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AI for Supply Chain Management: Disruptive Innovation or Innovative Disruption?

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ABSTRACT

This article examines the theoretical and practical implications of artificial intelligence (AI) integration in supply chain management (SCM). AI has developed dramatically in recent years, embodied by the newest generation of large language models (LLM) that exhibit human-like capabilities in various domains. However, SCM as a discipline seems unprepared for this potential revolution, as existing perspectives do not capture the potential for disruption offered by AI tools. Moreover, AI integration in SCM is not only a technical but also a social process, influenced by human sensemaking and interpretation of AI systems.

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This article offers a novel theoretical lens called the AI Integration (AII) framework, which considers two key dimensions: the level of AI integration across the supply chain and the role of AI in decision-making. It also incorporates human meaning-making as an overlaying factor that shapes AI integration and disruption dynamics. The article demonstrates that different ways of integrating AI will lead to different kinds of disruptions, both in theory and practice. It also discusses the implications of AI integration for SCM theorizing and practice, highlighting the need for cross-disciplinary collaboration and sociotechnical perspectives.

Keywords: artificial intelligence, disruption, sensemaking, metaphorical imagination, GPT-4

INTRODUCTION

Artificial intelligence (AI) has developed dramatically in a short time, embodied by the newest generation of large language models (LLM) launched in early 2023. For supply chain management (SCM) scholars and practitioners alike, this potential revolution necessitates re-evaluating the existing theoretical framework and practical applications. AI models are approaching or even transcending human-like capabilities in areas such as apparent reasoning (Espejel et al., 2023; Liu et al., 2023), text production (Garrido-Merchán, Arroyo-Barrigüete, & Gozalo-Brizuela, 2023), understanding other living beings' point of view (Sileo & Lernould, 2023), and data analysis (Mollick, 2023). The full range of capabilities of these models is not even understood by their creators (OpenAI, 2023). Still, early evidence suggests AI models are exceptionally powerful, surpassing humans in some advanced cognitive tests (Bubeck et al., 2023). As SCM scholars, we must ask ourselves: If these systems are as capable as they seem, how will this change supply chains and SCM research?

However, SCM as a discipline seems unprepared at a theoretical level for this revolution. Some researchers have recently explored the possibilities of digitalization and AI in making supply chains more efficient (Perano et al., 2023), while others have studied the potential of AI systems in mitigating disruptions caused by the COVID-19 pandemic (Nayal et al., 2022). While these perspectives are valuable, they do not capture the potential for disruption offered by AI tools. There are two primary reasons for this: First, newer and more capable AI systems are personalized chatbots. Unlike previous AI technological systems, this generation of AI does not need a large infrastructure to work; anyone with an internet connection can start using these AI tools right away, which eliminates a significant barrier to AI adoption. Second, the capability of the most advanced systems, especially GPT-4, is at a level where it can assist a professional human being in a large array of complex knowledge intensive or creative tasks (Bubeck et al., 2023; Mollick, 2023). This capability also entails challenges as we risk relying too much on AI tools, put undue trust in AI judgments, or allow AI-induced bias to cause problems for minorities and vulnerable groups. In other words, we are now living in a reality where every person on the planet – and thus, every SCM professional – has personal access to the most powerful AI system developed in human history. We are now experiencing the beginning stages of a true 4th industrial revolution (Gates, 2023).

In this article, I offer a novel theoretical lens that serves as a vehicle for understanding the range of possible disruptions and supply chain impacts brought about by increasingly capable AI systems. While the concept ‘disruption’ is sometimes used without clear definitions in SCM (Adel, Vries, & Donk, 2022; Ketchen & Craighead, 2021), I understand disruptions in SCM to be events that alter the flow of goods or services, requiring supply chain adaptation and innovation, and affecting social and environmental outcomes. I couple the theoretical lens with an interpretivist perspective (Darby, Fugate, & Murray, 2019) on how AI is understood by actors in the supply chain through a sensemaking perspective (Weick, 1995).

This novel perspective, which I call the AI Integration (AII) framework, is designed to provide a novel perspective on AI integration in SCM. In this article, 'integration' refers to the increasingly extensive use of AI systems to carry out work tasks throughout the supply chain. The purpose of the framework in combination with the interpretivist lens is to demonstrate that, depending on the trajectory and form of AI integration happening in a given supply chain, different sets of possible disruptions emerge. For example, a supply chain where AI is only sparingly used entails a completely different set of potential disruptions compared to a supply chain where virtually all functions are carried out by autonomous AI agents. Crucially, I demonstrate that AI integration in supply chains is both a technical, operational, and social process, and future SCM theorizing on this topic must take seriously this complexity.

