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SUPPLY CHAIN RESILIENCE AND RISK MANAGEMENT IN GLOBAL DISTRIBUTION NETWORKS: A REVIEW OF ADVANCES POST-DISRUPTION

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ABSTRACT
Global distribution networks fail through mechanisms that the operations literature has tended to study separately: supplier failure, asset breakdown, regulatory interruption, information system compromise, financial control failure and workforce unavailability. This paper reviews advances in supply chain resilience and risk management across a corpus of 180 studies published to 2021, drawn from procurement and energy infrastructure supply chains, analytics-driven and sustainable procurement, occupational and process safety risk governance, asset integrity and condition monitoring, enterprise information systems and cyber risk, financial control and audit, regulatory and trade compliance, infrastructure delivery, and agricultural and energy value chains.
Three findings emerge. First, the treatment of resilience has moved from recovery after failure toward the structural properties that determine whether failure propagates, with node criticality, geographic concentration and dependence on non-substitutable capacity recurring as the structural variables that matter. Second, procurement has been reframed from a cost function into the principal instrument of risk control, operating through vendor evaluation, contract and vendor governance, inventory positioned against criticality, and compliance screening. Third, and least recognised, the risk-management apparatus developed in adjacent engineering and control disciplines, particularly safety governance, asset integrity testing, condition-based maintenance and risk-based internal audit, is structurally equivalent to what supply chain resilience requires and is in several respects more empirically mature, yet it is almost never drawn upon in supply chain work.
The paper develops an integrated capability model in which exposure acts on network structure, structure determines propagation, four capability pillars moderate the relationship between structure and outcome, and visibility operates as an enabling condition spanning all layers rather than as a capability in its own right. Five propositions are derived in a form that permits empirical test. The review also documents that the corpus is dominated by conceptual frameworks, that measurement conventions are not shared across studies, that the cost of resilience is asserted rather than estimated, and that sub-tier visibility is treated as a technology problem when the binding constraint is an incentive problem.

Keywords:
Supply chain resilience; disruption risk management; global distribution networks; strategic procurement; supplier risk; asset integrity; condition monitoring; end-to-end visibility; safety risk governance; enterprise information risk

1. INTRODUCTION

Distribution networks fail in more ways than supply chain research normally models. A shipment can be delayed because a supplier cannot produce, because a terminal is congested, because a pump has not been maintained, because a customs classification is contested, because an access control failure has taken a planning system offline, because a payment has not settled, or because the people who operate the equipment are unavailable. Each of these has a mature literature attached to it, and those literatures have developed largely in isolation. The consequence for practice is that a firm receives competent guidance on each failure mode and very little on the system in which the failure modes interact.

The corpus reviewed here offers an unusual opportunity to address that fragmentation, because it spans the adjacent disciplines rather than a single field. Resilience frameworks developed for critical infrastructure and gas processing plants treat resilience as a property of the network and its critical nodes rather than as a reactive capability (Ogunwole et al., 2021), and supply chain risk management models for engineering, procurement and construction programmes treat risk as continuously managed across a lifecycle rather than as a contingency invoked on failure (Agbabiaka et al., 2019). Alongside these sit substantial bodies of work on occupational safety governance, asset integrity testing, predictive maintenance, enterprise information risk, internal audit and

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regulatory compliance, each of which has developed methods for anticipating and containing failure in complex operating systems.

That juxtaposition is the basis of this paper's argument. The claim advanced here is that the risk-management apparatus developed in engineering safety, asset integrity and financial control is structurally equivalent to what supply chain resilience requires, is in several respects more empirically mature, and is almost entirely absent from supply chain resilience work. Safety management systems already institutionalise hazard identification, near-miss reporting, contractor governance and organisational learning (Obogo, Arumosoye et al., 2021; Obriki & Arumosoye, 2021). Asset integrity programmes already infer failure risk from measured condition rather than from expert judgement (Atta et al., 2020). Risk-based internal audit already allocates assurance effort in proportion to exposure rather than to transaction volume (Akomolafe & Agu, 2019a). Supply chain resilience research has, in several instances, reinvented weaker versions of each.

The paper therefore does three things. It maps the corpus by capability rather than by discipline, so that equivalences between fields become visible. It develops a layered model positioning those capabilities relative to exposure, network structure and resilience outcome, and derives five propositions in testable form. And it assesses the weight of evidence behind each capability claim, which in a corpus dominated by conceptual frameworks is frequently lighter than the confidence of the framing suggests.

Section 2 sets out the methodology and the composition of the corpus. Section 3 presents the literature synthesis across seven capability domains. Section 4 develops the conceptual model. Section 5 discusses what the evidence supports, Section 6 draws implications for practice, Section 7 states the limitations of the review and of the corpus, Section 8 identifies priorities for future research, and Section 9 concludes.

2. METHODOLOGY

This is an integrative review bounded by a defined corpus rather than by an open database search. The corpus comprises 180 studies published to 2021, selected from a consolidated multidisciplinary reference list on two criteria. A study qualified if it addressed the structure, performance, governance or risk exposure of supply, procurement or distribution systems, or if it addressed a capability on which such systems demonstrably depend. The second criterion admits the adjacent literatures that give this review its comparative purchase: occupational and process safety, asset integrity and maintenance engineering, enterprise information systems and cyber risk, financial control and audit, regulatory and trade compliance, and infrastructure delivery.

The 2021 boundary is substantive rather than administrative. It places the review at the point at which the disruptions of 2020 and 2021 had occurred but the research response to them had not yet appeared, which is the condition under which practitioners were actually deciding. The review therefore reports what was available to inform those decisions rather than what was subsequently written about them. The corpus is weighted toward the most recent five years relative to that date: 84 per cent of the studies were published between 2019 and 2021, 61 per cent in 2020 or 2021, and 36 per cent in 2021 itself, so the synthesis reflects the state of the literature at the point of writing rather than an even sample of the preceding decade.

Coding proceeded in two passes. In the first, each study was assigned to a primary capability domain on the basis of its stated contribution rather than its publication venue, so that a paper on aerial inspection of transmission corridors was coded as condition monitoring rather than as energy engineering. In the second pass, studies were re-read for claims operating outside their own field, and a secondary domain was assigned wherever a study proposed a mechanism applicable beyond its stated setting. Two relations were then recorded across the coded set. Convergence was noted where studies from different domains proposed functionally equivalent mechanisms under different names, and these convergences supply the transfer argument developed in Section 5. Divergence was noted where studies addressing the same mechanism reached incompatible conclusions, and both positions are reported in Section 3 rather than reconciled. No quantitative weighting was applied at any stage, because the studies do not share outcome measures and any weighting would impose a false commensurability.

Seven capability domains were identified inductively and are summarised in Table 1. Three properties of the corpus condition every conclusion drawn from it. Conceptual and framework contributions substantially outnumber empirical studies, so the literature is rich in proposed architectures and poor in tested effects. Measurement conventions are not shared across studies, which prevents quantitative synthesis and makes cross-study comparison qualitative. And the corpus is weighted toward emerging-market and cross-border settings, particularly West Africa, which strengthens external validity in those contexts and limits it elsewhere. Synthesis proceeded by capability, with representative studies cited at the level of the claim rather than summarised individually, and with competing positions reported where the corpus contains them.

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Table 1. Composition of the reviewed corpus by capability domain.

