

An Improved AI-Powered Supply Chain Model with IoT Integration to Enhance Organizational Efficiency

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Abstract

Background: Supply chain management has undergone a revolution thanks to the incorporation of cutting-edge technology like artificial intelligence (AI) and the internet of things (IoT) in today's global business operations. A paucity of literature exists that comprehensively establishes the impact of AI-powered supply chain models with IoT integration that contributes to supply chain resilience and supply chain performance and how it brings about operational performance efficiency. **Aim:** This study is based on the technology organization environment framework and the resource base theory of the firm in the business domain that explored the impact of an AI-powered Supply chain model that with the integration of IoT and other factors brings about organization operational efficiency. **Method:** The study enhanced an AI supply chain model by addition of more factors; thus eight (8) factors were included, classified into external, instantaneous and temporal factors. The external factors are the input factors to the model, they are the independent variables, the instantaneous otherwise known as the mediating factors are time bounded factors with no delay while the temporal factors are the dependent variables, and they are also time-bounded factors with delay. Nodes was used to represent the factors and the casual relationship of the identified factors was represented in form of flow arrows to show its connectivity. This was how the conceptual model was derived. **Results:** The inclusion of the eight factors resulted in a robust AI-powered supply chain model, used to influence important decisions in business organizations.

Keywords: Artificial Intelligence capability, Internet of Things, Supply chain management, Risk Management Practice, Operational Efficiency.

1. Introduction

Supply chain management has undergone a revolution thanks to the incorporation of cutting-edge technology like artificial intelligence (AI) and the internet of things (IoT) in today's global business operations (Singh, Gupta & Shukla, 2021). AI can be defined as "the capacity of machines to carry out cognitive tasks similar to those of humans (Sullivan & Wamba, 2022). Organizations are deploying a range of AI tools and solutions such as machine learning and deep-learning to improve their forecast accuracy and detect problems at an early stage. AI, if used strategically to process information and reconfigure organizational resources, can help reduce complexity and uncertainty (Ransbotham et al., 2020; Burian, 2021).

IoT, also known as the Internet of Everything or the Industrial Internet, is a new technology paradigm that allows devices to communicate with each other through a global network. IoT is a network of physical objects that are digitally connected to sense, monitor, and interact both inside an organization and between the organization and its supply chain (Lee et al., 2022). The internet of things (IoT) presents new opportunities for

risk mitigation, complexity management, and tangible commercial advantages (Al-Talib et al., 2020). The importance of supply chain innovation to operational management strategies cannot be overstated, especially when it comes to developing original goods and services or making use of digital technologies. To gain long-term competitive advantages, supply chain performance must be enhanced (Malacina & Teplov, 2022).

A disruption in the supply chain can stop an organization's flow of products and services. As a result, supply chain disruptions can negatively impact a company's performance, lowering stock returns and its ability to compete in the market, just how the COVID-19 epidemic disrupted companies and had an increasing effect on their supply chains (Ivanov & Dolgui, 2020). This study explores the important role of an AI-powered supply chain models with IoT integration, alongside the introduction of other factors, grouped into external or input factors (Legal and regulatory compliance, Supplier and Partner risks, AI technology, Supply chain Collaboration and environmental uncertainty, Technological infrastructure, data security and privacy), mediating factors (Risk management practice, willingness to adopt AI, and IoT integration) and. Temporal factors (Supply chain resilience, supply chain performance and operational efficiency). The temporal factors are dependent on the input and mediating factors. All these factors contribute in enhancing supply chain organizational performance efficiency.

2. Related Works

The technology-organization-environment (TOE) framework is a framework used primarily in understanding the adoption of and implementation of new technologies within organizations (Wang & Pan, 2022). The Technology Context refers to the specific technology being adopted or considered for adoption within the organization. It could be a new software, system, hardware infrastructure, or technological innovation relevant for the organization's operations. A firm's existing technologies are important in the adoption process because they set a broad limit on the scope and pace of technological change that a firm can undertake (Collins et al. 1988).