THE EVOLUTION OF AI AND ITS IMPACT ON SUPPLY CHAIN MANAGEMENT

Previous iterations of different AI systems have revolved around machine learning (ML) and big data analytics to achieve efficiency gains or quality improvement (Kamble et al., 2021). This was the predominant perspective before December 2022, focusing on how ML infrastructure could be deployed to analyze very large amounts of data to provide humans with conclusions and results (Dubey et al., 2020). ML approaches have required extensive architecture and AI expertise, given that ML solutions would require local setup in organizations and specialized experts that could train the models to give useful output (Kinra et al., 2020).

It is no longer an exaggeration to say that this perspective was obsolete on the morning of the 1st of December 2022. The day before, OpenAI launched a conversational chatbot called ChatGPT, which could produce moderately complex text relating to a wide variety of topics. ChatGPT was powered by the GPT architecture, a relatively new form of AI that did not analyze input (like existing ML approaches), but predicted output based on user input. This approach, known as generative AI, did not replace ML systems, but it suddenly allowed everyone to open ChatGPT and chat with the AI about relatively complex topics. Moreover, unlike ML systems where only AI experts understood the systems and could operate or train them, ChatGPT could generate output for any user regardless of training or background. This is the first reason business approaches to AI changed so rapidly: ChatGPT demonstrated that AI systems could be made available and approachable to anyone, not just a select few AI engineers.

In March 2023, OpenAI revealed their new iteration of the GPT architecture called GPT-4. This model exhibits reasoning capabilities that outrank average humans on virtually every evaluation parameter and surpasses the best 5 % of humans on most evaluation parameters (Bubeck et al., 2023; OpenAI, 2023). When GPT-4 was given the ability to write, interpret, and execute code, it became capable of running fairly complex data analysis and visualizing (Mollick, 2023). When used simply as a chatbot, the standard model allowed any person to produce fairly complex material, with some even showing that GPT-4 could replace humans doing research (Hitch, 2023). GPT-4 is the most powerful generative AI model at the time of writing, but other models are being developed in parallel by other companies, such as Google. This competitive race to produce ever-more powerful AI systems that are widely accessible will ensure that increasingly capable AI systems will be in the hands of professionals sooner rather than later.

In SCM, there are already indications of how this will change the landscape. For example, early indications suggest that GPT-4 can carry out the analytical basis for supplier choice, such as evaluating a supplier profile based on a given set of parameters and instructions (provided by humans) (Bonde, 2023). It can also be integrated into sales, demand forecasting, production and logistics optimization, and customer sales, to name a few (Panigrahi, 2023).

However, the broader implications go beyond these items: How does it change a procurement manager's job when they have an expert-level AI at hand to assist in task solutions, workflow structuring, brainstorming, writing, and analytics? And how does a supply chain manager approach the well-known challenge of managing a complex supply chain beyond their horizon (Carter, Rogers, & Choi, 2015) when they have the capability of an AI readily available to help? I suspect these are questions managers may ask themselves sooner rather than later.

However, AI does not only pose a possibility for firms and individual professionals to improve productivity and quality. AI integration entails many pitfalls and dangers, such as the potential of overreliance on AI systems for carrying out tasks, delegating authority to AI systems when it is inappropriate, undue faith in AI evaluation, or unethical usage of AI systems with regard to employees or customers (Boiko, MacKnight, & Gomes, 2023; Panigrahi, 2023; Shevlane et al., 2023). In this sense, the possibility for disruption in supply chains is multi-dimensional. One dimension of disruption relates to the promissory nature of generative AI, given its approachability and personalized manifestation, where everyone can use it for their day-to-day tasks. Another dimension of disruption can emerge from the unintended consequences of any combination of pitfalls because these can be exacerbated throughout the supply chain. For example, if several companies in a chain use AI to produce analyses that are wrong or do not have the capability to use AI responsibly, what happens in the entire chain when an AI-based system breaks down? Could there be an "AI-bullwhip effect"?

AI ADOPTION AS A DISRUPTION OF THEORY

As AI systems become more widespread and widely adopted both at the individual and the organizational level, it changes the rules of the game for our theoretical models, assumptions, and frameworks. The reason for this is that the theories we use in SCM are predicated on the idea that humans and organizations are the building blocks of supply chains, and supply chains emerge as phenomena from these interactions (Carter, Rogers, & Choi, 2015; Choi, Dooley, & Rungtusanatham, 2001; Wieland, 2021). Yet, as AI becomes increasingly capable of generating not only text, analysis, and media but also making decisions and adjudicating choices, it calls into question to what extent our existing assumptions still hold.

