics, machine learning, and additive manufacturing. These technologies have moved into the testing phase to achieve 'smart factories'. It is our belief that by understanding the importance of Supply Chain 5.0, organizations who seek to establish 'smart factories' using the current Industry 4.0 technologies will have a clearer roadmap. This roadmap describes the changes necessary for their supply chain to evolve to a state where the factory at the epicenter manufactures the product with minimal human intervention using CPS and IoT-based production process with machine learning-based decision making and delivering up to the customized product at the cost and speed of mass-produced product. [3]

B. From Supply Chain 4.0 to Supply Chain 5.0

Supply Chain 4.0 marked a significant advancement in supply chain management, leveraging Industry 4.0 technologies to optimize processes and enhance efficiency. At its core, Supply Chain 4.0 integrated cutting-edge technologies such as artificial intelligence, blockchain, Internet of Things (IoT), and big data analytics across the entire supply chain ecosystem. This integration enabled unprecedented levels of connectivity, visibility, and agility, empowering organizations to respond rapidly to evolving market demands and disruptions.

One of the key features of Supply Chain 4.0 was its departure from traditional linear supply chains towards interconnected and dynamic networks. Information flowed directionally, facilitating real-time data exchange between various stakeholders—from suppliers to manufacturers to distributors to end consumers. This enhanced visibility into supply chain operations, enabling better decision-making and resource allocation. [25]

Moreover, Supply Chain 4.0 ushered in a new era of smart manufacturing, where technologies like cyber-physical systems (CPS), [26] additive manufacturing, and advanced robotics transformed production processes. These technologies enabled greater flexibility, customization, and efficiency in manufacturing operations, driving improvements in product quality and reducing time-to-market.

However, despite its transformative impact, Supply Chain 4.0 faced challenges, particularly in terms of sustainability and resilience. [27,28] The COVID-19 pandemic, in particular, exposed vulnerabilities in global supply chains, highlighting the need for greater resilience and adaptability in the face of unforeseen disruptions. [29]

Enter Supply Chain 5.0—a paradigm shift towards human-centric, sustainable, and resilient supply chains. Supply Chain 5.0 builds upon the achievements of its predecessor while placing a stronger emphasis on social and ethical considerations. It prioritizes the well-being of workers, environmental sustainability, and community engagement, aiming to create value not only for businesses but also for society. [30]

➢ *Key Principles of Supply Chain 5.0 Include:*

- **Human-Centric Approach:** Supply Chain 5.0 recognizes the importance of human expertise alongside technological advancements. It emphasizes collaboration between skilled workers and automation technologies to drive innovation and efficiency.
- **Sustainability:** Sustainability is a central pillar of Supply Chain 5.0. Organizations are encouraged to adopt environmentally friendly practices, reduce waste, and minimize their carbon footprint throughout the supply chain.
- **Resilience:** Supply Chain 5.0 places a strong emphasis on resilience, with organizations implementing strategies to mitigate risks and disruptions proactively. This includes diversifying supply sources, building robust contingency plans, and investing in technologies that enhance supply chain visibility and agility.
- **Mass Customization:** Supply Chain 5.0 promotes mass customization over mass production, allowing organizations to tailor products and services to individual customer needs. This not only enhances customer satisfaction but also drives operational efficiency by reducing waste and inventory holding costs.

Overall, the transition from Supply Chain 4.0 to Supply Chain 5.0 represents a significant evolution in supply chain management, driven by a holistic approach that combines technology, sustainability, and human-centric principles. By embracing these principles, organizations can create more resilient, sustainable, and socially responsible supply chains that deliver value to both businesses and society. [31] [32] [33]

II. KEY TECHNOLOGIES IN SUPPLY CHAIN 5.0

A. Internet of Things (IoT)

The Internet of Things is a system of interrelated, internet-connected objects that are able to collect and transfer data over a wireless network without human intervention. A system keeps improving as technology

