Assessing the Operational Limits and Decision-Making Accuracy of Agentic AI and Autonomous Multi-Agent Systems in Reconfiguring Modular Pharmaceutical Supply Chains under Sudden Geopolitical Trade Shocks

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ABSTRACT

Geopolitical trade shocks increasingly expose vulnerabilities in globally interconnected supply chains, creating a need for rapid and reliable reconfiguration of sourcing, production, and logistics networks. Agentic artificial intelligence (AI) and autonomous multi-agent systems offer the potential to detect disruptions, evaluate alternatives, coordinate distributed decisions, and initiate operational responses. However, autonomous action does not necessarily produce an accurate or appropriate decision, particularly when information is incomplete, operating conditions change rapidly, and regulatory constraints limit the available alternatives. These challenges are especially consequential in pharmaceutical supply chains, where supplier qualification, product quality, traceability, and patient safety must be maintained during disruption. This conceptual paper aims to develop an integrated framework for explaining the conditions under which Agentic AI and autonomous multi-agent systems can make accurate reconfiguration decisions in modular pharmaceutical supply chains exposed to sudden geopolitical trade shocks. Drawing on literature concerning geopolitical risk, supply-chain reconfiguration, autonomous multi-agent systems, AI accuracy, and modularity, the paper conceptualises decision-making accuracy as the principal outcome and identifies information quality, modular reconfiguration capability, multi-agent coordination, operational limitations, and human oversight as central explanatory constructs. The proposed framework distinguishes prediction accuracy from decision-making accuracy and argues that autonomous decision quality depends on both technical capability and compliance with operational and regulatory requirements. The paper develops research questions, objectives, propositions, and a conceptual methodology to guide future simulation-based and empirical research.

Keywords: Agentic AI; autonomous multi-agent systems; decision-making accuracy; geopolitical trade shocks; modular supply chains; pharmaceutical supply chains; human oversight.

INTRODUCTION

Global supply chains operate within an increasingly uncertain geopolitical environment. Armed conflicts, trade restrictions, economic sanctions, tariff increases, export controls, and disruptions to strategic maritime routes can change the availability, cost, and movement of goods across international markets. Such events can disrupt established supplier relationships, delay shipments, restrict access to critical materials, and expose firms to vulnerabilities arising from geographic concentration and interdependence. Empirical evidence indicates that geopolitical risk can weaken global supply-chain resilience through mechanisms including reduced trade credit and increased inventory costs (Chang et al., 2025). A review by Bednarski et al. (2025) similarly demonstrates the importance of examining how geopolitical disruptions influence supply-chain configuration, material flows, and management strategies. More recently, Liu et al. (2026) identified supply-chain reconfiguration, adaptive risk management, and diversification as important emerging themes in the literature on geopolitical risk.

The consequences of geopolitical disruption are also visible in maritime transportation. Bolat (2025), for example, examined the effects of attacks affecting Red Sea shipping routes using a framework that assessed changes around the Bab el-Mandeb Strait, the Suez Canal, and the Cape of Good Hope. Such events illustrate how a disruption at a strategic chokepoint can force organisations to reconsider transportation routes, transit times, and logistics arrangements. These conditions create a practical need for supply-chain systems that can identify emerging disruptions and evaluate feasible alternatives before operational consequences become severe.

Supply-chain reconfiguration provides one response to this challenge. It involves modifying existing network arrangements, such as substituting suppliers, reallocating production capacity, changing distribution routes, or adjusting the relationships among supply-chain participants. Modular supply-chain architectures may facilitate these changes by enabling components of a network to be recombined without redesigning the entire system. However, reconfiguration is not simply a matter of identifying an available alternative. Decisions must consider the compatibility of network components, the availability and reliability of information, coordination among stakeholders, and the consequences of changing established arrangements.

