A Theoretical Ecosystem Framework for Human-Centric AI in Multi-Tier Supply Chains: Aligning Incentives and Value Co-Creation

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Abstract: Modern supply chains, particularly multi-tier supply chains (MTSCs), increasingly grapple with mounting complexity, data fragmentation, and ethical challenges amid the rapid integration of Artificial Intelligence (AI). While AI offers transformative potential for coordination, forecasting, and decision support, conventional AI systems often suffer from opacity, algorithmic bias, and weak alignment with human and organizational values, constraining their real-world effectiveness in distributed and interdependent ecosystems. This paper is motivated by the need to bridge this dual gap, wherein AI's technical limitations amplify existing vulnerabilities within supply networks, and the structural heterogeneity of MTSCs further impedes responsible AI deployment.

The central problem addressed herein is the absence of explainability, ethical grounding, and stakeholder coordination in current AI implementations, which collectively undermine trust, transparency, and equitable outcomes across supply tiers. Addressing these challenges requires moving beyond siloed optimization toward systems that recognize the intertwined human, technological, and institutional dimensions of decision-making.

To this end, we propose a comprehensive ecosystem framework that fuses Human-Centric AI (HCAI) principles with the structural and operational realities of MTSCs. Our approach explicitly integrates mechanisms for incentive alignment, participatory governance, and value co-creation, ensuring that AI deployment serves collective rather than isolated interests. The framework articulates how responsible AI can be embedded into supply networks through multi-level design paradigms, encompassing data ethics protocols, human-in-the-loop decision architectures, and adaptive governance layers capable of managing evolving risks and ethical trade-offs. We further contribute a novel architecture that combines AI governance strategies with interdisciplinary collaboration models, bridging technological design, supply chain coordination, and ethical oversight. This architecture demonstrates how aligning stakeholder incentives and enabling participatory AI co-design can mitigate bias propagation, enhance algorithmic accountability, and foster stakeholder trust, key prerequisites for AI adoption in fragmented and globally distributed supply systems. Ultimately, embedding HCAI principles into MTSCs represents a socio-technical transformation, one that strengthens resilience, fairness, and sustainability while providing a blueprint for ecosystem-wide AI governance.

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1. Introduction

When we examine the current landscape of Artificial Intelligence (AI) adoption in supply chain management, we encounter a fascinating paradox that demands careful consideration. On one hand, AI presents unprecedented opportunities to transform how organizations manage their complex networks of suppliers, manufacturers, and distributors, offering capabilities that were simply unimaginable just a decade ago (Spera and Agrawal, 2025). The technology promises to automate routine decision-making processes, optimize inventory levels in real-time, predict demand fluctuations with remarkable accuracy, and enhance operational efficiency across multiple functional areas simultaneously (Spera and Agrawal, 2025). These advancements translate into tangible business benefits (Jayarathna et al., 2022), including dramatic improvements in productivity metrics, significantly faster response times to market changes, substantial reductions in operational costs, and the ability to scale operations to previously unattainable levels (Spera and Agrawal, 2025, Wasi et al., 2025b). However, as we delve deeper into the practical implications of these technological advances, we must acknowledge that the historical trajectory of AI development has been predominantly technology-driven, often prioritizing technical capabilities over human considerations (Xu et al., 2023). This approach has inadvertently created a host of challenges that supply chain professionals must now grapple with, including system vulnerabilities that can expose sensitive business data, algorithmic biases that may perpetuate unfair practices across different supplier tiers, and a troubling lack of transparency in how AI systems arrive at critical business decisions (Xu et al., 2023). Furthermore, many current AI implementations struggle with establishing clear causal relationships between inputs and outcomes, raising questions about their reliability in high-stakes supply chain scenarios (Xu et al., 2023, Wasi et al., 2025b,a). These limitations become particularly concerning when we consider issues related to system autonomy and the broader ethical implications of delegating critical supply chain decisions to algorithms (Xu et al., 2023). It is precisely these concerns that have catalyzed the emergence of Human-Centric AI (HCAI) as a more thoughtful and sustainable approach to technology integration (Xu et al., 2023). This design philosophy fundamentally shifts the focus from pure technological optimization to a more holistic consideration of human well-being, organizational values, and societal needs (Gil and Fu, 2022) throughout the entire AI lifecycle (Xu et al., 2023). The ultimate goal of HCAI is not merely to automate existing processes, but rather to create intelligent systems that genuinely augment human decision-making capabilities, enhance job satisfaction, and contribute to more equitable and sustainable supply chain practices (Xu et al., 2023). This approach requires organizations to carefully balance the pursuit of efficiency gains with the imperative to maintain meaningful human oversight and control over critical supply chain functions.

The implementation of AI within multi-tier supply chain (MTSC) environments presents a particularly complex set of challenges that extend far beyond the typical concerns associated with single-tier supplier relationships (Zeng et al., 2018). When we consider that modern MTSCs often encompass not just direct (Tier 1) suppliers, but also Tier 2, Tier 3, and sometimes even Tier 4 or 5 suppliers, the complexity grows exponentially with each additional layer of the network (Xu et al., 2023). This extended ecosystem creates significant difficulties in maintaining comprehensive end-to-end visibility, as information must flow seamlessly across multiple organizational boundaries, each with its systems (Karmaker et al., 2023), processes, and data quality standards (Xu et al., 2023). The challenge becomes even more pronounced when we recognize that effective collaboration requires not just data sharing, but also the establishment of common standards, protocols, and mutual understanding among dozens or even hundreds of distinct organizations (Xu et al., 2023). While AI technologies offer the potential to address some of these visibility and coordination challenges (Gil and Fu, 2022) through advanced analytics, predictive modeling, and automated risk assessment capabilities, they simultaneously introduce new layers of complexity that must be carefully managed (Log-hub, 2023). For instance, the implementation of AI-driven supply chain solutions requires unprecedented levels of data

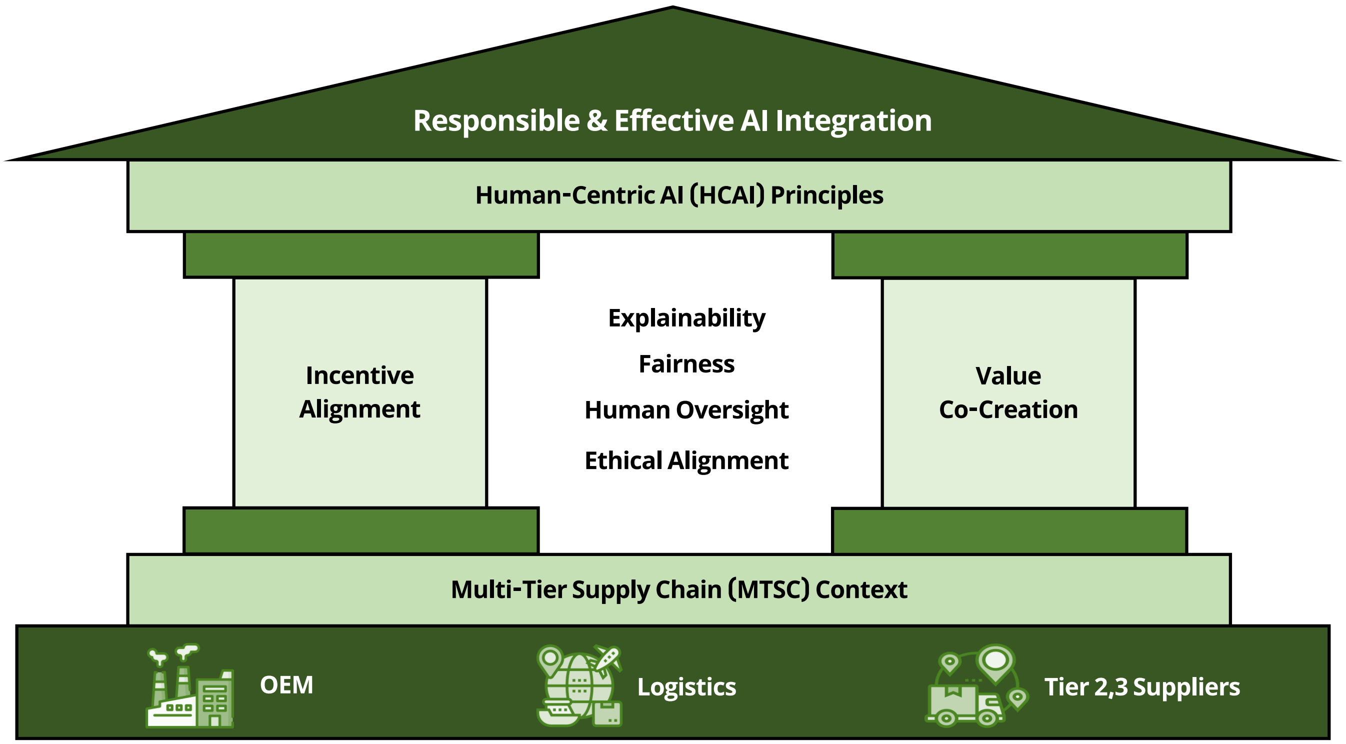

Figure 1: Proposed Comprehensive Ecosystem Framework

sharing among partners who may have historically guarded their operational information closely, raising concerns about competitive advantage, intellectual property protection, and data security (Log-hub, 2023). Building the necessary trust relationships to support such extensive data sharing becomes a critical success factor, yet it often conflicts with traditional competitive dynamics and established business practices. Moreover, the diverse range of stakeholders involved in MTSCs(Villar et al., 2023) (Helo and Hao, 2021) often have fundamentally different objectives, risk tolerances, and operational priorities, which can create tension when implementing standardized AI solutions across the entire network. This is where the concept of incentive alignment becomes absolutely crucial for sustainable AI adoption in supply chain environments (Liu et al., 2018). When incentives are misaligned among key players(Eriksson et al., 2025), such as raw material suppliersPan et al. (2025), component manufacturers, original equipment manufacturers, third-party logistics providers, and distributors, the resulting behavioral conflicts can severely undermine the effectiveness of even the most sophisticated AI implementations (Babai et al., 2022). These misalignments often manifest as reluctance to share critical data(Baldi et al., 2024), resistance to adopting new technologies, or optimization of individual organizational metrics at the expense of overall supply chain performance (Number Analytics, 2025b). Conversely, when organizations successfully foster a culture of value co-creation, where the benefits of AI implementation are designed to be mutually beneficial(Khedr and S, 2024) and fairly distributed across all ecosystem participants, the results can be transformative (Lee et al., 2024). This approach encourages collaborative problem-solving, shared investment in technology infrastructureVillar et al. (2023), joint development of AI capabilities, and collective optimization of supply chain performance metrics (Pan et al., 2025). The key lies in designing AI systems and implementation strategies that not only deliver technical capabilities(Eriksson et al., 2025) but also create win-win scenarios for all stakeholders(Jayarathna et al., 2022), ensuring that the long-term success of the AI initiative is supported by aligned economic incentives (Pan et al., 2025)and shared value creation opportunities across the entire multi-tier network.