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advances. This has a direct impact on the supply chain as a whole. The system on the IoT can provide a much more comprehensive understanding of what goes on in the supply chain. [4] Everything from the conditions that the product is made in, to the point in which it reaches the customer can be recorded and examined all from the data the IoT system has collected. IoT devices can provide an ecosystem of real-time information within the supply chain. The more that is known about the supply chain, the easier it is to optimize. IoT leaves no dark spots in the process, meaning that if there is a more efficient way to do something that saves time and resources, it can be implemented with much confidence because the effects of the changes can be monitored from the information the IoT has gathered. Another benefit of the IoT in supply chain is the improvement of traceability. [5]This feature on the IoT can provide a documented history of an item's movement throughout the supply chain, which is useful for recalling an item's history in the case of a problem. Items can be monitored every step of the way until they reach the consumer, providing a greater understanding of the amount of time it takes for something to happen, e.g. the delivery of a product to a certain place. This can help speed up processes in the supply chain and customer delivery. With a better understanding of the supply chain and more comprehensive data, comes more informed decision-making. With IoT data, simulations can be run to model potential supply chain changes and their outcomes, without the need to physically implement anything. This reduces the risk of implementing a new idea as the effects are already known, further optimizing the supply chain. [6]

B. Artificial Intelligence (AI)

This is a key technology in the coming years, as described earlier, when smart people previously had to think of a smart action before, with AI, this smart action can be repeated and improved on because the AI learns to recognize the effective parts of that chain and store it for future reference. This can be achieved in 5.0 through machine learning techniques, which will automate complex decision-making process by learning and adapting from experience. AI will also have a big impact in improving customer service in the 5.0 era, through the use of chatbots to provide more human-like interaction and taking over simple tasks previously carried out by human operators. This now leads to the possibility of fully automating warehousing tasks and delivery of products to customers without human intervention. [7,8,9]

C. Blockchain Technology

The next key technology is blockchain technology, which is a type of distributed ledger technology (DLT) that keeps a continuously growing list of records or transactions secured from tampering and revision. The enticing quality of blockchain technology is its potential for a new level of collaboration across the supply chain where all involved parties can work together, share data, and verify that data in an environment with a level of trust not seen before. [10] Immutable records of data and transparent smart contracts can facilitate the automation of business processes with a greater degree of control. This enables the decentralization and self-regulation of complex networks that are increasingly the reality in supply chain as organizations look to work together to share resources or fulfill customer demand. Blockchain technology has a current archetype in crypto currencies with their smart contracts. [11] Contracts between parties can be converted into lines of code and if both parties adhere to the contract terms described, the code executes with the agreed-upon actions. If one, party defaults or there is an activity outside of contract terms, the code does not execute and there is an indication of where the process failed. This eliminates the confusion and often money loss that comes from contractual breaches with a system of complete accountability. This concept can be extrapolated to every area in the supply chain such as the delivery of goods, collaboration in manufacturing, or strategic purchasing decisions and has global implications for every industry. [12]

III. SUPPLY CHAIN 5.0 CONSTRUCTS

In this segment, we delve into three pivotal constructs of supply chain 5.0 to grasp a deeper comprehension of how these elements are molding the future landscape of supply chain management. Through an extensive review of the literature, we aim to glean valuable insights into the hurdles and prospects posed by supply chain 5.0, and how organizations can adeptly gear up for and navigate through these transformative shifts.

A. Human-Centric Supply Chains (HCSCs)

At the core of the human-centric supply, chain (HCSC) lies the principle of human centricity, advocating for the subservience of machines and automation to humans, not the inverse [34]. HCSC, thus, redefines supply chain management by positioning individuals at the helm of the process. Leveraging technology, HCSC endeavors to sculpt a sustainable society that champions corporate social and environmental responsibility in the realm of supply chain development [35, 36].

As supply chains gravitate towards the Society 5.0 paradigm, the significance of the HCSC approach burgeons. Society 5.0, a Japanese initiative, envisages a "super-smart society" spotlighting human-centered and sustainable solutions, facilitated by technological innovation [37]. The Japanese government delineates 17 actionable items within Society 5.0 aimed at realizing the Sustainable Development Goals (SDGs) by 2030. These SDGs, endorsed by the United Nations in 2015, furnish a collective roadmap for fostering peace and prosperity for people and the planet, both presently and in the future [38, 39].

Big data, IoT, and AI emerge as indispensable Industry 4.0 (I40) technologies crucial for the transition to Society 5.0. Together, these technologies furnish the requisite processes for initiating and disseminating information vital for designing Society 5.0 solutions [40]. The assimilation of Industry 4.0 technologies into the development of Society 5.0 solutions necessitates the adoption of novel business models, services, and products by managerial stakeholders [41, 42].

