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DIGITAL SUPPLY-CHAIN VISIBILITY AND BUSINESS CONTINUITY IN EMERGING MARKETS: RESILIENCE UNDER ENVIRONMENTAL UNCERTAINTY

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Abstract

Recent disruptions have encouraged firms to invest in tracking platforms, enterprise integration, analytics, Internet of Things devices, and digital supply-chain twins. However, greater data availability does not automatically create resilience or business continuity. This integrative conceptual review examines how digital supply-chain visibility can support continuity through the mediating capability of supply-chain resilience and how environmental uncertainty conditions that relationship. Drawing on organisational information-processing theory and supply-chain resilience research, the paper distinguishes data connectivity from actionable visibility and resilience from robustness, recovery, and long-term viability. Visibility is defined through identity, location, status, event, and risk information across multiple supply tiers. The synthesis identifies sensing, interpretation, coordination, and reconfiguration as the mechanisms through which visibility becomes resilience. It also analyses countervailing risks: information overload, low-quality data, cybersecurity exposure, platform dependence, supplier exclusion, and false confidence in dashboards. Five propositions link visibility quality, relational integration, resilience, environmental uncertainty, and business continuity. A research design for manufacturing, logistics, retail, e-commerce, and refurbished-electronics firms is proposed that combines time-lagged survey data with operational disruption indicators. The paper contributes by treating visibility as an information-processing capability rather than technology possession and by explaining when visibility improves continuity, when its value rises under uncertainty, and when digital interdependence creates new vulnerabilities.

1. INTRODUCTION

Supply chains have faced disruptions due to pandemics, geopolitics, extreme weather conditions, cyber attacks, congestion, regulatory changes, and supplier failures. Companies' attempts to overcome these challenges include increasing their digital visibility. Real-time tracking, integration of enterprise systems, supplier portals, predictions, blockchain, and digital twins will help them understand where material is, its status, and risks that could disrupt flows (Iqbal et al., 2020).

Intuitively, more visibility leads to more resilience. However, there is no automatism in it. There may be detailed information on first-tier warehouses, but none on second and third-tier suppliers. Information can be received too late, be poorly defined or be siloed inside particular functions. Managers might see the disruption unfolding, but will lack alternative suppliers, capacity flexibility, decision-making authority, or coordination practices. The dashboard will display the vulnerability but will not enable an action (Khattak et al., 2017; Iqbal et al., 2024).

Academic research acknowledges the importance of information sharing and connectivity and emphasises organisational capabilities. For example, according to Brandon-Jones et al. (2014), information sharing and connectivity increase visibility, which affects resilience and robustness. Wieland and Wallenburg (2013) demonstrate that communication, cooperation, and integration increase resilience through relational competencies. Moreover, new research demonstrates the connection between digital supply chains and resilience to sustainability outcomes in a dynamic environment (Ali et al., 2024; Ibrahim et al., 2024). Thus, digital technology is used in interorganizational contexts and decision processes (Khattak et al., 2019; Iqbal et al., 2025a,b).

It is also important to distinguish between resilience and continuity. Resilience deals with preparation for, response to, and recovery from disruptions, while business continuity means maintaining and restoring key processes, services, dependencies, and recovery goals within time and performance criteria. The supply chain can recover financially over time, yet fail to provide essential products during a disruption. Thus, continuity implies prioritising the key processes, services, dependencies and recovery goals (Abbass et al., 2022; Khattak et al., 2019 ab).

Environmental uncertainty increases the need for information processing but undermines the reliability of historical information. High uncertainty about demand, regulation, suppliers and disruptions increases the value of visibility. Nevertheless, extremely high uncertainty can overload analysis systems and make predictions useless. The impact of uncertainty may be curvilinear or contingent on organisational interpretations and flexibility (Al-barrow et al., 2021; Bushra et al., 2022).

In this paper, the question is as follows: How is digital visibility in the supply chain transformed into a resilience capability? How is resilience translated into business continuity? When and how does environmental uncertainty strengthen or undermine these relationships? The conceptual framework is intended to be used by firms in emerging markets facing infrastructure issues, fragmented suppliers, informal practices, and varying levels of digital maturity.

