

(REVIEW ARTICLE)

Enhancing manufacturing supply chain resilience using data-centric ERP system design

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Abstract

Manufacturing supply chains have entered a stage in which resilience depends not only on redundancy, but also on the speed, quality, and governability of enterprise data. This review examines how data-centric ERP architecture can strengthen manufacturing supply chain resilience by repositioning ERP from a transactional repository to an operationally supported decision-making system. The article reviews recent peer-reviewed literature on resilience, digital supply chain twins, Industry 4.0 integration, analytics, blockchain-based traceability, and manufacturing recovery planning, especially with regard to architectural implications in the context of ERP-driven environments. Across the reviewed studies, common themes include the strategic importance of real-time visibility, semantic consistency across plants and partners, scenario-based replanning, and closed-loop execution control. At the same time, the literature remains divided: most resilience studies emphasize digital tools without addressing ERP data structures, whereas most enterprise-systems studies discuss integration without directly quantifying resilience. Important gaps remain in causal explanation, interoperability management, latency-sensitive master data design, and treatment of multi-tier manufacturing networks. A data-centric ERP design is therefore presented as one promising path for integrating sensing, planning, execution, and learning within a unified and robust information architecture.

Keywords: Data-Centric ERP; Digital Twins; Manufacturing Supply Chains; Resilience; Supply Chain Visibility

1. Introduction

Manufacturing supply chains are increasingly exposed to pandemic shocks, geopolitical disruptions, logistics failures, cyberattacks, and supplier-side capacity disruptions. In such conditions, resilience can no longer be understood merely as a recovery process activated after disruption. Recent resilience research increasingly frames the issue in terms of survivability, structural adaptability, and the persistence of decision quality under uncertainty, particularly in interdependent supply networks [1]. The change is important to manufacturing since disturbances seldom remain within a single place, plant, or planning node. Disruptions in material receipt, quality control, production scheduling, inventory positioning, customer service, and financial control can propagate across procurement, production, logistics, and commercial functions within hours. A resilience approach that is not grounded in enterprise data architecture therefore faces a structural limitation: the decisions can be well-intended but continue to be slowed or skewed by fragmented records, inconsistent definitions of items, poor event visibility, and disjointed planning logic.

This vulnerability of global production systems to data latency became especially visible in disruption-modeling studies published during the early stages of the pandemic. Simulation has shown that even limited epidemiological or mobility-related shocks can cause temporary supply-chain impacts to become acute as long as decision-makers are not provided with real-time data on changes in lead time, inventory levels, and network capacity [2]. The latter can be extended to situations outside of pandemics. Disruption response in manufacturing contexts depends on the ability to swiftly

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identify modifications in operations, model those modifications faithfully within enterprise systems, and transform new data into updated plans before a local disruption escalates into a global malfunction on the network. In this respect, transaction-centered ERP architectures often prove inadequate. Traditional ERP implementations have been effective for record keeping, financial control, and process standardization, but many remain configured around batch synchronization, rigid master-data structures, and slow response to external supply-chain events. These constraints undermine resilience since the backbone of information is unable to provide quick scenario creation, prioritization of exceptions, and coordinated recovery efforts.

Recent empirical studies on resilient manufacturing and service supply chains suggest that resilience depends on the quality of digital information, the intensity of coordination, and the speed of organizational decision-making [3]. In the automotive and airline cases, resilience has been attributed to visibility, intensity of collaboration and the ability to reconfigure processes when faced with stress compared to redundancy alone [3]. That finding has important implications for ERP design in manufacturing companies. ERP cannot be a passive ledger when resilience depends on reconfigurable coordination. A more robust design would need data structures to connect supplier signals, production constraints, logistics events, and commercial commitments in a manner that can be cross-functionally interpreted. In practice, this would translate to an increased emphasis on event-based data capture, harmonized master data, cross-entity identifiers and analytical layers which can be utilized to compare viable response options. The resulting architectural question is how ERP should be redesigned when the central objective is resilient adaptation rather than efficiency alone.

A second problem concerns the gap between practice and theory. Post-pandemic studies of resilient supply chains show that managerial demand tends to center on implementable capabilities such as visibility, flexibility, risk anticipation, and recovery governance, whereas much of the academic literature to date addresses individual tools, individual disruptions or individual functions [4]. This gap is central to the present topic. A lot of research on supply chain resilience typically discusses digital twins, analytics, control towers, and traceability, but does not frequently go further to address how the capabilities will be incorporated into the main enterprise systems. Conversely, enterprise-systems research is more likely to write about the adoption of ERP, integration, or the move to the cloud without connecting the architectural choices with the absorption of disruptions, rate of recovery, or control of propagation. This has left the literature without a mature account of data-centric ERP design as a resilience mechanism for manufacturing supply chains. The absence of such an integrative account inhibits scholarship and practice, as the performance of resilience performance in manufacturing is strongly mediated by the information models and process orchestration, as well as interface logic and decision rights in enterprise platforms.

The topic is especially timely in the current research environment. The Industry 4.0 discourse has broadened the digital frontier in manufacturing with cyber-physical systems, interoperability platforms, digital twins, and advanced analytics [5]. Nevertheless, this broader digital discourse does not always address the ERP problem. Manufacturing firms typically add sensory technologies, dashboards or custom applications to the underlying legacy ERP whose data logic is normally slow, siloed or semantically inconsistent. Local digital savvy can be in harmony with enterprise frailty in these situations. A plant may generate high-frequency machine data while still suffering from poorly integrated supplier events, a planning team can do high fidelity simulations if a master-data error corrupts the scenarios, a visibility dashboard can exist when execution confirmation is too slow to continue to integrate, etc. The general conclusion of this review is that resilience is not achieved simply by adding more digital tools, but by re-architecting ERP with the principles of data-centricity that have the potential to support resilient sensing, interpretation, decision-making, execution, and learning across the manufacturing supply chain.