Capability domain	Studies	Principal contribution to the review
Procurement, supplier management and materials readiness	28	Procurement optimisation, vendor evaluation and governance, inventory positioned against criticality, port and materials logistics
Enterprise information systems and cyber risk	35	Cloud and platform architecture, identity and access management, incident response, information risk embedded in supply chain transformation
Compliance, financial control and institutional governance	31	Risk-based internal audit, regulatory clearance, anti-money-laundering regimes, treasury and payment controls, statutory reporting
Asset integrity, maintenance and condition monitoring	24	Predictive maintenance, non-destructive testing, corrosion risk, corridor survey by unmanned aerial and geographic information systems
Operational and occupational risk governance	23	Hazard identification, near-miss systems, contractor safety governance, organisational learning, aviation safety oversight
Analytics, forecasting and financial decision systems	16	Demand forecasting, cost and capital allocation modelling, business intelligence and performance monitoring
Infrastructure delivery and sector value chains	16	Capital project delivery under regulation, healthcare and energy infrastructure, agricultural value chains
Workforce, process discipline and organisational capability	7	Talent and competence development, administrative process capability, workplace conduct, cross-cultural coordination

Domain boundaries are analytical rather than absolute; a number of studies address more than one capability and are discussed in more than one subsection.

3. LITERATURE SYNTHESIS

The synthesis is organised by capability rather than by discipline, on the reasoning that a firm operating a distribution network makes decisions about capabilities and not about literatures. Seven domains are treated in turn. Within each, the section states what the corpus proposes, identifies where contributions from different disciplines converge on the same underlying mechanism, and notes where supporting evidence is weaker than the framing suggests.

3.1 Resilience and Risk: Conceptual Foundations

The corpus shows a consistent movement away from resilience understood as speed of return to a prior operating state and toward resilience understood as a structural property. The clearest statement is the resilience framework for critical infrastructure and gas processing plants, which treats the capacity to sustain supply as a design characteristic of the node and its dependencies rather than as a capability activated after failure (Ogunwole et al., 2021). Supply chain risk management for engineering, procurement and construction programmes establishes the complementary position on the risk side, treating exposure as continuously managed across a programme lifecycle rather than as a contingency (Agbabiaka et al., 2019).

A second strand locates resilience in relationships rather than in assets. Supplier relationship management is argued to foster innovation, collaboration and resilience simultaneously across global supply networks, on the reasoning that a supplier who shares information early and allocates scarce capacity preferentially provides protection that no contractual instrument reliably secures (Ike et al., 2021). End-to-end visibility frameworks supply the informational counterpart, improving transparency, compliance and traceability across complex networks and functioning as the precondition for every downstream capability (Nnabueze et al., 2021).

The most developed conceptual material in the corpus, however, comes from outside supply chain research. Safety scholarship has an explicit account of how organisations learn from events that did not become failures, through systematic use of near-miss and hazard observation data (Arumosoye & Obriki, 2019) and through proactive hazard recognition and reporting systems (Obogo, Arumosoye et al., 2021). Organisational learning maturity models for continuous safety performance treat improvement between events as the object of design (Arumosoye & Obriki, 2021), and conceptual models for institutionalising life-preserving practices across project-based organisations address the retention of capability when teams disband (Obriki & Arumosoye, 2021). Supply chain resilience research contains no equivalent literature on learning between disruptions, and the absence is conspicuous given how consistently organisational memory of disruption is observed to decay. The built environment literature makes the complementary structural argument, treating resilience to recurrent flooding as a design property of the settlement rather than as a response capability (Nwafor et al., 2019a).

Risk prioritisation is likewise handled more rigorously in adjacent fields. Risk-based internal control models in banking and insurance allocate assurance effort in proportion to exposure rather than to transaction volume (Akomolafe & Agu, 2019a), data-driven risk evaluation models are developed for emerging-market financial

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institutions where data quality is poor (Akomolafe & Agu, 2019b), and integrated governance and compliance strategies are connected explicitly to financial resilience as an outcome (Akomolafe & Agu, 2019c). Technology-enabled risk assessment is proposed as the route to internal audit quality (Akomolafe & Agu, 2018). Security audit and enterprise risk assessment frameworks make the same move in the information domain (Dosunmu & Ogundele, 2019), and risk-based cybersecurity assurance work treats data availability rather than confidentiality alone as the outcome variable (Fadayomi et al., 2019). Risk stratification models for large-scale emergency preparedness extend the same logic to population-level exposure, ranking where preventive capacity should be placed before an event rather than after it (Oparah, Ezeh et al., 2021). Each is a more developed treatment of prioritisation under uncertainty than the probability-and-impact scoring that dominates supply chain risk practice.

The corpus is more careful with mechanism than with terminology, and the imprecision matters. Robustness, the capacity to maintain performance under a defined disturbance without structural change, is used in several places interchangeably with resilience, the capacity to absorb a disturbance and recover from it, and occasionally with reliability, the probability of functioning without failure over a stated period. The distinction is not merely semantic, because the three properties are bought with different investments: robustness with margin and redundancy, resilience with flexibility and recovery capability, and reliability with design quality and maintenance. The engineering literature in this corpus is precise about reliability and explicit about how it is estimated (Adaramola et al., 2018; Gideon et al., 2019), the safety literature is precise about prevention and about the difference between a hazard and a realised event (Obogo et al., 2019; Obriki & Arumosoye, 2020), and the supply chain literature is consistently precise about neither. The practical consequence is that two studies both claiming to improve resilience may be addressing different properties, and a firm adopting both may be buying the same protection twice while leaving a third exposure untreated.

3.2 Procurement, Supplier Management, and Materials Readiness

The corpus supports a strong reframing of procurement as the instrument through which network exposure is created or controlled. Frameworks for strategic procurement optimisation in oil and gas operations establish the position in an environment where interruption cost is high and supplier qualification is slow (Okonkwo et al., 2018a). Contract negotiation and vendor governance are developed as the mechanism through which cost reduction is achieved without transferring unmanageable risk to a supplier unable to bear it (Okonkwo et al., 2019), and process automation frameworks address procurement efficiency and transparency together, on the argument that manual intervention is simultaneously a cost and an integrity risk (Akinleye & Adeyoyin, 2021).

Supplier evaluation is where risk management becomes operational, and the corpus contains a distinctive contribution. Data-driven vendor evaluation and bid selection models incorporating geospatial intelligence extend assessment beyond price and past performance to the physical location and exposure of the supplier (Ahiaeke Patrick et al., 2021), which addresses directly the correlated-failure problem that arises when nominally diversified suppliers occupy the same hazard zone. Geographic information system enabled frameworks for enterprise resource planning procurement embed the same spatial reasoning in the transactional system rather than in a separate analysis (Ahiaeke Patrick et al., 2020). Regulatory-compliant procurement frameworks for high-risk energy environments add the compliance dimension, in which a supplier may be commercially sound and regulatorily disqualified (Okonkwo, Ogunwole et al., 2021).

Inventory is treated as a continuity instrument rather than as working capital to be minimised. Models for inventory availability and plant uptime improvement value stock by the production interruption it prevents rather than by its carrying cost (Okonkwo et al., 2018b), and materials readiness models extend this to maintenance-driven performance, where the operative question is whether the specific part required by a scheduled or emergent intervention is available at the moment of need (Okonkwo, Agbabiaka et al., 2021). This is a narrower and considerably cheaper prescription than the general call for more inventory that followed the disruptions of the period, and it depends entirely on the condition visibility discussed in Section 3.3.