To solve these issues, we introduce a novel ecosystem framework that bridges Human-Centric AI principles with multi-tier supply chain dynamics, establishing incentive alignment and value co-creation as core mechanisms for responsible AI deployment (Figure 1). Our framework specifically addresses the critical gap between AI technical limitations and supply chain operational challenges by treating them as interconnected rather than isolated problems. We demonstrate that AI limitations directly compound existing supply chain challenges (Dou et al., 2023). While AI systems suffer from bias(Khedr and S, 2024), lack of explainability(Karmaker et al., 2023), and ethical concerns (Xu et al., 2023), multi-tier supply chains simultaneously struggle with data quality issues(Helo and Hao, 2021), complexity, and visibility gaps (Xu et al., 2023, Wasi et al., 2025a). Our analysis reveals that AI's lack of explainability specifically amplifies visibility problems across supply tiers (Gaalman et al., 2022), creating cascading trust deficits that prevent effective human-AI collaboration and inter-tier integration (Dou et al., 2024). We identify how AI bias becomes systematically amplified through supply chain data characteristics, particularly in environments with sparse or deliberately corrupted data typical of certain supply network segments. This amplification creates propagating biased outcomes across multiple tiers, undermining both fairness and operational efficiency throughout the network. Our framework explicitly integrates HCAI principles (Hedenstierna et al., 2019)—particularly explainability and ethical alignment—with supply chain-specific operational challenges, providing targeted solutions rather than generic approaches (Liu et al., 2018). This integration enables true end-to-end HCAI adoption by addressing the unique interdependencies between AI technical requirements and the multi-tier operational realities of the supply chain.

2. Human-Centric AI (HCAI)

2.1. Defining HCAI: Philosophy, Principles, and Objectives

Human-Centric AI (HCAI) represents a fundamental shift in the approach to artificial intelligence, positioning humans at the core of every stage of an AI system's existence: its design(Davis, 1993), development, deployment, and ongoing use (Xu et al., 2023). This philosophy is driven by the overarching objective to maximize the beneficial impacts of AI while actively identifying and mitigating its potential negative consequences (Li et al., 2023). The aim is to ensure that AI systems serve to augment (Liu et al., 2024) and enhance human capabilities, improve overall well-being, and support human decision-making, rather than merely replacing human roles or causing harm (Xu et al., 2023). Key HCAI frameworks, such as Xu's "user-technology-ethics" model, underscore the necessity of integrating three critical perspectives: the technological capabilities of AI (Ma et al., 2022), the needs and experiences of the human user (emphasizing controllability, user-friendliness, and explainability), and robust ethical considerations (including human values, fairness, and privacy) (Xu et al., 2023). This systematic design approach fosters synergy and complementarity among these perspectives, leading to more responsible and effective AI.

2.2. Traditional AI and the Necessity of a Human-Centered Approach

Historically, the development and deployment of AI systems have often been characterized by a technology-centric bias, leading to a range of significant limitations. These include inherent vulnerabilities, the propagation of biases (often stemming from training data) (Mogale et al., 2023), a pervasive lack of explainability in complex models, the absence of robust causal models, challenges(Nardelli, 2023) related to autonomous decision-making (Ponte et al., 2016), and a host of ethical concerns (Xu et al., 2023). Evidence suggests that a substantial number of AI projects fail, frequently attributed to an insufficient focus(QIMAone, 2023) on crucial "human factors" such as poor user experience, a lack of system explainability and controllability (Rodrigues et al., 2021), unmet user needs, and the neglect of ethical considerations (Xu et al., 2023). These persistent challenges underscore the critical importance of adopting a human-centered approach to the design, development(Tse et al., 2022), and deployment of AI systems (Tse et al., 2022). By prioritizing human values, needs, knowledge, and roles throughout the AI lifecycle(Islam and Wasi, 2023), HCAI directly addresses the shortcomings of traditional, purely technical AI methods, fostering the creation of AI that is not only powerful but also trustworthy and beneficial (Xu et al., 2023).

3. Human-Centered AI Methodological Framework

To bridge the conceptual foundation of HCAI with its practical implementation, the Human-Centered AI Methodological Framework (HCAI-MF) (Davis, 1993)has been proposed as a comprehensive and structured methodology (Xu et al., 2023). This framework comprises five interconnected componentsTse et al. (2025), each designed to support and facilitate the effective practice of HCAI across the entire AI system lifecycle.

3.1. HCAI Requirement Hierarchy (HCAI-RH)

The HCAI Requirement Hierarchy (HCAI-RH) is designed to address the challenges associated with gathering and operationalizing HCAI requirements, which often remain abstract in existing guidelines (Xu et al., 2023). It organizes HCAI guiding principles(Jayarathna et al., 2022), design guidelines, and specific product requirements into a clear hierarchical relationship (Tse et al., 2025). At its apex are the broad HCAI Design Goals, which set the overarching objectives for AI systems, such as enhancing human capabilities and performance (Wang et al., 2018). These goals are supported by HCAI Guiding Principles, which are high-level, strategic rules intended to guide design practices across industries (Wang et al., 2018). Examples include Transparency and Explainability, Human Control and Empowerment (Xu et al., 2025), Ethical Alignment, User Experience, Human Augmentation & Collaboration with AI, Safety & Robustness, Accountability, and Sustainability (Xu et al., 2023). These principles then translate into HCAI Design Guidelines, which are more tactical, domain-specific rules outlining high-level requirements. Finally, at the most granular level are Product Detail Requirements, which are specific, measurable, and actionable functional and non-functional requirements that ensure the AI system adheres to the defined HCAI principles and guidelines. This structure ensures that human values and ethical considerations are systematically embedded from the very inception of AI development (Xu et al., 2023).

3.2. HCAI Approach and Method Taxonomy (HCAI-AMT)

The HCAI Approach and Method Taxonomy (HCAI-AMT) provides a catalog of actionable and effective methods to support HCAI practice, specifically addressing the difficulties non-AI professionals (Ponte et al., 2016) often face in engaging with HCAI activities (Xu et al., 2023). It categorizes HCAI approaches and methods into five key areas: human-centered strategy, computing & modeling, interaction technology and design(Liu et al., 2018), controllabilityLi et al. (2023), and governance (Xu et al., 2025). This taxonomy highlights how these approaches prioritize crucial human factors such as human needs, values, abilities, roles, and controllability, ensuring alignment with the overarching HCAI guiding principles (Zeng et al., 2023). Specific methodologies within HCAI-AMT include human value alignment (Zeng et al., 2023), human-centered machine learning, human-centered explainable AI (Zeng et al., 2018), machine behavior management, ethical AI standards and governance, algorithm governance, and data governance (Zeng et al., 2018). Each of these methods contributes to creating AI systems that are understandable, usable (Zhou et al., 2023), fair, and ethically aligned with human expectations (Xu et al., 2023).

3.3. HCAI Process

The HCAI Process component defines a comprehensive, structured series of activities that guide HCAI practice throughout the entire AI system development lifecycle (Xu et al., 2023). It achieves this by integrating the established Human-Centered Design (HCD) process with a generalized AI-based system development lifecycle. Key features of this process include a continuous human-centered focus, iterative improvement loops (Gaalman et al., 2022), an emphasis on ethical development, and the promotion of interdisciplinary collaboration. This ensures that human-centered principles are consistently applied at every stage (Babai et al., 2022), from initial data collection and preparation to model training, fine-tuning (Wang et al., 2018), deployment, and ongoing evaluation (Wang et al., 2018). For instance, in the context of large language models (LLMs) (Tse et al., 2022), the HCAI process specifically recommends prioritizing inclusive and fair data, implementing human oversight for harmful content removal (Tse et al., 2025), addressing privacy issues upfront, and conducting iterative testing with user-centered metrics that explicitly include fairness (Xu et al., 2023).

3.4. HCAI Interdisciplinary Collaboration Approach

Recognizing that effective HCAI practice necessitates diverse expertise, the HCAI Interdisciplinary Collaboration (Dou et al., 2023) Approach addresses the challenges of miscommunication and misaligned goals by fostering coordinated efforts across multiple disciplines (Xu et al., 2023). This approach emphasizes establishing shared goals (Rodrigues et al., 2021) among all involved parties, building truly interdisciplinary teams (Lee et al., 2024) that include experts from AI, human-centered design, ethics, and relevant domain knowledge (Liu et al., 2018). It promotes co-designing the AI system, adopting integrated HCAI processes and methods, defining clear decision-making frameworks, encouraging open and continuous communication (Ma et al., 2022), and measuring success holistically across technical, human, and ethical dimensions (Xu et al., 2023). This collaborative ethos is vital for overcoming the fragmentation often seen in complex AI projects.