This article therefore reviews recent peer-reviewed journal literature published between 2020 and 2025 that are most relevant to the improvement of manufacturing supply chain resilience in terms of data-centric design of ERP systems. The review is tightly coupled with manufacturing supply chains and with the architectural location of the ERP as the integrative enterprise backbone. The literature review below will be represented in thematic clusters, methodology, conceptual framework regarding the particular topic, comparison of the reported findings of the studies, contradictions and limitations, and future research directions that may help to turn the sphere of fragmented digitalization into the sphere of truly resilient ERP-based manufacturing systems.

2. Literature Review

One major stream of recent studies treats resilience as a network capability rooted in digital representation and analytical foresight rather than redundancy alone. Digital supply chain twin literature suggests that disruption management is more effective where the supply network can be modeled as an executable model that connects the structure, flows, constraints and scenario logic [6]. Survey evidence on resilience analytics suggests that there is a

developing methodological emphasis in simulation, predictive modelling, and decision support in the face of uncertainty [7]. The same idea is carried over to the digital twin literature in manufacturing which considers the virtual representation as a state change monitoring mechanism, alternative response testing mechanism, and reduces the temporal distance between events and decisions [8]. Empirical findings on Industry 4.0 and the supply chain performance also reveal that digital integration can improve the speed of coordination and responsiveness of operations but the impact on resilience depends on the level of implementation and not the availability of technology [9]. The ERP-related architectural implication of this cluster is clear: a robust manufacturing base would need to have an enterprise backbone that can sustain high-quality state representation across procurement, production, inventory, logistics and partner interfaces.

A second literature cluster focuses on disruption propagation, architectural reconfigurability, and digital maturity. Ripple-effect studies confirm the interaction between structural and operational shocks, i.e., local inventory or lead-time shocks may have an effect upstream and downstream when information delays prevent coordinated responses [10]. Supply Chain 4.0 research reinforces this finding by framing digital maturity as a shift from autonomous automation to interdependent, intelligent and responsive supply systems [11]. The role of the fact that data integration, analytics, and connectivity alter the viability of visibility and coordination in the supply chain processes as a matter of practice is also emphasized in research on the enablers of digital technologies [12]. Recent review evidence points to Industry 4.0 applications as resilience enhancers; however, numerous applications are still tool-focused and loosely regulated at the data architecture tier [13]. In other words, digital technologies may strengthen resilience, yet the literature repeatedly shows that the benefits are not fully realized because the underlying enterprise data structures are not interoperable, fail to offer decision traceability, and have no ability to re-plan in a short period.

Table 1 Summary of key findings

Ref	Focus	Key Findings
[6]	Digital supply chain twin for disruption-risk management	Digital twin logic can connect network structure, inventory, lead times, and scenario analysis, enabling faster disruption sensing and response design when integrated with enterprise planning data.
[7]	Resilience analytics review	Quantitative resilience research increasingly depends on simulation, optimization, and decision analytics, yet operational data architecture remains under-specified in many studies.
[8]	Digital twin literature in manufacturing	Digital twins support state visibility, monitoring, and what-if analysis, but value depends on reliable data links between physical operations and enterprise information systems.
[9]	Industry 4.0 effects on supply chain performance	Performance improvement follows from integrated digital implementation rather than isolated technology deployment, with responsiveness and coordination as major mechanisms.
[10]	Ripple effect and bullwhip interaction	Structural disruption propagation intensifies when operational control lacks timely, network-wide information and coordinated corrective action.
[11]	Supply Chain 4.0 maturity	Digital maturity progresses from process digitization toward connected intelligence, requiring integration across planning, execution, and decision layers.
[12]	Digital technology enablers in supply chain management	Connectivity, analytics, and information sharing improve visibility and coordination, but organizational and data-integration barriers limit realized value.
[13]	Industry 4.0 and supply chain resilience review	Digital tools can strengthen resilience through visibility, flexibility, and decision support, yet evidence remains heterogeneous and measurement remains inconsistent.
[14]	Production recovery planning under disruption	Formal recovery planning improves manufacturing response by reallocating capacity and inventory under disrupted demand-supply conditions.
[15]	Blockchain for supply chain management	Shared event validation and traceability can improve trust and information integrity, although scalability and integration with legacy enterprise systems remain challenging.

A third cluster focuses on recovery planning, traceability, and decentralized response under acute disruption. Recovery manufacturing studies indicate that production systems facing abrupt demand and supply shocks benefit from formal recovery models that reallocate capacity, materials and service promises under time pressure [14]. Although blockchain studies in supply chains do not directly address ERP design, they offer a useful perspective on data governance, namely, its indelibility, traceability of events and shared validation of shared states across organizational boundaries [15]. The industry 4.0 digitalization studies also reveal that each of the three components of sustainability, resilience, and the digital integration can be mutually reinforcing in case operational data become more transparent and operational throughout the value chain [16]. Its relevance to ERP design is that there is a requirement to balance the internal data discipline and the external event reliability. Resilience is not improved simply by increasing data volume. The improvement is conditional on the capacity to believe, interrelate and regulate supplier records, shipment events, production orders, inventory condition and exception signal in an enterprise platform that is decision capable.

