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Original Article

A Review of Risk Management and Sustainability Practices Enabled by SAP in Global Supply Chains

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Abstract *- Risk management practices and sustainability have been unveiled as important factors in the modern global supply chains to ensure resiliency, efficiency and competitiveness in the long term. The digitized solutions on SAP are central in overcoming these challenges through integration of real-time visibility, predictive intelligence, and intelligent automation of complex supply networks. SAP S/4HANA, SAP IBP, SAP Ariba, and SAP GRC provide organizations with the opportunity to detect, evaluate, and reduce risks efficiently and to encourage sustainable operations. They support responsible sourcing, resource management, regulatory compliance, and supplier collaboration, and they improve economic performance and social and environmental responsibility. The combination of new technologies, IoT, machine learning (ML), and blockchain, also makes supply chain management more resilient, allowing to make predictions and detect anomalies, as well as provide end-to-end product traceability. The combination of solutions enabled by SAP allows organizations to establish agile, transparent and sustainable supply chains to reduce disruption and generate long-term value to stakeholders in an increasingly dynamic global business environment.*

Keywords *- Sap S/4hana, Supply Chain Risk Management, Sustainable Supply Chain Management (Sscm), Real-Time Data Visibility, Digital Transformation.*

1. Introduction

Businesses are essential to a country's economic development; they grow both locally and abroad. Supply chains are no longer local when businesses expand internationally. This is seen when businesses expand internationally, sourcing from and selling to various organizations and/or individuals [1]. This reality makes the supply chain more complicated, and improper management of this complexity may lead to interruptions and increased expenses [2]. Local companies may be facing challenges related to social, political, economic, and domestic laws and regulations [3]. Business institutions are less constricted since the problems are still under control, therefore they may foresee such challenges more or less because they have previously encountered and been accustomed with them [4]. Business operations may be constrained in contrast to global business, when all elements beyond the borders may result in losses and the closure of less strong players' businesses.

ERP systems, specifically those provided by SAP, have a critical role in merging risk management functionality with sustainability-based operations to help organizations to comply with regulations, enhance operational effectiveness, and sustainability over time.

Sustainable Supply Chain Management (SSCM), which is characterized by the increasing academic and industrial research on green logistics, environmental responsibility, and socially responsible sourcing [5]. Digital solutions from SAP, including SAP Environment, SAP S/4HANA, and SAP Integrated Business Planning (IBP), Health, and Safety (EHS), and SAP Sustainability Control Tower, has become a key technological facilitator of the operationalization of the principles of SSCM in the global networks [6]. Those platforms enable real-time analytics, predictive analytics, and workflows so that they bring more visibility to risks, regulatory compliance, and sustainable value creation across the supply chain.

The review's foundation is the body of current research and industry displays of risk management and sustainability strategies that with the help of SAP and highlights technological innovations, implementation strategies and new trends that are emerging and defining resilient and sustainable global supply chains.

2. Organization of the Paper

The organization of this paper is as follows: Section II In SAP-Enabled Supply Chains introduces Risk Management. Section III discusses SAP-enabled sustainability practices in Global SCM. Section IV examines Digital Technologies Driving SAP-Based Risk & Sustainability. Section V presents a literature review of key studies, and Section VI concludes with important conclusions and potential avenues for future study.

2.1. Risk Management in Sap-Enabled Supply Chains

Risk management that is effective has turned into an essential element for today's supply chains that are in complicated and globalized areas. The integrated digital platforms of SAP are the main factor that helps organizations to spot, evaluate, and reduce risks throughout the entire chain of supply [7]. Full visibility and real-time monitoring of supply chain operations from beginning to end are provided by the SAP ecosystem, which consists of predictive analytics, SAP Ariba Risk Insights, SAP GRC, and SAP Integrated Business Planning (IBP).

2.2. Overview of SAP S/4HANA Digital Core

The digital foundation of the modern corporate enterprise is SAP S/4HANA and offers an intelligent and integrated platform that facilitates the adoption of cutting-edge analytics, AI-driven insights, and the use of cloud resources in an expandable manner [8][9]. SAP has changed its ERP environment and the change is taking the form of adoption of the new software. The new software has given companies not only a technological shift but a total turnover in the business operations [10]. The new software has been accompanied with simplified architectural design, real-time data process, and simplified interaction with various cloud environments, which are the key factors behind the facilitated new business models, accelerated decision-making, and operational responsiveness [11]. Therefore, installing SAP S/4HANA involves more than merely switching to a new system; it is equally a strategic movement that places businesses in a competitive position and ready for the future in a digital world that is changing rapidly.

