

Artificial Intelligence in Food Supply Chain and Logistics: A Conceptual Framework for Performance, Resilience, and Sustainability

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Abstract

It is challenging to deal with food supply chains. Products are perishable, demand is uncertain, food safety regulations are stringent, and sustainability demands are only increasing. Artificial Intelligence (AI) has proven to be one of the most promising solutions to address these challenges, which enhances decision-making processes, operational efficiency, and resilience in supply chain and logistics operations. However, the current research tends to be narrow in scope, examining a single application or function of AI, with few linking results with theory, and many linking with theory but only to a specific application or function of AI. To do so, this study adopts a conceptual framework. It creates a framework based on theory and integration, explaining the impact of AI capabilities on the food supply chains and logistics performance, based on the Resource-Based View (RBV), Dynamic Capabilities Theory (DCT) and Supply Chain Resilience (SCR) theory, placing AI as a strategic resource. Within the framework, AI has several key roles in the supply chain and logistics functions and its impact on performance is moderated by supply chain capabilities. The performance outcomes are: less food waste, better food quality and safety, reduced logistics costs, improved service levels, and increased sustainability and resilience. Contextual factors like regulatory compliance, product perishability, market uncertainty and readiness for digital infrastructure mediate such moderating relationships. This study provides a synthesis and aggregation of existing literature and empirical evidence to provide a better understanding of the role of AI in transforming food supply chains and serves as a foundation for further empirical studies and practical advice for food supply chain managers and policymakers.

1 Introduction

The food supply chain is one of the most complex and vulnerable networks in a modern economy. It covers sourcing, processing, storage, transportation, distribution and retail, and is closely linked to each other [1]. Food is perishable. Safety and quality are critical. Logistics needs to remain temperature-sensitive, fluctuate according to the seasons, and consumers are unpredictable [2], [3], [4]. The financial impact is only part of the price paid when getting it wrong; there is also the environmental toll as well as the impact on food security. Some 1 billion people worldwide lose or waste one-third of the food that is produced, which highlights shortcomings in the supply chain and logistics management [5]. Filling these gaps requires more intelligent, responsive solutions. That's where AI enters the picture: In the last couple of years, it has proved to be a genuine transformative element in managing the supply chain and logistics [6], [7]. AI encompasses various types of machine learning, deep learning, predictive analysis, computer vision, natural language processing, and optimisation algorithms, which are all trained on data, recognise patterns, and make decisions with minimal human involvement [8]. In supply chains, AI can handle real-time data, give more accurate forecasts, make decisions automatically, and adjust to uncertainty as they occur [9], [10]. It also aids in managing demand and supply fluctuations, monitoring the cold chain, optimising routes and inventory, tracking food movements, and ensuring compliance with food safety regulations, all of which contribute to a more digital and resilient future in the food supply chain [11], [12]. Given that the food and beverage industry is highly susceptible to short product life cycles and high levels of waste due to food spoilage, the adoption of AI in food and beverage supply

chains is gaining momentum, with increasing investment in demand forecasting, inventory management and logistics optimisation [6], [8]. When combined with the Internet of Things, sensors in warehouses, and transportation systems, AI has taken food supply chain visibility to the next level [13], [14]. A combination of AI-powered routing and scheduling, alongside predictive analytics, has reduced delivery times by up to 30 percent in the food distribution sector and enhanced prediction accuracy as well as reduced excess inventory [15], [9]. AI-powered monitoring is now a standard practice in refrigerated warehouses globally to ensure optimal conditions for refrigeration, humidity and storage, significantly reducing losses due to spoilage and maintaining food safety standards [16]. These advancements collectively highlight the potential of AI as a valuable tool for streamlining, enhancing quality and ensuring regulatory compliance within the food logistics industry, as noted by Dhal and Kar [17] and Reddy et al. [18]. Despite the growing number of empirical findings, the academic research on AI in food supply chains is fragmented and mainly applied to specific instances. Most of the studies focus on one application, such as machine learning-based demand forecasting [19], [20], [21], computer vision for quality control [22], [23], or robotics for food warehouses [24], [25]. These studies are all showing tangible benefits – but none of them provides a complete picture of AI technologies working together in the entire food supply chain and logistics system. Other strategic aspects like supply chain resilience, sustainability, ethical use of AI, and regulatory adherence are not as well discussed, especially in conceptual pieces [26]. Recent studies propose an integrative approach to link AI capabilities with overall supply chain performance with better theoretical argumentation [27]. A second (deeper) gap is theoretical.