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Against the backdrop of the evolution towards Industry 5.0, a human-centric approach to supply chain management assumes paramount importance, prioritizing the welfare of workers, consumers, and individuals alike. This approach harmonizes technological advancement with socio-environmental imperatives, thereby fostering sustainability and social responsibility within the manufacturing sector. By anchoring the human element at the nucleus of the manufacturing process, enhancements in job satisfaction, working conditions, and productivity are foreseeable [42].

Within the realm of Industry 5.0, the concept of "Operator 4.0" emerges as a pivotal paradigm shift. This perspective embodies a human-centric ethos, addressing the social sustainability and human-centric requirements inherent in Industry 5.0. Operator 4.0 redefines traditional manufacturing labor, making it safer, more enjoyable and offering greater autonomy and avenues for self-development. Achieved through the fusion of cognitive technologies with Industry 4.0 innovations, this transition elevates the traditional manufacturing worker into a smart and adept operator [43].

➢ *Industry 5.0: Toward an Efficient and Sustainable Future*

As Industry 5.0 unfolds, it paves the way towards a more efficient and sustainable manufacturing future. This entails a reshaping of the supply chain to prioritize the needs and well-being of workers and customers. [44] Anchored in the psychological and cultural paradigm of mass personalization, Industry 5.0 champions a human-centered approach, enriching manufacturing by unprecedentedly personalizing products and services [45, 46].

➢ *Key Elements of HCSCs:*

- *Human-Centered Technological Innovation (HCTI)*

Human-centered technological innovation epitomizes an approach to technology development that places paramount importance on people's needs while conscientiously considering the broader impact on the environment and society. Rooted in human-centered design principles, this approach underscores empathy, understanding, and collaboration with end-users to fashion technology that.

- *Human-in-the-Loop Technology (HITL)*

HITL technology entails the integration of human input into automated processes to enhance decision-making and quality control. It facilitates human oversight and final decisions on critical aspects such as product quality, safety, and regulatory compliance. Fostering effective collaboration between humans and machines, HITL ensures operational continuity even amidst equipment failures, while also facilitating ethical decision-making.

- *Human–Machine Interaction (HMI)*

The field of Human–Machine Interaction (HMI) represents a rapidly evolving interdisciplinary domain aimed at fostering seamless and efficient collaboration between humans and robots. Bridging disciplines like psychology, computer science, engineering, and human factors, HMI endeavors to create effective systems for human–robot collaboration (HRC). Despite inherent challenges, the future of HMI holds immense promise for enhancing HRC, generating new job opportunities, and propelling technological advancement.

- *Supply Chain Skill Development (SCSD)*

In the era of Industry 5.0, training programs for supply chain skill development emerge as a pivotal facet of business operations. Ensuring employees possess requisite skills to adeptly operate new technologies and undertake high-value tasks in production is imperative for sustained success and competitiveness in the marketplace. To meet this demand, virtual technologies like Augmented Reality (AR) and Virtual Reality (VR) are increasingly leveraged to offer safe and efficient training solutions, without disrupting ongoing processes or exposing workers to hazardous scenarios.

- *Human Rights and Well-being (HRWB)*

Within a human-centric supply chain (HCSC), the paramount concern is the welfare and rights of workers. HCSC places employees at the core of its operations, prioritizing their well-being and fundamental rights. By integrating social and ethical practices into its framework, a HCSC fosters a work environment that is safe, inclusive, and respectful of workers' autonomy, dignity, and privacy. Emphasizing both physical and mental health, this approach promotes fair labor practices, non-discrimination, and access to education and training, thereby supporting the personal and professional growth of workers, and enhancing their career prospects [47, 48, 49].

- *Human-Centered Human-Robot Collaboration (HC-HRC)*

Human-centered human-robot collaboration (HC-HRC) embodies a human-centric approach where robots are designed and deployed with a focus on ensuring human safety, comfort, and fulfillment of needs. Recent research underscores the significance of collaborative robots (cobots) in mitigating the risk of injuries and fatigue among workers, enhancing efficiency, and enabling the creation of specialized and personalized goods as well as encounters [50, 51], and 52].