2. Methodology

An integrative literature review of operations management, information systems, risk management, logistics, and organisational theory will be used in this study. Integrative synthesis is appropriate in this case due to differing definitions of supply-chain visibility and resilience, and research through surveys, case studies, simulations, theoretical models, and analyses (Snyder, 2019; Torraco, 2005).

Search terms consisted of “digital supply chain,” “supply-chain visibility,” “information sharing,” “supply-chain resilience,” “business continuity,” “environmental dynamism,” “disruption recovery,” and “digital twin.” Peer-reviewed empirical and conceptual articles were used, with seminal articles selected to define resilience, relational capability, and information processing. Data was coded based on information types, tier coverage, analysis approach, coordination capability, disruption stage, performance outcomes, uncertainty, and digital risks.

Concepts and relationships guide the organisation of the paper, following Webster and Watson (2002). This paper is not a systematic review and does not provide comprehensive coverage or causal effects. A proposition-based framework can emerge from this review and be suitable for empirical testing.

3. Theoretical Foundation: Organisational Information Processing

According to organisational information-processing theory, information needed to make decisions depends on the level of uncertainty. The organisations have three strategies to cope with uncertainty: reducing the need for information through buffers and standardisation, and increasing processing capacity through lateral ties, information systems, and coordination. Supply chains pose such challenges across organisational boundaries.

Viability provides greater information-processing capacity from a technological and organisational viewpoint. Technical capacity pertains to the processes of capturing, transporting, integrating, storing, and analysing information. Organisational capacity involves common interpretation, authority, processes, and relationships. When technical capacity increases while organisational capacity remains low, companies suffer from information overload and passive observation.

This approach helps understand why visibility is viewed as a capability. Connectivity is the antecedent of visibility; visibility is the capability to see and interpret information; resilience is the capability to use this information to prepare, react, and adapt. Business continuity is the result of this process.

4. Defining Digital Supply-Chain Visibility

Visibility is defined as the extent to which the relevant parties can obtain reliable and meaningful information about supply chain objects and events. This construct comprises at least five types of information. Identity information informs about which supplier, object, product batch, or asset is concerned. Location information informs about its location. Status information informs about quantity, state, quality, or stage. Event information reports delays, failures, inspections, handovers, or regulations. Risk information estimates exposure, likelihood, or expected impact.

The construct also features breadth and depth. Breadth refers to functions and processes, including procurement, production, inventory, logistics, and customer delivery. Depth refers to tiers above direct suppliers. Although many companies have internal transparency, most have no visibility into their upstream dependencies. High-tier visibility is hard to achieve due to limited technology, reluctance to disclose, and suppliers' commercial sensitivity.

Information must be as visible as possible. It should be accurate, up to date, sufficiently complete for decision-making, interoperable, and comprehensible. Extra information reduces visibility by burying critical signals in a deluge of data. Therefore, the construct should not be evaluated merely in terms of technology adoption.

5. From Visibility to Resilience

5.1 Sensing

Visibility enables early identification of anomalies and threats. Tracking can detect issues such as delayed transportation, unusual inventory depletion, malfunctioning equipment, poor-quality suppliers, or an unexpected change in demand. Predictive systems can combine internal and external information to detect patterns of risk. Digital supply chain twins can model disruptions and reaction scenarios (Ivanov & Dolgui, 2020).

Data limitations restrict sensing. New disruptions may have nothing in common with historical ones, while risks in upstream processes will go unnoticed. Companies need to combine digital information with communication with suppliers, market intelligence, and front-line insights.

5.2 Interpretation

The value of information depends on managerial interpretation. The same delay could be irrelevant for a nonessential product and critical for the unique component. The process of interpretation involves understanding dependencies, inventories, opportunities for substitution and time frames. Recovery time frames are usually easier for cross-functional teams than for analysts.

5.3 Coordination and reconfiguration

To be resilient, organisations have to react not only individually but collectively. Possible measures include reallocating inventory, adjusting transportation, finding substitutes, making changes to manufacturing, communicating with clients, and switching to alternative suppliers. Wieland and Wallenburg (2013) emphasise relational competencies, as cooperation is necessary in addition to information sharing.

Proposition 1: Digital supply-chain visibility will be positively associated with resilience when information is timely, decision-relevant, and supported by cross-functional and interorganizational interpretation routines.