3.5. HCAI Multi-Level Design Paradigms (HCAI-MDP)

The HCAI Multi-Level Design Paradigms (HCAI-MDP) extend the scope of HCAI practice beyond individual human-AI systems to encompass broader ecosystems and complex sociotechnical systems (Xu et al., 2023). This component introduces three progressive paradigms:

- **Human-AI Joint Cognitive Systems:**This paradigm views humans and AI as collaborative cognitive agents, focusing on their direct interactions, shared situation awareness, and the establishment of human-led collaboration in task accomplishment (Xu et al., 2023).
- **Human-AI Joint Cognitive Ecosystems:**This expands the focus to broader intelligent ecosystems, such as smart cities or healthcare networks. It considers the intricate interactions among multiple humans, various AI systems, and even AI-to-AI system communications, emphasizing systematic design thinking and distributed collaboration across the entire ecosystem (Xu et al., 2023).
- **Intelligent Sociotechnical Systems (iSTS):** This most comprehensive paradigm places AI systems within their broader sociotechnical context, integrating technical factors with non-technical elements such as society, culture, ethics, and organizational structures. The goal is joint optimization, ensuring that AI systems are aligned with human-centered principles and effectively address complex challenges like ethical AI within a holistic framework (Xu et al., 2023).

The HCAI-MF serves as a blueprint for building trust and ensuring the scalability of AI systems. The framework's core objective, as highlighted by its components, is to mitigate negative impacts and develop AI that genuinely serves human needs, directly addressing limitations like bias and explainability (Xu et al., 2023). The uncertainty surrounding AI risks is a significant barrier to widespread enterprise adoption (Tomei et al., 2025). The structured components of HCAI-MF, the Requirement Hierarchy, Approach & Method Taxonomy, Process, Collaboration, and Multi-Level Paradigms, collectively contribute to building trustworthy AI. Trust, which is cultivated through transparency, fairness, and human control, is a fundamental prerequisite for broad adoption, particularly in complex enterprise environments. By offering a comprehensive methodology, HCAI-MF aims to reduce the perceived "uncertainty around AI risks," thereby acting as a critical enabler for the scalability and adoption of AI solutions beyond mere technical performance metrics. This implies that HCAI-MF is not simply a design philosophy but a strategic framework for de-risking AI investments and fostering organizational confidence, which is essential for scaling AI solutions across diverse business units and external partners.

4. Dynamics of Multi-Tier Supply Chain Ecosystems

Characteristics and Structural Complexity of Multi-Tier Supply Chains (Tier 1, Tier 2, Tier 3+). A multi-tier supply chain (MTSC) represents a complex, multi-layered network that extends far beyond a company's immediate, direct suppliers (Tier 1). It encompasses their suppliers (Tier 2), and further upstream to the suppliers of those suppliers (Tier 3 and beyond), ultimately involving raw material providers, component manufacturers, sub-assemblers, and various logistics partners (Xu et al., 2023). This intricate, multi-layered structure inherently introduces significant complexity in terms of management, coordination, and the flow of information across numerous independent entities. Each tier operates with its own processes, systems, and objectives, contributing to a highly diversified and often opaque network.

Key Challenges: Visibility, Data Quality, Complexity, Supplier Collaboration, Risk Management. MTSCs face a myriad of critical challenges that can impede efficiency and resilience. A primary concern is maintaining end-to-end visibility across all tiers, as information often becomes fragmented or lost as it moves upstream or downstream (Xu et al., 2023). This lack of transparency makes it difficult to track products, identify bottlenecks, or monitor compliance effectively. Another significant hurdle is ensuring data quality and integration from disparate sources across the network. Data can be inconsistent, incomplete, or even intentionally corrupted, particularly in the context of illicit activities, making reliable analysis extremely difficult (Log-hub, 2023). The sheer complexity and enormous scale of operations within MTSCs further complicate management and optimization efforts, requiring advanced tools and skilled personnel (Xu et al., 2023). Moreover, fostering effective collaboration and building trust among numerous independent and sometimes competitive entities is a persistent challenge, often hampered by misaligned incentives and differing priorities (Xu et al., 2023). Finally, proactively mitigating risks, ranging from geopolitical events and natural disasters to supplier failures and ethical breaches, from various points in such an extended and interconnected chain demands sophisticated risk assessment and contingency planning (Log-hub, 2023).

Concept of a Supply Chain as an Interconnected Ecosystem. Moving beyond the traditional linear "chain" metaphor, a multi-tier supply chain is more accurately conceptualized as an intricate ecosystem. Within this ecosystem, various actors, including suppliers, manufacturers, logistics providers, customers, financial institutions, and even research bodies, interact dynamically, integrate resources, and collectively co-create value (Xu et al., 2023). This ecosystem is frequently oriented towards value co-creation, driven by customer demand, and increasingly supported by digital capabilities and robust data sharing. It relies on these digital enablers to conduct value-creating activities, establish strategic partnerships, and implement effective ecosystem governance, all with the overarching goal of achieving sustained health and sustainable development (Pan et al., 2025).

The inherent data challenges and lack of visibility within MTSCs do not merely complicate AI integration; they actively amplify the risks associated with AI. For example, if AI models are trained on biased or corrupted data originating from a Tier 3 supplier, a common issue in MTSCs due to poor visibility and data quality, the resulting AI bias can propagate throughout the entire supply chain. This means that decisions made by AI at every subsequent tier, from procurement and inventory management to logistics and customer interaction, could be tainted by these initial biases. This creates a systemic risk that is far greater and more pervasive than what might be observed in a single-company AI deployment. Therefore, implementing HCAI in MTSCs is not solely about mitigating AI risks; it is fundamentally about preventing the multiplication and systemic spread of those risks due to the complex, often opaque, and sometimes intentionally obfuscated nature of multi-tier data flows. This necessitates the development and implementation of robust data governance and auditability mechanisms that are designed to span across organizational boundaries and multiple tiers of the supply chain.

5. Aligning Incentives for Responsible AI Adoption

The Importance of Incentive Alignment in Multi-Stakeholder Supply Chains. In multi-stakeholder supply chains, where numerous independent entities collaborate to achieve a common objective, the alignment of incentives is paramount. It is the process of designing and implementing motivational structures that encourage diverse supply chain partners to work synergistically towards shared goals, rather than pursuing individual interests that may be conflicting or detrimental to the collective (Xu et al., 2023). When incentives are effectively aligned, partners are significantly more inclined to share critical information, engage in joint decision-making, and contribute actively to the overall efficiency, resilience, and success of the entire supply chain network (Number Analytics, 2025b). This collaborative environment is essential for navigating the complexities inherent in multi-tier structures.

Challenges of Misaligned Incentives and Their Impact on AI Adoption. Misaligned incentives arise when the goals and objectives of different supply chain partners are not congruent, leading to behaviors that can inadvertently undermine collective aims (Number Analytics, 2025a). A classic example is a manufacturer incentivizing a supplier solely on high production volume, which might inadvertently lead the supplier to compromise on quality or sustainability standards. Similarly, a logistics provider incentivized purely on cost reduction might neglect delivery times or service quality (Number Analytics, 2025a). Such misalignments create substantial barriers to the successful adoption of AI solutions within MTSCs. Partners may exhibit resistance to sharing sensitive data, adopting new AI technologies, or participating in collaborative AI initiatives if they perceive no direct benefit to their own interests, or worse, if they anticipate a disadvantage. Moreover, the inherent uncertainty surrounding AI risks is a significant barrier to widespread enterprise adoption across the economy (Tomei et al., 2025). This uncertainty can be exacerbated by misaligned incentives, as partners may be unwilling to bear the perceived risks of AI integration without clear, shared benefits.

5.1. Mechanisms for Incentive Alignment in AI Governance

To effectively address these challenges and foster responsible AI development and adoption, a range of mechanisms can be strategically deployed to align incentives across the multi-tier supply chain:

5.1.1. Market Governance Mechanisms

Market governance mechanisms are processes designed to structure economic behavior by directly aligning financial incentives with desired outcomes (Tomei et al., 2025). These mechanisms leverage capital flows to embed their own enforcement and incentive structures, providing a powerful alternative or complement to traditional regulatory approaches. Key market mechanisms include:

- **Insurance:**AI-specific insurance products can mitigate AI-related risks by pricing and transferring them, thereby incentivizing safer development practices and responsible deployment across the supply chain (Tomei et al., 2025). This provides a financial safety net that encourages adoption.
- **Auditing:** Independent auditing of AI systems provides objective verification of their performance, compliance with ethical guidelines, and adherence to HCAI principles. This builds trust among partners and enhances accountability, making AI integration more palatable (Tomei et al., 2025).
- **Due Diligence:** Thorough investigation of AI risks and capabilities before entering into partnerships or making significant investments drives responsible development. Companies performing due diligence on their AI-driven suppliers will naturally favor those demonstrating HCAI adherence (Tomei et al., 2025).
- **Procurement:** Organizations can leverage their procurement power to demand that AI solutions acquired from suppliers adhere to specific HCAI principles and responsible governance standards. This creates a market demand for human-centric AI (Tomei et al., 2025).

5.1.2. AI Disclosures for Risk Communication

The standardization of AI disclosures plays a crucial role in simplifying complex AI risk areas, making them comprehensible and accessible to a broad spectrum of market participants who may lack specialized AI expertise (Tomei et al., 2025). By adopting a common framework for papering AI-related risks, informed decision-making is facilitated across critical activities such as investment, insurance, and procurement. The absence of uniform metrics currently introduces significant challenges for stakeholders in assessing the financial and operational implications of AI risks, leading to inefficiencies in capital allocation (Tomei et al., 2025). A standardized risk framework provides consistent and comprehensible metrics for communicating complex AI risks to non-specialists within the market, even if it cannot capture every intricacy. This common language for risk is essential for fostering trust and encouraging adoption across the diverse entities in a multi-tier supply chain (Tomei et al., 2025).