However, few studies using AI examine the link between technological performance improvements and theories of the supply chain and organisation, like RBV, DCT or SCR [28]. Consequently, there is little information in the literature to guide its application in the development of long-term competitive advantage, flexibility or sustainability in food value chains. This is quite significant as the food industry is highly vulnerable to external shocks, such as climate change, pandemics, geopolitical instability and consumer preferences [26]. This study adopts a conceptual framework to fill these gaps and creates a holistic framework that connects the AI technologies with the operations of the food supply chain and logistics. What makes it special is scope it brings in AI functionalities throughout the procurement, production planning, inventory management, cold chain logistics, transportation and distribution processes, and maintains a focus on sustainability, food safety and resilience. It is based on the already known theory of the supply chain, which enables us to delve beyond description and offer a theoretically informed view of the potential of AI to disrupt, capture and reorganise resources as supply chains evolve.

The main objective of this study is to create a model that integrates the various factors and impacts of using AI to enhance supply chain and logistics effectiveness in the food sector. The study has brought together empirical and theoretical research on the use of AI in food supply chains, mapped out the key AI technologies and their functional applications and illustrated the impact of AI on efficiency, resilience, sustainability and compliance. The framework is intended to inform future empirical research and to provide a foundation for practitioners and policymakers to create resilient, sustainable and intelligent food supply chains.

2 Literature Review

2.1 Food Supply Chain and Logistics Structural Problems

The food supply chain is one of the most complex and high-stakes systems around, due to its short shelf life, perishability, seasonal production, sensitivity to quality, and strict regulation [29], [30], [31]. In contrast to durable goods, food must be moved in a timely fashion and under controlled conditions, or it will lose its safety and nutritional value. When the operation is inefficient, it can cost in every way – the researchers have correlated it with food wastage, increased costs and damage to the environment [32], [33]. The increased number of intermediaries, less integration of information and lack of real-time insights make coordinating across food supply networks even more difficult [34]. Historical data, linear forecasting and manual decisions remain the traditional methods. It is well suited to predictable demand and supply but does not perform very well in the face of demand shocks, supply failures, or even extreme weather or pandemics. COVID-19 has proven it: the food supply chain is so fragile, and the world so in need of logistics that can feel uncertainty and change accordingly.

2.2 The Digital Transformation and AI in Supply Chains

In the study of digital transformation, AI is now at the heart of the discussion on the new concept of Supply Chain 4.0. AI systems can be described in simple terms as systems that learn from new information, discover patterns and make decision or decisions to a varying degree of autonomy. When applied to supply chains, it facilitates the use of advanced analytics, automation, predictive modelling and smarter optimisation, which boosts the precision and agility of planning decisions. Wamba-Taguimdje et al. [35] have called it a transition from descriptive and diagnostic decision-making to prescriptive and predictive decision-making. All of that can be converted by AI systems to real-time, actionable insight when fed with structured and unstructured data, sensor readings, transaction records, and market signals. This is very important in the food value chain where quality choices can't be made at the last minute.

2.3 Artificial Intelligence in Demand prediction and inventory control

The use of AI in food supply chains is perhaps most researched, and for good reason: forecasting demand incorrectly in either direction results in wasted products on one hand, or shortages on the other. In such scenarios, where the demand trends are non-linear or fluctuating, machine learning models have proven to be more effective than traditional statistical models [36], [37], [38]. AI-based forecasting combines several data types simultaneously, including historical sales, promotions, weather patterns, consumer behaviour, and so on, resulting in predictions that are more accurate and provide the ability to update quickly. Advanced forecasts directly translate to advanced inventory decisions, reducing overstocking and spoilage. This is particularly relevant for fresh food, where shelf lives are short, and hence there is limited time to make the right replenishment decisions [39].