The Organization Context focuses on the internal aspects of the organization that influence technology adoption. It includes factors such as organization structure, culture, resources (both financial and human) and the decision-making processes within the organization (Baker, 2011). Environment Context refers to the external factors that impact technology adoption, it covers market conditions, industry standards, regulatory requirements, and technological trends in the external environment (Baker, 2011). In the context of organizational theory and strategic management, the resource base theory posits that firms' resources and capabilities are key determinants of competitive advantage and superior performance (Barney, 1991). The notion of resource base theory (RBT) is a management concept that highlights the internal resources of a firm as a means of achieving sustained competitive advantage. It suggests that internal resources such as capabilities and resources of a corporation can lead to better performance when strategically used (Mikalef, Pappas, Krogstie, & Giannakos, 2017). This theory suggests that resources are either tangible or intangible. capability factors and enhance the existing AI capability model that will enable business owners make quick and accurate decision which will result in business gains, the RBT was a suitable choice to serve as the study's underlying theoretical framework.

2.1 Factors of Research Model

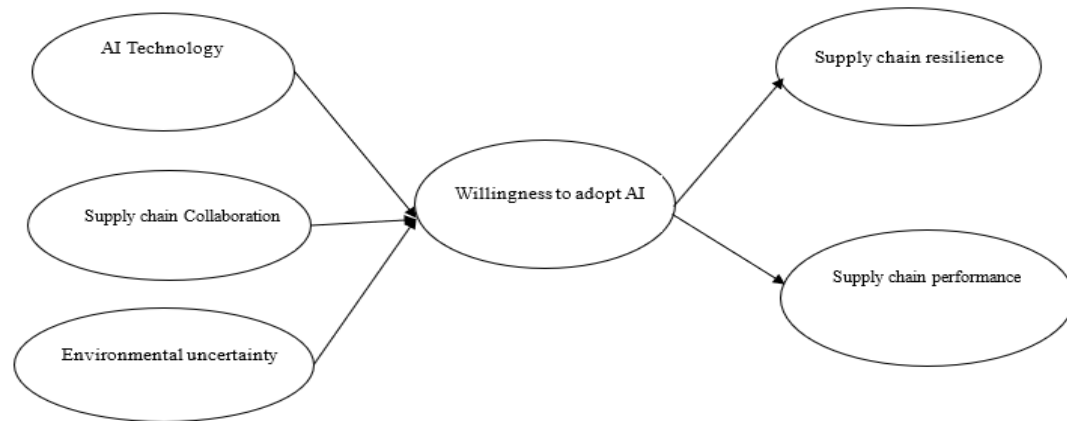


Figure 1. AI Research Model. **Source:** Adapted from Wang and Pan (2022).

The study by Wang and Pan (2022), aims to investigate and evaluate the factors that influence a firm's inclination to implement artificial intelligence technology and the potential benefits of such adoption for supply chain resilience and performance. Drawing on the technology-organization-environment framework and resource-based theory to support its findings. Result showed how the adoption of artificial intelligence technology is influenced by three main elements, such as: supply chain collaboration, environmental uncertainty, and the relative advantage of artificial intelligence technology.

Artificial intelligence (AI) is the ability of a system to acquire information by analyzing the data of the external environment and using the acquired information to adjust or make new plans against environmental changes. AI has seen rapid advancement and adoption across various fields due to its ability to automate tasks, analyze large amounts of data, and enhance decision-making processes (Gover, Kar, & Dwivedi, 2020). Organizational and individual differences interest to adopt AI are frequently caused by things like perceived benefits, cost-effectiveness, ethical issues, and degree of trust in AI systems (Kelly, Kye & Trespalacios, 2023).

Although AI brings organization performance, organizations are still struggling to integrate it into their business, despite the fact that AI technology have great potential in optimizing efficiency, if compatible with organization's operating system, organizations, if not compatible during the implementation process, may delay or not use them at all Baker (2011). Enterprise adoption of AI shows a shift from viewing AI as a novel technology to integrating it as a fundamental tool for enhancing productivity, innovation and competitiveness.

Supply chain collaboration, or SCC, is the joint efforts and strategic alignment of various supply chain network entities. It is made up of manufacturers, suppliers, distributors, and retailers. According to Soosay (2015), SCC promotes the deployment of AI by facilitating improved data sharing, reducing risk, enhancing operational effectiveness, and stimulating innovation and competition. The deployment of AI technology by supply chain partners working together helps to reduce risks and increase overall efficiency (Baryannis, Validi, Dani, & Antoniou, 2019). When AI is used to analyze data, it can improve data sharing by revealing insights, improving inventory control, forecasting demand, and increasing overall supply chain efficiency

(Aldoseri, Al-Khalifa & Hamouda, 2023). Cooperation amongst SC partners improves when partners are willing to utilize AI.