5.1.3. Collaborative Planning, Forecasting, and Contractual Incentives

Implementing collaborative planning, forecasting, and replenishment (CPFR) systems is a proven strategy to enable supply chain partners to share information and coordinate their activities effectively (Number Analytics, 2025b). Beyond information sharing, designing effective contracts with explicit incentive structures is critical. These can include financial incentives such as bonuses for meeting HCAI-aligned performance metrics (e.g., low bias rates, high explainability scores), discounts for early adoption of HCAI-certified AI tools, or penalties for non-compliance with ethical AI standards (Number Analytics, 2025b). Non-financial incentives, such as public recognition or awards for ethical AI practices, can also foster a culture of responsibility. Clear, measurable performance metrics tied to HCAI principles ensure that all partners are rewarded for behaviors that benefit the entire supply chain, promoting shared success and reducing conflicts of interest. These incentive structures must be regularly reviewed and adjusted to remain effective and aligned with evolving supply chain objectives (Number Analytics, 2025b).

Financial de-risking acts as a human-centric incentive for AI adoption. The uncertainty surrounding AI risks is explicitly identified as a major barrier to widespread enterprise adoption (Tomei et al., 2025). Market governance mechanisms, including insurance, auditing, due diligence, and procurement, are proposed as means to decrease AI risk by pricing, measuring, and mitigating the financial exposure incurred during AI deployment and development (Tomei et al., 2025). While these mechanisms appear purely financial, their impact on adoption is profoundly human-centric. By reducing financial uncertainty and risk, they directly address a fundamental human (and organizational) aversion to loss and unpredictability (Zhang et al., 2025). This de-risking transforms the perception of AI from a high-risk, uncertain venture into a more manageable, insurable, and auditable asset. This shift creates a powerful incentive for human decision-makers within enterprises to invest in and adopt AI, even when the direct benefits might not be immediately quantifiable. Therefore, effective HCAI implementation in MTSCs must extend beyond technical design and ethical guidelines; it must integrate robust financial and market governance mechanisms that align incentives by mitigating perceived risks for all stakeholders, thereby fostering trust and accelerating adoption throughout the complex network.

6. Fostering Value Co-Creation in AI-Driven Supply Chains

Defining Value Co-Creation as an Interactive and Innovative Process. Value co-creation is an innovative and highly interactive process where value is not solely produced by a single entity but is jointly created through the collaborative efforts of both supply and demand sides within an ecosystem (Pan et al., 2025). This process involves individuals, groups, and organizations actively connecting, collaborating, solving shared problems, and collectively satisfying diverse and heterogeneous needs and expectations. It signifies a fundamental shift from a traditional, linear value delivery model to one where all ecosystem members actively participate in and enhance resource integration, leading to mutually beneficial outcomes (Pan et al., 2025).

Role of Digital Capabilities and Data Sharing as Catalysts for Co-Creation. Digital capabilities and robust data sharing are indispensable catalysts for facilitating and accelerating value co-creation within supply chain innovation ecosystems (Pan et al., 2025). These digital enablers allow for enhanced resource integration, streamline complex interactions, and facilitate the formation of strategic partnerships across the network. They are foundational for establishing effective ecosystem governance and ultimately promoting the healthy and sustainable development of the entire supply chain. Technologies such as cloud-based platforms, advanced analytics tools, Internet of Things (IoT) devices for real-time monitoring, and blockchain technology for secure and transparent data sharing are instrumental in supporting this enhanced information exchange and coordination, thereby enabling deeper co-creative processes (Number Analytics, 2025b).

6.1. Strategies for Fostering Co-Created Value in Innovation Networks

Effective management of innovation through value co-creation relies heavily on the sustained engagement of all individual stakeholders over time. This can be achieved through several key strategies:

6.1.1. Adaptable Structures and Routines

Adopting flexible structures and mutually agreed-upon routines is crucial for uncovering the diverse needs, expectations, and backgrounds of different stakeholders within the innovation network (Nardelli, 2023). This adaptability reduces complexity in inter-organizational relationships, as various parties learn to interact more effectively over time. By utilizing participatory and open-ended innovation activities and support

Table 1: Incentive Mechanisms for HCAI Adoption in Multi-Tier Supply Chains

Incentive Type	Mechanism/ Description	Application in MTSC for HCAI	HCAI Principle Supported
Financial	Performance Bonuses/Discounts	Rewarding suppliers for high-quality, unbiased data; Discounts for HCAI-certified tools	Bias Mitigation, Data Quality, Adoption
	Risk-Sharing Agreements	Jointly bearing costs of AI-induced disruptions if HCAI principles followed	Accountability, Safety, Trust
Non-Financial	Reputation Enhancement/Awards	Public recognition for partners demonstrating exemplary ethical AI practices or HCAI adherence.	Ethical Alignment, Transparency, Trust
	Access to AI Tools/Resources	Providing partners with access to advanced HCAI tools or training programs.	Human Augmentation, Collaboration
Contractual	Data Sharing Agreements	Clauses requiring transparent and ethical data sharing for AI development and deployment across tiers.	Transparency, Data Governance, Fairness
	HCAI Compliance Clauses	Mandating adherence to HCAI principles (e.g., explainability, human oversight) in all AI-driven operations	Human Control, Explainability, Ethical Alignment
Market-Based Governance	AI Risk Insurance	Insuring against financial losses from AI-induced supply chain disruptions (e.g., due to algorithmic errors or biases	Risk Mitigation, Accountability
	AI Auditing Requirements	Mandating independent audits of AI systems used by partners to verify HCAI compliance.	Transparency, Accountability, Trust
	Ethical Procurement Policies	Prioritizing suppliers who develop and deploy AI systems aligned with HCAI principles.	Ethical Alignment, Responsible AI

routines, the network can maintain structural flexibility, allowing it to easily adapt to changing circumstances and evolving requirements. This ensures that the co-creation environment remains responsive and inclusive.

6.1.2. Facilitated Interactions and Trust-Building

Organizing regular opportunities for stakeholders to meet, share knowledge, and cooperate is essential for building and sustaining inter-organizational trust (Nardelli, 2023). These facilitated interactions foster mutual commitment, promote common goals, encourage open dialogue, and highlight shared interests. While the primary aim of these activities is value co-creation, the recurrent interactions also lay the groundwork for trust, which is vital for overcoming potential downsides such as information asymmetry, power imbalances, or opportunistic behavior. Openness and transparency in addressing these challenges further support fruitful interactions and strengthen collaborative bonds (Nardelli, 2023).

6.1.3. Participant Self-Empowerment

Empowering participants to retain their agency is a critical aspect of value co-creation. This involves enabling users to experiment, engage in trial-and-error, and build their own workflows, thereby fostering a sense of self-actualization (Nardelli, 2023). This approach shifts the focus from merely delivering a pre-defined outcome (which AI alone may struggle to guarantee given diverse user expectations) to a process-orientation. By providing users with easy-to-assemble tools and AI that understands and improves their workflows, AI acts as an enabler for human agency, allowing users to integrate AI as a powerful tool within their own processes, leading to more meaningful and personalized value creation (Narechania et al., 2025).

6.2. How AI Can Act as an Active Collaborator in Co-Creation, Focusing on Agency and Control Mechanisms

Artificial Intelligence is increasingly transcending its role as a mere auxiliary tool to become an active collaborator and teammate in co-creation processes (Gao et al., 2025). As AI agents assume more autonomous roles, understanding the distribution and dynamics of agency, how control manifests in practice, becomes paramount for effective human-AI collaboration (HAC) (Spera and Agrawal, 2025). HCAI strongly emphasizes human leadership in this collaborative paradigm, necessitating innovative research perspectives and paradigms to address the unique challenges of HAC (Gao et al., 2025). This involves designing interfaces that effectively support supervisory control and situational awareness for human operators, ensuring that information is presented clearly, contextually, and hierarchically (Spera and Agrawal, 2025). Such interface design enables humans to detect anomalies, understand AI system states, and make informed decisions, thereby guiding autonomous AI agents effectively and ensuring that human judgment, empathy, and ethical supervision remain integral in high-stakes or ambiguous scenarios (Spera and Agrawal, 2025). HCAI serves as the fundamental philosophy for sustainable, ecosystem-wide value co-creation. Value co-creation is defined as a collaborative, interactive process involving multiple stakeholders and the integration of diverse resources (Pan et al., 2025). HCAI, in turn, prioritizes human needs, values, and control, aiming to augment human capabilities (Xu et al., 2023). Human-AI co-creation and the importance of human agency are central to this (Gao et al., 2025). The inherent connection is that HCAI is not merely a technical design choice; it is the enabling philosophy for sustainable value co-creation in AI-driven supply chains. By ensuring that AI systems are understandable, controllable, ethical, and genuinely augment human capabilities, HCAI builds the essential trust and empowers the human agency required for diverse supply chain actors to willingly engage in co-creation. Without a human-centric approach, AI might optimize narrow metrics but fail to foster the broad, interactive collaboration and shared problem-solving that defines true value co-creation across an ecosystem. If humans feel replaced or disempowered by AI, as the limitations of technology-centric AI suggest (Xu et al., 2023), they will naturally be reluctant to participate in co-creative processes. Therefore, value co-creation in AI-driven MTSCs is a direct outcome of successful HCAI implementation, signifying a shift from AI simply delivering value to AI facilitating value creation among human stakeholders, leading to more resilient, adaptable, and mutually beneficial supply chain ecosystems.