Illustrative Case: Machine Learning for Vegetable Demand Forecasting

Priyadarshi et al. [40] offer a concrete test of this idea at the retail stage for a set of vegetables. They then compared a Box-Jenkins ARIMA model with some machine learning-based models such as long short-term memory networks and support vector regression, and concluded that the machine learning models gave smaller error rates than the traditional model. The benefit was simple: improved forecasts reduced the amount of produce waste on shelves, minimised stockouts and reduced the time between ordering and sales. The study is a reminder that if the product is truly perishable with a very short shelf life, the type of forecasting method is not something that can be overlooked; it can mean the difference between food being wasted before it reaches the customer or being sold, enjoyed and appreciated.

2.4 Artificial Intelligence in Cold Chain Management and Temperature-Controlled Transportation

The failure of cold chain logistics will bring about the dark side, such as food insecurity, food spoilage, and food waste [41], [3]. AI has proven to be a good solution for cold chain issues, especially when it comes to real-time monitoring, anomaly detection, and predictive maintenance. AI-powered systems can be used in conjunction with IoT sensors to monitor temperature, humidity, and equipment performance during transportation and storage [42]. Machine learning models detect deviations from optimal conditions early enough to take corrective action before the quality of the product is compromised, thereby reducing the losses associated with it and ensuring the operations are in line with food safety standards like HACCP [43], [44]. This sort of AI-powered tracking also does an improved job of transparency and traceability, which both consumers and regulators are clamouring for increasingly annually.

Illustrative Case: AI-Driven Capacity Planning at Americold

A recent MIT-led study provides a real-world example of how cold chain planning can become a reality with AI. Jackson et al. [45] tested machine learning and statistical forecasting models, such as Prophet and SARIMA, over 385 customers and approximately 73,000 pallet positions over 3.5 years of operational data, in collaboration with the world's second-largest refrigerated logistics provider, Americold. The best-performing model had a site-level forecast error of approximately 5 per cent, and a customer segmentation approach on top of this forecast further increased the accuracy of planning for various customer types. The case is a good illustration that AI doesn't have to be one size fits all, and the forecasting method for each segment was more important than the technology itself. It also puts the propositions used in this study into a real-world context: improved forecasting directly supporting improved capacity utilisation that exactly the type of AI-powered function to the capability of the supply chain that Proposition 2 is seeking to provide.

2.5 Artificial Intelligence to control quality, traceability, and food safety

The second key point of AI research in the food logistics sector is related to food quality and food safety. Quality control and food safety is another prominent focus in AI research that is relevant to food logistics. The area of food safety and quality control is another major field of AI research in food logistics. In fact, deep learning and computer vision have transformed automated inspection systems, making them highly capable of identifying defects, contamination and other quality deviations with accuracy that is superior to human inspection [46–48]. These tools not only help reduce the manual workload on checks, but also improve the level of consistency and real-time evaluation in logistics and warehouse systems. AI also enhances traceability, it brings together and correlates the data from all the nodes in the supply chain, which helps in recall management and lowers the risk. Better traceability, in turn, would build trust, particularly in products like meat, dairy, and seafood, in which consumers and supply chain partners want to be informed about problems and have them solved quickly [49].

2.6 Artificial Intelligence in Transport, Routing, and Distribution Logistics

Plenty of research is also dedicated to transportation and distribution, since they are costly and are a very expensive environmental mistake to make. AI routing and scheduling algorithms can optimise delivery routes in real-time, taking into account factors such as traffic, weather conditions, and delivery constraints [50]. One of the most important applications of AI in the food logistics sector is to ensure timely delivery, thereby preserving freshness and minimising food deterioration, which is the essence of transportation management with AI [24]. Research indicates that AI-driven transportation is more efficient, better utilises vehicles and fuel and is more consistent, which aids sustainability efforts and reduces emissions. It can also improve coordination between the partners on the upstream and downstream side, which is reflected in the actual performance in last-mile delivery within a city's food distribution system.