- *Customer-Centric Supply Chains (CCSCs)*

Customer-centric supply chains (CCSCs) prioritize the preferences and needs of customers throughout the entire supply chain process, from sourcing to production and delivery of goods and services. This approach necessitates adaptive, intelligent, and flexible production lines capable of meeting evolving customer demands. Leveraging technologies like virtual reality (VR), augmented reality (AR), sensors, and AI enhances the customer experience, from purchasing to post-sale support. However, ethical considerations regarding data privacy must be addressed when providing customized services [53,52]. Transitioning from mass production to personalized production enables the creation of unique and tailored products and services for individual customers, driving competitiveness, revenue, and fostering stronger customer relationships [54].

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- *Human-Centric Manufacturing Automation (HCMA)*

In the era of Industry 5.0, the manufacturing landscape is being reshaped by autonomous machines, cobots, and digital technologies aimed at enhancing efficiency and reducing waste. However, a human-centric approach to manufacturing automation, which integrates human creativity and automation, amplifies the benefits of Industry 5.0. By eliminating unpleasant and hazardous tasks, while creating more fulfilling roles for workers, HCMA cultivates a positive work environment. Investing in education programs to equip workers with the necessary skills for evolving roles is crucial for the successful integration of automation. With the right approach and investment, Industry 5.0 promises workers new opportunities for skill development and more rewarding careers, propelling the manufacturing industry forward [55].

B. Sustainable Supply Chains (SSCs)

Industry 5.0 heralds a transformative shift in manufacturing, emphasizing a departure from system-centric approaches toward human-centric ones with a strong focus on sustainability. By integrating advanced technologies, Industry 5.0 aims to empower human workers while minimizing environmental and social footprints. Supply Chain 5.0 places paramount importance on sustainable manufacturing alongside the well-being of human operators and productivity goals, fostering a holistic approach to industrial development that sets the stage for a more sustainable and equitable future [56].

➢ *Sustainable Supply Chain (SSC)*

Sustainable supply chain (SSC) entails the integration of sustainable development principles into the management and operation of supply chain activities, adopting a triple-bottom-line approach that balances economic, social, and environmental sustainability. This involves ensuring economic growth while also being socially responsible and environmentally conscious throughout supply chain operations.

➢ *Sustainable Supply Chain Management (SSCM)*

Sustainable supply chain management (SSCM) involves the strategic and transparent management of supply chain activities with a sustainability focus. Implementation of SSCM can lead to reduced operational costs, improved company image, and better monitoring of environmental actions. The entire life cycle of a product or service, from raw material sourcing to end-of-life disposal, is considered to account for economic, social, and environmental impacts.

➢ *United Nations Sustainable Development Goals (SDGs)*

The United Nations Development Program (UNDP) introduced 17 Sustainable Development Goals (SDGs) in 2015, driving action in critical areas for humanity and the planet over the next 15 years. These goals span economic, social, and environmental aspects, providing a framework for businesses to operate more sustainably and responsibly. Supply chains play a crucial role in contributing to these goals, necessitating collective efforts from governments, civil society, the private sector, and individuals worldwide.

➢ *Dimensions of Triple Bottom Line (TBL) Sustainability in Supply Chains*

- *Economic Perspective of Sustainable Supply Chains (SSCs)*

The economic perspective of SSCs seeks to balance economic growth with social well-being and environmental sustainability. By implementing sustainable practices and considering the triple bottom line, SSCs aim to create value for all stakeholders, reduce costs, improve efficiency, and enhance competitiveness while promoting social justice and environmental protection.

- *Social Perspective of Sustainable Supply Chains (SSCs)*

In Industry 5.0, social sustainability takes center stage, focusing on the physical and psychological well-being of human operators, their skills and competencies, and the integration of digital technologies. This includes fair wage policies, safe work environments, ethical business practices, and increased transparency through sustainability reporting.

- *Environmental Perspective of Sustainable Supply Chains (SSCs)*

The environmental aspect of SSCs aims to reduce negative environmental impacts, promote sustainability, and responsible resource use. Key strategies include implementing circular economy principles, circular supply chains, green supply chain management (GSCM), and leveraging technologies like big data analytics (BDA) and the Industrial Internet of Things (IIoT) to optimize processes and reduce environmental footprints. Green housing serves as a prime example of GSCM, emphasizing sustainable materials, construction practices, and energy-efficient systems throughout the supply chain.

C. Resilient Supply Chains (RSCs)

Resilience stands as a multifaceted capability crucial for system success, encompassing anticipation, withstand, adaptation, and recovery from disruptions. In the context of Industry 5.0, achieving resilience is paramount for navigating the rapidly evolving landscape. The concept of Resilient Operator 5.0 aims to enhance adaptability and responsiveness in manufacturing workforce and systems, fostering a new breed of operators capable of swiftly adjusting to changes and disruptions.