Recent developments in Agentic AI and autonomous multi-agent systems introduce new possibilities for managing this complexity. A multi-agent system consists of multiple interacting agents that perform specialised tasks and coordinate towards individual or shared objectives. When integrated with contemporary foundation models, such systems may support more flexible interaction, reasoning, and decision making across supply-chain activities. Xu et al. (2024), for example, identify opportunities for combining foundation models and multi-agent systems to support autonomous supply chains, while highlighting implementation challenges and the black-box nature of these technologies. Giannakis and Louis (2016) demonstrate how a multi-agent architecture incorporating big-data analytics can support autonomous corrective actions and supply-chain agility.

Nevertheless, the ability to act autonomously should not be equated with the ability to make accurate decisions. An AI system might correctly predict that a supplier will become unavailable but still select an unsuitable alternative because of inadequate information, incompatible production capabilities, or regulatory restrictions. Zhang et al. (2020) highlight the importance of accuracy and transferability in autonomous systems, while Buçinca et al. (2020) demonstrate why AI-assisted decision making should be evaluated through actual decision performance rather than relying solely on proxy tasks or subjective perceptions of trust.

These distinctions are especially important in pharmaceutical supply chains. Decisions involving active pharmaceutical ingredients, manufacturing facilities, product formulation, packaging, and temperature-sensitive distribution must account for product quality, traceability, supplier qualification, and applicable regulatory requirements. A seemingly efficient reconfiguration may be inappropriate if an alternative supplier or facility is not qualified for the relevant product or if a proposed logistics arrangement cannot maintain the required handling conditions. Consequently, the accuracy of autonomous decisions must be assessed in relation to both operational objectives and non-negotiable constraints.

Although research has examined geopolitical disruption, supply-chain resilience, modularity, and AI-enabled supply-chain management, the literature considered in this paper suggests that these areas remain insufficiently integrated. In particular, a clear conceptual explanation is needed of how geopolitical shock characteristics, modular reconfiguration capability, information quality, multi-agent coordination, operational limitations, and human oversight jointly influence the accuracy of autonomous reconfiguration decisions in pharmaceutical supply chains.

Accordingly, this paper proposes an integrated conceptual framework for assessing the operational limits and decision-making accuracy of Agentic AI and autonomous multi-agent systems under sudden geopolitical trade shocks. The paper contributes by shifting attention from whether autonomous systems can act quickly towards the more consequential question of whether they can select feasible, appropriate, and compliant actions under uncertainty.

LITERATURE REVIEW AND THEORETICAL FOUNDATIONS

Geopolitical trade shocks and supply-chain reconfiguration

Geopolitical trade shocks are external events or policy changes that disrupt the conditions under which international supply networks operate. They include armed conflicts, sanctions, tariffs, export restrictions, and interruptions at critical transport chokepoints. Such shocks can affect the availability of inputs, supplier reliability, trade finance, transportation costs, and the feasibility of established sourcing arrangements.

Chang et al. (2025) provide empirical evidence that geopolitical risk undermines supply-chain resilience, with trade credit and inventory costs acting as important channels. Bednarski et al. (2025) review the effects of geopolitical disruptions on global supply chains, while Liu et al. (2026) identify reconfiguration and diversification as emerging responses to geopolitical risk. Together, these studies support the argument that organisations must be able to revise supply-network configurations when existing arrangements become unreliable or infeasible.

However, geopolitical shocks differ in their nature and implications. A temporary maritime disruption may require a change of route or shipment schedule, whereas sanctions or export bans may make a supplier, product, or transaction legally unavailable. The first type of disruption may be addressed through operational rerouting; the second may require a more fundamental change to sourcing, production, or market arrangements. This distinction suggests that the suitability of autonomous decision making may depend not only on the magnitude of a shock but also on its type, speed, and regulatory implications.

Supply-chain reconfiguration therefore represents more than a rapid operational response. It requires selecting an alternative network arrangement that remains feasible under changed conditions. The present paper conceptualises geopolitical shock characteristics through three dimensions: shock severity, shock velocity, and shock type. Severity reflects the extent of operational disruption; velocity concerns how quickly the situation changes; and shock type distinguishes disruptions such as transportation interruptions from policy-based restrictions. These dimensions provide a foundation for analysing the demands placed on autonomous reconfiguration systems.