2.7 AI, Sustainability, and Reduction of Food Waste

With the food value chain's massive environmental impact, sustainability can no longer be ignored in food value chain research. The importance of supporting more sustainable supply chains (SC) through AI comes from food waste alone accounting for a large portion of GHG emissions and resource loss, so that's why researchers constantly return to how AI can help a more sustainable SC [51], [52]. With the help of AI capabilities, such as demand forecasting, inventory optimisation, and logistics planning, the issue of overproduction, food waste, and excess stock can be addressed. AI also aids in optimising transportation routes, improving the energy efficiency of warehouses, and predicting equipment failure by pinpointing maintenance requirements in advance. The potential of AI to deliver sustainable food systems is growing its recognition as a key tool to meet both economic and environmental goals in food

systems. But it's essential to recognize that the benefits of these only come when governance is effective, data is high-quality, and AI technology is integrated into the organization's goals.

2.8 Theory on AI in Food Supply Chains

There are a few theoretical perspectives that can help to understand how AI is affecting the supply chain. There are a few theories that can explain how AI is impacting the supply chain. There are multiple theoretical approaches that explain the impact of AI on the supply chain. There are several different theoretical frameworks through which to examine the effects of AI on the supply chain. The RBV approach is based on the concept that the value, scarcity, and successful integration of AI into an organization's processes can impart a competitive advantage [53]. From the food supply chain perspective, AI can be applied to data as a tool that can support organisations in making informed decisions and coordinating in the food supply chain [54]. Dynamic Capabilities Theory chimes in in yet another way: AI can assist companies to detect disruption, take advantage of chances, and reconfigure operations as circumstances shift [55]. Supply Chain Resilience Theory, however, highlights the use of AI to enhance the visibility, adaptability and resilience to disruption [56]. All of these theories have something of value to say, but are rarely used in combination and so can only begin to explain complex, real-world food supply chains.

2.9 Research Gap and Conceptual Positioning of the Current Research

There is a significant body of literature that covers the use of AI in the global supply chain and logistics management context; however, the literature specific to food is limited and fragmented [42]. Most of the studies focus on individual applications of AI, or individual steps of the supply chain: machine learning to predict demand [57], computer vision to monitor quality [58], or optimisation algorithms to design transportation routes [59]. While these studies do provide insight into the functions of the individual technologies, none of them illustrates how these AI technologies could be used together in an entire food supply chain. Additionally, there is a literature selection bias on what is measured. Much of it remains techno-centric, seeing the use of AI primarily in terms of cost savings, prediction accuracy, speed and operational efficiency [35].

The strategic aspects, regulatory requirements, food safety assurance, environmental aspects, and ethical aspects receive comparatively little attention [58]. However, this is a difficult argument to make in the context of food's fragility, the rigorous safety and traceability standards and the new expectations of citizens for sustainability and responsibility. Both theory building and managerial application are suboptimal without a view from the industry that is integrative. While RBV, DCT and SCR have been used individually in the context of digital transformation of supply chains, the interaction of these three in the context of AI-driven food supply chains has not been sufficiently studied [56].

The consequence is a shallow attempt at demonstrating how the capabilities of AI are translated into greater supply chain capabilities and greater performance. In view of these gaps, this study creates a

conceptual framework that brings together the different empirical observations and theoretical understandings to present a concise and industry-specific narrative of the transformation of the food supply chain and logistics management through AI. There are two aims: advancing theory and making it truly applicable in an uncertain environment, under the pressure of regulations and growing expectations around sustainability.