To exemplify the broader theoretical implications, consider two theories used in SCM: transaction cost economics (TCE) (Hobbs, 1996; Ketokivi & Mahoney, 2020; Tate, Ellram, & Dooley, 2014) and complex adaptive systems theory (CAS) (Choi, Dooley, & Rungtusanatham, 2001; Nair & Reed-Tsochas, 2019). These two theories are good exemplars because they entail different assumptions and are used by scholars to explain different SCM phenomena. In TCE, the core focus is how to structure the governance of a supply chain (or any relationship or transaction) in such a way that it is the most efficient, given objectives (Ketokivi & Mahoney, 2020, p. 1012; Williamson, 1979). Two foundational assumptions in this perspective are that actors are boundedly rational and opportunistic if given a chance, and because of this, actors are constrained in their ability to engage in efficient transactions depending on the context. But now, imagine a situation where two actors have extensive AI assistance. This immediately changes the idea of bounded rationality, or at least relaxes this constraint, because any given actor has extensive capability to analyze and act upon information.

Similarly, sufficiently advanced AI systems may guide users toward long-term benefits rather than short term gains. Long-term utility maximization for all transaction participants is a better outcome for a time-independent AI. Perhaps most insidiously, we can ask ourselves: In a situation where it is no longer humans but rather autonomous AI systems that negotiate with each other, how does TCE even work? What can we assume about AI behavior in such a situation?

Complex Adaptive Systems (CAS) have been integral to Supply Chain Management (SCM) theories since the early 2000s, with the underlying concept being that supply chains emerge from the interaction of internal mechanisms within the system and the external environment, leading to co-evolution in a chaotic and nonlinear fashion (Choi, Dooley, & Rungtusanatham, 2001; Nair & Reed-Tsochas, 2019, p. 81). This paradigm may be fundamentally altered in a context where advanced generative AI becomes a ubiquitous tool available to all professionals across different firms.

The system's unpredictability may amplify substantially as AI-driven workflows swiftly transform across the supply chain. Concurrently, the 'environment'—encompassing markets, consumer behaviors, regulatory landscapes, and even competing supply chains—increasingly integrates AI technologies. These factors, changing and adapting quickly in less predictable ways, set the stage for supply chains and their socio-political contexts to co-evolve at an unprecedented pace. For instance, AI systems could react instantaneously to fluctuating demand patterns identified by AI-enabled market analysis tools or adjust supply chain processes in response to regulatory changes. This AI-driven dynamism in the environment introduces a new layer of complexity to supply chains. More fundamentally, deeply integrated or autonomous AI systems could challenge CAS's traditional explanations for supply chain emergence, as the role of 'actor' shifts from humans to AI systems. This may redefine measures of information and entropy in CAS, as generative AI could pioneer novel communication and computation modes that exceed traditional metrics. Furthermore, AI could enable new forms of adaptation and learning, surpassing the bounds of human agency and rationality as understood in traditional CAS theories (Yu, Lakemond, & Holmberg, 2023). Consequently, the introduction of generative AI into SCM necessitates a critical reassessment of CAS theories concerning system emergence and complexity.

This is a partial outline of the potential theoretical import of the fourth industrial revolution. Yet, it shows that even with some very simple examples, the core ideas of these theories should be considered in this new light. New SCM research in the "age of AI" (Gates, 2023) should work on clarifying what our theories can and cannot handle, how we should develop or revise our assumptions about the world, and how we theoretically explain supply chain mechanisms and dynamics emerging from increasing integration of AI.

THE AI INTEGRATION FRAMEWORK IN SCM

As the possible disruptions to both theory and practice stemming from AI integration become clearer, SCM needs a way to categorize and understand AI integration across supply chains. In the simplest terms, different ways of integrating AI will lead to different kinds of disruptions, both in theory and practice. For example, light and surface-level AI integration across a supply chain is a different challenge than a supply chain that operates almost entirely on autonomous AI agents.

Accordingly, SCM scholars can understand the trajectory of AI integration and its associated potential for disruptions through the lens of the AII framework. AII is developed as a theoretical model designed to capture the complexities and nuances of AI integration in supply chains, and to contextualize a certain disruptive potential depending more easily on the specifics of the AI integration in a given supply chain. Additionally, while AI is used by individuals or firms that are part of larger supply chains, the emergent (Choi, Dooley, & Rungtusanatham, 2001; Sawyer, 2004) effects of AI manifest at the supply chain level as disruptions that are larger than the sum of their parts. Accordingly, the AII framework operates at the supply chain level because the emergent effects stemming from individualized technologies can be more disruptive. The framework is based on two key dimensions: the level of AI integration across the supply chain and the role of AI in decision-making. By considering these two dimensions, the AII provides a comprehensive perspective on AI integration in SCM, capturing the potential disruptions and transformations that can occur due to AI adoption.