Modular supply-chain architecture and reconfiguration capability

Modularity concerns the extent to which a system is organised into components that can be combined or substituted through defined interfaces. In supply-chain settings, modularity can involve products, production processes, logistics services, or relationships among supply-chain participants. Bask et al. (2010) discuss the concept of modularity and its application across manufacturing and service production, providing a basis for considering modular arrangements beyond individual products.

For the present study, modular reconfiguration capability refers to an organisation's ability to identify, validate, and combine alternative supply-chain components when existing arrangements are disrupted. These components may include qualified suppliers, manufacturing facilities, transport routes, distribution centres, or logistics service providers.

Modularity may reduce the scope of change required during a disruption because a firm may be able to substitute a component rather than redesign the entire supply network. Nevertheless, modularity does not automatically guarantee rapid or successful reconfiguration. Alternative components must be compatible with existing processes, possess sufficient capacity, and satisfy relevant contractual and regulatory conditions. A nominally available pharmaceutical supplier, for example, may not be an acceptable substitute if the supplier has not been qualified for the particular ingredient or product.

Modularity should therefore be treated as an enabling capability rather than as a guarantee of decision quality. Its contribution to decision-making accuracy depends on whether autonomous agents can correctly identify feasible alternatives and evaluate their consequences.

Agentic AI and autonomous multi-agent coordination

Agentic AI refers here to AI systems designed to pursue specified goals through some combination of perception, planning, reasoning, tool use, and action execution. The term does not imply unrestricted autonomy or that every agentic system possesses reliable reasoning capabilities. Rather, the degree of autonomy depends on the tasks delegated to the system, the tools it can access, the constraints imposed on its actions, and the extent of human supervision.

Multi-agent systems extend this approach by distributing specialised responsibilities across interacting agents. In a supply-chain application, separate agents might monitor geopolitical developments, evaluate supplier risks, assess transportation alternatives, estimate inventory requirements, or check regulatory restrictions. Their outputs must then be coordinated to produce a coherent reconfiguration decision.

Giannakis and Louis (2016) show how multi-agent architectures can combine data processing with autonomous corrective control actions to support supply-chain agility. Xu et al. (2024) examine the potential of foundation models to enable more general-purpose agents and self-orchestrating supply-chain systems, while identifying implementation difficulties and challenges associated with opaque decision processes.

These studies suggest that agentic systems may improve the speed and breadth of supply-chain analysis. However, a multi-agent system can also introduce coordination problems. Different agents may operate with inconsistent information, prioritise conflicting objectives, or make locally reasonable decisions that collectively produce an unsuitable outcome. A procurement agent may prioritise price, a logistics agent may prioritise speed, and a quality-control agent may reject an alternative that the other agents consider attractive.

Multi-agent coordination capability is therefore defined in this paper as the ability of interacting agents to exchange relevant information, reconcile competing objectives, manage dependencies, and produce a consistent reconfiguration decision. The conceptual argument is that agent autonomy must be accompanied by effective coordination if the overall system is to make appropriate decisions.

Decision-making accuracy and operational limitations

Decision-making accuracy is the central outcome of this paper. It concerns whether a selected action is appropriate, feasible, and consistent with the objectives and constraints relevant to a decision situation. It is distinct from prediction accuracy, which concerns the correctness of an estimated event or condition, and decision speed, which concerns the time required to produce or execute a decision.

This distinction matters because an accurate prediction can still lead to an inappropriate action. An AI system might correctly identify that a maritime route is disrupted but recommend a replacement route that cannot meet the temperature-handling requirements of a pharmaceutical shipment. Similarly, it might identify an available manufacturer without verifying the manufacturer's eligibility for the product concerned.

Research on autonomous-system accuracy and transferability highlights the importance of assessing how AI performs across different tasks and operating conditions (Zhang et al., 2020). Work on AI-assisted decision evaluation also cautions against relying on indirect indicators of decision quality, such as subjective trust or proxy tasks, instead of actual performance (Buçinca et al., 2020).