A fourth literature cluster focuses on patterns of implementation and organization preparedness in manufacturing. The studies relating Industry 4.0 with lean manufacturing have shown that the performance benefits are based on process discipline, standardization, and consistent integration instead of being sporadic in the use of technology [17]. Implementation-maturity studies support the view that maturity should be assessed at strategy, data, technology, people, and governance levels, and not at hardware level [18]. This particularly matters to the ERP-oriented resilience since most manufacturing companies still have fragmented module designs, inconsistent product and supplier master data and cross-functional ownership of event semantics. The literature therefore supports a major conclusion: resilience-focused ERP design is not merely a software-selection issue, but an enterprise-architecture problem involving data models, interface logic, role definition, and response time.

A comparative reading of Table 1 indicates that there is a common pattern. The greatest resilience gains are achieved when there is data continuity in terms of sensing, planning, execution and inter-organizational coordination. Studies concentrating on analytics or recovery models tend to assume that data are already in a designed, up-to-date and interoperable state. Research focusing on digital technologies is usually based on the assumption that operational advantages would ensue after the introduction of tools. Both assumptions are problematic in manufacturing practice. This is precisely the core of ERP design, as ERP specifies the capability of product, supplier, order, capacity and inventory information to execute workflows that are resilient without distorted semantics or unacceptable latency.

A strong contradiction is also visible across the literature. Several articles have reported increased responsiveness with the introduction of digital integration [6], [9], [13], yet the same literature sources report over and over again haphazard implementation, ineffective cross-platform integration, and uneven maturity [11], [12], [18]. Such contradiction shows that simply the names of the technology cannot be applied to derive resilience benefits. A manufacturing company may deploy digital twins, blockchain, or Industry 4.0 tools while still retaining ERP architectures built on assumptions of periodic control and stable processes. This literature thus underpins a more specific research question than a generic argument of digitalization: what ERP data-centric design decisions can best turn digital information into the robust manufacturing supply chain results?

3. Methodology

The reviewed literature draws on several methodological traditions, which provide various insights into the current topic. Simulated and digital-twin based studies include disruption propagation and scenario testing, and network response under uncertainty [6], [10]. Analytical surveys and systematic reviews chart the growing range of digital and resilience concepts and pinpoint common measurement gaps, interoperability, and implementation logic gaps [7], [8], [13]. Empirical operations studies explore the performance implications of Industry 4.0 implementation and may be grounded by surveys or mixed-method designs, reflecting the depth of implementation, responsiveness and coordination patterns [9], [17], [18]. Recovery-planning work offers operational models that transform disruption to production and allocation choices [14]. Taken together, these approaches highlight a critical point: none fully specifies the architectural role of ERP as the stable data backbone linking manufacturing transactions, external events, analytical models, and execution feedback.

This fragmentation creates a major methodological limitation. Simulation papers often represent inventory in abstract terms, capacities and lead times, and implicitly represent enterprise data lineage. Review papers identify digital capabilities and often ERP is considered background infrastructure. Survey-based studies can be employed to prove the existence of association between digital maturity and performance, although this kind of design typically fails to provide an indication of what kind of data structures, semantic controls or patterns of integration bring about the observed effect. Technical expositions of traceability and blockchain show a data-trust issue [15], but most of them do not go as far as to address how externally validated events are expected to be internalized into internal planning, costing, and

execution documents. This has led to considerable evidence on the importance of digital information to resilience in the literature but less on the design variables of ERP that make digital information viable in manufacturing.

Figure 1 summarizes the most consistent results in the literature into a data-centric ERP architecture for resilient manufacturing supply chains. The figure is intentionally layered rather than linear, reflecting the recursive interaction among data capture, harmonization, decision analytics, governance, and execution control in the formation of resilience. A further feature of the architecture is that ERP is not portrayed as a monolithic core, but as the coordinating backbone of a broader event-driven system.