On the flow side, the model for demurrage elimination and port logistics efficiency in emerging economies frames dwell cost not as an unavoidable cost of trade but as a measurable consequence of documentation delay, clearance friction and weak coordination between carrier, terminal and consignee (Okonkwo et al., 2020). The framing matters because it renders part of congestion cost addressable by the shipper, in contrast to berth scarcity, which is not. Demand-side analytics complete the picture: predictive models improve forecasting accuracy while reducing inventory management inefficiency (Aifuwa et al., 2020), machine learning approaches to demand forecasting are connected to revenue projection and financial planning accuracy (Tonoyan et al., 2021a), and predictive cash flow modelling addresses working capital optimisation in retail (Tonoyan et al., 2021b). Geomarketing analytics connects spatial demand estimation to expansion and penetration decisions (Seyi-Lande et al., 2020), predictive modelling of customer churn and lifecycle value addresses the stability of the demand a network is sized against (Oziri et al., 2020), and analytics-driven market entry frameworks address the compliance

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and sustainability constraints that now condition where a firm may profitably distribute (Sanni & Atima, 2021a). Measurement itself is treated as a problem in regulated settings, where attribution of return to a commercial action is constrained by what may lawfully be observed and communicated (Sanni et al., 2020a), and where differentiation must be established within rules that limit the claims a firm can make (Sanni et al., 2020b).

Sustainability enters procurement here as a risk discipline rather than as a reporting obligation. Environmental, social and governance integrated supply chain models are developed for corporate responsibility and environmental performance (Okojie et al., 2020), and decision frameworks for post-consumer recycled polymers in consumer goods packaging balance chemical safety regulation, lifecycle emissions and circular economy targets in a single structure (Okojie & Abioye, 2020). The connection to resilience is direct: a supplier disqualified on environmental or regulatory grounds is as unavailable as one disqualified by fire, and usually with less warning. Analytical tooling is addressed through profitability analysis in retail procurement operations using widely available software (Akin-Oluyomi et al., 2020), which matters because it addresses the large population of firms for which advanced platforms are out of reach.

Sector value chains supply the context in which these instruments operate. Work on agricultural value chains examines access to enterprise finance as a determinant of supplier survival (Michael & Ogunsola, 2019a), digital tools as a route to inclusive food systems (Michael & Ogunsola, 2021b), data-driven policy models for production efficiency and resource optimisation (Michael & Ogunsola, 2021c), climate-smart practices as a contributor to household food security and income stability (Michael & Ogunsola, 2021d), and extension services as the mechanism of innovation adoption among smallholders (Michael & Ogunsola, 2021e). Policy alignment work connects these to national sustainable development priorities (Michael & Ogunsola, 2021a), and entrepreneurial competency development addresses the formation of the supplier base itself (Michael & Ogunsola, 2019b). For a network sourcing from fragmented smallholder supply, these are not contextual details but determinants of whether supply exists at all.

3.3 Visibility, Asset Integrity, and Condition Monitoring

Every capability in this review depends on knowing what the network contains and what condition it is in, and this is the domain in which the adjacent engineering literature is furthest ahead of supply chain research. End-to-end visibility frameworks state the requirement at network level (Nnabueze et al., 2021) and materials readiness models state it at inventory level (Okonkwo, Agbabiaka et al., 2021), but neither specifies how condition is actually established. The maintenance and integrity literature does.

Predictive maintenance and condition monitoring in critical power and energy infrastructure sets out the core method, which is inference of remaining useful life from observed condition rather than from elapsed time (Adaramola et al., 2018). Work on the transition from reactive to predictive maintenance in mechanical systems documents the organisational and technical shift this requires (Sunday et al., 2020), and reliability engineering and failure analysis in complex engineering systems supplies the methodological base for reasoning about failure modes and their consequences (Gideon et al., 2019). Applied to distribution, these methods address the availability of the assets that move goods, which is a constraint inventory buffers cannot relieve. Thermodynamic efficiency and control work on conditioning systems illustrates the same logic in a building services setting where continuous operation is the requirement (Sunday et al., 2019).

Integrity assessment is treated with comparable rigour. Advances in non-destructive testing for weld integrity evaluation in high-capacity power infrastructure address the detection of defects before they become failures (Atta et al., 2021), and critical review of non-destructive testing based integrity management connects inspection method to corrosion risk decision in refining assets (Atta et al., 2020). Work on green corrosion inhibitors addresses the degradation mechanism itself, which is the level at which prevention rather than detection operates (Atta et al., 2018). The transferable principle is that exposure is measured on the asset rather than estimated from a register, which is precisely the move supply chain risk assessment has not made.

Remote sensing extends condition assessment across geography. Frameworks for integrating unmanned aerial vehicles into national grid inspection programmes address institutional arrangements as well as technology (Dagodzo, 2018a), and reviews of aerial applications in transmission line inspection assess methods and limitations (Dagodzo, 2018b). Pipeline and corridor monitoring reviews extend the application to linear infrastructure (Dagodzo & Ahiaeke Patrick, 2020), geographic information system applications are reviewed for utility asset management and infrastructure planning (Dagodzo & Ahiaeke Patrick, 2021a), and an integrated framework combines unmanned aerial systems, light detection and ranging, and geographic information systems for corridor management (Dagodzo & Ahiaeke Patrick, 2021b). A distribution network is a corridor problem in exactly this sense, and the methods transfer with little modification.

The power and energy cluster supplies the failure-prediction analogue. Interpretable machine learning is applied to early failure prediction in distributed renewable assets, with interpretability treated as a requirement

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rather than a refinement because operators must act on the prediction (Komi & Adamolekun, 2021). Hybrid deep learning for wind power forecasting connects prediction to grid stability and market access for small generators (Komi, 2021), and grounding system design optimisation addresses reliability in medium-voltage distribution networks (Adeniji et al., 2020). Affordability and technical performance are co-optimised in microgrid design for underserved communities (Komi & Adeniji, 2020), hydrogen integration is modelled as substitution of one energy carrier for another at national scale (Shittu et al., 2019), distributed settlement is addressed through peer-to-peer energy trading models (Shittu et al., 2021), and statistical modelling of daily solar radiation supplies the resource estimation on which distributed generation planning depends (Odejobi & Ahmed, 2018a).

A final strand in this domain concerns spatial risk modelling, which is the methodological bridge between condition data and network decision. Data-driven frameworks for predicting subsurface contamination pathways in complex remediation programmes model the movement of a hazard through a medium from sparse observations (Azeez & Badmus, 2018), and spatially explicit risk modelling extends this to the tracking of contaminant migration where the consequence is measured in liability as well as in physical damage (Lamidi & Olamide, 2018). Hydrological modelling for assessing climate-induced watershed vulnerability applies the same approach to exposure that accumulates over time rather than propagating from a discrete event (Badmus & Olamide, 2019), and interpretation of multispectral satellite imagery demonstrates the inference of subsurface condition from remote observation alone (Dagodzo, 2018c). For a distribution network the transferable object is the method rather than the application: estimating the state of something that cannot be directly inspected, from observations that are sparse, indirect and spatially distributed. That is precisely the sub-tier visibility problem.

3.4 Enterprise Information Systems and Information Risk

Distribution now runs on enterprise systems, and this is the largest domain in the corpus. Architecture work addresses the substrate: conceptual frameworks for scalable and secure cloud architectures for enterprise messaging (Ahmed & Odejobi, 2018a), resource allocation models for energy-efficient virtual machine placement (Ahmed & Odejobi, 2018b), algorithmic models for constraint satisfaction in cloud network resource allocation (Ahmed et al., 2019), and predictive models for cloud resource scaling using machine learning (Ahmed et al., 2020). Approximation complexity models for cloud-based database optimisation address the tractability of the underlying problems (Odejobi et al., 2019), and performance evaluation work on multi-tenant deployments under high concurrency addresses behaviour at load (Odejobi & Ahmed, 2018b), which is the condition a planning system encounters precisely when a disruption is unfolding.