There are other recent conceptual efforts on AI and SC resilience approaches that it is important to differentiate from. For example, Riad et al. [10] suggest a broad industry-neutral, supply chain resilience framework which is based on three general industry-resilience dimensions: risk management, operational efficiency, and real-time visibility. That is not a framework based on any single sector's constraints, and it is also not a framework with a theoretical approach that is a joint RBV-DCT-SCR. The present study, however, takes off from it in two ways. First, it is food-specific: perishability, cold chain requirements, food safety regulation and the volatility of the seasonal demand are treated as part of the context and not as incidental details. Second, it unites three theoretical perspectives (RBV, DCT, SCR Theory) in one mediated model as opposed to just considering resilience as an outcome itself, making the framework more comprehensive in explaining both the likelihood of an influence by AI and how it cascades from capability through function to capacity to performance.

3 Conceptual Framework

This section outlines, in a step-wise manner, the impact of AI on the performance of food supply chain and logistics, as depicted in Fig. 1. Underpinning AI are tools such as machine learning, deep learning, predictive analytics, computer vision, and optimisation algorithms that allow for intelligent data processing, pattern recognition, and autonomous decision-making for all supply chain activities [57], [60]. They are applied through concrete applications such as demand forecasting, procurement and supplier selection, inventory management, cold chain management, transportation planning, warehousing, and quality inspection and traceability [42]. The food supply chain has perhaps more need for these applications than any other one, because the food products are perishable and sensitive to temperature, the demand for the product is highly erratic, and food safety regulations are highly stringent [58].

The use of AI in these fundamental functions enhances prediction accuracy, immediate reaction and interoperability throughout the supply chain [59], [60]. Notably, the framework does not consider a direct impact from AI on performance. Rather, it comes through the higher-order supply chain capabilities that act as a mediation between it and the supply chain outcomes: operational efficiency, real-time visibility, decision accuracy, agility and flexibility, proactive risk identification, and cross-functional coordination [61], [62], [63]. These capacities enabled the transition of food supply chains to be more dynamic, agile and resilient to shocks, such as price jumps, shortages, and uncertainty about the environment [56]. The next step is improved performance, which improves food waste, logistics and operating costs, food safety and quality assurance, delivery lead times, service levels, sustainability performance and overall resilience [64]. This aligns with the current empirical evidence from the fields of food logistics and food

sustainability research, where all studies have shown that AI is an essential tool for waste reduction, optimal management of food transport and cooling systems, and food supply chain disruption management [65].

The theoretical bases for the framework, as shown in Fig. 1, are RBV and DCT, which describe the role of AI as an important, scarce, and difficult-to-imitate strategic asset that enables firms to perceive environmental change, capitalise upon opportunities that emerge, and reorganise supply chain processes in uncertain environments [66], [55]. A layer of theory has been added to SCR, explaining why AI contributes specifically to food supply chain resilience, flexibility, adaptability and disruption management [67], [59]. Last, the framework acknowledges contextual moderators that influence the impact of AI on performance, like regulatory requirements (food safety and traceability, etc.), product perishability, demand and market uncertainty, and access to digital and data infrastructure. These conditions largely influence the ability of AI-enabled capabilities to improve outcomes in various food supply chain contexts.

4 Research propositions

Building on the conceptual framework and its theoretical grounding, this section sets out eight research propositions. Together they capture the presumed relationships between AI capabilities, AI-enabled supply chain functions, supply chain capabilities, and food supply chain performance outcomes (see Table 1), and are intended to guide future empirical testing.

Proposition 1

(P1): The use of AI, such as machine learning, predictive analytics, computer vision, and optimisation algorithms, has a positive impact on supply chain and logistics operations, which are enabled by artificial intelligence and sparked by AI within the food industry.

Proposition 2

(P2): The supply chain and logistics functions, which are AI-enabled, including demand forecasting, inventory optimisation, cold chain monitoring, transportation routing and quality traceability, are beneficial to the food supply chain in terms of their ability to improve operational efficiency, real-time visibility, and decision accuracy.

Proposition 3

(P3): The connection between the supply chain functions of AI and the overall performance of the food supply chain is mediated by food supply chain capabilities.

Proposition 4

(P4): The improved food supply chain capabilities have a positive impact on the operational performance outcomes, such as decreased food wastage, lower logistics expenses, reduced delivery time, and improved service levels.