➢ *Resilient Operator 5.0 Vision*

The vision for Resilient Operator 5.0 encompasses two main objectives: promoting "self-resilience" among the workforce and fostering "system resilience" within human-machine systems in smart manufacturing. Self-resilience pertains to the individual's capacity to adapt, endure, and recover from challenges, integrating various biological, physical, cognitive, and psychological factors. System resilience, on the other hand, focuses on enabling human-machine systems to act collaboratively and responsively, facilitating real-time responses to evolving demands and conditions across the factory, supply chain, and customer requirements.

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➢ *Smart Resilient Manufacturing System*

In manufacturing, a Smart Resilient Manufacturing System denotes a flexible and agile system capable of responding to operational changes and disturbances, ensuring continuity under both normal and abnormal conditions. Reconfigurability is pivotal, enabling real-time adaptation to changes and disruptions. End-to-end visibility within an increasingly integrated and connected supply chain is essential for enhancing decision-making quality across procurement, manufacturing, logistics, and sales operations, thereby bolstering efficiency, productivity, resilience, and sustainability.

➢ *Supply Chain Resilience (SCR) in Industry 5.0*

Supply chain resilience (SCR) is viewed as a means to advance the United Nations' Sustainable Development Goals (SDGs) within Industry 5.0. The fusion of resilience and sustainability has spurred interest in sustainable-resilient supply chains, emphasizing adaptability to disruptions and market fluctuations while minimizing environmental impact and promoting social responsibility. Approaches such as green supply chain management, circular economy, and corporate social responsibility have been instrumental in enhancing supply chain resilience and sustainability, aligning with organizational goals for long-term competitiveness and environmental stewardship.

- *Digital Technology in Building Sustainable-Resilient Supply Chains*

Utilization of digital technology in constructing sustainable-resilient supply chains encompasses various aspects:

❖ *Data Collection and Processing :*

✓ IoT sensors and devices: monitoring energy usage, emissions, and environmental factors.
✓ Industrial Internet of Things (IIoT) and Green IIoT: managing and analyzing data for sustainable practices and energy efficiency.
✓ Cyber-physical systems (CPS): integration of digital technologies into manufacturing systems for enhanced visibility and control.

❖ *Data Management and Analysis:*

✓ Big data analytics (BDA): extracting insights for monitoring performance, risk mitigation, and agility.
✓ Machine learning and artificial intelligence (ML-AI): analyzing data for optimized operations and demand forecasting.
✓ Cloud computing (CC) and edge computing (EC): facilitating real-time collaboration and decision-making in the supply chain.

- *Applications for Supply Chain Optimization:*

In pursuit of supply chain optimization, various technologies and methodologies are employed:

❖ *Blockchain Technology (BT):*

✓ Facilitates secure and transparent tracking of goods and transactions, reducing fraud, errors, and delays.
✓ Enables faster and more accurate tracking of inventory and shipments, improving efficiency and reducing waste.

❖ *Digital Twins (DTs):*

✓ Digital simulations offer insights into complex production systems, allowing for the development and testing of new operating policies.
✓ Virtual experimentation and validation aid in reducing development time and costs, enabling proactive identification of inefficiencies.

❖ *Additive Manufacturing Technology (AMT):*

✓ Revolutionizes production and distribution by minimizing waste and energy consumption while increasing flexibility and speed.
✓ Capable of quickly producing customized products on-demand, reducing lead times, inventory costs, and transportation expenses.

❖ *5G Technology :*

✓ Enhances communication speed and reliability in the supply chain, enabling real-time monitoring and better coordination among partners.

❖ *Collaborative Robots (Cobots):*

✓ Utilizes AI and ML to analyze data collected by embedded IoT sensors, improving efficiency, safety, accuracy, and productivity.
✓ Dynamically allocates tasks and roles, reducing waste and increasing supply chain resilience.

❖ *Augmented Reality (AR) and Virtual Reality (VR):*

✓ Enhance warehouse operations and logistics by providing real-time information, training, and visualization.

❖ *Supply Chain as a Service (SCaaS):*

✓ Outsourcing certain aspects of supply chain management to third-party providers enhances sustainability and resilience.
✓ Reduces dependence on single suppliers or logistics providers, mitigating risks associated with disruptions.