Identity, access and configuration control receive substantial treatment, and they matter for distribution because they determine who can change a shipment, a price or a purchase order. Secure identity and access management models are developed for distributed and federated systems (Oshoba et al., 2019), and identity and access management integration strategies are reviewed for hybrid and multi-cloud environments (Mbonu et al., 2020), which is the environment most multinational distribution operations now run in. Lessons from offline assessment of security-critical directory systems document how access infrastructure fails (Ladapo et al., 2018), with implementation work addressing the management of enterprise networks in practice (Ladapo et al., 2019). Blockchain-enabled compliance and audit trail models for cloud configuration management address the integrity of the record of change (Oshoba et al., 2020), and infrastructure-as-code governance addresses the control of environments that are defined in software rather than provisioned manually (Mbonu et al., 2020b). Identity-centric zero trust architecture extends the same principle to enterprise security governance as a whole, replacing network location with verified identity as the basis of authorisation (Ogbole, Okoruwa, Fadayomi et al., 2021).

Platform and integration engineering is represented through Salesforce-centric work that generalises to any customer- and order-facing platform: systematic review of continuous integration and deployment pipeline strategies (Badmus et al., 2018), conceptual models for extract, transform and load design and data integration (Badmus et al., 2019a), and governance frameworks for platform management in regulated environments (Badmus et al., 2019b). Comparative evaluation of deployment tooling addresses the operational question of how change is released without interrupting service (Badmus et al., 2020). Artificial intelligence techniques for secure software testing and automated regression address the same concern from the assurance side (Mbonu et al., 2021b).

Information risk is treated as a first-order operational risk rather than as a technical specialism. A conceptual framework for agile supply chain digital transformation with embedded information technology risk and compliance controls is the corpus contribution that connects the two domains most directly, and it is notable for treating risk controls as part of the transformation design rather than as a subsequent audit (Mbonu et al., 2020a). Enterprise log analytics and automated incident response architectures address detection and containment (Mbonu, Iwuanyanwu et al., 2019), intrusion detection and prevention models address defensive effectiveness (Dosunmu & Ogundele, 2020), and incident response and digital forensics strategies address rapid containment after compromise (Dosunmu & Ogundele, 2021). Insider threat classification and risk modelling addresses the

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exposure that perimeter controls do not reach (Akeju et al., 2018), which in a distribution context includes the people with authority to release goods and approve payment. Deep learning driven malware classification for cloud-native microservices addresses detection in the architecture that increasingly hosts planning and execution systems (Idika et al., 2021), and human factors work on information-security awareness and records confidentiality addresses the behavioural layer on which every technical control ultimately depends (Onche et al., 2020).

Governance of data itself completes the domain. Legal and ethical risk modelling in enterprise data protection governance addresses obligations that constrain how supply chain data may be shared (Mbonu et al., 2018), and comparative review of data protection regulation and secure cloud implementation strategies addresses the cross-jurisdictional case that any global network faces (Mbonu, Aliliele et al., 2019). Risk-based business intelligence architecture is proposed for financial technology platforms (Mbonu et al., 2021a), forensic analytics for fraud detection and regulatory compliance monitoring extends the same reasoning to transaction streams (Mbonu et al., 2021), and privacy-centric security engineering addresses the design of systems in which data protection is a structural property rather than a configuration setting (Okoruwa et al., 2020). Operational technology security is represented by work on securing control networks in electric utilities against regulatory standards (Adegbite et al., 2020) and by zero trust architecture for operational technology in critical infrastructure (Ahmed et al., 2021). The practical implication for distribution is that the reliability of ports, terminals and warehouses depends on control systems whose security typically sits outside the supply chain function's remit and inside its risk exposure.

Analytics for management decision sit on top of this substrate. Integrated data visualisation models are developed for continuous business performance monitoring (Ogbole, Okoruwa, Babatope et al., 2021), business intelligence dashboard frameworks address the executive visibility gaps that prevent senior decision-makers from seeing exposure in time to act on it (Sanni & Atima, 2021b), data-driven executive decision systems for strategic financial planning are conceptualised (Lawal & Oduleye, 2019b), and predictive maintenance modelling for commerce systems connects analytics to asset availability (Mayo et al., 2021). Cost management models address the translation of analysis into financial planning and performance evaluation (Oduleye & Medon, 2021).

3.5 Operational and Occupational Risk Governance

The safety literature in this corpus is the most operationally mature risk-management material available, and its transferability to distribution is high because it addresses the same problem: preventing low-frequency high-consequence events in a system operated by many parties under production pressure.

Hazard identification is the entry point. Systematic review of hazard identification and risk control practices in urban construction addresses the method (Obogo et al., 2019), near-miss and hazard observation data utilisation addresses the use of signals that did not become incidents (Arumosoye & Obriki, 2019), and proactive hazard recognition and near-miss reporting systems address the organisational conditions under which people report at all (Obogo, Arumosoye et al., 2021). Human error causation frameworks for high-risk activities address why controls fail in execution rather than in design (Obriki & Arumosoye, 2020), and data-driven occupational safety risk control in large-scale energy infrastructure addresses the instrumentation of the whole (Obriki & Arumosoye, 2018). The parallel with supply chain disruption is exact: most disruptions are preceded by signals that were observable and not acted upon.

Contractor and multi-party governance is the second contribution, and it maps directly onto supplier management. A governance-oriented model for contractor safety performance in multi-contract industrial projects addresses accountability where work is performed by parties the principal does not employ (Arumosoye & Obriki, 2020), a construction safety risk governance model addresses the multi-contractor high-rise case (Obogo et al., 2019b), and review of contractor safety compliance systems addresses verification (Obogo, Uduokhai et al., 2021). A distribution network is a multi-contract system in exactly this sense, and the supply chain literature has no comparable treatment of how a principal holds a contractor to a standard it cannot directly supervise.

Assurance and improvement complete the domain. Internal quality, health, safety and environment audit systems are advanced for industrial engineering operations (Obogo et al., 2020a), and review of occupational safety management systems in oil and gas maintenance projects assesses what such systems achieve in practice (Obogo et al., 2020c). Conceptual risk management for heavy lifting and crane installation demonstrates the method at task level (Obogo et al., 2020b), incident prevention modelling addresses maintenance environments specifically (Obogo, Obriki et al., 2021), and integrated heat stress risk modelling addresses an exposure that is increasingly relevant to warehouse and terminal operation in hot climates (Arumosoye & Obriki, 2018). Leadership-driven safety culture transformation (Obogo et al., 2019a) and work linking management walkthrough frequency and coverage to culture outcomes (Obriki & Arumosoye, 2019) address the behavioural layer, and organisational learning maturity modelling addresses improvement over time (Arumosoye & Obriki, 2021).

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Aviation supplies a regulated-oversight analogue. A predictive compliance monitoring framework detects systemic safety risk through accumulated compliance data rather than through individual findings (Adeyelu, 2018), an adaptive safety management system implementation model addresses aerodromes in developing economies (Adeyelu, 2019), risk quantification is applied to wildlife strike hazard (Adeyelu, 2020), and a framework addresses encroachment and unauthorised structures around airport boundaries (Adeyelu, 2021). The first of these is the most transferable: it treats an accumulation of minor compliance failures as a leading indicator of systemic risk, which is precisely the inference a supplier quality or customs compliance programme should be making and generally does not.