However, we know from recent SCM contributions that human interpretations of systems and technologies matter for how SCM practice emerges, and practices are shaped (Darby, Fugate, & Murray, 2019, 2022; Wieland, 2021). Thus, I propose that in addition to considering the level of AI integration and the role of AI in decision-making, scholars should pay attention to the way supply chain professionals engage in the sensemaking of AI systems and how they ascribe meaning and identity to them (Scott, 2014, pp. 55–63; Weick, 1995; Weick, Sutcliffe, & Obstfeld, 2005). As humans mentally categorize AI systems and make sense of them, humans maintain agency over how, whether, and why AI integration in a supply chain manifests. The framework consists of the two axes mentioned – yielding a 2×2 model – but with human meaning-making overlaid and given as an interpretation of how AI-induced disruptions can play out in a given supply chain.

The following paragraphs help explain the two axes and how the 2×2 model yields ways of understanding different ways AI can be integrated into supply chains. First, metaphors are attached to each quadrant to assist in imagining the kind of supply chains and work situations that may arise from each combination (Stephens et al., 2021; Tsoukas, 1993). Then, the explanation shifts to explain how socially constructed sensemaking processes give rise to different understandings of what AI can and should do in a supply chain. Taking all this together, the potential for disruptions in each quadrant is discussed, including how sensemaking can yield agency to humans in steering this, and what this means for the trajectory of AI integration. Finally, it explains how these disruptions can change supply chain management scholarship and practice.

Dimensions of the AI Integration Framework

The AII is based on two key dimensions: the level of AI integration across the supply chain and the role of AI in decision-making. The level of AI integration across the supply chain refers to the extent to which AI is integrated into the various activities and processes of the supply chain. At one end of the spectrum, AI integration is low, with few actors in the supply chain adopting AI or only using AI for specific tasks. This could be likened to the early stages of AI adoption, where AI is used as a tool for specific tasks such as demand forecasting or inventory management but in a limited capacity. In this stage, AI acts as an assisting system, enhancing human capabilities but not replacing them, and never making autonomous decisions or executing without human direction.

At the peak of AI integration, numerous supply chain actors incorporate AI deeply into their operations, spanning tasks from demand forecasting to delivery and wider operations management. High integration isn't merely about extensive infrastructure within a single firm but refers to supply chain actors leveraging AI tools like ChatGPT across all job functions. While the tools might be individualized, their collective usage across the supply chain leads to an emergent, robust AI-driven supply chain. The versatility of these tools outmatches earlier ML infrastructure solutions, allowing for effective use within various tasks across firms. Despite varied integration strategies across companies, the emergent nature of AI usage contributes to unique supply chain dynamics.

The second axis is the role of AI in decision-making. It refers to the extent to which AI systems are given autonomy and decision-making power. At one end of the spectrum, AI plays an assistive role, providing data analysis, finding information, and providing 1:1

assistance for employees. In this role, AI is primarily a tool that enhances human capabilities, providing support for decision-making but not making decisions autonomously. This can be likened to the role of a trusted advisor or assistant, who provides valuable insights and recommendations but does not have the authority to make decisions.

AI takes on an autonomous role at the other end of the spectrum, analyzing and executing independently. In this role, AI systems are given autonomy and decision-making power, potentially making decisions that significantly impacts the supply chain. This can be likened to the role of a manager or director, who provides insights and recommendations and has the authority to make decisions and implement changes. This shift from an assistive to an autonomous role represents a significant change in supply chain dynamics. Furthermore, it raises crucial questions about the balance of power between humans and AI systems, the accountability and control mechanisms that need to be in place, and the ethical implications of delegating decision-making power to AI systems.

As noted earlier, the model operates at the level of the supply chain. As individual firms implement AI into their operations, AI dynamics at the supply chain level becomes an emergent phenomenon (Choi, Dooley, & Rungtusanatham, 2001; Sawyer, 2004). Firms will most likely begin with partial integration with AI in an assistive role but depending on the characteristics of the supply chain in question, firms may then either move towards other quadrants or maintain limited AI integration. This depends on the specifics of the supply chain in question and the operational situation in the firms involved. The important thing to note here is that firm-level AI implementation strategies leads to AI integration dynamics across the supply chain.