Building on these perspectives, the paper proposes that decision-making accuracy in pharmaceutical supply-chain reconfiguration should be evaluated across five dimensions:

- Alternative-selection appropriateness: whether the chosen supplier, route, facility, or configuration is suitable for the disrupted situation.
- Operational feasibility: whether the alternative has sufficient capacity and can meet relevant delivery, production, and resource requirements.

- Regulatory and quality compliance: whether the decision respects applicable requirements for product quality, qualified suppliers, traceability, and handling.
- Robustness under uncertainty: whether the selected decision remains defensible when information changes or relevant assumptions prove inaccurate.
- Objective attainment: whether the decision supports the intended operational outcome, such as maintaining medicine availability without unacceptable cost or delay.

These dimensions constitute a proposed conceptualisation for future validation, not an already established or validated measurement scale. In particular, the framework should distinguish the quality of the decision at the time it is made from its eventual outcome. An appropriate decision can still experience an adverse outcome because of a subsequent unexpected event; conversely, an inappropriate decision may succeed by chance.

Operational limitations are the conditions that restrict the ability of an autonomous system to generate and execute appropriate decisions. They include incomplete or delayed information, data incompatibility, reasoning errors, coordination failures, cybersecurity threats, model opacity, and regulatory restrictions. These limitations are not necessarily identical: some constrain the information available to agents, while others limit which actions can legitimately be taken.

The conceptual framework treats operational limitations as conditions that can weaken the relationship between autonomous capability and decision-making accuracy. Greater autonomy may expand the system's ability to respond rapidly, but it may also increase exposure to errors if the system is not equipped to recognise uncertainty, verify information, or respect action boundaries.

Information quality, regulatory constraints, and human oversight

Information quality is critical because autonomous agents rely on information to detect disruptions and evaluate alternatives. In this paper, information quality comprises completeness, timeliness, consistency, verifiability, and relevance to the decision. During geopolitical shocks, information may be delayed, conflicting, or insufficient to establish whether a supplier or route remains viable. High-quality information can support more accurate risk assessments and alternative selection. However, information quality alone is not sufficient: even reliable information may be interpreted incorrectly or applied to an unsuitable decision objective. It should therefore be examined alongside agent coordination and operational constraints.

Pharmaceutical supply chains also operate within regulatory and quality boundaries. A decision that reduces delivery time or procurement costs is not acceptable if it violates an applicable legal requirement, product-quality condition, or supplier qualification rule. These constraints should be represented as explicit decision boundaries rather than treated merely as additional costs in an optimisation model. Human oversight provides a further governance mechanism. Human-in-the-loop oversight can involve reviewing recommendations, authorising high-consequence actions, resolving conflicts between agents, and intervening when the system encounters uncertainty or a potential compliance violation. Oversight need not mean that humans manually approve every routine action. Instead, the level of required intervention can be proportionate to the risk, reversibility, and regulatory implications of the proposed decision.

The proposed framework consequently treats human oversight as a mechanism for governing autonomy, particularly when a decision is difficult to reverse or may affect medicine quality and availability. Its purpose is not to assume that humans are invariably more accurate than AI, but to examine how appropriately designed human–AI arrangements can reduce the consequences of autonomous errors.

Theoretical foundations

Three theoretical perspectives provide complementary foundations for the proposed framework.

Information processing theory explains why decision quality depends on the relationship between the information-processing demands of a situation and an organisation's capacity to process relevant information.

Galbraith (1974) argues that uncertainty increases the need for information processing in organisational design. In the proposed study, sudden geopolitical shocks increase uncertainty, while information quality and multi-agent coordination determine how effectively the system processes that uncertainty.

Modularity theory provides the structural foundation for understanding how a supply network can be decomposed into components and recombined when circumstances change. Bask et al. (2010) offer a relevant conceptual foundation for examining modularity across manufacturing and service systems. Applied here, modular reconfiguration capability determines whether suitable alternative components can be identified and integrated without reconstructing the entire network.