3.6 Compliance, Financial Control, and Institutional Governance

Goods move only if the transactions around them clear, and the corpus treats this with more attention than the supply chain literature usually does. Trade-side work reviews legal barriers to import and export participation that prevent smaller firms from trading at all (Jones & Ominyi, 2020), and frameworks link agricultural value chains to household economic stability, connecting trade structure to development outcome (Jones & Ominyi, 2021). Regulatory clearance frameworks for cross-border mergers and acquisitions in African financial markets address a related coordination problem (Ominyi & Anichukwueze, 2020), and systematic review of anti-money-laundering and anti-bribery compliance regimes across emerging and developed markets addresses the screening obligations that now sit on cross-border payment and counterparty onboarding (Ominyi & Anichukwueze, 2021). Predictive analytics models for anti-money-laundering detection address the operational burden those obligations create (Atakpa, 2021), and integrated cybersecurity and anti-money-laundering governance frameworks treat financial crime and system compromise as a single exposure rather than as two programmes (Fadayomi et al., 2021), which is the same consolidation this review argues for across physical and informational risk.

Compliance is also treated as an organisational design problem. Post-merger compliance integration in multi-jurisdictional banking addresses the assimilation of one control environment into another (Ominyi, 2020), privacy-by-design embedding in corporate restructuring addresses the same question for data obligations (Ominyi, 2021), and global marketing law and consumer protection work addresses the multinational compliance frame (Anichukwueze et al., 2019). Ethics and compliance training frameworks designed for measurable behavioural change address the point at which policy becomes conduct (Anichukwueze et al., 2020), which is where most compliance programmes fail. Work on translating finance bills into strategy through sectoral impact mapping and regulatory scenario analysis addresses the anticipatory side, converting pending regulation into an assessable exposure before it takes effect (Akinola et al., 2020).

Payment and treasury capability determines whether a supplier remains solvent and willing to supply. Fintech-enabled transformation of transaction banking and digital lending is examined as a catalyst for small enterprise growth (Okafor et al., 2021), high-throughput digital collections platforms are engineered for large payment ecosystems (Osuji et al., 2021), and blockchain-based architectures are proposed for tamper-proof regulatory recordkeeping and audit readiness (Anichukwueze et al., 2021). Multinational cash flow consolidation and foreign exchange risk control through tiered treasury architecture addresses the liquidity side directly (Dada et al., 2021a), customer relationship management based sales forecasting supports the demand input to that planning (Dada et al., 2021b), and chief financial officer led strategic finance models address joint venture and cross-border partnership structures (Isiekwu et al., 2021) of the kind through which most distribution capacity in emerging markets is actually held.

Financial control and analytics supply the measurement layer. Strategic accounting systems are modelled as instruments of financial transparency and regulatory reliability (Bola-Sadipe et al., 2019), financial analytics is connected to enterprise value creation (Lawal & Oduleye, 2018a), and tax governance and cross-border compliance analytics address the obligations attaching to international movement of goods (Lawal & Oduleye, 2018b). Transfer pricing risk assessment addresses the pricing of intra-group flows that constitute much of global distribution (Lawal & Oduleye, 2019a), capital allocation decision modelling addresses where investment goes (Lawal & Oduleye, 2021a), and integration of financial planning analytics with corporate strategy addresses alignment (Lawal & Oduleye, 2021b). Public sector treatments add the governance analogue: budget compliance and statutory reporting review (Dogbatsey & Ebhojie, 2018), reconciliation control and financial workflow redesign (Dogbatsey et al., 2019), and cross-border segregation of duties and access control (Dogbatsey et al., 2021), the last of which is the financial counterpart to the access management discussed in Section 3.4.

Product-regulated distribution is represented by the pharmaceutical work in the corpus, which demonstrates what a fully governed chain looks like. Traceability and chain-of-custody integrity frameworks establish the identity of product at every transfer (Aneke & Adesemoye, 2019), risk-based decision-making frameworks structure judgement in good manufacturing practice environments where deviation is inevitable and the question is which deviations are tolerable (Aneke & Adesemoye, 2020), and risk-based interdiction models reframe import

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compliance as an active risk function rather than a documentary check (Aneke & Adesemoye, 2021). Few commercial distribution networks operate to this standard, and the corpus offers no assessment of what it would cost them to do so.

Finally, infrastructure delivery determines whether distribution capability arrives at all. Capital project delivery models are developed for high-risk healthcare infrastructure in developing health systems (Aminu-Ibrahim et al., 2019), sustainable diagnostic laboratory infrastructure models address resource-constrained settings (Aminu-Ibrahim et al., 2018), and infrastructure-driven expansion addresses access across underserved regions (Aminu-Ibrahim et al., 2020). Programme management models address coordinated multi-site expansion (Aminu-Ibrahim et al., 2021), risk-managed construction strategies address highly regulated facility development (Ogbete et al., 2021), and regulatory-compliant design systems address controlled environments (Ogbete et al., 2019). Analytical frameworks for efficiency in public infrastructure delivery address the procurement and delivery system through which such capacity is actually built (Nwafor et al., 2019b). Quantitative evaluation of locally sourced construction materials addresses the sourcing decision within that delivery system, where local availability trades against specification (Nwafor et al., 2019c), and analysis of climatic variables in building envelope optimisation addresses the design parameters that determine a facility's operating cost over its life (Nwafor et al., 2018). Spatial planning work connects facility layout to operational outcome (Ogbete et al., 2018), and sustainable materials and energy efficiency work addresses lifecycle cost (Ogbete et al., 2020). These are distribution nodes in the healthcare system, and the delivery risks they document are the same risks that attend the construction of any terminal, warehouse or processing facility. The system layer around them is addressed through governance and architecture frameworks for the data backbone of health system transformation (Ilodigwe & Adesemoye, 2021), pharmacy-led delivery and access models that constitute the last mile of medicine distribution (Ilodigwe & Adesemoye, 2020), financing and provider payment reform as the mechanism that funds that distribution (Ilodigwe & Adesemoye, 2019a), and analysis of why scientific innovation fails to reach health systems at all (Ilodigwe & Adesemoye, 2019b), which is a distribution failure described in another vocabulary. Frameworks for scaling mobile health solutions address the last mile directly, where the constraint on reaching a dispersed population is neither product nor transport but the channel through which service is delivered and sustained (Oparah, Gado et al., 2021).

3.7 Capability Building, Process Discipline, and the Organisational Layer

The least modelled and arguably most decisive determinant of resilience is organisational. Supply chain talent development models address capability building across distributed operations, where the scarce resource is not headcount but people able to exercise judgement under uncertainty at the point where a decision is required (Falemi et al., 2020). This is the only study in the corpus addressing supply chain workforce capability directly, which is itself a finding given that workforce unavailability was among the binding constraints of the period.

Process discipline is better represented. A systematic review and adapted define, measure, analyse, improve and control framework is developed specifically for small enterprises, recognising that standard implementations assume resources such firms do not have (Ambali et al., 2021). Multi-stakeholder governance alignment in joint venture operations provides a framework for coordinating processes across parties with divergent objectives (Eyetsemitan et al., 2020), which is the normal condition in contract logistics. Translating tax and regulatory requirements into compliance workflows addresses the conversion of external obligation into executable process (Eyetsemitan et al., 2021), and data-driven operations management frameworks address performance improvement in institutional settings (Efobi et al., 2021). Administrative process capability, which determines whether documentation, scheduling and record-keeping function under load, is addressed through work on contemporary office management practice (Onche, 2021) and on the personal and professional attributes of administrative staff as a determinant of organisational success (Onche et al., 2021). Professional ethics and workplace conduct research addresses the behavioural conditions under which those processes are performed honestly (Onche & Ogbonna, 2021), which matters in a distribution context because documentation integrity is a control and not a formality.