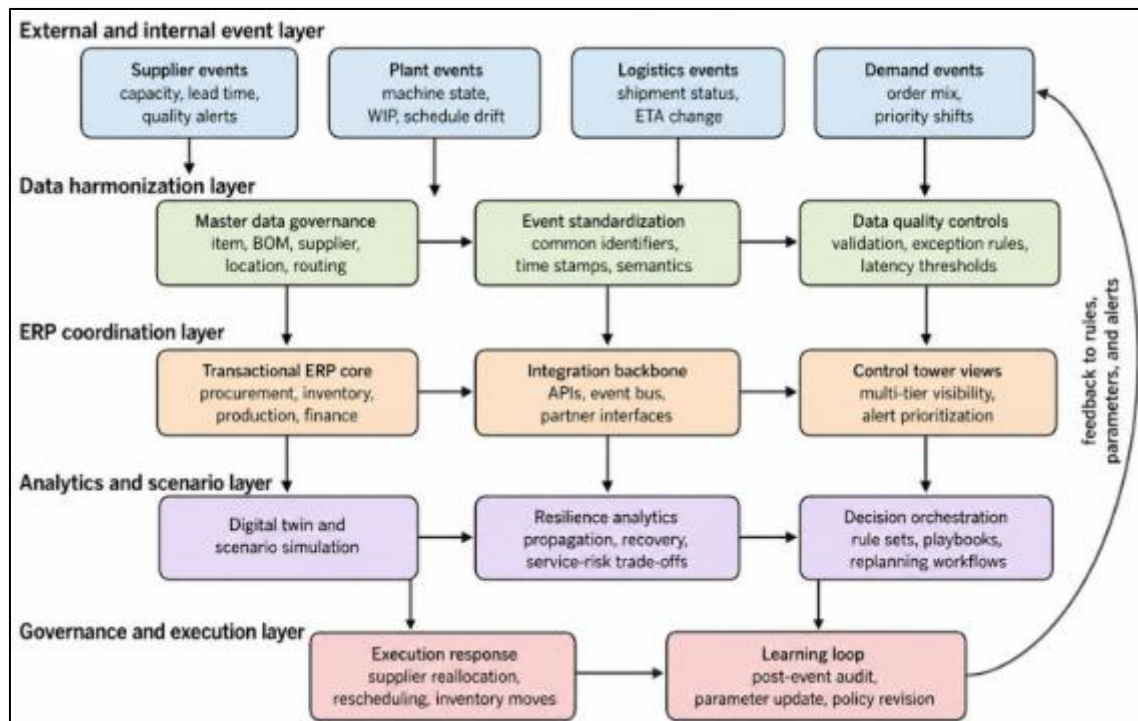


Figure 1 Layered data-centric ERP architecture for manufacturing supply chain resilience

The model points out six design principles that could be found throughout the literature. First, disruption events must enter the enterprise system with minimal latency and with stable identity across systems. Second, master data governance is not an administrative side issue; rather, it is a resilience requirement since the quality of the scenario is determined by clean item, routing, supplier, and location records. Third, ERP should provide an integration backbone capable of linking partner events and analytical tools in a semantically traceable way. Fourth, digital twins and resilience analytics must be run on an identical enterprise state model that is used in execution. Fifth, decision rules and escalation paths should be explicitly governed rather than improvised during disruption. Sixth, local recovery should be followed by post-event learning that revises parameters, thresholds, and playbooks.

It is also in this conceptual framing that future empirical studies will be able to transcend the generalizations about digitalization. Instead of asking a question regarding the level of digital technologies in increasing resilience in a broad sense, the studies may investigate the impact of some design variables of ERP on the outcome of the manufacturing supply chain. Examples are event-latency thresholds, completeness of master data, supplier-identifier consistency, extent to which an API connects with partners, alignment of objects in simulation with those in ERP, and responsiveness of closures upon the identification of a disruption. These variables would allow more causal explanation than most of the existing studies that would prefer to assume resilience by the extent of technology adoption or perception of the managerial alone [7], [13], [18].

4. Discussion

The strongest shared finding across the reviewed literature is that resilience improves when manufacturing decisions rely on timely, interconnected, and context-rich enterprise data rather than isolated functional records. Research on digital twins and resilience analytics puts a special focus on visibility and responsiveness to scenarios [6], [7], [8]. Other

studies of similar nature apply Industry 4.0 which emphasizes the benefits of performance in case data flows related to operation are combined between planning and execution [9], [17]. However, the literature also shows that visibility alone is insufficient. A dashboard can show signs of disruption but cannot assist in taking resilient action without an underlying ERP environment free from product-hierarchy mismatches, slow inventory updates, incomplete supplier mapping, or planning objects not consistent with the actual production constraints. In this respect, resilience depends less on the mere presence of information than on the design quality of the data backbone through which information is validated, linked, and acted upon.

A second important finding concerns the distinction between detection and controllability. Epidemic simulation studies and ripple-effect research show that the early warning is not always a guarantee that the successful containment of propagation will take place [2], [10]. Whether the enterprise system can translate new situations into updated procurement, production, and logistics decisions before the instability spreads is important. Recovery-planning studies show that formal decision models can be very useful to improve quality of response when high-demand or supply-constrained situations occur [14]. However, these models can only be operationalized when high-quality data are available. In the absence of a data-centric ERP layer, recovery algorithms are hard to institutionalize due to the need to manually reconcile all disruption events across spreadsheets, modules that are not linked, or partner feeds that are not consistent. A resilient design thus requires data preparedness for action, not merely data presence.

Table 2 Method comparison

Ref	Method	Strengths	Limitations
[2]	Simulation-based disruption impact analysis	Captures temporal propagation and sensitivity to lead-time and capacity shocks; useful for testing policy alternatives before real events occur.	Abstracts enterprise data structures; operational deployment depends on integration with live ERP objects and planning records.
[6]	Conceptual digital twin architecture	Provides a strong bridge between resilience theory and executable network representation; well suited to scenario-rich disruption management.	Frequently remains architecture-level; implementation details for ERP master data, interfaces, and governance are often not fully specified.
[7]	Systematic review of resilience analytics	Maps methodological diversity and highlights the rise of quantitative decision support for resilience.	Aggregates methods effectively but offers limited guidance on manufacturing ERP design variables.
[8]	Systematic literature review on digital twins	Clarifies monitoring, representation, and control roles of digital twins in manufacturing systems.	Many reviewed studies remain asset-centric and do not fully address multi-tier supply chain integration through ERP.
[9]	Empirical performance analysis of Industry 4.0 adoption	Connects digital implementation with observable supply chain performance dimensions.	Resilience outcomes are often inferred indirectly, and architectural causality inside ERP remains underdeveloped.
[13]	Systematic review on Industry 4.0 and resilience	Identifies repeated resilience mechanisms such as visibility, flexibility, and real-time decision support.	Heterogeneous evidence base limits cross-study comparability and leaves specific ERP design prescriptions uncertain.
[14]	Recovery-planning modeling in manufacturing supply chains	Produces actionable response logic for disrupted production and allocation decisions.	Depends on accurate, current operational data; poor ERP data quality can undermine model usefulness.
[15]	Conceptual and technical analysis of blockchain in SCM	Illuminates shared event validation, provenance, and inter-organizational trust mechanisms.	Integration overhead, scalability constraints, and ERP alignment challenges can limit direct adoption in manufacturing networks.