--Insert Figure 1 Approximately Here---------------------------------

In quadrant one, the metaphor for understanding (Stephens et al., 2021) is Human Sherlock, Robot Watson, referring to the classic fictional universe of the detective Sherlock Holmes. Here, AI is partially integrated and serves in an assistive role. That means humans are in the lead, and AI is used sparingly in select use cases across the supply chain. In this way, the Human Sherlock has full ownership of the tasks, sets directions, makes decisions, while Robot Watson does a lot of the legwork, pulls together material, and follows instructions as best as possible. Picture a warehouse where employees are selecting items for order fulfillment. AI assists by scanning inventory data and providing the optimal route for picking items, thus aiding human workers without making the ultimate decisions. Human Sherlock directs operations, while Robot Watson expedites tasks and offers advice based on data. However, like Watson, AI can also challenge Human Sherlock's ideas when they are unreasonable or goes against best available knowledge, and it can make Human Sherlock aware that there are perspectives Sherlock may be missing. Thus, while Sherlock is still in control and solves the case, Watson serves as a valuable asset not only in terms of menial legwork, but also in an intellectual capacity.

As we increase integration, we move towards quadrant two. Here, the metaphor is that of a Robot Cartographer that lays out the entire map and relates it to the territory (Fabbe-Costes, Lechaptois, & Spring, 2020). This means the AI is used in most or all advanced and general functions, conducting data analysis, planning and organizing information inside and outside the organizational boundary. Consequently, integration in this quadrant will be more focused and organized by the firm in question. However, the AI only does this to assist humans in making final decisions. An example could be a complex multi-echelon supply chain scenario where AI is employed to forecast demand, identify supply chain risks, monitor supplier performance, and suggest optimal distribution strategies. While AI lays out the entire map of data and strategies, the human "captain" uses this information to make final decisions. In this quadrant, humans universally take on supervisory roles in the supply chain, making decisions and organizing ideas and strategies based on ubiquitous AI assistance in all functions.

Even with partial integration, we can give AI systems authority to make decisions, leading us to quadrant three. Here, the metaphor is Chess Grandmaster, where the AI system is used in specific tasks but is also allowed to make decisions itself. Much like a Chess Grandmaster is expert at a very narrow set of choices relating to the game of chess, AI systems in these supply chains are used deliberately on specific tasks. In this instance, AI might autonomously analyze different vendors based on price, delivery times, reliability, and past performance. It then selects the best option without direct human intervention. However, given that AI systems in these situations interface with human-led systems, humans still have final authority to override AI choices if it conflicts with other parts of the workstreams or production flows.

Finally, in quadrant four, supply chains may be organized so that AI is both fully integrated into all functions and given the authority to make decisions autonomously. The metaphor here is that of an AI Ecosystem. When all actors in a supply chain have fully integrated AI capabilities in all their main tasks and give the AIs authority to decide and act (given some predefined instructions), the supply chain transforms into an AI-led ecosystem. Envision a supply chain where AI is used to control all aspects - from demand forecasting, inventory management, order fulfillment to logistics and customer service. Each AI system communicates and cooperates with others, making autonomous decisions based on set instructions and reacting to changes in real-time. This ecosystem learns and adapts, forming a complex, interconnected network that operates with minimal human intervention.

Moving from the theoretical metaphors that demonstrate various stages of AI integration, it's essential to understand that these are not just abstract notions. Instead, these metaphors represent the reality of how AI interacts with and influences the supply chain process, with significant implications for supply chain management. However, the true impact of AI depends on more than just its integration or autonomy. It's also contingent on the perception of the individuals interacting with these systems – the human agents in our supply chain. This brings us to an important aspect of AI integration: the human sensemaking of AI systems and the potential for disruption. The human understanding of AI, shaped by their experiences and perspectives, significantly influences the interpretation and acceptance of these systems within the supply chain.

Human sensemaking of AI systems and the potential for disruption

The integration of Artificial Intelligence into supply chains is not merely a technical or operational endeavor; it deeply intersects with the realm of the social. To grasp the intricacies of this integration, we must consider the pivotal role of human actors who actively interact with these AI systems daily. They interpret the potential and limitations of these technologies, manage their implementation, and guide their utilization. Their perceptions and beliefs about AI, shaped by their individual experiences, professional backgrounds, and their specific roles within the supply chain, significantly influence the degree of AI integration and its role in supply chain operations. These human actors determine whether AI is deployed minimally or widely across various supply chain activities, whether it plays an assistive or autonomous role, and the potential disruptions that could arise from its use.