The safety literature again supplies what the supply chain literature lacks. Leadership-driven safety culture transformation in large workforces addresses how behaviour changes at scale (Obogo et al., 2019a), management walkthrough frequency and coverage are linked to culture outcomes in a form that is measurable (Obriki & Arumosoye, 2019), and organisational learning maturity modelling addresses the accumulation of capability between events (Arumosoye & Obriki, 2021). Institutionalising practice across project-based organisations addresses the specific problem of capability loss when temporary organisations dissolve (Obriki & Arumosoye, 2021), which is directly analogous to the loss of disruption-response capability when a crisis team is stood down. Competence formation is addressed from the educational side through professional development frameworks for practitioners managing non-standard cases (Yeboah et al., 2019) and through data-informed digital learning

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platforms that make capability development measurable rather than assumed (Orise & Niniola, 2020), and cross-cultural communication research addresses the coordination problem that arises when a network spans jurisdictions, languages and working conventions (Lilian et al., 2020). Energy sector work on integrating solar power into small-scale manufacturing (Sunday & Omoegun, 2018) and on optimising electrical load distribution for hybrid installations (Sunday & Omoegun, 2019) illustrates the same capability question in operations where technical skill is the binding constraint, programmatic strategy for renewable integration draws the lessons at portfolio level (Yeboah & Ike, 2020), and systematic review of product management strategies in network rollouts across emerging markets addresses the coordination of distributed deployment where local capability varies widely (Sanni et al., 2020c).

4. CONCEPTUAL MODEL

Section 3 identifies capabilities that the corpus develops in disciplinary isolation. This section integrates them into a single model of resilience in global distribution networks, shown in Figure 1. The model is offered as an organising structure and a set of testable propositions rather than as a validated theory, which is consistent with the state of the evidence described in Section 7.

The model has four layers and one spanning condition. Layer 1 is exposure, comprising the propagation mechanisms set out in Table 2. Layer 2 is network structure, comprising node criticality, geographic concentration, sub-tier convergence, coupling tightness and dependence on shared capacity the firm cannot unilaterally expand. Layer 3 is capability, organised as four pillars: procurement and supplier governance, digital systems and analytics, asset integrity and operational control, and risk governance and capability. Layer 4 is the resilience outcome, expressed as depth of service loss, survivable duration before failure, time to restore, extent of propagation and continuity of supply. Spanning all four layers is end-to-end visibility, which the corpus treats as the precondition for every other capability rather than as a capability in its own right (Atta et al., 2020; Nnabueze et al., 2021; Okonkwo, Agbabiaka et al., 2021).

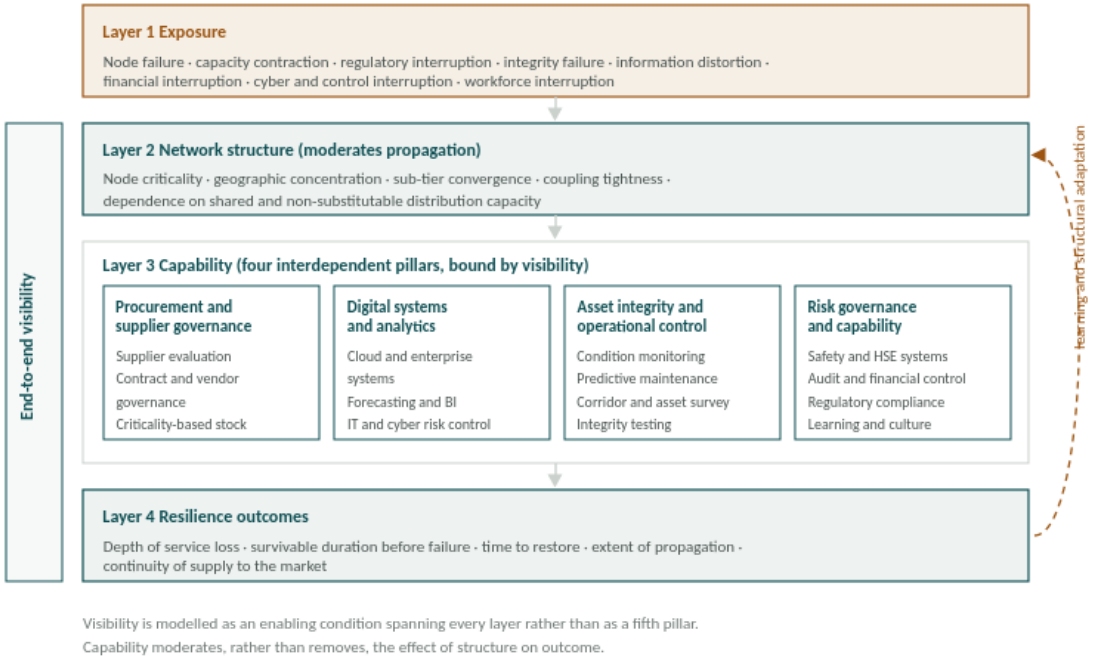

Figure 1. A layered model of resilience in global distribution networks, integrating the capability domains synthesised in Section 3. Exposure acts on network structure, structure determines propagation, capability moderates the relationship between structure and outcome, and outcome feeds back into structure through learning and adaptation. Visibility spans the model as an enabling condition.

Five propositions follow. Proposition 1. The severity of a disruption is determined more by network structure than by the magnitude of the initiating event, so that two firms exposed to the same shock will experience materially different outcomes according to node criticality and geographic concentration rather than according to the size of the shock (Agbabiaka et al., 2019; Ogunwole et al., 2021). This is the proposition the corpus supports most consistently and tests least.

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Proposition 2. Capability moderates rather than removes the effect of structure. A firm with strong analytical and procurement capability and a structurally concentrated network will detect disruption earlier and respond faster but will not avoid the interruption, because the substitution options that capability exploits do not exist in a concentrated structure (Ahiaeke Patrick et al., 2021; Okonkwo, Ogunwole et al., 2021). The distinction matters because much of the corpus implicitly treats capability investment as a substitute for structural change, and it is testable by comparing detection speed against realised service loss.

Proposition 3. Visibility is an enabling condition rather than a fifth pillar, and its marginal value is conditional on the authority and capacity to act on what it reveals. A visibility investment made without a corresponding change in decision rights should therefore produce no measurable improvement in resilience outcome, which is a strong and falsifiable claim (Arumosoye & Obriki, 2020; Nnabueze et al., 2021; Obriki & Arumosoye, 2019).

Proposition 4. The four pillars are complements rather than substitutes, and the binding constraint sits at the weakest pillar rather than at the average. A firm with advanced forecasting, automated procurement and a well-governed supplier base will still fail if its access controls are compromised, its critical assets are unmaintained or its contractors are ungoverned, because the pillars address different propagation mechanisms and none substitutes for another (Adaramola et al., 2018; Mbonu et al., 2020a; Obogo, Uduokhai et al., 2021).

Proposition 5. The feedback path from outcome to structure, through learning and post-event adaptation, is the mechanism by which resilience improves between disruptions, and it is the least instrumented part of the system in supply chain research though it is well instrumented in safety research (Arumosoye & Obriki, 2019; Arumosoye & Obriki, 2021; Obriki & Arumosoye, 2021). This asymmetry is the single clearest opportunity for transfer that the corpus reveals.

The model's use is diagnostic rather than prescriptive. It directs attention to the layer at which a given exposure must be addressed: a structural exposure cannot be remediated by capability investment, a capability gap cannot be remediated by restructuring, and neither can be located at all without the visibility that spans them.

Table 2. Propagation mechanisms in global distribution networks and where the corpus addresses them.