[18]	Distributed manufacturing case study	Demonstrates practical reconfiguration under emergency conditions and highlights the value of flexible production allocation.	Context specificity and emergency focus reduce generalizability to routine industrial ERP environments.
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One reason for the limited direct evidence on data-centric ERP design is the methodological imbalance summarized in Table 2. Many analytically powerful techniques such as simulation and optimization often simplify enterprise information structures, but such studies are often approached in a broad way by rich empirical studies through digital infrastructure. The mismatch results in a significant gap in research. The execution of decisions with an ERP-based workflow is becoming a key issue in manufacturing resilience, but the literature seldom assesses whether master data discipline, interface latency, event semantics or partner connectivity is a significant factor in resilience performance variation.

Figure 2 maps the reviewed literature in order to clarify the dominant evidence patterns in terms of the most common resilience stage and the most common ERP-related design focus. The chart does not claim bibliometric completeness, but the reviewed evidence is put into a comparative map of the focus of scholarly attention. The strongest concentration is on response and recovery, especially on visibility integration and digital-twin/scenario support and digital twin or scenario support, and adaptation is a less investigated ERP learning problem.

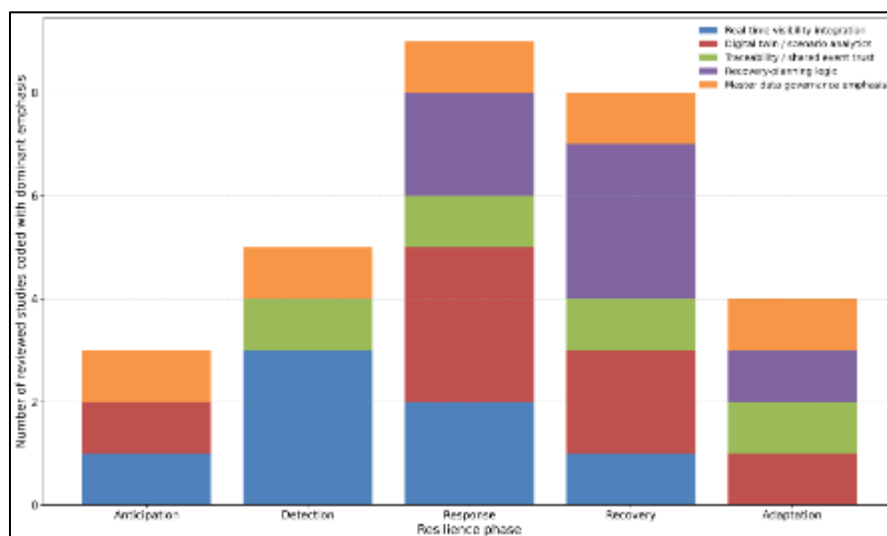


Figure 2 Literature-coded distribution of design emphases across resilience phases

The critical interpretation of the literature as opposed to the purely descriptive interpretation is supported by figure 2. Scholarly attention has focused on detection, response, and recovery since disruption episodes render those stages instantly apparent and empirically available. By contrast, adaptation and data-governance capabilities remain far less developed, yet the long-run resilience in manufacturing is frequently dictated by the lack or existence of post-event learning in ERP rules, identifiers, thresholds, and integration policies. The literature thus runs the risk of overestimating tools of rapid response and underestimating slower architectural work which would ascertain whether rapid response is repeatable.

Another outcome is related to the trade-off between the scope of integration and controllability. Resilience-oriented deployment requires semantic, permission, and exception-routing discipline [11], [12], whereas research on Supply Chain 4.0 and digital-technology research often emphasizes wide connectivity. Blockchain and distributed-manufacturing studies add a further layer by suggesting that broader network participation can improve flexibility and traceability, but only when governance complexity is kept within manageable bounds [15], [18]. This implies that a data-centric ERP design should not aim to connect with everything in manufacturing practice. Instead, design should emphasize resilient connectivity: subset of interfaces, identifiers, event models, and analytical connections that enable anticipation, coordinated response, and recovery in a significant way without overwhelming governance capacity.

Figure 3 represents such logic of comparison because it locates typical patterns of architecture on two dimensions, which are resilience-related: responsive to recovery and burden of governance. The positions are derived from the reviewed literature rather than from universal measures; they should therefore be read as analytical comparisons rather than meta-analytic results. The trend is that the most promising designs are neither the extremes, but the architectures that can strike a balance between the rich visibility and scenario capability, and manageable data-governance requirements.