Table 2: Value Co-Creation Strategies for Human-Centric AI in Multi-Tier Supply Chains

Co-Creation Strategy	Description	Application in MTSC for HCAI	Expected Outcome/Benefit
Adaptable Structures	Flexible governance models and routines that accommodate diverse stakeholder needs.	Dynamic data-sharing protocols across tiers, allowing partners to customize data access based on HCAI principles (e.g., privacy, relevance).	Enhanced agility, reduced complexity, improved trust
Facilitated Interactions	Organized opportunities for stakeholders to meet, share knowledge, and cooperate.	Regular cross-tier HCAI design sprints and workshops involving suppliers, OEMs, logistics, and AI developers to co-design AI features.	Increased trust, shared understanding, collaborative problem-solving
Participant Self-Empowerment	Enabling users to retain agency, experiment, and build their own workflows with AI.	AI tools that allow supply chain managers to customize optimization algorithms or simulation parameters based on their expertise and specific needs.	Improved decision-making, user satisfaction, human capabilities
AI as Active Collaborator	AI systems acting as teammates, supporting human judgment and decision-making.	AI agents assisting human planners in real-time with scenario analysis, risk prediction, and anomaly detection, providing explainable rationales.	Synergistic problem-solving, increased efficiency, enhanced accountability

7. Integrated Ecosystem Framework for Human-Centric AI in Multi-Tier Supply Chains

Our proposed framework represents a holistic and integrated conceptual model that merges the robust principles of the Human-Centered AI Methodological Framework (HCAI-MF) with the inherent characteristics and complex dynamics of multi-tier supply chains. This framework explicitly positions incentive alignment and value co-creation as dynamic, interconnected forces that are fundamental to driving the successful, responsible, and sustainable integration of AI. It views the multi-tier supply chain not merely as a linear sequence of transactions, but as a complex sociotechnical ecosystem where human-AI collaboration must be meticulously orchestrated to achieve optimal outcomes.

7.1. Inter-connected Components

Our integrated framework comprises several inter-connected components, each drawing from the HCAI-MF and tailored to the unique context of multi-tier supply chains:

7.1.1. Human-Centric AI Design & Development within MTSC

Applying the HCAI-MF's core components to the multi-tier supply chain ensures that human values, needs, and roles are prioritized at every stage and across every tier.

- The **HCAI Requirement Hierarchy (HCAI-RH)** dictates that HCAI principles, such as fairness, transparency, and human control, must be defined and adhered to at every level of the supply chain, from the sourcing of raw materials (Tier 3) to the final product delivery to the end-consumer (Xu et al., 2023). This systematic embedding of ethical and human-centric considerations from the outset prevents the propagation of biases or the generation of harms upstream or downstream within the complex network.
- The **HCAI Approach & Method Taxonomy (HCAI-AMT)** provides specific methodologies for developing AI that directly addresses MTSC challenges. For instance, human-centered machine learning techniques can be applied to predictive analytics for forecasting supply chain disruptions, ensuring that these models not only provide accurate predictions but also offer sufficient explainability for human operators across different tiers to understand and trust their outputs (Xu et al., 2023). Crucially, the data governance methods within HCAI-AMT are vital for managing the quality, security, and ethical use of the vast amounts of data flowing through the multi-tier network, mitigating risks of bias and misuse (Xu et al., 2023).
- The **HCAI Process** guides the iterative development and deployment of AI solutions, ensuring that continuous human feedback loops and rigorous ethical evaluations are integrated throughout the entire multi-tier lifecycle. This means that human oversight and input are incorporated from the initial data collection (e.g., at a Tier 3 supplier) through model training and fine-tuning, to the final system use by logistics personnel or procurement managers (Xu et al., 2023).

7.1.2. Interdisciplinary Collaboration Across Tiers

Leveraging the HCAI-MF's emphasis on interdisciplinary collaboration, this component focuses on fostering coordinated efforts among the diverse stakeholders that constitute a multi-tier supply chain. This includes direct suppliers, OEMs, logistics providers, AI developers, and crucially, end-users who interact with the final product or service (Xu et al., 2023). The framework necessitates establishing shared goals for HCAI adoption across the entire ecosystem, building interdisciplinary teams that transcend organizational boundaries (e.g., bringing together IT, procurement, legal, ethics, and external supplier representatives), and collaboratively designing AI systems that serve the collective needs of the ecosystem. Effective communication strategies and clearly defined decision-making frameworks are paramount to overcome the inherent challenges of differing terminologies, organizational cultures, and perspectives that are common in complex, multi-tiered supply chains (Xu et al., 2023).

7.1.3. Multi-Level Design Paradigms for Ecosystem-Wide Impact

Extending the HCAI-MF's multi-level design paradigms is critical for addressing the systemic nature of multi-tier supply chains.

- The **Human-AI Joint Cognitive Systems** paradigm applies to individual human-AI interactions occurring within a specific tier, such as a human planner utilizing an AI forecasting tool to optimize inventory within their own organization (Xu et al., 2023, Islam and Wasi, 2023).
- The **Human-AI Joint Cognitive Ecosystems** paradigm is particularly relevant for MTSCs, as it shifts the focus to the complex interactions among multiple humans, various AI systems, and even AI-to-AI system

communications across different tiers. An example would be an OEM's AI system interacting with a Tier 1 supplier's AI system for demand forecasting, with human oversight maintained at both ends (Xu et al., 2023). This paradigm emphasizes systematic design thinking and distributed collaboration across the entire MTSC, ensuring that AI systems integrate seamlessly and ethically across organizational boundaries.
- The **Intelligent Sociotechnical Systems (iSTS)** paradigm is paramount for considering AI systems within the broader societal, cultural, ethical, and organizational context of the entire multi-tier supply chain. This holistic view ensures the joint optimization of both technical and non-technical factors, enabling the framework to address complex challenges such as ethical sourcing, fair labor practices, and environmental sustainability throughout the extended supply network (Xu et al., 2023).

The HCAI-MF's multi-level paradigms provide the conceptual scaffolding necessary for AI to truly scale within complex MTSCs while remaining human-centric. Without moving beyond individual human-AI interactions to considering the entire supply chain as a "Joint Cognitive Ecosystem" and an "Intelligent Sociotechnical System," AI solutions risk becoming siloed. This siloed approach can create new points of friction or bias at inter-tier interfaces, undermining the overall efficiency and ethical integrity of the supply chain. The iSTS paradigm, in particular, compels a comprehensive consideration of the broader societal and ethical impacts across the entire supply chain, which is crucial for the sustainable and responsible scaling of AI. Therefore, the HCAI-MDP components are critical enablers for robust, ethical, and scalable AI integration across all tiers, ensuring that AI's pervasive influence is managed in a human-centric manner.

7.1.4. Incentive Alignment as an Enabler

This component underscores that aligned incentives are not merely a desired outcome but a fundamental driver for the successful adoption and responsible deployment of HCAI across the multi-tier ecosystem (Number Analytics, 2025b). By strategically implementing market governance mechanisms such as AI risk insurance, independent auditing, and ethical procurement policies, the framework actively reduces perceived AI risks and fosters trust among supply chain partners, directly addressing major adoption barriers (Tomei et al., 2025). Furthermore, transparent contractual agreements and shared performance metrics ensure that all tiers of the supply chain benefit from HCAI initiatives and are motivated to comply with the established HCAI principles, fostering a shared commitment to responsible AI (Number Analytics, 2025b).

7.1.5. Value Co-Creation as an Outcome and Driver

Value co-creation processes are both a desired outcome of successful HCAI implementation and a continuous driver for its refinement and expansion within the multi-tier supply chain (Pan et al., 2025). By fostering adaptable structures, facilitating continuous interactions, and promoting participant self-empowerment, the framework encourages all supply chain actors to actively contribute to and benefit from AI integration. This iterative co-creation of value, where AI acts as an active collaborator rather than a replacement, reinforces HCAI principles by ensuring that AI solutions continuously evolve to meet the dynamic human needs and ethical standards across the complex ecosystem (Gao et al., 2025). This symbiotic relationship ensures that AI solutions remain relevant, beneficial, and ethically aligned in the long term.

Table 3: Integrated Ecosystem Framework: HCAI-MF Components in Multi-Tier Supply Chains

HCAI-MF Component	**Specific Manifestation/Consideration in MTSC**	**Contribution to Incentive Alignment**	**Contribution to Value Co-Creation**
HCAI Requirement Hierarchy	Tier-specific HCAI principles and ethical guidelines for AI development and use (e.g., data privacy standards for Tier 2 suppliers, explainability for OEM logistics AI)	Establishes clear, shared ethical standards and performance expectations for all partners; reduces risk of non-compliance	Provides a common language and framework for co-designing AI features that meet diverse stakeholder needs and values
HCAI Approach & Method Taxonomy	Implementation of data governance across tiers to ensure unbiased, high-quality data; human-centered ML for predictive analytics in complex supply networks	Enables shared metrics for responsible AI performance (e.g., bias reduction targets); facilitates joint risk mitigation through transparent methods	Fosters collaborative problem-solving by providing actionable methods for human-AI interaction and ethical design across the ecosystem
HCAI Process	Cross-organizational HCAI lifecycle management, integrating human feedback loops from all tiers (e.g., supplier input on AI-driven forecasting)	Supports joint risk assessments and continuous improvement, aligning incentives around shared quality and ethical goals	Promotes iterative, collaborative development, ensuring AI solutions evolve to meet the collective needs and preferences of all partners
HCAI Interdisciplinary Collaboration Approach	Formation of joint HCAI teams involving representatives from OEMs, Tier 1/2/3 suppliers, logistics, and AI developers	Builds trust through shared goals and transparent communication; helps overcome misaligned interests by fostering mutual understanding	Enables co-creation of AI solutions that address the unique challenges and opportunities at each tier, leveraging diverse expertise
HCAI Multi-Level Design Paradigms	Viewing the entire MTSC as an Intelligent Sociotechnical System (iSTS) where human, AI, and organizational factors are jointly optimized	Ensures systemic alignment of incentives across the entire ecosystem, addressing ethical and societal impacts beyond individual transactions	Drives synergistic ecosystem development, where AI facilitates collaboration and resource integration across all levels for collective benefit

8. Addressing Adoption Barriers and Bias Propagation within the Framework

8.1. How Our integrated framework Systematically Addresses HCAI Adoption Barriers

The proposed integrated framework directly addresses the multifaceted challenges that impede the widespread adoption of Human-Centric AI, drawing heavily on the HCAI-MF's structured approach. A primary barrier to HCAI adoption has been the lack of a comprehensive, executable methodology to bridge the gap between its philosophical underpinnings and practical implementation (Xu et al., 2023). This framework provides precisely that, offering actionable guidance, structured processes, and adaptable design paradigms that simplify the implementation of HCAI across the complex multi-tier supply chain. Its inherent flexibility allows for customization to the specific needs of different tiers and projects, ensuring its ongoing relevance as HCAI practices evolve (Xu et al., 2023). Furthermore, the framework's emphasis on **Interdisciplinary Collaboration** is crucial for overcoming resistance to adoption. By providing clear strategies for effective cross-disciplinary teamwork, it addresses situations where non-AI professionals or external supply chain partners may lack sufficient AI knowledge, or vice versa (Xu et al., 2023). This fosters shared understanding, builds confidence, and reduces the friction that often arises from disparate knowledge bases. Most significantly, the explicit integration of **Incentive Alignment** (as detailed in Aligning Incentives for Responsible AI Adoption Section) directly tackles the "uncertainty around AI risks" which is a major impediment to enterprise adoption (Tomei et al., 2025). By incorporating market governance mechanisms and contractual incentives, the framework actively de-risks AI investments for all stakeholders. This structured approach to risk mitigation encourages buy-in from diverse partners across the supply chain, transforming perceived liabilities into shared opportunities and thereby accelerating adoption.