Environmental uncertainty according to Wang and Pan (2022), arises from external changes, in situations of heightened uncertainty, companies perceive that adopting new technologies ahead of competitors ensures they maintain a competitive edge and enhance their role in supply chain integration and operational performance, therefore they examined and showed how environmental uncertainty is expected to positively influence the adoption of AI technology in the supply chain.

Willingness to adopt AI enhances supply chain resilience through improved predictive capabilities, efficiency gains via automation, and enhance adaptability to changing conditions. Through empirical investigation, Mogill et al. (2021) show that a supply chain with AI support may systematically build resilience in both its network and structure. Willingness of organization to adopt AI positively impacts supply chain performance (Wang & Pan, 2022).

The willingness of firms to adopt AI in supply chain brings about improvements in efficiency, decision-making capabilities, collaboration and help with effective risk management contributing to supply chain performance and increased competitive advantage (Ganesh & Kalpana, 2022).

Factors of the AI research model is summarized in table 2.1.

Table 2.1. Factors of AI Research Model

External	Instantaneous	Temporal
1.AI Technology	1. Willingness to adopt AI	1. Supply Chain Resilience
2.Supply chain collaboration		2. Supply chain Performance
3.Environmental Uncertainty		

Based on the factors stated in table 2.1 and figure 2.1 respectively, there is a need for a comprehensive AI-Powered supply chain model that has detailed factors for organization operational efficiency. Such as, (Temporal) Legal and regulatory compliance, Supplier and Partner risks, AI technology, Supply chain Collaboration and environmental uncertainty, Technological infrastructure, data security and privacy, (Mediating) Risk management practice, willingness to adopt AI, and IoT integration, (Temporal) Supply chain resilience, supply chain performance and operational efficiency. The temporal factors are dependent on the input and mediating factors. All these factors contribute in enhancing supply chain organizational performance efficiency.

3. Methodology

In this session, a framework underlying the design structure of the study is given. The framework implemented is adapted from Mustapha (2019) and Mustapha et al. (2021). As a result of the complex and dynamic nature of the business environment, this methodology is applicable for formal specification and representation. This research methodology serves as a guide to develop and evaluate the AI-powered supply chain model grouped into two (2) stages, (Domain and Design) used as a basis for the model construction. Factors identified were categorized into three namely: External, Instantaneous and Temporal factors. The causal relationship of the identified factors of the model (Wang & Pan, 2022) were based on the Technology, organization framework and Resource base theory (RBT) of the firm. For the identification of these factors, the internet and library resource were used to review relevant literatures from experts in various domains, especially in the domain of AI and IoT.