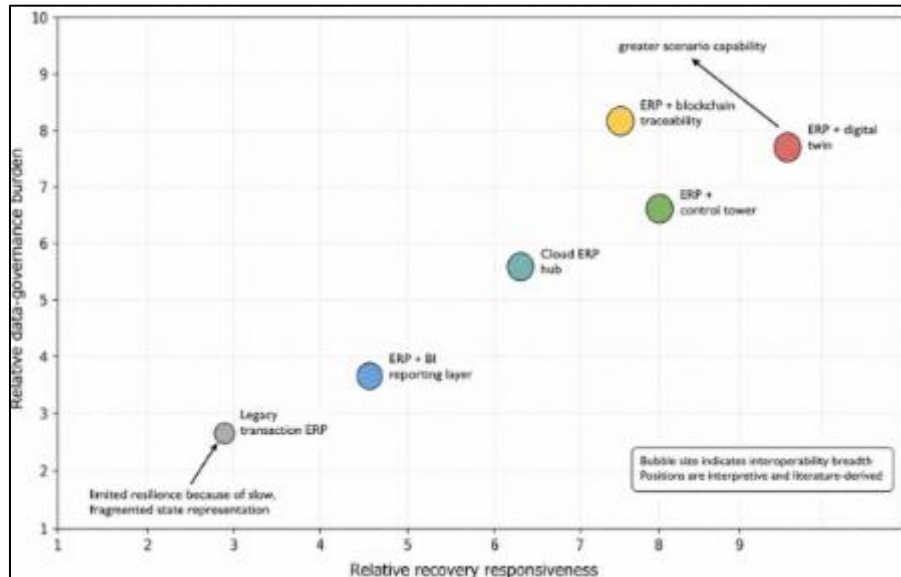


Figure 3 Comparative positioning of manufacturing information architectures for resilience

Figure 3 has several implications regarding relative positioning. Legacy transaction-centered ERP may appear to impose a lower governance burden only because data complexity is often externalized into manual workarounds, shadow systems, and slower coordination. On the other end, ERP-based architectures that are connected with digital twin and multi-party traceability are more likely to be resilient, yet the weight of governance increases exponentially unless item identities, event semantics and decision rights are tightly controlled. Literature therefore points toward a design path to data-centric ERP ecosystems rather than uncontrollable data proliferation of digital layers.

The reported results of the main studies support this interpretation. Digital-twin and resilience-review papers report the benefits of speed in scenarios, clarity of the states and the quality of coordination [6], [7], [8]. The industry 4.0 and digital-enabler studies [9], [12], [17] report the gains in responsiveness, integration and performance of processes. According to recovery modeling studies, there is better disruption management where production and allocation choices are recalculated formally [14]. Work with traceability is more intact in terms of information integrity across boundaries of the organization [15]. However, ERP-specific evidence is less robust than the more general evidence of digital-resilience. Most studies do not test this relationship quantitatively, but they consistently imply that stronger enterprise data backbones support greater resilience. This implication is robust, but a significant gap in the empirical evidence as well.

Table 3 shows broad indirect convergence across the reviewed studies. The benefits reported are always around the areas of visibility, response quality, recovery coordination and reconfiguration flexibility. Meanwhile, there is a paucity of research that compares alternative ERP data designs side by side. This lack is important since the results of resilience can vary significantly between, e.g., a batch-based ERP of poor external interfaces and an event-driven ERP of shared identifiers, scenario-ready data structures, and controlled feedback loops. The literature thus provides convincing building blocks, but still fails to provide conclusive comparative evidence on the ERP design options.

Table 3 Results comparison

Ref	System / Context	Metric / Basis of Comparison	Outcome
[6]	Digitally represented supply network with disruption scenarios	Ability to model risk propagation and evaluate alternative responses	Strong improvement in scenario-based decision speed and network-wide visibility, contingent on integrated planning data.
[9]	Supply chains adopting Industry 4.0 capabilities	Comparative supply chain performance effects of digital integration depth	Higher performance and responsiveness associated with deeper, coordinated digital implementation rather than isolated technology deployment.
[10]	Supply chains exposed to structural and operational disturbances	Interaction between ripple effect and bullwhip amplification	Disruption propagation worsens when information delay and coordination failure prevent timely corrective action.
[13]	Reviewed Industry 4.0-enabled resilient supply chains	Reported resilience mechanisms across literature	Visibility, flexibility, and data-supported decision-making recur as dominant resilience pathways, but outcome measurement remains heterogeneous.
[14]	Manufacturing supply chain facing demand-supply disruption	Recovery planning quality under constrained production conditions	Formal recovery plans improve allocation and service continuity when accurate current-state data are available.
[15]	Multi-party supply chain traceability setting	Information integrity and shared event trust	Better provenance and validation potential, but integration with enterprise records remains a practical barrier.
[17]	Manufacturing operations integrating lean and Industry 4.0	Process coherence and implementation pattern comparison	Benefits depend on disciplined process integration; fragmented deployment weakens operational impact.
[18]	Emergency-oriented distributed manufacturing response	Reconfiguration flexibility and local production adaptability	Rapid production reallocation can improve continuity, but scalability and stable ERP integration remain unresolved.

Figure 4 addresses the operational aspect of that gap by indicating how data-centric ERP architecture can set up a manufacturing disruption response over time. The figure is practical, not just a theoretical one, since resilience in this area of the topic should be assessed in the rate and consistency of cross-functional response following an incident. The order underlines that sensing, validation, scenario generation, execution release, and post-event learning should be a part of a coordinated time logic as opposed to departmental activities.

One of the key arguments of this review is explained in figure 4. Resilience does not only deal with the ability to spot a disruption early; resilience is based on whether enterprise data can move the organization from signal detection to validated action within a reduced operational time frame. Each stage of this timeline is supported by the literature on epidemic modeling, digital twins, and manufacturing recovery [2], [6], [14], but the entire sequence is explored as an ERP design problem in a small number of studies. This disjuncture helps explain why many digital resilience initiatives appear compelling in demonstration settings but are much harder to institutionalize in routine production.