Mechanism	Description	Distribution consequence	Representative treatment
Node failure	Loss of a supplier, facility or terminal	Interruption of a flow path until substitution or repair	Critical infrastructure resilience (Ogunwole et al., 2021); programme risk model (Agbabiaka et al., 2019)
Asset degradation	Equipment condition deteriorates below serviceable limits	Throughput falls without any external event	Predictive maintenance (Adaramola et al., 2018); integrity testing (Atta et al., 2021)
Capacity contraction	Available capacity falls below committed demand	Allocation, rationing and queueing	Inventory and uptime modelling (Okonkwo et al., 2018b); materials readiness (Okonkwo, Agbabiaka et al., 2021)
Regulatory interruption	Compliance, licensing or customs failure halts a lawful flow	Goods present but legally immobile	Regulatory-compliant procurement (Okonkwo, Ogunwole et al., 2021); import interdiction (Aneke & Adesemoye, 2021)
Integrity failure	Product or record loses chain-of-custody assurance	Rejection, recall and loss of substitute supply	Traceability and custody (Aneke & Adesemoye, 2019); audit trail integrity (Oshoba et al., 2020)
Information distortion	Ordering and forecast signals diverge from demand	Amplified swings and stranded inventory	Forecast accuracy and inventory efficiency (Aifuwa et al., 2020)
Financial interruption	Settlement, liquidity or counterparty failure	Supplier withdrawal despite physical capability	Treasury and FX control (Dada et al., 2021a); collections platforms (Osuji et al., 2021)
System compromise	Loss of control over the systems that direct movement	Assets intact but undirectable	Incident response (Dosunmu & Ogundele, 2021); zero trust for control systems (Ahmed et al., 2021)
Execution failure	Controls exist but are not performed as designed	Latent exposure until an event reveals it	Human error causation (Obriki & Arumosoye, 2020); contractor compliance (Obogo, Uduokhai et al., 2021)

The mechanisms are not mutually exclusive, and the characteristic feature of a severe disruption is their simultaneous and interacting operation.

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5. DISCUSSION

Three claims are well supported by the corpus. The first is the structural turn in resilience. Across procurement, infrastructure and safety contributions, severity is consistently attributed to the configuration of the system rather than to the size of the initiating event (Agbabiaka et al., 2019; Arumosoye & Obriki, 2020; Ogunwole et al., 2021). The practical corollary, which the corpus states less often than it implies, is that a firm cannot analyse its way out of a structurally concentrated network.

The second is the elevation of procurement into the central instrument of risk control. The corpus supports this through vendor evaluation incorporating physical exposure (Ahiaeke Patrick et al., 2021), contract and vendor governance (Okonkwo et al., 2019), inventory positioned against criticality rather than volume (Okonkwo, Agbabiaka et al., 2021; Okonkwo et al., 2018b), and compliance screening treated as a sourcing constraint rather than a downstream check (Okonkwo, Ogunwole et al., 2021). This is a more specific prescription than the general call for resilience that followed the disruptions of the period, and it is actionable within a procurement function's existing authority.

The third, and the contribution this review is most confident in, is the structural equivalence between supply chain resilience and the risk disciplines that surround it. Safety management has hazard identification, near-miss reporting and contractor governance where supply chain management has risk registers and supplier audits (Arumosoye & Obriki, 2019; Obogo et al., 2019; Obogo, Uduokhai et al., 2021). Asset integrity has measured condition where supply chain management has estimated likelihood (Atta et al., 2021; Atta et al., 2020). Internal audit has risk-proportionate assurance where supply chain management has uniform supplier coverage (Akomolafe & Agu, 2019a; Akomolafe & Agu, 2019b). Information risk has embedded control design where supply chain management has post-hoc compliance (Mbonu et al., 2020a). In each pairing the adjacent discipline has the more developed method, and in each case the transfer is straightforward because the underlying problem, allocating scarce preventive attention across a large population of potential failure points, is identical.

Two boundary conditions qualify that transfer argument, and stating them is necessary if the claim is to be useful rather than merely attractive. The first is measurability. Condition monitoring works because the state of a physical asset is observable by instrument, so a measurement can replace a judgement (Adaramola et al., 2018; Atta et al., 2020). The state of a supplier is not observable in the same way: its financial position, its own upstream dependencies and its production reliability are disclosed selectively and at the supplier's discretion. The inferential apparatus therefore transfers while the measurement does not, and the gap must be closed either by contractual disclosure or by the kind of indirect spatial inference that the contamination and vulnerability modelling literature develops for systems that cannot be directly inspected (Azeez & Badmus, 2018; Badmus & Olamide, 2019; Lamidi & Olamide, 2018). The second boundary condition is authority. Contractor safety governance works partly because a regulator can withdraw permission to operate and a principal can remove a contractor from site, so the sanction behind the standard is credible (Arumosoye & Obriki, 2020; Obogo, Uduokhai et al., 2021). A buying firm holds no equivalent sanction over a supplier on which it depends more than the supplier depends on it. These mechanisms therefore transfer most readily where the buyer holds concentrated purchasing power and least readily in exactly the fragmented, capacity-constrained conditions where resilience matters most, which is a limitation of the argument rather than an objection to it.

Table 3 summarises the capability levers, the mechanism through which each is argued to operate, and the weight of evidence supporting it within this corpus. The pattern is instructive: the levers with the strongest evidence are those inherited from engineering and audit disciplines, and the levers with the weakest evidence are those native to supply chain research.

Table 3. Capability levers, mechanisms and weight of evidence in the reviewed corpus.

Capability lever	Mechanism argued	Evidence weight	Principal limitation
Criticality-positioned inventory	Extends survivable duration at items whose absence halts operation	Moderate	Depends wholly on condition and inventory visibility
Vendor evaluation with spatial exposure	Detects correlated exposure before it becomes interruption	Moderate	Not validated against realised supplier failure
Contract and vendor governance	Allocates risk to the party able to bear it	Moderate	Enforcement under market-wide scarcity untested
Condition-based maintenance	Infers failure risk from measurement rather than judgement	Strong	Rarely applied to distribution assets in the corpus
Non-destructive integrity testing	Detects defects before they become failures	Strong	Confined to energy and process assets

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Capability lever	Mechanism argued	Evidence weight	Principal limitation
Remote corridor monitoring	Extends condition assessment across geography	Moderate to strong	Not yet connected to supply chain decision systems
Hazard and near-miss systems	Converts weak signals into preventive action	Strong	No supply chain equivalent exists
Contractor safety governance	Holds parties the principal cannot supervise to a standard	Moderate to strong	Not transferred to supplier governance in the corpus
Risk-based assurance and audit	Allocates scarce assurance effort in proportion to exposure	Moderate to strong	Applied to financial rather than physical exposure
Identity, access and change control	Prevents undirected change to orders, prices and movements	Moderate	Owned outside the supply chain function
Predictive demand analytics	Reduces inventory inefficiency and improves planning	Moderate	Degrades under structural break in demand
Workforce capability development	Converts awareness into timely decision at the point of need	Low	Almost entirely unaddressed in this corpus

Evidence weight is assessed relative to this corpus only, and reflects the balance of empirical to conceptual treatment together with the directness of the outcome measured.

6. IMPLICATIONS FOR PRACTICE

Five implications follow with reasonable confidence. First, rank exposure by consequence rather than by estimated likelihood. Probability estimates for rare events are unreliable, whereas the operational consequence of a node being unavailable for its expected restoration period is estimable from engineering and contractual facts, and the risk-based assurance literature consistently supports this orientation (Akomolafe & Agu, 2019a; Akomolafe & Agu, 2019b; Dosunmu & Ogundele, 2019).