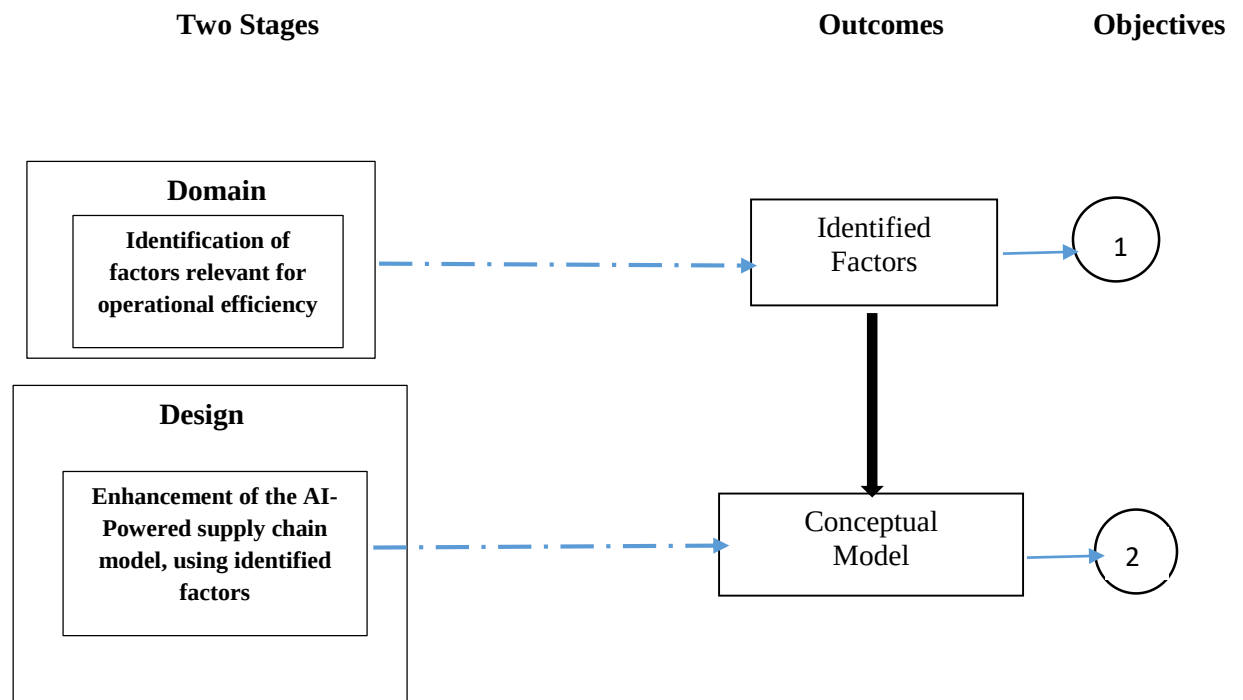


Figure 3.1. Research Methodology. **Source:** Adapted from: (Mustapha, 2019; Mustapha et al. 2020).

3.1. Domain model stage.

In this stage, the factors relevant for organizational operational efficiency are identified. The stated model has fourteen (14) factors as against the six factors identified by Wang and Pan. (2022). The Fourteen (14) factors identified were categorized into three namely: external, instantaneous and temporal factors. The causal relationship of the identified factors was based on the technology organization framework and Resource base theory (RBT) of the firm. For the identification of these factors, the internet and library resource were used.

3.2. Design model stage

In the design model stage, Eight (8) AI-powered supply chain factors such as Legal and regulatory compliance, Supplier and Partner risks, Technological infrastructure, data security and privacy, Risk management practice, IoT integration, and operational efficiency. All these factors were obtained by the expansion and addition of more factors from other related literatures, combined to enhance the AI-powered supply chain model, each of the factors in the model is represented by a node, and the casual relationships between the factors are shown using flow arrows. To create a model of enhanced efficiency, the direct and indirect relationships were taken into account based on the theories of each concept. The model's variables were divided into external, instantaneous, and temporal factors.

4. Result and Discussions

In enhancing the integrated AI model, factors relevant for organization operational efficiency were identified based on the technology-organization-environment framework and theories of the RBT and

scholarly literatures on AI, IoT, and supply chain. The factors identified include Legal and regulatory compliance, supplier and partner risks, Technological infrastructure, data security and privacy, risk management practice, IoT integration, and operational efficiency. Hence, details on how the factors were identified in our present study and the casual relationship based on literatures are as follows.

Legal and regulatory compliance

Legal and regulatory compliance play an important role in risk management within the supply chain, through Risk Identification, Compliance requirements help in identifying potential risks that could arise from failing to meet legal standards or regulations (Sendawula, 2021). These risks can include fines, legal actions, or reputational damage. Regular risk assessment regulations often dictate standards for product safety, environmental impact, labor practices, etc. Non-compliance with these can lead to supply chain disruptions or penalties, affecting operations and financial stability (Setembre-Blundo, et al., 2021). Adhering to regulations minimizes the likelihood of legal issues, disruptions, or unexpected costs. It involves implementing processes and controls to ensure compliance throughout the supply chain.

Kazancoglu et al. (2020) proposed a framework highlighting policy-related barriers for a supply chain in the transition to create value. This may have an effect on investor confidence, customer trust, and the long-term viability of the company. In essence, integrating legal and regulatory compliance into supply chain risk management strategies helps mitigate various operational, financial, and reputational risks, ensuring smoother and more sustainable business operations.

Supplier and partner Relationship

Suppliers and partners directly influence product quality and reliability. Poor quality materials or unreliable partners can lead to defects, delays, and customer dissatisfaction (Leels, et al., 2020). Suppliers and partners must comply with regulatory requirements and ethical standards. Non-compliance can result in legal issues, fines, or damage to the organization's reputation (Kashmania, 2018).