Understanding the phenomenon of human sensemaking, the process by which people give meaning to their collective experiences, is paramount in this context. Their individual interpretations, borne from their unique beliefs, experiences, and professional viewpoints, are integral in shaping the trajectory of AI adoption and its ultimate utility in the supply chain context. For instance, a procurement manager with a positive outlook towards AI might see it as a strategic tool to streamline procurement decisions, while a logistics manager who harbors skepticism about AI's reliability might view it as a potential risk. These divergent interpretations can significantly shape how AI is deployed and managed within the same supply chain, thereby determining the potential benefits, challenges, and disruptions that could emerge. Recognizing this social aspect of AI integration, alongside the critical technical considerations, is vital for effectively managing AI technologies within supply chains. This dual understanding equips organizations with the necessary insights to harness the potential of AI, minimize its risks, and thereby create more resilient and efficient supply chains.

While each quadrant represents its own set of possible disruptions both in practice and in theory, it is important to emphasize that the approach to AI integration in any supply chain is contingent on humans' interpretation of these systems (Berger & Luckmann, 1967; Darby, Fugate, & Murray, 2019; Wieland, 2021). AI integration is not just a technical process – it is also a social process. The basic premise here is that humans, when faced with a new situation, phenomenon, or technology, interprets this novel event by relating it to existing experience (Bendoly, 2016; Weick, Sutcliffe, & Obstfeld, 2005). This process is idiosyncratic across organizations and supply chains, resulting in divergences from supply chain to supply chain in terms of how AI is understood and interpreted. In the table below, I summarize a few main types of interpretation, but not exhaustive, as social sensemaking processes are complex and defies neat categorization.

---Insert Table 1 Approximately Here-----------------------------------

Each way of understanding and interpreting what AI is and its role leads to vastly different ways that humans think about how to integrate it into existing structures. For example, suppose humans in a supply chain understand AI systems to be a threat (due to security issues, displacement of human jobs, or vulnerability due to technological dependency). In that case, integration will be done with that in mind – i.e., AI integration on non-critical issues, separation from human tasks, firewalling from core processes, and more. Alternatively, a supply chain that understands AI as a competitive capability will aim to enhance all supply chain actors' ability to integrate AI to ensure the supply chain is competitive.

Depending on the sensemaking processes that play out, the potential for disruptions in each quadrant will pan out differently. In quadrant one, humans who understand Robot Watson as a threat will be more hesitant to rely on AI output or use AI systems in critical work processes. This means disruptions in the supply chain as a whole are less likely given that human actors are careful not to allow AI systems to threaten core functions. However, if Robot Watson is seen as a useful partner, disruptive potential increases, but is contingent on the supply chain practices that are already in place due to the role as a partner. When integration increases and we move to a Robot Cartographer, human actors may emphasize the risk of the Cartographer producing wrong maps – i.e., producing wrong inferences – if they think of the AI as a tool. This also means that the type of disruption changes, from a potential systemic shock to a supply chain to a limited problem that is local to a few supply chain actors. Thus, the set of possible disruptions emerging from a given type of integration depends critically on how human actors make sense of these systems.

The general picture that emerges is one where human sensemaking is evocative of the agency human actors have in directing AI integration. Different metaphors and interpretations of AI systems lead to different ways of thinking about how AI systems should be integrated, what risk assessments and risk management strategies supply chain actors should implement, and what type of AI integration a company should aim for, with a given velocity of change. All of this happens, in a given supply chain context (Bille & Hendriksen, 2022) which shapes the specific mechanisms. Based on the AII combined with the sensemaking perspective, it is important to underline that future SCM research on AI integration must recognize the social component of AI integration. A purely technical perspective risk ignoring the considerable importance of social interactions that give rise to differential AI implementation strategies, and by extension the possibilities for disruptive events. With this, I will now turn to a forward-looking discussion of future theorizing in SCM and the practical implications arising from these ideas.

IMPLICATIONS FOR THEORIZING IN SCM AND THE NATURE OF AI DISRUPTIONS IN PRACTICE

I will now delve into the broader implications and forward-looking perspectives. Drawing on the insights and evidence that have been discussed so far, I aim to highlight the transformative role of AI and the accompanying challenges and opportunities.

AI as Active Participants in SCM

The exploration of AI integration in SCM, underpinned by the AII framework and our understanding of the ways humans interact with AI, reveals a need to reorient SCM theories towards acknowledging AI as more than just a passive tool in human decision-making. Recognizing AI as active participants in supply chain interactions signifies a shift in perspective that acknowledges the agency and autonomy of AI systems. These systems are no longer mere extensions of human ability but possess their own capacities to influence and shape supply chain dynamics. From this perspective, it does not matter whether AI systems are sentient or self-conscious. Instead, it is important to recognize that AI systems by virtue of their capabilities can impact supply chains in similar ways to humans.