Proposition 2: Relational integration will strengthen the positive relationship between digital visibility and supply-chain resilience.

6. Resilience, Robustness, and Business Continuity

Robustness is the capability to resist disruptions without significant performance losses. Resilience is about preparation, response, recovery, and adaptation. Agility refers to fast adaptation. Viability is an extension of the timeframe from resilience to long-term survival and service performance of the supply chain under change. The concepts share elements but are not interchangeable.

Business continuity is the implementation of resilience through specified operational objectives. Companies determine critical goods and services, maximum allowable downtime, recovery time objective, minimal required level of service, dependencies, and responsible personnel. Supply-chain resilience supports business continuity by ensuring the protection and recovery of these factors, rather than cost optimisation.

According to Wieland (2021), supply chain resilience must be understood as the capability to revert to a previous state and the ability to transform the supply chain relationships and structures. This concept is relevant for business continuity since some disruptions require not reverting but changing the supply chain network.

Proposition 3: Supply-chain resilience will mediate the positive relationship between digital visibility and business continuity performance.

7. Environmental Uncertainty

Environmental uncertainty encompasses demand variability, supply vulnerability, technological change, regulatory uncertainty, infrastructure vulnerability, and competitive volatility. With increasing environmental uncertainty, a firm requires more timely and varied information, making digital visibility of higher marginal value, as it can reduce detection and coordination delays.

At the same time, uncertainty diminishes predictability. Data based on stable times may not reflect how things unfold under uncertainty; high-frequency alerts may become too numerous for decision-makers; and competitors may be unwilling to share their data under uncertainty. In extreme situations, the use of modularity, redundancy, and decentralised judgments may become as important as analysis.

This implies a conditional relationship between uncertainty and visibility. Visibility becomes especially valuable when firms can respond to the problem. Under high constraints with no substitutes, visibility might point to issues without continuity preservation.

Proposition 4: Environmental uncertainty will strengthen the positive relationship between digital visibility and resilience up to the point where data reliability and response capacity become insufficient.

8. Digital Vulnerabilities and the Visibility Paradox

Digital integration produces fresh vulnerabilities. Cyberattacks, software downtime, corrupted data, supplier collapse, and disconnectedness can affect many partners at once. A centralised system will help with coordination, but also create potential points of failure. Companies might also feel

overconfident since dashboards create the illusion of control.

The visibility paradox lies in the fact that too much information can coexist with little actionable information. Companies may have a lot of information to monitor, but lack specific criteria and decision-making thresholds. An alert can become ordinary and overlooked. Information-sharing obligations might prevent small suppliers from providing data or force them to provide low-quality information. Strategic misreporting can result from commercial sensitivity.

Security and continuity planning must be combined. Important systems require alternative communication channels, manual processes, access restrictions, incident management, data verification, and disaster recovery testing. Technology architecture should be modular where possible.

Proposition 5: Digital dependence will weaken the visibility-continuity relationship when cybersecurity, data governance, and system-recovery capabilities are underdeveloped.

9. An Integrated Resilience Framework

The framework starts with connectivity and data-sharing practices. Such resources become visible when there is proper quality, range, and depth of information. Visibility facilitates sensing and interpretation. Relational integration and decision rights facilitate coordination and reconfiguration, leading to resilience. Resilience ensures continuity via preparedness, reaction, recovery, and adaptation. Environmental uncertainty increases information requirements but sometimes exceeds the capabilities for prediction and response. Digital risks provide another path from integration to disruption risk.

This framework clarifies that buying tracking technology alone is not enough. The firm requires governance around information ownership, definition, escalation, partnership, and response. The integrated use of technology, relations, and operational flexibility generates resilience.

10. Empirical Design Proposal

This model can be tested in manufacturing, logistics, retail, e-commerce, and circular-economy firms. Sectors in emerging markets that rely on imported parts and have fragmented suppliers are especially interesting. Data collection should involve supply chain, procurement, operations, logistics, and risk managers. Using more than one respondent will minimise single-informant bias.

Using a time-lagged approach, digital visibility and relational integration should first be measured, followed by resilience capability, and finally continuity consequences after an interval or disruption event. Perceptual measures should be complemented by objective criteria such as detection time, recovery time, fill rates, backorders, downtime, switching time for suppliers, and customer service continuity.