Second, measure condition rather than infer it. The single clearest transfer available to a distribution operation is the substitution of measured asset condition for estimated asset risk, using the inspection and monitoring methods already standard in energy and process industries (Adaramola et al., 2018; Atta et al., 2021; Atta et al., 2020; Sunday et al., 2020). A register that records what a firm owns is not a substitute for data that records what state it is in.

Third, govern contractors as the safety literature governs them. Distribution is executed largely by parties the principal does not employ, and the mechanisms for holding such parties to a standard, namely defined accountability, verified compliance and consequence, are better developed in contractor safety management than in supplier management (Arumosoye & Obriki, 2020; Obogo et al., 2019b; Obogo, Uduokhai et al., 2021).

Fourth, build a near-miss capability. Most disruptions are preceded by observable signals that were not acted upon, and the organisational conditions under which people report such signals are well understood in safety research and absent from supply chain practice (Arumosoye & Obriki, 2019; Obogo, Arumosoye et al., 2021; Obriki & Arumosoye, 2020).

Fifth, fix decision rights before investing in visibility. Response speed is limited by authorisation rather than by information, and a visibility investment made without a corresponding change in who may decide and commit will produce documentation rather than capability (Mbonu et al., 2020a; Nnabueze et al., 2021; Obriki & Arumosoye, 2019).

7. LIMITATIONS

Four limitations of the corpus and two of the review itself should temper confident reading of any conclusion drawn here. Within the corpus, conceptual and framework contributions substantially outnumber empirical studies, so most claims are proposals rather than tested effects; the studies that report outcomes, largely in the safety and maintenance domains (Obogo et al., 2020c; Sunday et al., 2020), are the exception rather than the pattern. Measurement conventions are not shared, so resilience is variously operationalised as a framework property, a performance indicator, a forecast accuracy figure and a narrative assessment, and these are not comparable. The cost of resilience is asserted throughout and estimated nowhere, so no study establishes what a given increment of continuity actually costs in a specified network. And sub-tier visibility is consistently treated as a platform and technology problem (Nnabueze et al., 2021) when the binding constraint is the incentive of a supplier to disclose its own dependencies, a question the corpus does not address at all.

A further limitation concerns the unit of analysis. The corpus reasons predominantly at the level of the firm, the facility or the project, whereas several of the mechanisms identified in this review operate at the level of the network or the sector. Propagation, allocation under scarcity and the exhaustion of shared distribution capacity

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are all properties of a system of firms rather than of any one of them, and none of the studies reviewed here observes a network in aggregate. Conclusions about network-level resilience are therefore inferred from firm-level evidence, an inference that holds only where individual behaviour aggregates without interaction effects. The disruptions that motivate this literature are precisely the cases in which that assumption fails, since simultaneous rational responses by many firms, each protecting itself, are what convert a shortage into a scarcity. The corpus does not test the aggregation assumption, and this review cannot resolve it.

Two limitations attach to the review. The corpus is bounded by a supplied reference list rather than by an exhaustive search, so it is a defensible sample of the relevant literature rather than a complete census, and studies outside it may qualify or contradict the conclusions reached here. The corpus is also weighted toward emerging-market and West African settings, which strengthens the external validity of its infrastructure and institutional findings in those contexts and limits generalisation to networks operating under different regulatory and capacity conditions. Finally, the 2021 boundary that gives the review its vantage point also excludes the substantial body of work published subsequently, and conclusions about what the field had achieved should be read as bounded by that date rather than as current assessments.

8. FUTURE RESEARCH

Eight priorities follow from the limitations and from the transfer opportunity identified in Section 5.

1) Test the transfer directly. The central claim of this review, that safety, integrity and audit methods outperform their supply chain equivalents at the same task, is testable by applying hazard identification, near-miss reporting or risk-proportionate assurance to a supplier base and comparing detection and prevention rates against conventional supplier audit (Akomolafe & Agu, 2019a; Arumosoye & Obriki, 2019; Obogo et al., 2019).

2) Establish measurement standards. Operationally defined and independently verifiable resilience metrics are required before cumulative empirical progress is possible. Condition-based measures drawn from integrity engineering are a more promising foundation than survey scales, because they are observable by a third party (Adaramola et al., 2018; Atta et al., 2020).

3) Estimate the cost of continuity. The trade-off between resilience and cost is asserted throughout the corpus and quantified nowhere. Estimating the marginal cost of an additional period of survivable duration in a specified network, and how it varies with structure, is feasible with existing methods (Okonkwo, Agbabiaka et al., 2021; Okonkwo et al., 2018b).

4) Validate spatial supplier risk assessment. Geospatially informed vendor evaluation should be tested against observed supplier failure, so the field can distinguish models that detect correlated exposure from models that describe it after the event (Ahiaeke Patrick et al., 2020; Ahiaeke Patrick et al., 2021).

5) Address the disclosure incentive problem. Sub-tier visibility should be studied as a mechanism design question rather than a platform specification question, including what disclosure arrangements are individually rational for a supplier and what role a trusted intermediary could play (Mbonu et al., 2018; Nnabueze et al., 2021).

6) Connect information risk to physical continuity. Access control, change management and incident response are modelled as information outcomes and not as delivery outcomes (Dosunmu & Ogundele, 2021; Mbonu et al., 2020a; Oshoba et al., 2019). Joint models of system compromise and physical flow interruption would address a failure mode neither literature currently captures.

7) Instrument the learning path. The feedback from disruption to structural change is well instrumented in safety research and absent in supply chain research (Arumosoye & Obriki, 2021; Obriki & Arumosoye, 2019; Obriki & Arumosoye, 2021). Longitudinal designs that observe what a firm actually changes after a disruption, and whether the change survives, would address the decay of organisational memory directly.

8) Study decision capability under disruption. Workforce and authority questions are almost entirely unaddressed in this corpus (Falemi et al., 2020). Research designs that observe how quickly and how well distributed organisations decide under stress would address the variable practitioners consistently identify as decisive.

9. CONCLUSION

This review set out to map what was known about resilience and risk management in global distribution networks by 2021, across a corpus deliberately drawn from supply chain research and the engineering, information and control disciplines that surround it. Three conclusions follow.

The first is that the field's own centre of gravity had already shifted from recovery toward structure. Severity is attributed to node criticality, geographic concentration and dependence on capacity the firm cannot expand, rather than to the magnitude of the initiating event (Agbabiaka et al., 2019; Ogunwole et al., 2021). The second is

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that procurement, not logistics, had become the operative instrument of risk control, through vendor evaluation, governance, criticality-based inventory and compliance screening (Ahiaeke Patrick et al., 2021; Okonkwo et al., 2018b; Okonkwo, Ogunwole et al., 2021; Okonkwo et al., 2019).

The third conclusion is the one this paper contributes. The disciplines adjacent to supply chain management had, by 2021, already solved several problems that supply chain resilience research was still formulating. Measuring condition instead of estimating risk, converting weak signals into preventive action, governing parties one cannot supervise, and allocating assurance in proportion to exposure are all mature practices in integrity engineering, safety management and internal audit (Akomolafe & Agu, 2019a; Arumosoye & Obriki, 2019; Arumosoye & Obriki, 2020; Atta et al., 2020). Their absence from supply chain resilience work is not a gap in knowledge but a gap in transfer, and it is the most tractable opportunity the corpus reveals.

What the corpus does not yet offer is evidence commensurate with its ambition. It is rich in architecture and poor in tested effect, it has no shared measurement convention, and it costs nothing it recommends. Until indices are validated against realised disruption, supplier risk models tested against observed failure, and continuity investments costed against the interruption they demonstrably prevent, firms operating global distribution networks will continue to make the most consequential decisions in their operating model on the basis of judgement supported by argument rather than by measurement.

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