These active AI systems engage in intricate interactions with humans that go beyond one-way manipulation. They co-evolve and exert mutual influences, suggesting that theories of AI in

SCM might need to center around understanding human-AI relationships and collaboration. Much like how previous SCM literature has deciphered human collaboration across supply chains, future theories could aim to demystify AI-human relations in this context (Blome, Paulraj, & Schuetz, 2014; Danese, Molinaro, & Romano, 2020; Frohlich & Westbrook, 2001). Depending on the trajectory of AI development and integration, this could be an important topic for future SCM theorists.

New Constructs and Philosophical Perspectives in SCM Theorizing

Incorporating AI as active participants necessitates that our theories accommodate new constructs, such as the idea of "AI autonomy"—which encapsulates the extent to which AI systems can operate independently, making decisions without human intervention. Additionally, there is the potential construct of "AI-human collaboration," representing the synergistic interaction between humans and AI and its impact on supply chain performance. It's crucial that theorists also face the possible conflicts that might emerge from AI integration, like power struggles between human and AI actors, ethical considerations of AI decision-making, and the control mechanisms required to regulate AI behavior. This is particularly important given the potential for AI-induced disruptions stemming from irresponsible use of AI.

To fully comprehend the integration of AI in SCM, researchers may need to pull from multiple philosophical perspectives. The infusion of AI into supply chains is a complex, unpredictable process involving many variables and possible outcomes. Thus, the integration of both positivist, interpretivist, and critical realist perspectives can aid in providing a more comprehensive understanding. A positivist approach can help to identify general patterns and relationships associated with AI integration, whereas an interpretivist perspective can illuminate the nuanced ways humans interpret and interact with AI. A critical realist perspective can recognize both the existence of objective realities in AI-driven SCM operations and the influence of subjective interpretations on these realities while shifting focus to causal mechanisms underpinning disruptive effects (Beach & Pedersen, 2019; Illari & Williamson, 2012). Ironically, AI systems like GPT-4 allow SCM researchers to consider and evaluate different philosophical perspectives much easier. This is because the model can provide a perspective or argument from another philosophical point of view, allowing researchers to evaluate different perspectives much faster and easier than before.

AI Disruptions and the Role of Social Processes

The disruption that AI brings to SCM is not just technologically determined but also shaped by social processes, adding another layer of complexity to theorizing in SCM. This warrants the evolution of sociotechnical theories that can capture the interplay between the technical aspects of AI integration and the social reactions and responses of human actors. These theories might need to examine the role of organizational culture, norms, and values in shaping AI adoption and use, along with the sensemaking processes guiding AI interpretation. The impact of these interpretations on AI integration and disruption dynamics should also be taken into account (Bille & Hendriksen, 2022; Darby, Fugate, & Murray, 2019; Touboulic, McCarthy, & Matthews, 2020; Wieland, 2021).

Moreover, AI integration in SCM offers a unique opportunity for cross-disciplinary collaboration. SCM researchers can partner with experts from diverse fields like computer science, engineering, sociology, psychology, and more to develop a more nuanced understanding of AI and its implications for supply chains (Kamble et al., 2021; Trautrims, Defee, & Farris, 2016). This could lead to theoretical insights that break through the typical constraints of SCM theorizing, integrating concepts from human-computer interaction, information systems, data analytics, and behavioral sciences (Bogers et al., 2017).

Practical Implications and Cross-Disciplinary Collaboration for AI in SCM

When considering practical implications for everyday supply chain practices, AI integration presents both opportunities and challenges. Organizations must pay attention to not only the technical aspects of AI adoption but also the human elements, such as managing human perceptions and reactions towards AI, fostering an AI-aware culture, and providing training for effective AI-human collaboration. Ethical and accountability issues associated with delegating decision-making power to AI must also be addressed. Control mechanisms to prevent misuse and monitor AI behavior, as well as potential job displacement and other social issues resulting from AI integration, need to be considered.

AI disruptions can vary across supply chains, requiring a systemic approach to manage them. This includes creating robust systems for monitoring AI performance, establishing measures for disruption mitigation, and developing contingency plans. Coordination and collaboration with other supply chain actors— aligning AI strategies and developing shared best practices for AI integration and management— are integral to this approach. However, at a more fundamental, supply chain managers must consider whether they have capabilities to integrate AI systems in a meaningful way (Barney, 1991; Teece, Pisano, & Shuen, 1997). This entails operational considerations as well as responsible management practices. A situation where firms integrate AI into core functions without considering how to do it responsibly constitutes a major risk for disruptive effects. Consequently, supply chain managers must carefully consider how AI integration can be done in a responsible manner.