2.3. SAP S/4HANA risk management for SCM

These SAP initiatives are known to be difficult as many of them don't get the desired results or aren't finished on schedule or within budget [12]. Mature risk management practices are therefore crucial since they guarantee early risk detection and suitable project risk reduction. Common instances of risk management initiatives include:

- Program Governance and Risks: Provide updates on risks and issues found during performance, deliverables, and program/project governance process evaluations. To properly understand all the risks, risk workshops should be held with the several stakeholders. Examining the preparations to create Operational Readiness prior to go-live before the handover to operations, as well as the formally established go-live go/no-go criteria.
- Business Processes and Testing: To guarantee accurate and thorough financial reporting after go-live, find out if the testing approach involves checking the current application controls and business processes. It is crucial to closely monitor if the new features provided by SAP S/4HANA are taken into account and incorporated into the updated operating protocols.
- HANA Infrastructure: The data centers need to be equipped with new technology and hardware in order to run the new SAP S/4HANA systems. Important contributions include the SAP landscape infrastructure service model, the specific HANA architecture, and the protocols in place to provide security, control, and compliance over the newly constructed or renovated data centers.
- Data Migration and Reconciliation: In many businesses, the SAP environment is disjointed. SAP S/4HANA is being used by these companies to integrate and simplify their operations. Assessing the risks associated with data movement is crucial, as it can lead to complex migration initiatives.
- General IT Controls: Evaluating fundamental IT controls is essential since SAP S/4HANA offers new operational techniques and technologies. Change management protocols, backup and restore protocols, and interface integration are affected by the accelerated SAP release cycle and the redesigned SAP platform. SAP S/4HANA is a brand-new, state-of-the-art enterprise resource planning (ERP) system that rapidly handles and analyzes massive volumes of data using in-memory computing. This enables businesses to make faster, more accurate data-driven choices. Regarding the supply chain management, SAP S/4HANA provides various tools to streamline inventory optimization, demand forecasting, supplier co-operation and logistics management.

2.4. The Role of SAP Solutions in Addressing Risk SCM Challenges.

The SAP solutions provide a holistic solution to these challenges in that SCM functions are integrated into one platform. Businesses may use this interface to automate their supply chain, give real-time data insight, and do sophisticated analytics.

- Real-time Data Visibility: SAP solutions provide a central depository of data in the supply chain, which all the stakeholders can access in real-time. Such visibility guarantees timely and precise information to the decision-makers thereby planning and executing better.
- Advanced Analytics and Automation: SAP solutions use sophisticated analytics and automation to optimize the supply chain operations [13]. The SAP Extended Warehouse Management (EWM) system applies automation and real-time

tracking to optimize warehouse processes, lowering the time required to process orders, thereby enhancing inventory accuracy. Equally, SAP Transportation Management (TM) supports logistics planning and implementation, as well as adequate and cost-effective goods delivery on time.

- Enhanced Supplier Collaboration: SAP Ariba is a procurement and supplier relationship system which provides smooth communication and cooperation between companies and their suppliers. This platform matches the supplier objectives with the business objectives so that deliveries are in time and minimize the risks posed in operations.
- Regulatory Compliance: SAP solutions are used to have a resource to control and monitor regulatory adherence in the various regions. This guarantees that companies follow all applicable laws, lowering the possibility of legal issues and preserving the integrity of their brands.

3. Sap-Enabled Sustainability Practices in Global Supply Chains.

SAP S/4HANA makes the supply chain more visible, faster, and more accurate in terms of decision-making through predictions, thus allowing the global operations to be efficient, resilient, and digitally integrated are below:

3.1Sustainability Practices Enabled by SAP

The concept of SSCM has grown over the last few years, which can be attributed to the increased interest of the global population in responsible business practices and environmental awareness. The initial ones focused on enhancing the economic performance of supply chains, which were upgraded to include green practices that incorporated environmental impacts in the operations of supply chains, such as sourcing of materials, product design, logistics and end-of-life management [14].