Structural equation modelling would allow examination of mediation and moderation, whereas configurational analysis would help identify alternatives to resilience paths based on visibility, redundancy, flexibility, and collaboration. Environmental uncertainty should be decomposed into demand, supply, regulatory, and infrastructure aspects. Common-method bias tests cannot replace design-based approaches like temporal separation and multi-source data.

11. Managerial Implications

First, companies need to map critical products, processes, suppliers, systems, and continuity objectives. The investment in visibility should focus on gaps relevant to decision-making, not on maximising data collection. It is important to establish which disruptions trigger alerts, which roles interpret them, who is authorised to respond, and how to contact partners.

Incentives and proportional requirements will facilitate supplier engagement. Major buyers can provide simple interfaces, training, or standards instead of shifting all technology costs onto suppliers. The data sharing agreement should define its purpose, access, retention, cybersecurity, and commercial confidentiality.

Continuity exercises need to include both physical and digital disruptions. A simulation can show whether the company is capable of acting even if the main platform is down. Continuity reviews should assess detection, decision-making, coordination, and recovery independently. An organisation that detects disruption early but responds slowly possesses different capabilities than an organisation that misses information upstream.

11.1 Designing an information architecture

Good visibility architecture should start from decisions, not from devices. First, managers should determine which continuity decisions need to be made, the minimum information required for each decision, the allowable lag,g and the appropriate person to make the decision. Based on that, the company can choose data sources and technologies. This back-decision approach minimises indiscriminate information collection and clarifies information quality standards.

Information needs to be structured. Operational managers need immediate information about events and statuses; tactical managers need information about trends, dependencies, and options; strategic leaders need information about concentration risk, network architecture, and scenario implications. The escalation rules need to be both automated and include a judgment component. A delay in the delivery of a commonly supplied product does not have to be reported to higher authorities. In contrast, a small delay in the delivery of a sole-source critical component may require escalation.

11.2 Resilience portfolios rather than a single solution

Visibility is just one of the many resilience resources. Redundancy, flexible capacity, multi-sourcing, modular product design, safety stock, supplier development, insurance and continuity plans can complement visibility. These resources involve trade-offs. Redundancy raises costs, while over-lean operations may eliminate buffers. Portfolio analysis evaluates combinations of these resources against a particular disruption profile.

Digital information can help firms manage their portfolios more effectively. Companies can add buffers at critical network points, develop suppliers, and simulate response scenarios. At the same time, managers should avoid treating the historical probability as the only parameter of rare or systemic events. Scenario planning is essential when estimates are unstable.

11.3 Governance of supplier data

Supplier data are relational assets. Demanding detailed data on capacities, inventories, costs, and locations can reveal the company's commercial weaknesses. Suppliers may be reluctant to provide information that the buyer can use for negotiation or bypassing intermediaries. Therefore, trust and contract protection impact data quality.

Governance should regulate the purpose of data exchange, access, and retention; cybersecurity; error correction; and the prohibition of secondary use of data. Mutual value helps encourage participation. In addition to reporting requirements, suppliers should be provided with forecasts, alerts or analytics. Independent platforms or standards may balance the power, but their governance and funding need to be considered.

11.4 Human expertise in digitally visible chains

While digital systems minimise search time, they do not substitute for expertise. Experienced planners know the limitations of substitutions, supplier behaviour, client tolerance, and informal arrangements. Deskilling workers and centralising all interpretations may harm resilience when the system is down or an unprecedented situation occurs.

Training needs to develop both analytical and operational skills. The team has to practice responding to challenging alerts, validating external information and acting without the main system. The disruption review should explain why human judgment deviated from the

recommendations and whether such deviation produced a positive result.

11.5 Measuring continuity value

The case for visibility is usually made in terms of efficiency, while the benefit in continuity terms is hypothetical until the disruption occurs. Companies can evaluate continuity value by avoiding downtime, minimising detection lag, lowering expediting costs, preserving revenue, fulfilling contractual agreements, and improving customer retention. These parameters should be interpreted carefully because losses in a counterfactual world are uncertain.