Bounded rationality explains why decision makers cannot always identify an objectively optimal choice when information, time, and computational capacity are limited. Simon (1955) provides a foundational account of rational choice under constraints. In autonomous supply chains, these limitations may arise from incomplete information, uncertain geopolitical developments, computational restrictions, or conflicts between operational objectives and regulatory requirements. Agentic autonomy does not eliminate these limitations; it changes how they arise and how they must be governed. Taken together, these perspectives suggest that decision-making accuracy depends on the fit between disruption-related information demands, the structural flexibility of the supply network, the coordination of autonomous agents, and the constraints governing action execution.

PROBLEM STATEMENT

Geopolitical trade shocks create a need for supply chains to reconfigure sourcing, production, and logistics arrangements under conditions of uncertainty. Existing research has established that geopolitical risk can weaken supply-chain resilience and that reconfiguration and diversification are important responses to disruption (Bednarski et al., 2025; Chang et al., 2025; Liu et al., 2026). Meanwhile, research on multi-agent systems and foundation models indicates that autonomous agents may support distributed decision making and more adaptive supply-chain operations (Giannakis & Louis, 2016; Xu et al., 2024).

However, the ability to reconfigure a supply chain autonomously does not establish whether the resulting decisions are accurate, feasible, and appropriate. A system may detect a disruption correctly but select an alternative that is operationally unsuitable or inconsistent with applicable constraints. This problem is particularly important in pharmaceutical supply chains, where decisions must consider product quality, supplier qualification, traceability, and patient safety in addition to cost and delivery performance. The central problem is therefore the absence of a sufficiently integrated conceptual explanation of how geopolitical shock characteristics, modular reconfiguration capability, information quality, multi-agent coordination, operational limitations, and human oversight influence decision-making accuracy in autonomous pharmaceutical supply-chain reconfiguration. The literature reviewed here provides relevant foundations for each of these domains, but the proposed relationships require more explicit conceptual integration and subsequent empirical testing.

Without such a framework, research risks evaluating autonomous supply-chain systems mainly through speed, cost, or resilience outcomes while overlooking whether the actions selected by AI were appropriate at the point of decision. This could lead organisations to grant autonomous systems more decision-making authority than their information quality, coordination capability, and compliance controls can justify. Accordingly, this paper develops a conceptual framework to explain the conditions under which Agentic AI and autonomous multi-agent systems can make accurate reconfiguration decisions in modular pharmaceutical supply chains exposed to sudden geopolitical trade shocks. It also identifies how operational limitations and human oversight may constrain or govern autonomous decision making.

RESEARCH QUESTIONS AND RESEARCH OBJECTIVES

Research questions

The paper is guided by the following research questions.

RQ1: How do the characteristics of sudden geopolitical trade shocks influence the decision-making accuracy of Agentic AI and autonomous multi-agent systems in modular pharmaceutical supply-chain reconfiguration?

RQ2: How do information quality, modular reconfiguration capability, and multi-agent coordination contribute to the accuracy of autonomous reconfiguration decisions?

RQ3: How do operational and regulatory limitations affect the relationship between Agentic AI autonomy and decision-making accuracy?

RQ4: How does human oversight help govern autonomous decision making when pharmaceutical supply-chain reconfiguration decisions involve high operational or regulatory risk?

Research objectives

The corresponding research objectives are:

RO1: To conceptualise the relationship between geopolitical shock characteristics and decision-making accuracy in autonomous pharmaceutical supply-chain reconfiguration.

RO2: To examine the proposed roles of information quality, modular reconfiguration capability, and multi-agent coordination in supporting accurate autonomous decisions.

RO3: To explain how operational and regulatory limitations may constrain the relationship between Agentic AI autonomy and decision-making accuracy.

RO4: To develop a conceptual framework explaining the role of human oversight in governing autonomous reconfiguration decisions under geopolitical uncertainty.

These objectives are aligned with the paper's conceptual purpose. They do not claim to measure or test actual effects within this paper; rather, they establish the constructs and relationships to be examined in subsequent research.

PROPOSED CONCEPTUAL FRAMEWORK

Structure of the framework

The framework positions decision-making accuracy as the principal outcome. Geopolitical shock characteristics define the decision environment, while information quality, modular reconfiguration capability, and multi-agent coordination represent important conditions supporting accurate decisions. Operational and regulatory limitations constrain the actions that can be selected, and human oversight governs the degree of autonomy appropriate for different decisions.