8.2. Mechanisms within the Framework to Mitigate Bias Propagation

Our integrated framework systematically embeds mechanisms for bias mitigation throughout its components, ensuring that ethical considerations are not an afterthought but an integral part of AI development and deployment:

- **HCAI Requirement Hierarchy (HCAI-RH):** From the very outset, HCAI-RH emphasizes defining human values and ethical alignment, which inherently includes ensuring fairness in data collection and proactively mitigating bias during model development (Xu et al., 2023). This top-down approach ensures that bias prevention is a foundational requirement.
- **HCAI Approach and Method Taxonomy (HCAI-AMT):** This component provides a rich set of specific methodologies dedicated to addressing bias. Categories such as "Human Value Alignment with AI," "Human-Centered Machine Learning," "Human-Centered Explainable AI," "Machine Behavior Management," "Ethical AI Standards and Governance," "Algorithm Governance," and "Data Governance" all contribute to this effort (Xu et al., 2023). These methods focus on critical practices like diverse data collection, ensuring transparency and interpretability of AI decisions, implementing human feedback loops, conducting regular ethics audits, and establishing clear guidelines for bias mitigation across the AI lifecycle.
- **HCAI Process:** The iterative nature of the HCAI Process encourages ethical development at every stage. Specifically, it recommends prioritizing inclusive and fair data practices, implementing robust human oversight for identifying and removing harmful content, and addressing privacy issues proactively during data collection and preparation (Xu et al., 2023). It also emphasizes the use of human feedback and ethical evaluations during model training and fine-tuning, along with iterative testing that incorporates user-centered metrics for fairness (Xu et al., 2023).

- **Intelligent Sociotechnical Systems (iSTS) Paradigm:** This paradigm highlights the profound impact of non-technical factors, such as societal norms, cultural contexts, and ethical considerations, on AI systems (Xu et al., 2023). By considering the broader sociotechnical context of the multi-tier supply chain, the iSTS paradigm ensures that AI systems are aligned with human-centered principles, actively addressing challenges like ethical AI development and redesigning work systems to prioritize fairness and equity.

8.3. Specific Considerations for Bias and Adoption in Multi-Tier Supply Chain Contexts

The unique characteristics of multi-tier supply chains introduce specific challenges related to bias and adoption that the framework must address:

- **Data Sparsity and Quality:** Multi-tier supply chains often suffer from sparse, incomplete, or even intentionally corrupted data, particularly in the context of illicit activities (Log-hub, 2023). This inherent data challenge significantly exacerbates the risk of AI bias, as models trained on such compromised data will inevitably perpetuate and amplify existing inequities or inaccuracies. The framework's strong emphasis on data governance and human oversight (through HCAI-AMT and the HCAI Process) becomes absolutely paramount in this environment.
- **Complexity and Lack of Visibility:** The sheer complexity and pervasive lack of end-to-end visibility across MTSCs make it exceedingly difficult to track data provenance and precisely identify where biases might be introduced, amplified, or propagated (Log-hub, 2023). The HCAI framework's focus on explainability and transparency (embedded within HCAI-RH and HCAI-AMT) is therefore crucial for shedding light on these opaque areas, enabling stakeholders to understand AI's decision-making processes and pinpoint sources of bias.
- **Trust and Collaboration:** Adoption barriers in MTSCs are frequently rooted in a fundamental lack of trust among partners, a reluctance to share sensitive data, or a fear of losing competitive advantage (QIMAone, 2023). Our integrated framework directly addresses this by explicitly integrating incentive alignment and value co-creation. These components are designed to build trust by demonstrating mutual benefits and fostering a collaborative environment, thereby encouraging the necessary data sharing and collective adoption of human-centric AI solutions.

A critical feedback loop exists between bias propagation and adoption barriers in MTSCs. While the HCAI-MF details mechanisms to address bias 3, and AI risk uncertainty is known to be an adoption barrier 12, the specific data issues in supply chains, such as sparse or corrupted data, and the inherent lack of trust and collaboration among MTSC partners create a compounding effect (Log-hub, 2023). If AI systems deployed in one tier, for instance, for supplier selection or logistics optimization, are perceived as biased or unfair by other tiers, it directly erodes trust, significantly increases the perception of risk, and generates strong resistance to further AI integration or data sharing. For example, if an AI system unfairly penalizes a Tier 2 supplier due to biased historical data, that supplier will be considerably less likely to collaborate on future initiatives or adopt new AI-driven processes proposed by the OEM. This creates a significant, systemic adoption barrier that ripples across the entire ecosystem. Consequently, addressing bias in MTSCs is not merely an ethical imperative; it is a strategic necessity for achieving widespread and sustainable AI adoption. Our integrated framework must proactively break this detrimental feedback loop by designing and implementing transparent, auditable, and fair AI systems that actively foster trust and demonstrate equitable value distribution across all tiers of the supply chain.

9. Challenges and Recommendations for Implementation

9.1. Challenges in Implementing the Proposed Integrated Framework

Implementing a comprehensive Human-Centric AI ecosystem framework within the intricate context of multi-tier supply chains presents significant hurdles, many of which mirror the general challenges faced by the HCAI-MF in broader applications (Xu et al., 2023).

- **Data Quality and Integration Across Tiers:** Ensuring consistent, high-quality, and unbiased data across the disparate systems and independent organizations within a multi-tier structure is immensely complex. This challenge is exacerbated by the potential for data sparsity, incompleteness, or even intentional obfuscation, particularly in sensitive or illicit supply chain activities (Xu et al., 2023). Achieving a unified, trustworthy data foundation is foundational but exceptionally difficult.
- **Managing Complexity and Scale:** The sheer number of actors, processes, and data points involved in multi-tier supply chains makes holistic framework implementation and ongoing oversight a daunting task. This necessitates not only advanced analytics tools but also a highly skilled workforce capable of interpreting and acting on the generated insights across organizational boundaries (Xu et al., 2023).
- **Fostering Supplier Collaboration and Trust:** Building and sustaining trust, along with establishing robust data-sharing agreements among competitive or independent entities across multiple tiers, is inherently difficult. This challenge is frequently hampered by pre-existing misaligned incentives and differing organizational priorities, which can lead to reluctance in sharing critical information or adopting common AI standards (Xu et al., 2023).
- **Adapting Regulatory Approaches:** Existing regulatory frameworks often struggle to keep pace with the rapid evolution and pervasive influence of AI, particularly within the dynamic and interconnected nature of multi-tier ecosystems. This necessitates the development of new, flexible, and adaptive regulatory approaches that can effectively govern AI while fostering innovation (Tomei et al., 2025).
- **Organizational Change and Skill Gaps:** Internal resistance to organizational change, a widespread lack of HCAI-specific expertise, and significant resource constraints (including time, budget, and skilled personnel) within individual organizations and across the broader ecosystem can severely impede the successful adoption and scaling of the framework (Xu et al., 2023).

9.2. Recommendations for Stakeholders

To facilitate the successful adoption and implementation of this integrated framework, a concerted effort from all key stakeholders is essential:

- **Policymakers:** Should proactively leverage market mechanisms, such as AI risk insurance, independent auditing requirements, and the standardization of AI disclosures, to create powerful incentives for responsible AI development and to de-risk AI investments (Tomei et al., 2025). This approach fosters a competitive market for safe and ethical AI solutions. Furthermore, policymakers should actively support public-private collaborations and champion the development of dynamic regulatory approaches that can adapt effectively to AI's pervasive influence and rapid advancements (Tomei et al., 2025).
- **Enterprises (OEMs, Tier 1s):** Must commit to significant investments in advanced analytics and HCAI-specific tools. It is crucial for them to foster strong, trust-based relationships with their suppliers across all tiers, ensure robust data governance mechanisms are in place throughout the multi-tier network, and actively develop a skilled workforce capable of implementing and overseeing HCAI principles (Xu et al., 2023). These enterprises should lead by example in adopting HCAI-MF components and

championing incentive alignment through transparent contracts and clearly defined shared goals with their partners (Number Analytics, 2025b).

- **AI Developers:** Should prioritize HCAI principles from the initial design phase, focusing on building AI systems that are inherently explainable, mitigate bias, allow for meaningful human control, and provide an intuitive user experience (Xu et al., 2023). They must actively engage in interdisciplinary collaboration, seeking to deeply understand the unique operational contexts and ethical considerations prevalent in multi-tier supply chains. Additionally, AI developers should contribute to the standardization of AI disclosures, promoting transparency and accountability across the industry (Xu et al., 2023).