Proposition 5

(P5): The improved ability in the food supply chain has a positive strategic performance outcome, such as resilience, sustainability of the supply chain, and adherence to food safety.

Proposition 6

(P6): Food safety and traceability standards and other regulatory compliance requirements moderate the connection between AI-enabled supply chain functions and food supply chain performance.

Proposition 7

(P7): The positive contribution of AI-enabled supply chain functions on supply chain capabilities is enhanced by product perishability and market uncertainty.

Proposition 8

(P8): Digital infrastructure moderates the connection between AI potential and AI-enabled supply chain functions in the food industry.

Table 1
Research Propositions and their expected outcomes

Proposition	Relationship Examined	Theoretical Basis	Expected Outcome
P1	AI capabilities → AI-enabled supply chain functions	RBV	Improved adoption and effectiveness of AI-driven logistics operations
P2	AI-enabled functions → supply chain capabilities	Dynamic Capabilities	Enhanced efficiency, visibility, and decision accuracy
P3	Mediating role of supply chain capabilities	RBV + Dynamic Capabilities	Indirect impact of AI on performance
P4	Supply chain capabilities → operational performance	Operations & SCM Theory	Reduced food waste, lower costs, faster delivery
P5	Supply chain capabilities → strategic performance	Resilience Theory	Improved sustainability and supply chain resilience
P6	Moderating role of regulatory compliance	Institutional Theory	Strengthened the AI–performance relationship
P7	Moderating role of perishability & uncertainty	Contingency Theory	Higher AI effectiveness under uncertainty
P8	Moderating role of digital infrastructure	Technology Readiness Theory	Enhanced AI deployment and scalability
Source: Author's compilation			

Taken together, these propositions operationalise the conceptual framework and give future researchers a systematic base for empirical testing, whether through surveys, case studies, or secondary data analysis. They also make it possible to examine both direct and indirect effects, which should deepen our understanding of how AI is actually changing food supply chains.

5 Implications for the Manager and Policy

There are several important implications for managers in food supply chain and logistics positions. At its core: AI should not be considered as a collection of individual technological solutions but as a key strategic capability that can transform the whole system. It involves more than simply optimising efficiency or merely focusing on the advantages of AI for visibility, coordination, and resilience in general. Applications like demand forecasting, cold chain monitoring, inventory optimisation and quality inspection can make a significant impact in improving the accuracy of decisions, response and risk management, particularly in such a perishable and volatile industry. The framework also provides for the most useful benefit of AI when integrated with the right supply chain capabilities – agility, real-time visibility, and cross-functional integration are among these. If managers are looking to realise these benefits, they shouldn't just invest in technology – they also need to invest in their organisation,

capabilities and data governance to have a real chance of reducing food waste, enhancing service levels and being more resilient when faced with disruption. There's a policy element to this, as well. AI has the potential to enhance the monitoring, tracking, and reporting of food safety and sustainability, and while regulatory clarity and institutional support are crucial for successful adoption, regulators and policymakers can use AI to improve their tools for food safety surveillance, traceability, and sustainability reporting. Governments have a crucial part to play in this regard: investing in digital infrastructure, standardising the rules for data sharing, and creating rules that ensure fair and responsible use of AI. It is critical in emerging economies where there is a differential readiness of the players of the food value chain.

6 Conclusion

The study contributes to the body of literature on the use of artificial intelligence in food supply chain (FSC) and logistics management, which has been scattered across various sources and has largely been empirical. This study is a contribution to a growing body of literature that has been produced on the use of artificial intelligence in food supply chain (FSC) and food logistics management, which has been empirical and spread across different sources. The study provides a more comprehensive view of how AI-driven transformation is realised in food supply chains by showing how AI capabilities and AI-enabled supply chain functions are intertwined and mediated by supply chain capabilities, leading to performance outcomes.