One final aspect of the discussion concerns conflicts in the evidence base. On the one hand, digital maturity, traceability, and analytical ability are recurrently linked with enhanced resilience potential [11], [13], [15]. On the other hand, implementation studies point to a continued fragmentation, uneven preparedness and challenge of governance [12], [17], [18]. This strain is indicative of the fact that resilience is not a purchasable application layer. Manufacturing supply-chain resilience is more likely to improve when ERP is designed around coherent, governable information structures: the enterprise object, event notifications of partners, models of analytics and execution workflows ought to be all based on an informational basis that is logical and governable. Without such a rationale, digital tools can at most be additive and not transformative.

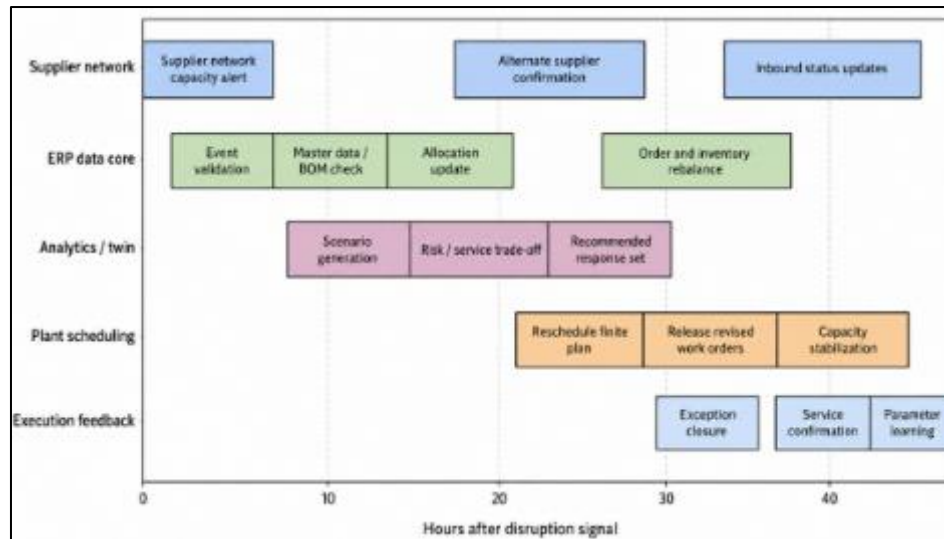


Figure 4 Application-oriented disruption response swimlane for a data-centric ERP environment

5. Architectural Case Study: Event-Driven Triggering, Auditable Pegging, and Localized Replanning

The preceding sections show that batch-only ERP architectures are poorly suited to the velocity and locality of modern supply-chain disruptions. This section explains how a data-centric planning system can address this limitation through fine-grained replanning scopes and an end-to-end auditable pegging trail. Rather than relying on continuous streaming, the design enables disruption signals to trigger corrective actions with reduced latency while preserving operational safety in a manufacturing environment.

Run triggering is event-based. Instead of polling a fixed schedule, the planning engine listens for run-request and anomaly events through fan-out message exchanges. Run-request events are generated by upstream systems, including order management, purchasing, transportation management, and manufacturing execution, whenever a material change occurs. The engine then initiates an appropriate planning run for the affected warehouse without requiring manual operator action. Upon completion, the engine emits a structured anomaly record containing the run identifier, run type, warehouse, initiating user, success indicator, and exception details. These records are consumed by downstream anomaly-detection and observability pipelines and can trigger Teams-based alerts for ERP and transportation-management synchronization failures. During post-processing, run exceptions are also stored in a dedicated planner-alert table with a deep link to the planner workspace, warehouse, part, and subscription group.

The system supports several distinct run types, and the choice of run type determines the scope of recomputation. A standard production run reconciles the full demand and supply universe for the targeted warehouses; a demand-refresh run reuses prior allocation state and re-pegs only the demand side, materially reducing latency when the disruption is demand-driven; a simulation run executes against a hypothetical scenario without committing results; and a reduction-planning run disables incoming-supply hydration and re-plans against on-hand inventory only, which is the appropriate response when an upstream supply disruption forces a defensive replan. The architecture therefore offers a graduated set of replanning scopes rather than a single all-or-nothing batch, and the choice of scope can be driven either by an operator or, increasingly, by the upstream event itself.

A defining feature of the system is its detailed audit trail. Each pegging decision is recorded in two forms: a normalized pegging table and a denormalized pegging storyline. The normalized table captures the demand identifier, supply identifier, pegging reason, and supersession path. The storyline records the netting sequence, want date, receive date, ship date, available supply at the time of pegging, quantity consumed, remaining available quantity, pegging action code, and free-text reason. Pegging reasons are coded for actions such as seed-stock netting, internal-demand netting, supersession-direction gating, and propagation netting. Supersession-aware pegging follows a configured sequence of part substitutions, draining each substitute in priority order and recording a remap reason whenever residual demand crosses substitution-chain boundaries. This level of auditability supports operational trust, regulatory traceability, and post-mortem reconstruction of planning outcomes.