In this regard, Sustainability Practices Enabled by SAP have gained more significance, with SAP digital platforms and tools helping organizations to carry out, measure and improve the sustainability efforts along the global supply chains. These solutions assist companies in operationalizing the principles of SSCM by enhancing the transparency, facilitating responsible sourcing, resource making use of, and ensuring the adherence to the environment and social standards.

3.2. The Role of Supply Chains around the World.

Their uniqueness in comparison with other supply chains is their large scale and sophistication. A number of tiers of suppliers, manufacturers, distributors, and logistics companies participate in the ultimate delivery of goods and services, each of which fulfills its own function. There is a complicated network of interdependencies that occurs upon integrating numerous services in two or more distinct geographic locations. Though this global network represents organizations with the prospect of reduced costs, new market opportunities and enhanced skills, it also places the organizations at risk, where they are also susceptible to numerous risks. The potential for a disruption is one of the most significant concerns in managing global supply chains. The other causes of disruptions are numerous, including manufacturing delays, transportation bottlenecks, and supplier insolvencies. The relationship between these systems in the global supply networks implies that even the slightest interruption can be devastating.

3.3. SAP Tools for Supply Chain Risk Management

SAP offers a complete set of integrated tools, which enhance transparency and offer an opportunity to handle the risk in advance in all the supply chains in the world. Their solutions enable continuous monitoring, forecasting of events and quick reactions to interruptions.

3.3.1. SAP Integrated Business Planning (IBP) for Risk

SAP IBP for Risk is the name of the solution that offers organizations the ability to see right through the supply chain's weak spots in real-time. It does so by merging the process of demand planning, the process of supply planning, and the analysis of different scenarios [15]. The software allows the company to try out the different disruptions, compute their effect on the production and the logistics, and come up with proactive strategies to reduce risks. Taking it’s what-if scenario generation feature into account, it is able to support strategic decision-making and help companies create supply chain networks that are more resistant to risks.

3.3.2. SAP Ariba Supply Chain Risk Insights

SAP Ariba Supply Chain Risk Insights takes risk management related to suppliers to the next level by sharing information about the suppliers regarding their performance, financial stability, ESG compliance, geopolitical issues, and possible operational risks. The tool uses risk data from outside sources as well as supplier analytics to provide instant alerts and give risk scores [16]. Thus, the organizations can keep a closer check on their supplier base, make proper sourcing decisions, and improve the transparency of multi-tier supply chain.

3.3.3. SAP Risk Management and SAP GRC (Governance, Risk, and Compliance)

SAP Risk Management and GRC are among the solutions that assist companies to pinpoint, evaluate, and keep an eye on risks throughout their global operations. The centralization of risk data, automated compliance checks and ensuring that the organizations adhere to the regulatory requirements are one of the key characteristics of these tools [17]. When risk visibility is

incorporated into operational processes the companies find themselves in a place to react to disruptions at a more positive rate, ensure that business continues and be regulatory compliant even in those situations where there is complexity in the regulatory environment.

3.3.4. SAP S/4HANA Predictive Analytics And Embedded AI

The capabilities of predictive analytics and AI are built into SAP S/4HANA to identify the first signs of trouble in the entire supply chain activities. The system works through historical and real-time data about operations to see disruptions, demand peaks, production delays, or even transportation jams. With these predictive features, companies are able to make a post-facto decision and hence, they can reduce risks and continually optimize their supply chain business processes.

3.4. The Impacts of SAP S/4HANA on Supply Chain Management

To a great extent, within the literature, both academia and industry have discussed the transformation of the health technology sector through the previous ten years of SAP S/4HANA adoption in its supply chain management. The existing studies and industry analyses provide the necessary understanding of SAP S/4HANA's impact on supply chain performance, resilience, and strategic shifts in high-tech sectors.