These technologies and methodologies collectively contribute to supply chain optimization, promoting efficiency, sustainability, and resilience in an ever-evolving business landscape.

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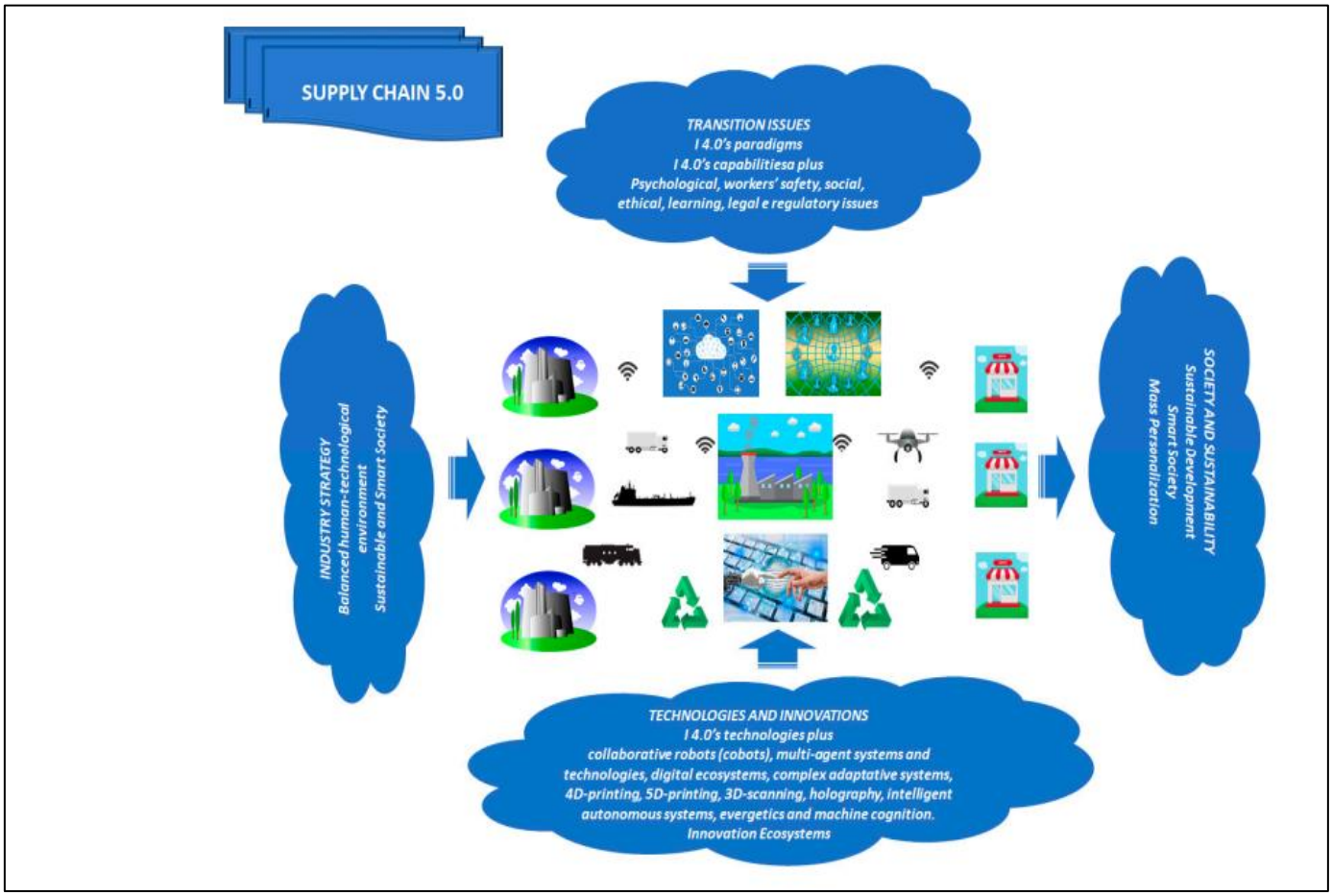

Fig 1 : Supply Chain 5.0 Framework and Concept[57].

Supply Chain 5.0 aims to strike a balance, between involvement and technology while fostering an sustainable society. This approach relies on a mix of technologies including those from Industry 4.0 and emerging fields within an ecosystem of innovation.