The framework is grounded in RBV, DCT and SCR Theory, which provides depth and relevance to the framework. The propositions and conceptual model offered here are intended as a beginning, not the end, of empirical research in the future. Further research could examine these relationships via surveys, case studies or secondary data, at the subcategory level of food and across the region. Comparative analysis might help to measure changes in the impact of AI over time, while longitudinal analysis could reveal the differences between developed and developing economies in this regard. There is also a need to explore more deeply the ethical issues, data management concerns, and the wider social implications of AI in food supply chains, as will be addressed in the following research.

This framework is not only relevant for theory, but also for several United Nations Sustainable Development Goals. It is explained how AI helps to minimise food loss and waste, which addresses SDG 2 (Zero Hunger); reduces emissions from transportation, cold chain and warehouses while supporting efficient and less wasteful production and consumption patterns, which addresses SDG 12 (Responsible Consumption and Production); and reduces emissions associated with cold chain operations and warehouses, which addresses SDG 13 (Climate Action). The choice of placing the framework in relation to these objectives is not coincidental, as it makes clear that using AI in food systems is not just an operational issue, but a food security and environmental sustainability issue at a global level.

Declarations

Competing Interests

The authors have no relevant financial or non-financial interests to disclose.

Ethics Approval and Consent to Participate

This article does not contain any studies with human participants or animals performed by any of the authors. Not applicable.

Consent for Publication

Not applicable.

Conflict of Interest

The authors declare no conflicts of interest.

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Author Contribution

Anshul Agrawal: Conceptualization, Methodology, Investigation, Writing – Original Draft, Writing – Review & Editing. Sanjeev Kadam: Conceptualization, Investigation, Writing – Review & Editing, Supervision. Both authors read and approved the final manuscript.

Data Availability

Data sharing is not applicable to this article, as this is a conceptual paper and no datasets were generated or analysed during the current study.

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Figures

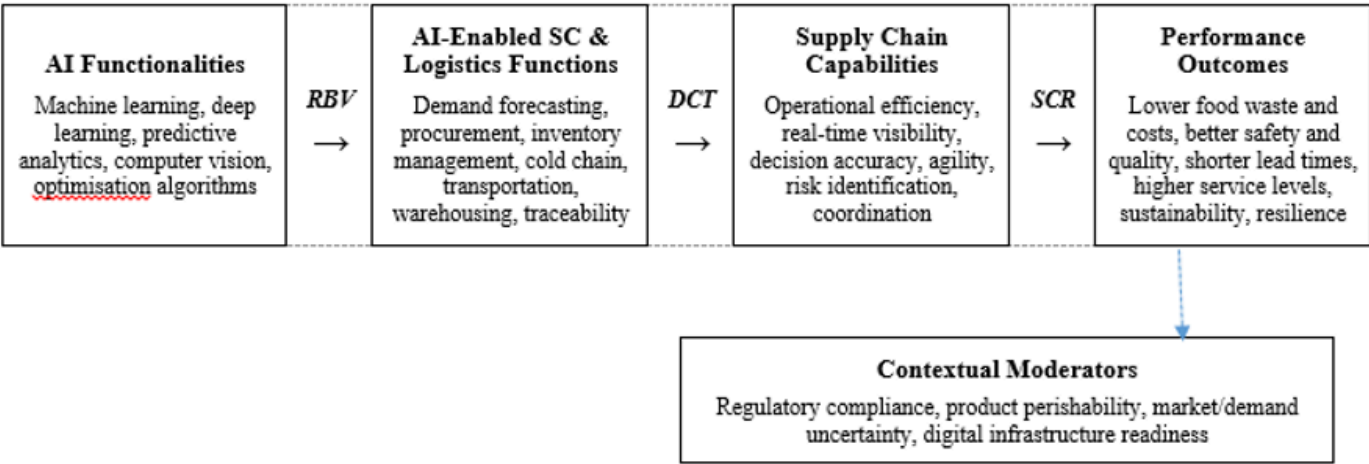


Figure 1

Conceptual Framework of AI-driven Capabilities and Performance Outcomes in Food Supply Chain and Logistics

Note: Solid arrows represent direct relationships, while dotted arrows indicate moderating effects