A second defining property is the system's treatment of cross-warehouse propagation. When demand at one warehouse must be propagated upstream to a fulfilling warehouse, the propagation service first nets the gross demand against on-hand inventory at the requesting warehouse before staging the residual to the fulfiller. This horizontal netting, which the author introduced as a corrective measure after observing that gross-propagation behavior was inflating demand at upstream warehouses by quantities already covered locally, is performed by joining incoming demand against an outer-applied on-hand supply view in the underlying SQL and then maintaining a per-part running balance in the consuming application service so that the earliest-dated demands consume on-hand first. The same logic was retrofitted into both the original MRP propagation path and the newer DRP propagation path, eliminating a class of ripple failures in which a small downstream disruption would cascade unchecked into upstream planning networks.

The safety-stock subsystem operates along the same principles. Three policy models are supported: static, dynamic, and composite; each is computed in a dedicated stage during pre-allocation rather than inline within the allocation loop, which keeps the allocation hot path clean and allows the safety-stock projection to be regenerated independently when its driving inputs change. The dynamic model, in particular, recomputes projections using date-aware sourcing rules so that safety stock tracks the time-varying supplier and lead-time topology rather than a static configuration.

Together, event-driven triggering, graduated replanning scopes, end-to-end auditable pegging, propagation netting, and dynamically projected safety stock translate the data-centric resilience principles of the preceding literature into a deployed reference implementation that absorbs disruption signals without resorting to brittle continuous-streaming architectures.

6. Future Directions

The next stage of research should move beyond broad claims about digital capabilities and toward explicit analysis of ERP design variables that condition resilience performance in manufacturing supply chains. The reviewed literature strongly suggests that master-data quality, semantic consistency, interface governability, and event latency are central determinants of resilience, yet these variables remain poorly measured. Empirical research must thus contrast manufacturing locations or organizations based on architecture-related measures such as how often critical supply events are updated, whether the ERP item structure and digital twin object align, the quality of supplier-location mapping, and the time it takes to implement a change in response to disruption identification to a revised execution release. This would allow stronger causal explanation than simple counts of adopted technologies [6], [7], [13].

A second area of research interest is about multi-tier visibility and interoperability of partners. Current literature remains largely focused on focal-firm operations and immediate supplier relationships, whereas real disruption propagation often occurs at deeper tiers and logistics dependencies [10], [12]. The data-centric ERP design research should therefore focus on how the shared identifiers, API governance, and event validation protocols affect resilience on the various levels of manufacturing networks. This agenda is also an easy entry point to traceability research. Blockchain studies emphasize the value of shared-state validation [15], but direct comparison between blockchain-enabled and non-blockchain ERP integration patterns remains limited. Future studies can examine the traceability architectures which provide the best balance of trust, speed, cost, and governance complexity under the circumstances of manufacturing disruption.

Time-sensitive integration between the models of analysis and execution is a third stream. Digital-twin research has expanded rapidly, but there is still too little evidence on how scenario outputs are translated into concrete business actions [8]. A study would be more valuable to the research on manufacturing resilience as it would look at the conversion of the outputs of simulations to purchase-order adjustments, finite scheduling adjustments, allocation decisions, and customer promise adjustments within ERP based processes. This will require methodological combinations that remain rare in the current literature: longitudinal fieldwork, design science, event-log analysis and cross-functional process tracing. This kind of work would help to understand how resilience acquisition relies more on the model sophistication, data quality, or the organizational rules through which recommendations are accepted and implemented, play a role.

A fourth direction concerns governance, workforce roles and post-event learning. The implementation and preparation studies demonstrate that digital maturity depends on strategy, processes, and organizational capability as much as on technology [17], [18]. Future research should therefore examine ownership of resilience-relevant master data, authorization of cross-plant exception logic, post-event audit practices, and the conversion of local improvisation into enterprise learning. Design-wise, an ERP setting that integrates event-based data capture, controlled analytic services, formalized resilience playbooks, and formal feedback into data definitions and planning rules is probably the most

promising direction. Such a move would take the field out of the isolated digital instruments to a reliable manufacturing information platform that can be audited, scaled and applied in practice.

7. Conclusion

This review has examined how data-centric ERP design can strengthen the resilience of manufacturing supply chains. The literature suggests that resilience depends not only on redundancy, flexibility, or digital-tool adoption, but on the ability of the enterprise information backbone to reflect real-time operational conditions, link internal and external events, facilitate quick scenario analysis and coordinate response actions through procurement, production, logistics, and customer-service processes. ERP design is therefore not merely an implementation issue, but a resilience issue in its own right.

The analyzed articles converge on several insights. Digital twins, resilience analytics, recovery planning, and traceability mechanisms all become more effective when operational execution is grounded in enterprise data that are timely, semantically consistent, and tightly interconnected. The structures produced to reduce the amount of time lag between a disruption signal and replanned action are particularly beneficial in the manufacturing setting. Simultaneously, the existing evidence base is still disjointed. A significant portion of the resilience literature assumes functional data integration and a significant portion of the enterprise-systems literature discusses digital integration without explicitly measuring the resilience outcomes. There is still a paucity of direct comparative evidence on alternative ERP design configurations.

The central scholarly implication is that manufacturing supply-chain resilience is as much an information-architecture problem as it is an operational one. A data-centric ERP system transforms the role of ERP as a fixed transaction recording system into an efficient coordination platform that can facilitate sensing, interpretation, simulation, execution and learning. The most significant unresolved questions concern measurable design variables, multi-tier interoperability, governance burden, and long-run adaptation after disruption. Progress on these issues would move the field toward a more rigorous and practically useful body of knowledge on how enterprise-system design shapes manufacturing supply-chain resilience under continuing uncertainty.

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