A study by Tarigan et al. Tarigan et al. (2020), investigated the effects of supply chain agility, resilience, collaboration, and internal integration on sustainable advantage, result validates the nine theories included as: Interdepartmental data sharing facilitates internal integration, which impacts supply chain (SC) resilience, agility, and collaborations. Furthermore, SC partnerships enhance SC resilience, agility, and sustainable advantages by managing demand fluctuations and ensuring timely material delivery. SC resilience and sustainable advantage are impacted by SC agility, which controls production capacity and maintains the smooth operation of the production process. By guaranteeing consistent sales volumes and prompt product delivery during pandemic situations, SC resilience enhances sustainable advantage.

Data Security and Privacy

Data security is critical to IoT integration in supply chain management, the importance of data Privacy, because IoT devices collect vast amounts of data, including sensitive information about products, shipments, and operations (Pal & Yasar, 2023). Ensuring data privacy protects against unauthorized access and misuse, maintaining compliance with regulations. IoT devices are vulnerable to cyberattacks, such as malware or ransomware. Breaches can disrupt operations, compromise sensitive data, and lead to financial losses or reputational damage.

Cyber security threats in globalized supply chains (SCs) have been found to have a significant impact on SC performance. Pandey, Singh, Gunasekaran, and Kaushik (2020) conducted a study to investigate these risks. Vulnerabilities and exposure to security threats may arise simultaneously from a company's information and communication technology, which improves efficiency and effectiveness in the SC. In

order to improve performance, the study's findings highlight the different cyber security risks and cyberattacks in globalized SC.

Hence, the safeguard of sensitive information, protect against cyber threats, ensure regulatory compliance, can enhance overall resilience and trust across the supply chain ecosystem.

Organizational Change and Cultural Transformation

Organizational change and cultural transformation play an important role in successful AI and IoT integration in supply chain management by aligning people, processes, and technology towards common goals of innovation, efficiency, and resilience that can significantly impact business growth (Imran, Shahzad, Butt & Kantola, 2021).

According to Errida and Lotfi (2021), effective organizational change requires strong leadership and a clear vision for integrating new technology, leaders need to communicate the benefits of AI and IoT, such as enhanced visibility, efficiency, and cost savings, to gain buy-in from stakeholders.

Nwakwo et al. (2020) point out that enterprises facing challenges in implementing emerging technologies like artificial intelligence (AI) and the Internet of Things (IoT) face traditional obstacles because people are social creatures and are not interested in the convenience these technologies offer. To mitigate these issues, the authors advise organizations integrating these technologies to understand the principles of sociotechnical systems in functional organizations. This will help the organizations become more competitive and sustainable.

Information Technology Infrastructure

Information technology infrastructure (IT) plays an important role in modern supply chain chains by enabling efficient communication, collaboration, data management and decision making across the entire network. IT infrastructure significantly enhances the implementation and effectiveness of IoT in supply chain through data integration and management, real-time visibility and monitoring, enhanced automation efficiency among others (Attaran, 2020).

Attaran (2020), Observe how Digital trends and SCM changes are driven by many technologies such as AI and robots, cloud computing, blockchain, AR, RFID, IoT, 3D printing, and advanced analytics are a few of them and how these technologies are altering the sector, bringing forth a multitude of changes to supply chains, sales, goods, business models, and services. In order to determine current research and directions regarding how these technologies might facilitate, improve, and simplify the performance of digital supply chains (DSCs), the study conducted a review of the literature, discussed the significance of these technologies for logistics and supply chains is, along with their trends and difficulties in enhancing the performance of the digital supply chain.

Internet of Things (IoT)

The IoT has revolutionized the supply chain management by enabling unprecedented level of connectivity, visibility, and efficiency.

The Internet of Things (IoT) may have many advantages for businesses, but as with other technological adoptions, there may be unanticipated risks that call for significant organizational changes. Brous, Janssen, and Herder's (2019) study examined IoT adoption by businesses and assessed the advantages and disadvantages of IoT adoption. Performing an extensive literature review results in a Big, Open, Linked Data (BOLD) classification of the anticipated advantages and hazards of IoT. To investigate the real-world benefits and hazards, extensive case studies in the asset management domain were subsequently carried out. To comprehend the relationships between technology and organization, the study applies the theoretical

framework of technological duality. The outcomes support the paradox that realizing IoT's benefits for asset management leads to unanticipated risks and make the necessary organizational changes. There is a need to introduce changes to the organization, processes and systems, to develop capabilities and ensure that IoT fits the organization's purpose.