9.3. Future Research Directions

The complexity and dynamism of AI integration into multi-tier supply chains open several promising avenues for future research:

- **Developing Standardized Metrics and Tools:** Future research should focus on creating standardized metrics and practical tools for quantifying HCAI compliance and its tangible impact across complex multi-tier supply chains. This would enable objective measurement of progress and effectiveness.
- **Exploring Novel Incentive Mechanisms:** There is a need to investigate novel contractual and market-based mechanisms specifically designed to align incentives for ethical AI data sharing and collaborative HCAI development among diverse, often competing, supply chain partners.
- **Investigating Long-Term Societal and Economic Impacts:** Comprehensive studies are required to understand the long-term societal and economic impacts of HCAI adoption in complex global supply chains, particularly concerning issues such as labor displacement, economic equity, and environmental sustainability.
- **Researching Adaptive Governance Models:** Future efforts should concentrate on developing adaptive governance models that can dynamically respond to the evolving risks and opportunities presented by AI in highly interconnected and often opaque multi-tier environments.

The combination of rapidly evolving AI capabilities and the inherent dynamism and complexity of multi-tier supply chains necessitates a fundamental shift from static regulatory frameworks to "adaptive governance." The primary challenge for AI governance is developing dynamic regulatory approaches that can adapt to AI's pervasive influence 12, while multi-tier supply chains are characterized by inherent complexity and dynamic structures (Log-hub, 2023). This implies that governance mechanisms, encompassing both market-based approaches and traditional regulations, must be sufficiently flexible to evolve alongside technological advancements and changes in supply chain structures. Imposing rigid rules risks them becoming quickly obsolete or even anti-competitive. This adaptive approach is crucial for simultaneously encouraging innovation and effectively mitigating emerging risks in a human-centric manner. Therefore, future research and policy efforts should prioritize the creation of agile governance models that can continuously learn and adjust, ensuring that HCAI principles remain relevant and effective as AI permeates deeper into the complex, interconnected layers of global supply chains.

10. Conclusion

Proper integration of Artificial Intelligence into multi-tier supply chains holds immense promise for enhancing efficiency and driving innovation. However, realizing this potential responsibly and sustainably necessitates a profound commitment to Human-Centric AI (HCAI). This paper has articulated a comprehensive ecosystem framework that strategically integrates the Human-Centered AI Methodological Framework (HCAI-MF) with the unique characteristics of multi-tier supply chains, critically leveraging incentive alignment and value co-creation as foundational pillars. The analysis demonstrates that the inherent limitations of AI, such as bias and lack of explainability, are significantly amplified within the complex, often opaque, and data-challenged environment of multi-tier supply chains. This amplification creates a critical feedback loop where bias propagation directly exacerbates adoption barriers, eroding trust and hindering collaboration across the ecosystem. The proposed framework directly confronts these challenges by embedding HCAI principles throughout the design, development, and deployment of AI systems across all tiers. By systematically applying the HCAI Requirement Hierarchy, Approach and Method Taxonomy, Process, Interdisciplinary Collaboration Approach, and Multi-Level Design Paradigms, the framework ensures that AI solutions are not only technically proficient but also ethically aligned, transparent, controllable, and truly augment human capabilities.

Furthermore, the framework highlights that effective incentive alignment, through mechanisms such as market governance and standardized AI disclosures, is not merely a beneficial outcome but a fundamental enabler for responsible AI adoption. By de-risking AI investments and fostering a shared understanding of AI's benefits and risks, incentives motivate diverse supply chain partners to embrace human-centric approaches. Concurrently, fostering value co-creation, through adaptable structures, facilitated interactions, and participant self-empowerment, transforms AI from a mere tool into an active collaborator, ensuring that AI solutions are continuously refined to meet evolving human needs and ethical standards across the entire ecosystem. This symbiotic relationship between HCAI, incentive alignment, and value co-creation is crucial for building resilient, adaptable, and mutually beneficial supply chain networks. Successful implementation of this integrated framework demands a concerted, collaborative effort from all stakeholders, policymakers, enterprises, and AI developers alike. It requires a shared commitment to human well-centricity, a willingness to invest in robust data governance and inter-organizational collaboration, and an embrace of adaptive governance models that can evolve with technological advancements. By prioritizing human values and needs at every stage, Human-Centric AI has the profound potential to transform multi-tier supply chains into more resilient, equitable, and human-empowering systems, ultimately driving sustainable value for all participants.

Conflict of Interest

The authors declare that there are no conflicts of interest regarding the publication of this paper. All research procedures followed ethical guidelines, and the study was conducted with integrity and transparency. The authors have no financial, personal, or other relationships that could inappropriately influence or bias the content of this work.

Data, Code and Materials Availability

The data, code, and materials supporting the findings of this study are available from the corresponding author on reasonable request.

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During the preparation of this work, the author(s) utilized AI-based tools to assist with grammar correction and to improve writing clarity only. Following the use of these tools, the authors thoroughly reviewed and manually edited the content as necessary and accept full responsibility for the final version of the manuscript.

Author Contributions

ATW conceptualized the study, designed the theoretical framework, developed the methodology, conducted all analyses, created the visualizations, wrote the initial manuscript draft, and provided overall supervision and leadership throughout the project. RNP and MAK contributed to the literature review, background research, and co-wrote portions of the manuscript. AR supported the development of visual representations of the framework and contributed to manuscript writing and refinement. MSI provided guidance and was actively involved in reviewing and editing the manuscript. All authors critically reviewed, edited, and approved the final version of the manuscript.

References

M. Zied Babai, Yong Dai, Qinyun Li, Aris Syntetos, and Xun Wang. Forecasting of lead-time demand variance: Implications for safety stock calculations. *European Journal of Operational Research*, 296(3):846–861, February 2022. ISSN 0377-2217. doi: 10.1016/j.ejor.2021.04.017. URL http://dx.doi.org/10.1016/j.ejor.2021.04.017.

Benedetta Baldi, Ilenia Confente, Ivan Russo, and Barbara Gaudenzi. Consumer-centric supply chain management: A literature review, framework, and research agenda. *Journal of Business Logistics*, 45(4), October 2024. ISSN 2158-1592. doi: 10.1111/jbl.12399. URL http://dx.doi.org/10.1111/jbl.12399.

Tom Davis. Effective supply chain management. *MIT Sloan Management Review*, 34(4):35–46, 1993. URL https://blogt.ethz.ch/ETHambassadors/files/2018/06/Davis-Effective-SCM.pdf.

Runliang Dou, Yanchao Hou, Kuo-Yi Lin, Shubin Si, and Yixin Wei. Transforming digital value chain ecosystems for dual-carbon target: An exploration of the bds-ras framework. 2023. doi: 10.2139/ssrn.4611885. URL http://dx.doi.org/10.2139/ssrn.4611885.

Runliang Dou, Xin Liu, Yanchao Hou, and Yixin Wei. Mitigating closed-loop supply chain risk through assessment of production cost, disruption cost, and reliability. *International Journal of Production Economics*, 270:109174, April 2024. ISSN 0925-5273. doi: 10.1016/j.ijpe.2024.109174. URL http://dx.doi.org/10.1016/j.ijpe.2024.109174.

David Eriksson, Per Hilletofth, Wendy Tate, and Kim Hua Tan. Value creation across organizational borders: Towards a value gap theory. *European Business Review*, 37(1), 2025. doi: 10.1108/EBR-02-2024-0086. URL https://www.emerald.com/insight/content/doi/10.1108/EBR-02-2024-0086/full/html.

Gerard Gaalman, Stephen M. Disney, and Xun Wang. When bullwhip increases in the lead time: An eigenvalue analysis of arma demand. *International Journal of Production Economics*, 250:108623, August 2022. ISSN 0925-5273. doi: 10.1016/j.ijpe.2022.108623. URL http://dx.doi.org/10.1016/j.ijpe.2022.108623.

Qi Gao, Wei Xu, Hanxi Pan, Mowei Shen, and Zaifeng Gao. Human-centered human-ai collaboration (hchac). *arXiv preprint arXiv:2505.22477*, 2025. URL https://arxiv.org/abs/2505.22477. Accessed: 2025-07-15.

Nuno Gil and Yongcheng Fu. Megaproject performance, value creation, and value distribution: An organizational governance perspective. *Academy of Management Discoveries*, 8(2):224–251, June 2022. ISSN 2168-1007. doi: 10.5465/amd.2020.0029. URL http://dx.doi.org/10.5465/amd.2020.0029.

Carl Philip T. Hedenstierna, Stephen M. Disney, Daniel R. Eyers, Jan Holmström, Aris A. Syntetos, and Xun Wang. Economies of collaboration in build-to-model operations. *Journal of Operations Management*, 65(8): 753–773, April 2019. ISSN 1873-1317. doi: 10.1002/joom.1014. URL http://dx.doi.org/10.1002/joom.1014.

Petri Helo and Yuqiuge Hao. Artificial intelligence in operations management and supply chain management: an exploratory case study. *Production Planning and Control*, 33(16):1573–1590, April 2021. ISSN 1366-5871. doi: 10.1080/09537287.2021.1882690. URL http://dx.doi.org/10.1080/09537287.2021.1882690.

MD Shafikul Islam and Azmine Toushik Wasi. Optimizing inventory routing: A decision-focused learning approach using neural networks, 2023. URL https://arxiv.org/abs/2311.00983.

Chamari Pamoshika Jayarathna, Duzgun Agdas, and Les Dawes. Exploring sustainable logistics practices toward a circular economy: A value creation perspective. *Business Strategy and the Environment*, 32(1): 704–720, June 2022. ISSN 1099-0836. doi: 10.1002/bse.3170. URL http://dx.doi.org/10.1002/bse.3170.