- Research findings suggest that SAP S/4HANA enables businesses to manage real-time big data, hence providing the latter with an expedited response mechanism to any disruption in the supply chain. The technology industry is able to modify its activities as per the latest news, and this leads to the most effective management of the stocks, production, which is scheduled efficiently and the logistics, which are nothing short of smooth.
- The ability of the platform to bring together key supply chain operations and processes such as procurement, inventory, manufacturing and logistics within a shared platform that helps break down organizational divisions and provides visibility throughout the whole supply chain, consequently leading to supplier collaboration, fast information exchange and capability to construct strategic decisions using a holistic, end-to-end supply chain perspective.
- These latest techniques of forecasting, which are employed in SAP S/4HANA, have enhanced the functionality of forecasting of the system. The software not only analyzes the past data of the company but also predicts the emerging trends, thus being able to predict the demand with very high accuracy. The information gained through these forecasts enables businesses to strategize on the output, cut down on their stock, as well as, meanwhile, eliminate the possibility of running out of inventory or having excess.
- Supply chain resilience is at the forefront of management practices as a major factor to be considered in modern times. Among various methods, monitoring and analyzing SAP S/4HANA real-time Features may be used to lower supply chain risks, which, increase the company's efficacy in that regard through research, which, besides the regular scheduling of deliveries and contingencies for supply disruptions, predictive analytics in SAP S/4HANA, if deployed suitably.
- SAP S/4HANA was the primary driver for digital transformation in high-tech companies. The very fact that the platform is able to render the complete process transparent, the automation of the non-core processes, and the incorporation of contemporary technology such as the IoT and AI put high-tech enterprises in a position to innovate and stay competitive even in a market that is changing quickly.

4. Digital Technologies Driving Sap-Based Risk & Sustainability.

The flexibility of the blockchain technology allows the non-erasable and unchangeable recording of product flows within the global supply chains, which incredibly facilitates the tracing and transparency of risks. When the blockchain gets merged with SAP systems, companies are able to know where the products come from, check the reliability of the supplier's data, and pinpoint the faulty products with a great deal of precision, therefore, minimizing supply risks and ensuring sustainability compliance.

4.1. The Role Of SAP In Leveraging IOT For Business Transformation

The IoT has frequently been conceptualized as a networked system of physical items, with a focus on their ability to connect and share data. But SAP thinks it has even greater promise. The IoT is essential to an Intelligent Enterprise, where data drives intelligence, streamlines procedures, and stimulates creativity. Most companies have systems that capture operational data on purchasing, vendor contracts, production, expenses, and human resource management [18]. Dashboards and reports offer insights and help forecast the next logical move. However, corporations cannot influence future occurrences unless they have more knowledge about how customers engage with products, employees, the company, and the brand. The data processing system, applications, and products are shown in Figure 1.

Fig 1: Systems, Applications & Products In Data Processing

To understand the relationships and the interdependencies, businesses need an experience platform that compiles everything in one location. Every time a customer, employee, product, or brand interacts with SAP Intelligent Enterprises, data is collected. Customer, employee, product, and brand experience optimization is made simple with SAP's Qualtrics solution. Managing manufacturing, supply chain, finance, logistics, and other standard business operations is made simple with the SAP Intelligent Suite [19]. AI, intelligent robotic process automation, cloud and edge IoT, and data-driven information are all included in SAP's intelligent technologies platform.

4.2. Integration of Machine Learning In SAP Financial Systems

Automated risk assessment in SAP financial systems might be greatly improved by machine learning (ML) approaches. ML algorithms can offer real-time insights and prediction skills required for efficient risk management by utilizing the massive volumes of structured and unstructured data produced by SAP ERP modules (as seen in Figure 2).

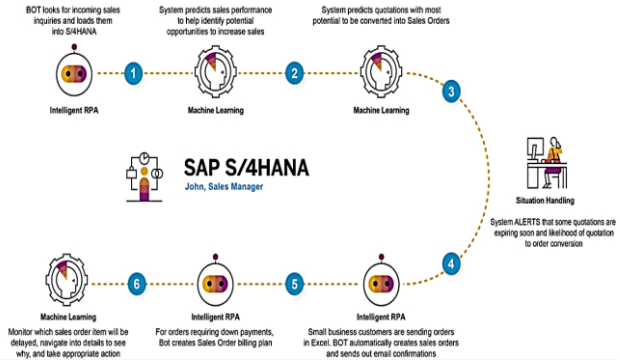

Fig 2: Machine Learning Capabilities In The Sap Community

4.2.1. Data Integration and Preprocessing

To obtain financial reports, transactional data, client information, and any other pertinent data, the ML algorithms have to be able to effectively interact with the SAP data infrastructure [20]. Cleaning, converting, and preparing diverse data across SAP modules is necessary for consistency and quality of data in risk assessment.