It can be noted from the review of literatures on IoT that IoT has transformed the supply chain management by providing unprecedented visibility, efficiency and agility. Organizations that harness IoT technologies effectively, can achieve significant improvements in supply chain performance, customer satisfaction and overall efficiency.

Risk management practices

Globalization, e-trade, advanced technologies and emerging production techniques have increased supply chains' efficiency and added value. However, despite numerous advantages, these factors make supply chains more fragile and vulnerable to risks (Kırılmaz and Enrol, 2017). It involves identifying, assessing, prioritizing and mitigating risks that could potentially impact an organization's objectives. These practices are important in ensuring resilience and sustainability. Adequate risk management in the supply chain management system will ensure smooth operation and mitigate disruptions that can impact production, delivery schedules and customer satisfaction (Kırılmaz and Enrol, 2017).

El Baz and Ruez (2020) investigate the role that supply chain risk management techniques have in mitigating COVID-19. In light of the COVID-19 pandemic, the paper examines how supply chain risk management (SCRM) might be used to lessen the impact of interruptions on the robustness and resilience of the supply chain. The fundamental principles of the resource-based view and organizational information processing theories about the combining of dynamic resources to meet disruptions are unclear, according to the results of structural equation modeling applied to survey data from 470 French enterprises. The results also demonstrate the important role that SCRM practices play in promoting supply chain robustness and resilience, as well as their mediating effect.

Therefore, organizations who integrate robust risk management practices, into their supply chain, operations, can build resilience, reduce vulnerability to disruptions, and sustain business continuity in a dynamic and uncertain business environment.

Organization Performance Efficiency

Organizational performance efficiency refers to the ability of organizations to utilize its resources effectively in order to achieve desired outcomes (Alshurideh et al., 2022).

A theoretical influence mechanism of "supply chain digitalization, supply chain resilience, and supply chain performance" was proposed by Zhao Hong and Lau (2023) based on dynamic capability theory. Survey data from 210 Chinese manufacturing companies is used to validate the claimed linkages. The findings support the notion that supply chain performance can be enhanced in a volatile environment through the use of digitalization and supply chain resilience.

Siagian et al. (2021), notes how Supply Chain Integration Enabled resilience, flexibility, and innovation to Improve Business Performance during the COVID-19 Era. Through supply chain flexibility, resilience, and innovation system in Indonesia's manufacturing companies, the study explores the effect of supply chain integration on business performance.

The ability of supply chain integration to communicate entire product information and production planning has been found to have an impact on the innovation system, supply chain flexibility, and supply chain resilience. Supply chain resilience is increased by innovation systems and supply chain flexibility,

which enable the chain to adapt quickly to changes in customer demand and production issues. In the COVID-19 age, supply chain integration enhances corporate performance through innovation, flexibility, and resilience.

In essence, supply chain resilience not only protects against disruption but also enhances supply chain performance across key business areas thereby enhancing organizational efficiency.

Table 2.2. Factors of Enhanced AI-Powered Supply Chain Model

External	Instantaneous	Temporal
1. Legal and Regulatory compliance 2. Supplier and Partner relationship 3. AI technology 4. Supply chain collaboration 5. Environmental uncertainty 6. Data security and Privacy 7. Organization changes and cultural transformation	1. Risk Management Practice 2. Willingness to adopt AI 3. IoT Integration	1. Supply Chain Resilience 2. Supply chain Performance 3. Organizational operational efficiency