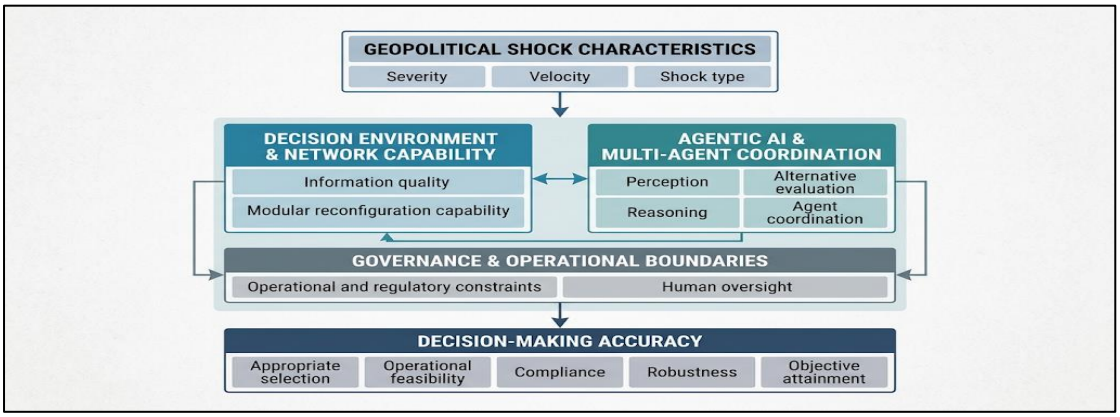

Figure 1: Proposed conceptual framework.

Construct definitions and proposed roles

The propositions below specify the relationships requiring further examination.

Construct	Proposed conceptual definition	Role in the framework
Geopolitical shock characteristics	Severity, velocity, and type of a geopolitical event affecting supply-chain operations	Defines disruption conditions and decision complexity
Information quality	Completeness, timeliness, consistency, verifiability, and relevance of information available to agents	Enabling condition for accurate decisions
Modular reconfiguration capability	Ability to identify, validate, and recombine alternative supply-chain components	Structural capability supporting feasible alternatives
Agentic AI autonomy	Degree to which AI can perceive, plan, evaluate, and initiate actions without human approval	Main technological capability under investigation
Multi-agent coordination	Ability of specialised agents to exchange information and reconcile interdependent decisions	Coordination capability supporting coherent decisions
Operational and regulatory limitations	Constraints relating to capacity, system integration, quality, qualification, traceability, and applicable rules	Restricts the feasible decision space and may weaken autonomous performance
Human oversight	Review, approval, intervention, or escalation by an authorised human decision maker	Governance mechanism for high-risk decisions
Decision-making accuracy	Degree to which a selected action is appropriate, feasible, compliant, and robust in the circumstances	Principal outcome

A key conceptual decision is to keep decision-making accuracy separate from subsequent supply-chain performance. Decision accuracy concerns the quality and validity of the selected action, whereas performance concerns what happens after the action is implemented. Outcomes such as recovery time, service continuity, and cost can be examined as downstream consequences in a future expanded model.

Proposed research propositions

The following propositions are designed to be theoretically defensible and suitable for future empirical testing. They are not findings established by the present paper.

Proposition 1 (P1): Greater geopolitical shock velocity and severity increase the information-processing demands of autonomous pharmaceutical supply-chain reconfiguration, thereby increasing the risk of inaccurate decisions when information quality is insufficient.

Proposition 2 (P2): Higher information quality is positively associated with decision-making accuracy in Agentic AI-enabled pharmaceutical supply-chain reconfiguration

Proposition 3 (P3): Greater modular reconfiguration capability is positively associated with decision-making accuracy when alternative supply-chain components are operationally compatible and appropriately qualified.

Proposition 4 (P4): Greater multi-agent coordination capability is positively associated with decision-making accuracy in autonomous supply-chain reconfiguration.