4.2.2. Algorithm Selection and Development:

In order to categorize data into a set of predetermined groups (fraud vs. nonfraud, for example), the algorithms look for historical trends. They able to identify potential threats in the SAP environment, such as fraudulent transactions or noncompliance with regulations.

- Regression models use historical data patterns to predict the values (numbers, such as credit ratings or financial losses). They can be used to assess financial risks, such as market volatility or credit default risks.
- Algorithms for anomaly detection find odd trends or outliers in data that don't behave as predicted [21]. They can identify anomalies in transaction volumes, spending trends, or inventory disparities that could be signs of danger in SAP financial systems.

4.2.3. Model Training and Deployment

ML models are trained using historical data to identify trends and connections pertinent to certain risk situations in SAP systems. Proactive risk management is made possible by deployed models that continually real-time analysis of incoming data streams to promptly identify and assess risks.

4.3. Blockchain Integration for Traceability

A product's traceability is crucial and directly relates to supply risk; if the product's origin can be precisely identified and traced, it will provide precise manufacturing information, such as the product's location, date of manufacture, and suppliers [22]. Keeping track of information about which farm produces a given product and what fertilizers are used for it is essential in the food supply chain, product origin tracking is particularly crucial [23]. Because of this degree of monitoring, any impacted products are found and taken from the market [24]. Only the impacted product is subject to this calling back; the entire batch of items is not. Blockchain is a great tool for tracking down the source of materials or components used in product manufacture because of its unchangeable record.

5. Literature Review

The analyzed research works present the development of cloud-based SCM, risk management, and ERP–MES integration as the main features of enhanced visibility and reactivity. Besides, the studies reflect the increasing use of SAP and SCM technologies in all sectors. Table I provides a summary of the focus, the approach, the findings, and the limitations of the studies reviewed.

Giannakis, Spanaki and Dubey (2019) Examining This study aims to understand the architecture of a cloud-based supply chain management (C-SCM) ecosystem and explore how it may enhance supply chain responsiveness (SCR). Design, methodology, and approach. The authors begin by reviewing the literature in order to evaluate any possible advantages that cloud computing may offer over more conventional SCM information systems and solutions. The authors conceptualize supply chain visibility, supply chain flexibility, and quick change detection and response before developing the whole C-SCM system. As cloud environments are used, the suggested ecosystem provides an insight into SCM and related processes [25].

Fan and Stevenson (2018) to analyze previous theory application, propose future research objectives, and provide comprehensive explanation and conceptual framework for SCRM, include monitoring, detection, treatment, and risk assessment. The identification of risk classes and the proposal of risk mitigation measures have received a lot of attention. A new, thorough definition of SCRM is offered, addressing the method, SCRM's goals and process, leading to a conceptual framework. Organizational responses to supply chain hazards have been the main focus of research, and theory has been applied quite infrequently [26].

Oman et al. (2017) investigates the impact of integrating Manufacturing execution systems (MES) and enterprise resource planning (ERP) in the context of a medium-sized company in the automotive supply chain. An intermediate document (IDoc) link facilitates data flow between the two distinct systems. The value reference model (VRM), which guarantees quantifiable indications in several dimensions, was used to evaluate the outcomes of the MES-ERP integration. Prior to and following integration, the assets, costs, and velocity of two processes were evaluated. Measured and validated were improvements in the chosen KPIs. Real-time decision-making is made possible by Supply chain (SC) controlled change management is ensured via MES-ERP integration [27].

Chandrashekhar et al. (2017) intended to investigate the importance of utilizing SAP as an ERP in order to enhance overall operations and production, with a focus on the auto component manufacturing sector in the Pune and Aurangabad regions. This study has shown that SAP is a very practical ERP solution, and because it provides competitive advantages, it is extensively employed. Enterprise resource planning (ERP) technology combines the core business functions of the company to provide a single business function. With regard to ERP, SAP is the world's largest independent ERP software vendor [28].

Singh and Sharma (2017) to ascertain the degree to which various industries employ supply chain management strategies and technologies, to comprehend the difficulties encountered during the implementation of supply chain systems, to pinpoint the main obstacles to supply chain cooperation, and to comprehend the current status of the SCM systems market. According to the study results, businesses have many difficulties while putting supply chain systems into place. Leading industry analysts claim that business applications including Enterprise resource planning, customer resource management, and supply chain management are all still developing. Manufacturers were surveyed, and the results confirm the experts' forecast [29].