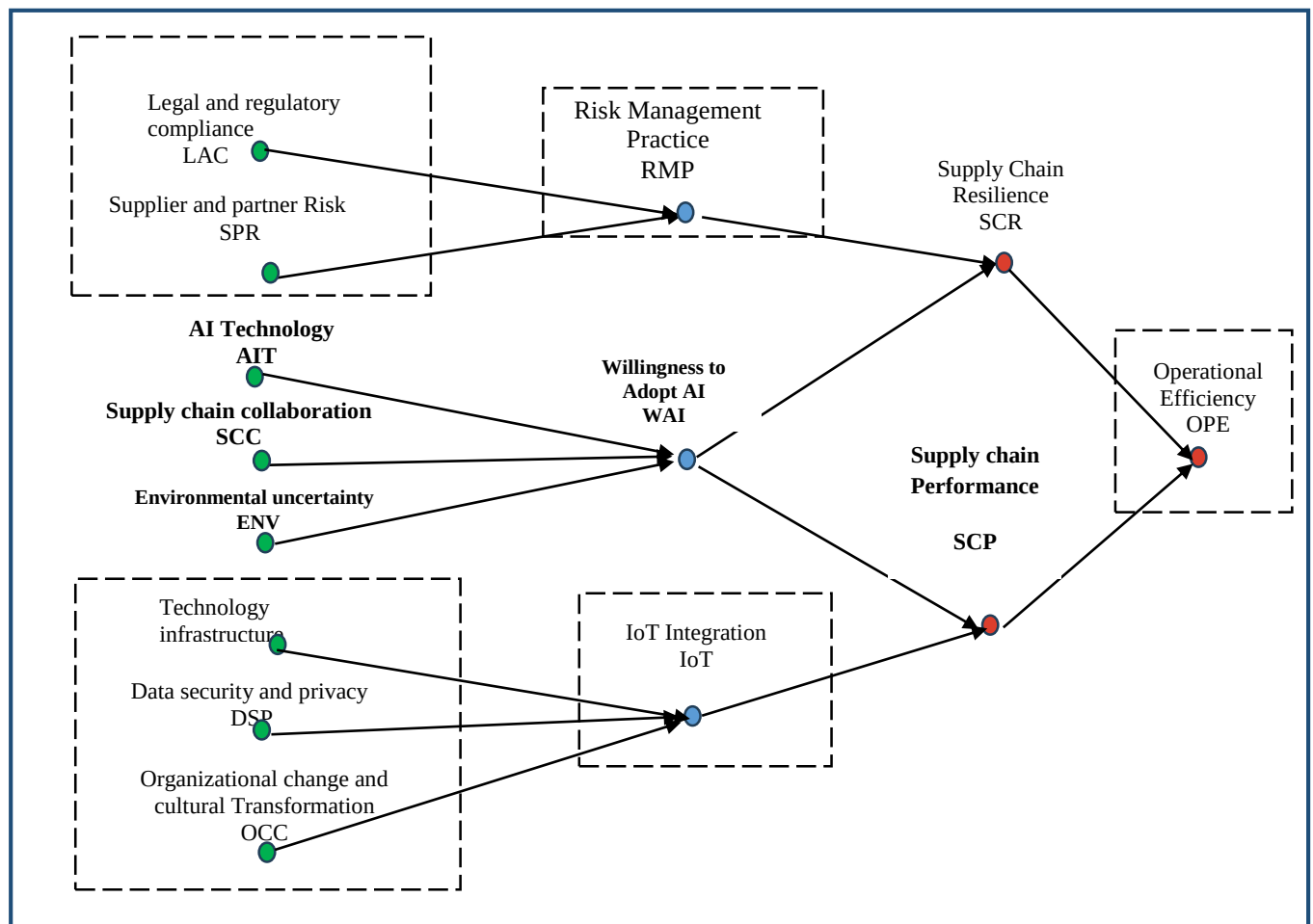


Figure 4.1. An Enhanced AI-Powered Model of Supply

5. Conclusion

This study presented an AI-Powered supply chain model in the business domain that can assist managers, business owners in making quick and accurate decisions. The study enhanced an AI supply chain research model by addition of more factors to have a comprehensive Conceptual model. the study presented a total of fourteen (14) factors, six (6), from previous research while a total of eight (8) factors were added, these factors were obtained based on the technology-organization-environment framework and Resource-based theory of the firm and other related literatures, were reviewed and used as a guide in obtaining these factors. The findings underscore the important role of AI and IoT in modernizing supply chain operations, enhancing resilience, and thereby improving organizational performance efficiency.

The enhanced AI-powered supply chain model factors such as AI technology, data security and privacy, Environmental uncertainty, Supply chain collaboration, Legal and regulatory compliance, supplier risk management, and technological adoption are crucial input factors that contribute positively to the enhanced model. The study confirms that leveraging advanced technologies like AI and IoT, mitigate risks, fosters collaboration, and adapts to environmental uncertainties, ultimately optimizing supply chain dynamics and organizational outcomes, for future work, the model can be formalized and verified mathematically.

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