Yet transitioning to Supply Chain 5.0 brings forth challenges linked to Industry 4.0 principles, capabilities and various factors like aspects, worker safety, social implications, ethics, legality and compliance with regulations.

The main goal of Supply Chain 5.0 is to nurture the growth of an more sustainable community from both environmental perspectives. Moreover it encourages tailored offerings in products and services, across supply chains at scale.

IV. CHALLENGES IN SUPPLY CHAIN 5.0

A. Integration of Emerging Technologies

A recent technology, which has seen a rapid increase in investment from large companies, is AI, which can potentially be a disruptive technology for supply chains. AI can automate and optimize complex processes, with the potential to self-learn and adapt in real-time. An example being in production scheduling, where AI can assess the entire supply chain and make decisions to ensure a balanced and efficient utilization of resources. It is suggested that AI could create a more autonomous supply chain in the future, in which it can anticipate and correct problems before they occur. This AI technology would also be closely linked to IoT, in which it could make decisions based on a constant feed of real-time data. With these emerging technologies, it is important that companies weigh the potential improvements along with the high level of investment and risk. [13]

By integrating emerging technologies into supply chain networks, companies are aiming to create a smarter, more efficient, and self-correcting supply chain. This can be seen through the increase in IoT technology, in which it is thought there will be over 50 billion connected devices by 2020, generating an unprecedented amount of data. In terms of supply chains, this will greatly increase traceability and visibility. [14]An example being in the food industry, a sensor could be placed in a food package, which can monitor location and temperature to ensure the quality of the product for the end customer. This increase of data will further lead companies to invest into analytics technology, to make sense of the data and aid decision making. A study by Accenture found that 86% of high performing companies in supply chain say that big data analytics is very important to their operations.

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Along these developments toward supply chain Supply Chain 5.0., businesses must critically increase their level of efficiency and connectivity across supply chain networks. It embraces the crucial element of supply chain integration that leads to cross-industry cooperation and establishment of more substantially connected networks. With respect to technology, the combination of IoT, AI, Big Data Analytics, and blockchain is very high in demand. [15]

B. Data Security and Privacy Concerns

The way, the firms have been attending to the customer's and supplier's information by a huge extent is that now there is a wide range of threats of hacking and more chances of cyber-attacks. Cyber assaults which would be characterized by data breaches, the act of either inequity intentionally or unintentionally revealing secure or private information to a non-secure entity, have become an ever-increasing problem. EU General Data Protection Regulation is getting effected in May 2018. [16]Therefore, any companies that are not compliant with the regulation could be penalised up with a fines of 4% of their global annual turnover, whichever is greater than, €20 million. data breaches can have tremendous financial consequences but what resilience rate there is of supply chains are not known. The erosion of one of the links in the chain of supply network by its natural course can cause a disastrous blow to the other members of the same network subsequently.

When the latest study on the cost per data breach became public among tech giants (such as IBM), and the data revealed that the cost of data breaches in the US is even higher than it is on a global level, then this sends alarm bells to US companies that are already a bit scared of potentially very expensive transition into the technologies that are related to the new Industry 4.0. [17]The total amount is paid to detect and escalate the breech and to inform for the firms then the nationalization cost to pay. Increased detection escalation costs include costs that are observed from day one to day 30 of the detection of the breach and in the landscape of Supply Chain 5.0, cyber terrorism can really boost the magnitude of the detection escalation costs due to the increased complexity and connectivity of the platform. In America, notification costs are higher because litigation in America is much more expensive than elsewhere. [18]

C. Workforce Adaptability and Skill Gaps

Adaptability of workforce and skill gaps increase the problem of skill gap, and now it has become an important issue in the age of Industry 4.0. Nevertheless, those problems remain as the key challenges of the day. As indicated in the "Future of Jobs" research conducted by the WEF on the influence of Industry 4.0, by 2022, at least 54% of all employees will require substantial re-skilling and up-skilling. More recently, the DHL and others conducted the 2019 Logistics Trend and Insights survey, on which respondents said "access to a skilled workforce" is the number one concern for the supply chain leaders. Such fears arise out of the faster pace of innovation that puts new skills in demand while abandoning others permanently. [19] For example, along with autonomous systems and vehicle systems, there is growing demand for engineers with the skills in automation and robotics, but this reduces the demand of humans in manual labor and driving. It is an obstacle which discloses the skill gaps between the areas where employment is decreased and those where new skills are not widespread enough. At the same time, the annual survey conducted by DHL confirms this position since they indicate that the pool of skillful supply chain management workers is shrinking.