As we progress deeper into this era of AI-driven supply chains, we must balance the use of AI for efficiency with maintaining transparency, fairness, and accountability. This requires continuous revisiting, refining, and reimagining our understanding and management of AI in SCM. As we forge ahead, we carry the agency over how AI can and will be integrated into supply chains. But such an integration demands a solid theoretical grounding upon which we can construct our understanding—a foundation that can help us shape the future of supply chain management in the AI era.

CONCLUSION

In this article, I have argued that AI integration in SCM is a potential revolution that challenges existing theories and practices. I have proposed the AI Integration Framework (AII) as a novel theoretical lens to understand how AI can be integrated into supply chains and the associated potential for disruptions. I have also highlighted the role of human sensemaking processes in shaping the interpretation and adoption of AI systems in SCM. I have suggested that SCM scholars and practitioners need to revisit their assumptions and frameworks to account for the agency and autonomy of AI systems, the interplay between technical and social aspects of AI integration, and the ethical and accountability issues that arise from delegating decision-making power to AI systems.

The AII framework is not meant to be a definitive or comprehensive model of AI integration in SCM, but rather a starting point for further exploration and dialogue. As AI systems evolve and become more capable, the AII must be updated and refined to capture new developments and applications. Moreover, the AII can be complemented by other theoretical perspectives that can offer deeper insights into specific aspects of AI integration, such as institutional theory, stakeholder theory, or resource-based view. Future research can also empirically test and validate the AII using a more complete AI-enabled toolbox of various theoretical and methodological approaches. This article will stimulate further research and debate on this important topic and inspire new ways of thinking about and managing supply chains in the AI era.

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FIGURE 1

AI Integration Framework for supply chains

	Partial Integration	Full Integration
Assistive Role	1. Human Sherlock, Robot Watson: AI provides insights for specific supply chain activities like inventory management, supporting human-led decision-making.	2. Robot Cartographer: AI provides end-to-end supply chain visibility and generates insights for decision-making, but strategic decisions are still made by humans.
Autonomous Role	3. Chess Grandmaster: AI takes charge of specific activities like supplier selection or inventory replenishment, but humans retain the final approval authority.	4. Artificial Ecosystem: AI takes charge of end-to-end supply chain management, from demand forecasting to delivery, with minimal human intervention.

TABLE 1

Sensemaking of AI and implications for SCM theories and supply chain dynamics

Sensemaking of AI	Impact on Theoretical Assumptions in SCM	Changes in Supply Chain Dynamics
AI as a Tool	AI is viewed as an instrument that enhances human capabilities. Theories in SCM would need to incorporate the idea of AI as a powerful extension of human decision-making, reducing transaction costs, and improving efficiency.	Leads to automation of routine tasks, reducing manual errors and increasing operational efficiency. It can also lead to job displacement due to automation.
AI as an Actor	AI is perceived as an autonomous entity capable of decision-making. Theories must grapple with the concept of AI as an active participant in SCM, challenging traditional definitions of an 'actor' in the supply chain.	AI takes over certain decision-making tasks, leading to significant changes in roles and responsibilities within the supply chain. It also presents potential challenges in accountability and control.
AI as a Partner	AI is seen as a collaborator, working alongside human actors. Theories need to consider the synergistic relationship between humans and AI, focusing on	Creates a human-AI collaboration in decision-making, leading to enhanced decision quality. However, it could also lead to overreliance on AI or

	collaborative decision-making and shared responsibilities.	issues with trust and acceptance among human workers.
AI as a Threat	AI is perceived as a potential risk, displacing human workers or introducing new vulnerabilities. Theories would need to factor in the potential downsides and risks associated with AI integration.	Could lead to job displacement, new vulnerabilities like AI system failures or cyber-attacks, and potential social and ethical issues.
AI as a Competitive Capability	AI is seen as a strategic asset that can provide competitive advantage. SCM theories would need to integrate the concept of AI as a source of differentiation and competitive edge.	Enhances the competitive positioning of the organization, driving innovation, and improving customer service. However, it could also lead to increased competition and the risk of falling behind if not adopted effectively.
AI as a Factor of Production	AI is considered as a new category of production factor, akin to labor or capital. Theories would need to re-evaluate traditional factors of production to include AI.	Changes the cost structure and efficiency of supply chain operations. It could also lead to new business models and value creation strategies.
AI as Relief	Theories must incorporate AI's role in alleviating mundane tasks and enabling strategic focus for humans.	AI handles routine tasks, increasing efficiency. This leads to shifts in human roles toward more strategic

		tasks, possibly introducing a skills gap.