Chitra Lekha Karmaker, Ridwan Al Aziz, Tazim Ahmed, S.M. Misbauddin, and Md. Abdul Moktadir. Impact of industry 4.0 technologies on sustainable supply chain performance: The mediating role of green supply chain management practices and circular economy. *Journal of Cleaner Production*, 419:138249, September 2023. ISSN 0959-6526. doi: 10.1016/j.jclepro.2023.138249. URL http://dx.doi.org/10.1016/j.jclepro.2023.138249.

Ahmed M. Khedr and Sheeja Rani S. Enhancing supply chain management with deep learning and machine learning techniques: A review. *Journal of Open Innovation: Technology, Market, and Complexity*, 10(4): 100379, December 2024. ISSN 2199-8531. doi: 10.1016/j.joitmc.2024.100379. URL http://dx.doi.org/10.1016/j.joitmc.2024.100379.

Carmen Kar Hang Lee, Ying Kei Tse, Eric Ka Ho Leung, and Yichuan Wang. Causal recipes of customer loyalty in a sharing economy: Integrating social media analytics and fsqca. *Journal of Business Research*, 181:114747, August 2024. ISSN 0148-2963. doi: 10.1016/j.jbusres.2024.114747. URL http://dx.doi.org/10.1016/j.jbusres.2024.114747.

Beibin Li, Konstantina Mellou, Bo Zhang, Jeevan Pathuri, and Ishai Menache. Large language models for supply chain optimization. *arXiv preprint arXiv:2307.03875*, 2023. doi: 10.48550/arXiv.2307.03875. URL https://arxiv.org/abs/2307.03875.

Jing Liu, Yacheng An, Runliang Dou, and Haipeng Ji. Dynamic deep learning algorithm based on incremental compensation for fault diagnosis model. *International Journal of Computational Intelligence Systems*, 11(1): 846, 2018. ISSN 1875-6883. doi: 10.2991/ijcis.11.1.64. URL http://dx.doi.org/10.2991/ijcis.11.1.64.

Xueyuan Liu, Ying Kei Tse, Yan Yu, Haoliang Huang, and Xiande Zhao. Managing quality risk in supply chain to drive firm's quality performance: the mediating role of supply chain quality integration. *Industrial Management & Data Systems*, 125(2):797–821, December 2024. ISSN 1758-5783. doi: 10.1108/imds-03-2024-0241. URL http://dx.doi.org/10.1108/IMDS-03-2024-0241.

Log-hub. Multi-tier supply chain analytics & optimization, 2023. URL https://log-hub.com/multi-tier-supply-chain-analytics-and-optimization/. Accessed: 2025-07-15.

Jie Ma, Ying Kei Tse, Minhao Zhang, and Jill MacBryde. Quality risk and responsive actions in sourcing/procurement: an empirical study of food fraud cases in the uk. *Production Planning & Control*, 35(4):323–334, May 2022. ISSN 1366-5871. doi: 10.1080/09537287.2022.2080125. URL http://dx.doi.org/10.1080/09537287.2022.2080125.

D. G. Mogale, Xun Wang, Emrah Demir, and Vasco Sanchez Rodrigues. Modelling and analysing supply chain disruption: a case of online grocery retailer. *Operations Management Research*, 16(4):1901–1924, August 2023. ISSN 1936-9743. doi: 10.1007/s12063-023-00405-9. URL http://dx.doi.org/10.1007/s12063-023-00405-9.

Giulia Nardelli. How value co-creation can boost your innovation process, 2023. URL https://www.hypeinnovation.com/blog/how-value-co-creation-boost-your-innovation-process. Accessed: 2025-07-15.

Arpit Narechania, Alex Endert, and Atanu R Sinha. Agentic enterprise: Ai-centric user to user-centric ai, 2025. URL https://arxiv.org/abs/2506.22893. Accessed: 2025-07-15.

Number Analytics. Maximizing supply chain performance through incentive alignment, 2025a. URL https://www.numberanalytics.com/blog/maximizing-supply-chain-performance-incentive-alignment. Accessed: 2025-07-15.

Number Analytics. Ultimate guide to supply chain incentive alignment, 2025b. URL https://www.numberanalytics.com/blog/ultimate-guide-supply-chain-incentive-alignment. Accessed: 2025-07-15.

Qiaohong Pan, Liandong Zhou, Qifeng Wang, and Justin Z. Zhang. The impact mechanism of value co-creation on manufacturing supply chain innovation ecosystems. *Enterprise Information Systems*, July 2025. ISSN 1751-7583. doi: 10.1080/17517575.2025.2524695. URL http://dx.doi.org/10.1080/17517575.2025.2524695.

Borja Ponte, Xun Wang, David de la Fuente, and Stephen M. Disney. Exploring nonlinear supply chains: the dynamics of capacity constraints. *International Journal of Production Research*, 55(14):4053–4067, October 2016. ISSN 1366-588X. doi: 10.1080/00207543.2016.1245884. URL http://dx.doi.org/10.1080/00207543.2016.1245884.

QIMAone. Multi-tier supply chain visibility: Benefits & challenges, 2023. URL https://www.qimaone.com/resource-hub/sc-visibility-series-multi. Accessed: 2025-07-15.

Vasco Sanchez Rodrigues, Emrah Demir, Xun Wang, and Joseph Sarkis. Measurement, mitigation and prevention of food waste in supply chains: An online shopping perspective. *Industrial Marketing Management*, 93:545–562, February 2021. ISSN 0019-8501. doi: 10.1016/j.indmarman.2020.09.020. URL http://dx.doi.org/10.1016/j.indmarman.2020.09.020.

Cosimo Spera and Garima Agrawal. Reversing the paradigm: Building ai-first systems with human guidance. *arXiv preprint*, 2025. doi: 10.48550/arXiv.2506.12245. URL https://doi.org/10.48550/arXiv.2506.12245.

Philip Moreira Tomei, Rupal Jain, and Matija Franklin. Ai governance through markets, 2025. URL https://arxiv.org/abs/2501.17755. Accessed: 2025-07-15.

Ying Kei Tse, Shiyun Wang, Xiaohong Liu, and Chun Ho Wu. Untangling operational performance implication of ambidextrous blockchain initiatives: an empirical investigation of chinese manufacturers. *Industrial Management & Data Systems*, 123(2):556–577, December 2022. ISSN 0263-5577. doi: 10.1108/imds-05-2022-0298. URL http://dx.doi.org/10.1108/IMDS-05-2022-0298.

Ying Kei Tse, Shuqi Dong, and Wenjuan Zeng. *Supply chain quality risk management*. Elsevier, 2025. ISBN 9780443157851. doi: 10.1016/b978-0-443-28993-4.00183-9. URL http://dx.doi.org/10.1016/B978-0-443-28993-4.00183-9.

Alice Villar, Stefania Paladini, and Oliver Buckley. Towards supply chain 5.0: Redesigning supply chains as resilient, sustainable, and human-centric systems in a post-pandemic world. *Operations Research Forum*, 4(3), July 2023. ISSN 2662-2556. doi: 10.1007/s43069-023-00234-3. URL http://dx.doi.org/10.1007/s43069-023-00234-3.

Junwei Wang, Runliang Dou, R.R. Muddada, and Wenjun Zhang. Management of a holistic supply chain network for proactive resilience: Theory and case study. *Computers & Industrial Engineering*, 125:668–677, November 2018. ISSN 0360-8352. doi: 10.1016/j.cie.2017.12.021. URL http://dx.doi.org/10.1016/j.cie.2017.12.021.

Azmine Toushik Wasi, MD Shafikul Islam, and Adipto Raihan Akib. Supplygraph: A benchmark dataset for supply chain planning using graph neural networks, 2025a. URL https://arxiv.org/abs/2401.15299.

Azmine Toushik Wasi, MD Shafikul Islam, Adipto Raihan Akib, and Mahathir Mohammad Bappy. Graph neural networks in supply chain analytics and optimization: Concepts, perspectives, dataset and benchmarks, 2025b. URL https://arxiv.org/abs/2411.08550.

Mao Xu, Ying Kei Tse, Ruoqi Geng, Zhenyuan Liu, and Andrew Potter. Greenwashing and market value of firms: An empirical study. *International Journal of Production Economics*, 284:109606, June 2025. ISSN 0925-5273. doi: 10.1016/j.ijpe.2025.109606. URL http://dx.doi.org/10.1016/j.ijpe.2025.109606.

Wei Xu, Zaifeng Gao, and Marvin Dainoff. An hcai methodological framework (hcai-mf): Putting it into action to enable human-centered ai. *arXiv preprint arXiv:2311.16027*, 2023. doi: 10.48550/arXiv.2311.16027. URL https://arxiv.org/abs/2311.16027.

Wenjuan Zeng, Mike YK Tse, and Minmin Tang. Supply chain quality management: An investigation in the chinese construction industry. *International Journal of Engineering Business Management*, 10, January 2018. ISSN 1847-9790. doi: 10.1177/1847979018810619. URL http://dx.doi.org/10.1177/1847979018810619.

Wenjuan Zeng, Ying Kei Tse, and Robert Mason. Guanxi and information sharing in supply chain quality management: a multi-method investigation. *Production Planning & Control*, 35(16):2349–2369, November 2023. ISSN 1366-5871. doi: 10.1080/09537287.2023.2270473. URL http://dx.doi.org/10.1080/09537287.2023.2270473.

Shuning Zhang, Hui Wang, and Xin Yi. Exploring collaboration patterns and strategies in human-ai co-creation through the lens of agency: A scoping review of the top-tier hci literature. *arXiv preprint arXiv:2507.06000*, 2025. URL https://arxiv.org/abs/2507.06000. Accessed: 2025-07-15.

Yuxuan Zhou, Xun Wang, Jonathan Gosling, and Mohamed M. Naim. The system dynamics of engineer-to-order construction projects: Past, present, and future. *Journal of Construction Engineering and Management*, 149(5), May 2023. ISSN 1943-7862. doi: 10.1061/jcemd4.coeng-12926. URL http://dx.doi.org/10.1061/JCEMD4.COENG-12926.