The balance of evaluation includes benefits from regular operations and option value during the disruption. The concept of real options suggests that information and flexibility create choices whose value grows with uncertainty. This approach can rationalise selective investments without claims that every technology brings positive returns.

12. Policy Implications for Emerging Markets

Policymakers can help build interoperable standards, cybersecurity capabilities, logistics infrastructure, trade information, and the digitisation of SMEs. Shared platforms should be designed to avoid vendor lock-in and provide accessible interfaces for small suppliers. Rules of data governance should ensure confidentiality and coordination.

Public institutions can also help by providing early warning information on weather, transportation, customs, health, and regulation issues. However, public dashboards are only useful when the data are timely and reliable. Continuity policy should acknowledge digital infrastructure, payment systems, cloud services, and telecommunications as supply chain dependencies.

13. Limitations and Future Research

The theoretical framework calls for longitudinal and event-based validation. Firm-level perceptions of resilience may fail to predict performance during severe disruptions. Future research will benefit from comparing anticipated capability and performance in recovery. Network-level studies will be required, as firm-level surveys may overlook dependencies and power asymmetries.

Measurement must distinguish between potential and the use of visibility. System coverage, data frequency, and integration are components of potential capacity, whereas access, interpretation, and action are the components of enactment. Combining these components into a single scale may lead to the misrepresentation of a firm that has sophisticated technologies but uses them ineffectively. Future research should also clarify whose visibility will be measured. For example, a buyer can see its suppliers, while suppliers have no access to demand information. In such a case, there will be asymmetric visibility rather than shared visibility.

Event-based sampling is a promising design. The researchers could measure baseline network and capability characteristics, and then collect structured observations when transport delays, supplier failures, cyber incidents, or changes in demand happen. Sequencing data collection would make it possible to trace detection time, escalation, decision making, partner communication, and recovery. This way, it would reveal which mechanisms function, rather than relying on generalised memory.

Visibility, ethics, and competition must be studied in the future. Information sharing improves continuity but may be used for surveillance, price pressure, or even exclusion. Supplier's willingness to share data may depend on procedural fairness and reciprocal value. A comparative study of buyer-owned, industry-owned, and independent platforms would reveal the governance structures that provide reliable information without excessive concentration of power.

Researchers need to examine the non-linear effect of uncertainty and visibility. Excessive monitoring leads to overload, while moderate redundancy yields better performance. Studies must examine the sustainability trade-off in questions such as whether emergency sourcing increases environmental or labour risks. Digital twins and

AI-based alerts call for an assessment of model error and user behaviour in addition to technical accuracy.

One important direction for future research will be the deterioration of visibility during the crisis period. Data quality, reporting frequency, and partner willingness to share information may decrease precisely at the moment when information becomes the most valuable. To test the resilience of a supply chain under stress, researchers could compare regular dashboards with those collected in the disruption period.

Small-firm research should be careful not to equate limited technological availability with a lack of visibility. Small businesses can use direct relationships, messaging tools, and experience, which allow them to receive information instantly but informally. Formal systems help continuity,y but can replace flexible communication with bureaucratic reporting. Comparative studies will help explore a hybrid arrangement that combines simple digital instruments and relational coordination. Research should also focus on the economic aspects of visibility – the affordability and interoperability of solutions, since subscription fees, integration, and data standards can determine the participation of smaller partners in the network.

Conclusion

Visibility via digital means can help improve business continuity, but only when achieved through resilience. The right and relevant information has to be analysed and communicated, connecting it to action and agility. Environmental uncertainty calls for greater visibility and makes predictions and coordination harder. Digital integration introduces cybersecurity and platform risks. Resilient supply chains incorporate technology and relational capacity, governance, agility, and recovery processes.

Declerations

Ethical Considerations and Declarations

This study was reviewed and approved by the Research Committee of the NUST Business School (NBS). This study was conducted in accordance with the ethical standards of the approving institution.

Declaration of Generative AI and AI-Assisted Technologies

During the preparation and revision of this manuscript, the authors used ChatGPT and Paperpal to support language editing, grammatical correction, and improvements in clarity and readability. These tools were not used to generate or modify research data, conduct statistical analyses, fabricate references, or make substantive research decisions. The authors critically reviewed and verified all AI-assisted content and accept full responsibility for the accuracy, originality, and integrity of the published work.

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