Dealing with this challenge implies a full knowledge of how the nature of supply chain work is changing over the course of technology development and how the needed skills will look like in the future. Conforming this knowledge will lead to development of strategic programs to re-skill and up-skill the workforce, and to help the new generation of workers to pick the right career streams. On the one hand, the organizations could define competency frameworks for the supply chain professions taking into account the changes introduced by technology. DDI and SCM World have demonstrated this with the development of a Supply Chain Leader Profile outlining skillsets and competencies for future leaders in the field of supply chain management. [20]

The use of simulation and scenario planning tools makes it possible to create virtual sandboxes for supply chain management; here the strategies being developed and tested are safe without affecting any existing system. The interaction can serve as the basis for on-job training and analysis, which would be of great use for development of the critical thinking skills. Hence, it would be essential for cooperation with academia more to help the students go into the right career, and make the classes conducive to the demands of industry. [21]

D. Sustainable and Resilient Supply Chains

Sustainability and the resilience factor have become very popular phrases in various supply chain settings, but not many people can give their correct meanings, and it is not always evident their real ramifications on the supply chain. Sustainability will be reaching its highest level when the "current generation can have the right to meeting the needs today without compromising the abilities of future generations to fulfill their needs too".[22] This term "sustainability", which is mentioned first, in the Brundtland Report of 1987 has undoubtedly influenced business strategies and mission statements of various companies in the last two decades. Roughly speaking the definition is generalized and different companies have different approaches for 'sustainability' issue and the implementation of sustainability strategies is governed by benefits gained from various initiatives. Resilience is usually synonymous with sustainability and has already been in the supply chain context since the day following the deadly September 11th terrorist attack. [23]

Resilience stands for the ability to 'recover' to the previous state when a perturbation messes up the balance. This may be summarized as the sales channel perspective were the business is capable of maintaining customer's needs in the event of a supply disruption and then return to regular operations as soon as the issue is

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resolved. In connection with this, the principle goal is to ensure integrity of supply chains. Two researchers, Christopher and Peck (2004), made the following statements, which highlighted the positive effects of disruption: "Mostly, all implemented measures make the system more efficient. This means that most of the system is moving towards maturity and being based on the best practices of a supply chain instead of the hazard of lower costs accompanied by lower quality."It is crucial to highlight here, as this is the major issue that supply chain managers or executives can face – while investments in such practices will not affect the efficiency, they will give preventive measures only. [24]

V. CONCLUSION

In conclusion, our comprehensive literature review has provided a nuanced exploration of the implications, applications, and challenges of Supply Chain 5.0. Through an in-depth analysis of existing research, industry insights, and emerging trends, we have illuminated the transformative potential of Supply Chain 5.0 in reshaping the future of logistics and operations management.

By tracing its evolution, examining its key technologies, elucidating its core constructs, and addressing its challenges, we have offered valuable insights for stakeholders, policymakers, and practitioners alike. Our review underscores the strategic imperatives and considerations involved in embracing this new era of supply chain management.

Despite the promises of enhanced efficiency, flexibility, and innovation, the transition to Supply Chain 5.0 is not without its hurdles. Concerns regarding data security, privacy, interoperability, ethical considerations, and potential workforce displacement necessitate careful consideration and proactive mitigation strategies.

Moving forward, it is essential for organizations to adopt a proactive approach in navigating the complexities of Supply Chain 5.0. This involves leveraging the opportunities presented by advanced technologies while addressing the associated challenges in a holistic manner.

Furthermore, our review highlights the need for ongoing research and collaboration to address the knowledge gaps and uncertainties surrounding Supply Chain 5.0. By fostering a deeper understanding of its implications and applications, we can unlock the full potential of Supply Chain 5.0 and drive sustainable growth and competitiveness in the digital age.

In summary, our literature review serves as a foundation for further exploration and discussion on Supply Chain 5.0. By synthesizing existing knowledge and identifying areas for future research, we hope to contribute to the ongoing discourse surrounding supply chain management and pave the way for the successful implementation and optimization of Supply Chain 5.0 in diverse industrial contexts.

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