Proposition 5 (P5): The positive relationship between Agentic AI autonomy and decision-making accuracy is weakened when operational and regulatory constraints are not adequately represented in the system's decision rules and execution controls.

Proposition 6 (P6): Risk-proportionate human oversight strengthens the relationship between Agentic AI autonomy and decision-making accuracy for high-consequence pharmaceutical reconfiguration decisions.

Proposition 7 (P7): The positive relationship between Agentic AI autonomy and decision-making accuracy varies according to geopolitical shock type, with operational rerouting disruptions and policy-based restrictions presenting different decision requirements.

Conceptual contribution

The proposed framework makes three contributions.

First, it separates autonomy, prediction accuracy, decision-making accuracy, and operational performance. These concepts are related but not interchangeable. A system can act autonomously, predict a disruption accurately, and respond quickly while still selecting an inappropriate alternative. Second, it integrates modular reconfiguration capability with multi-agent coordination and decision accuracy. Modularity creates potential alternatives, but coordination is required to assess whether those alternatives are suitable across interdependent supply-chain activities. Third, it incorporates operational constraints and human oversight into the explanation of autonomous performance. Instead of treating human intervention as an obstacle to automation, the framework treats oversight as a governance mechanism that can help establish appropriate boundaries for autonomous action. The framework is intended as a foundation for further research, rather than a claim that all proposed relationships have already been demonstrated in pharmaceutical supply chains.

METHODOLOGY

Research design

This paper adopts a conceptual research design based on an integrative literature review and theory synthesis. A conceptual approach is appropriate because the primary purpose is to develop a theoretically grounded explanation of how Agentic AI and autonomous multi-agent systems may influence decision-making accuracy in modular pharmaceutical supply-chain reconfiguration under geopolitical uncertainty. The paper does not claim to test hypotheses, estimate causal effects, or report empirical findings.

The methodology consists of three connected activities: identifying relevant literature, synthesising theoretical insights across the literature streams, and developing a conceptual framework with propositions for future research.

Literature identification and selection

The literature identification process draws on the Scopus-exported BibTeX records supplied for this project. The records cover three broad areas: geopolitical risk and supply-chain reconfiguration; multi-agent systems and AI-enabled supply-chain management; and autonomous-system accuracy and decision making.

For a reproducible final manuscript, the literature search should be documented using combinations of the following terms:

- Geopolitical risk, geopolitical shock, trade restrictions, tariffs, sanctions, and supply-chain disruption.
- Supply-chain reconfiguration, supply-chain modularity, modular networks, and supply-chain resilience.
- Agentic AI, autonomous agents, multi-agent systems, foundation models, and autonomous decision making.
- Decision-making accuracy, AI reliability, information quality, human oversight, and operational constraints.
- Pharmaceutical supply chains, active pharmaceutical ingredients, supplier qualification, cold-chain logistics, and regulatory compliance.

The search should cover publications available up to the final search date, with particular attention to peer-reviewed journal articles and relevant scholarly conference papers. Foundational theoretical works should also be included where they directly support the constructs and relationships in the framework.

The final manuscript should report the actual search date, exact search strings, database filters, number of retrieved records, duplicate count, screening exclusions, and final number of included publications. These figures should be established from the final search and screening process rather than inferred from the number of records in the supplied BibTeX files.

Literature screening and synthesis

The screening process should assess relevance to at least one of the paper's principal domains: geopolitical disruption, modular supply-chain reconfiguration, Agentic AI and multi-agent coordination, decision-making accuracy, or pharmaceutical operational constraints. Records should be excluded where they do not meaningfully address the research questions, lack sufficient bibliographic information for verification, or offer no substantive conceptual or empirical contribution to the proposed framework. Non-journal sources should be identified clearly, and their inclusion should be justified where they offer relevant technical or theoretical insights.

The selected literature should then be organised into a synthesis matrix containing the publication details, research purpose, theoretical perspective, method, principal findings, limitations, and relevance to the proposed constructs. This will help distinguish established findings from conceptual assumptions that still require investigation.