Giannakis and Papadopoulos (2016) considers supply chain sustainability as a risk management process and looks at it from an operational perspective. It looks at the characteristics of supply chain risks associated with sustainability, distinguishes them from other kinds of supply chain risks, and develops an analytical approach to their management. An empirical research is conducted to gather ideas for a thorough approach to risk management related to sustainability. A thorough survey across many industrial sectors and two exploratory empirical case studies in two textile manufacturing companies are then conducted to assess and examine a variety of sustainability-related risk indicators [30]

Table 1: Risk Management and Sustainability Practices Enabled by Sap In Global Supply Chains

Author(s) & Year	Study Focus	Approach	Objectives	Key Findings	Limitations
Giannakis, Spanaki & Dubey (2019)	The ecology of supply chain responsiveness (SCR) and cloud-based supply chain management (C-SCM)	Comprehensive literature review; Architecture development	To develop a C-SCM architecture and investigate how cloud computing improves SCR's flexibility, visibility, and quick response	Cloud computing improves flexibility, real-time visibility, and responsiveness; Proposed architecture shows how SCM practices change in cloud environments	Lacks empirical validation; Conceptual framework not tested in diverse industries
Fan & Stevenson (2018)	Supply chain risk management definitions, concepts, and theoretical applications (SCRM)	Thorough examination of the literature	To examine risk assessment, monitoring, mitigation, and identification; Give a thorough explanation and conceptual structure.	Existing research focuses more on risk types and mitigation strategies; Limited theoretical grounding; Introduces an updated holistic SCRM definition and framework	Reliance on secondary literature; Limited empirical support; Does not provide industry-specific insights
Oman et al. (2017)	The effects of MES and ERP integration on automotive supply chains	Case study; Performance assessment using Value Reference Model (VRM)	To evaluate how MES-ERP integration affects assets, expenses, and velocity	Positive improvements in KPIs; Integration enables improved change management and real-time decision-making	Single-company case study limits generalizability; Intermediate document method may vary across systems
Chandrashekhar et al. (2017)	SAP ERP's contribution to the auto component industry's operational and production enhancements	Empirical study in Pune & Aurangabad manufacturing firms	To explore significance of SAP ERP in improving operations and manufacturing performance	SAP provides unified business integration, improves efficiency, and offers competitive advantages; Widely adopted ERP	Geographic and sector-specific focus; Results may not apply to non-manufacturing industries
USID (2017)	Adoption and challenges of SCM technologies across sectors	Industry-wide survey	To understand adoption levels, challenges in SCM system implementation, barriers to collaboration, and market growth	Companies face major challenges in SCM implementation; Strong projected growth in ERP, CRM, and SCM adoption	Survey-based and may include biased responses; Lacks deep qualitative explanations
Giannakis & Papadopoulos (2016)	Supply chain risks associated with sustainability and integrated risk management	Large-scale survey + two case studies	To conceptualize sustainability risks, distinguish them from traditional risks, and propose an integrated management framework	Sustainability risks differ in scope and require integrated, holistic management; Empirical cases validate process steps	Limited to certain sectors (textile); Framework may require adaptation for complex global supply chains

6. Conclusion and Future Work

The use of SAP-enabled solutions has dramatically changed the risk management and sustainability practice in international supply chains. Businesses can improve decision-making, operational efficiency, and resilience by leveraging products such as SAP S/4HANA, SAP IBP, SAP Ariba, and SAP GRC to gain real-time visibility, predictive analytics, and automation. Such tools allow the identification and mitigation of risks in advance, and also promote sustainable practice by means of responsible

sourcing, resource optimization, and adherence to environmental and social standards. Transparency, traceability, and predictive capacities are further enhanced when combined with emerging technologies like blockchain, IoT, and ML, allowing businesses to respond quickly to disturbances. In general, the digital transformation made by SAP helps business entities to balance between financial performance, environmental care, and social accountability, creating a future-oriented supply chain that will be able to adapt to the complicated situations around the world and remain competitive.

Further studies can be performed to address how enhanced predictive risk management and sustainability may be integrated with SAP systems through the use of advanced AI-based optimization, edge computing, and digital twins. Also, exploring the strategies of cross-industry adoption and effects of the emerging regulations on the SAP-driven supply chains will further inform the scalable and resilient global supply chain practices.

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