Framework development and proposition formulation

The framework will be developed through cross-domain synthesis. Findings from geopolitical risk and reconfiguration research will establish the external disruption conditions. Modularity literature will inform the structural capability to substitute or recombine supply-chain components. Research on autonomous agents will inform the technological and coordination dimensions, while work on AI accuracy and human–AI decision making will inform the outcome and governance dimensions.

The constructs and their proposed relationships will be compared for conceptual consistency, redundancy, and logical ordering. Propositions will then be formulated to express relationships that are theoretically plausible but not yet established for the specific context of autonomous pharmaceutical supply-chain reconfiguration under sudden geopolitical trade shocks.

Finally, the framework should be refined through expert review involving supply-chain management scholars, pharmaceutical supply-chain practitioners, AI or multi-agent systems specialists, and professionals familiar with pharmaceutical quality and regulatory requirements.

Expert review would help establish whether the constructs are sufficiently clear, whether the proposed relationships are plausible, and whether the framework adequately represents operational constraints. This validation is proposed as a subsequent step; it has not been conducted as part of the present conceptual paper.

Directions for future empirical testing

The framework could be examined through simulation-based experiments or digital-twin environments representing pharmaceutical supply networks. Different geopolitical shock scenarios could be introduced, including maritime route disruption, tariff escalation, export bans, and supplier unavailability.

Researchers could compare rule-based systems, single-agent AI, autonomous multi-agent systems, and human–AI decision-making arrangements. The decision outcomes could be evaluated against expert-defined feasible alternatives and applicable operational constraints.

Potential measures include the proportion of selected alternatives that are feasible and compliant, the rate of inappropriate supplier or route selection, the frequency of constraint violations, decision robustness under changing information, and the time required to reach an acceptable decision. Cost, service continuity, and recovery time could be assessed separately as downstream performance measures.

This design would allow researchers to investigate whether greater autonomy improves decision-making accuracy under particular conditions, whether information quality and coordination reduce errors, and when human approval provides meaningful additional protection.

DISCUSSION AND CONCLUSION

This conceptual paper addresses the challenge of autonomous supply-chain reconfiguration under sudden geopolitical trade shocks. The literature establishes that geopolitical disruptions can undermine supply-chain resilience and create a need for reconfiguration, while research on multi-agent systems indicates the potential of autonomous technologies to support more adaptive and coordinated operations (Bednarski et al., 2025; Chang et al., 2025; Giannakis & Louis, 2016; Liu et al., 2026; Xu et al., 2024).

However, autonomous capability alone does not establish decision-making accuracy. The suitability of an autonomous reconfiguration decision depends on whether the system can identify feasible alternatives, process reliable information, coordinate interdependent decisions, and respect the operational and regulatory boundaries governing pharmaceutical supply chains.

The proposed framework brings these considerations together by positioning decision-making accuracy as the principal outcome and identifying geopolitical shock characteristics, information quality, modular reconfiguration capability, multi-agent coordination, operational limitations, and human oversight as central elements of the explanation. It also distinguishes the accuracy of a selected decision from the performance achieved after its implementation.

The framework's principal contribution is to shift the research question from whether Agentic AI can make supply chains more responsive towards under what conditions autonomous AI can make appropriate reconfiguration decisions, what limits its reliability, and how the boundaries of autonomy should be governed. This distinction is particularly important in pharmaceutical supply chains, where an inappropriate decision may have consequences beyond financial loss or delayed delivery.

The paper has limitations. It is conceptual and does not establish the causal relationships proposed in the framework. Its claims about the pharmaceutical context also require further validation against specialist literature and applicable regulatory requirements. In addition, decision-making accuracy must be operationalised carefully to distinguish a poor decision from an adverse outcome caused by an unpredictable event after a decision has been made.

Future research should therefore validate the proposed constructs, refine the propositions through expert assessment, and test the framework through scenario-based simulation, digital-twin experiments, or empirical studies of AI-supported supply-chain decisions. Such work would provide evidence about the conditions under

which autonomous systems can be trusted, the circumstances requiring human intervention, and the governance arrangements necessary for responsible deployment in pharmaceutical supply chains.

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