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Resilience vs. Efficiency: Strategic Supply Chain Management in the Indian Automobile Industry under Disruption and Digitalisation

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***Abstract*— The Indian automobile industry stands at a pivotal strategic inflection point. As the world's third-largest automotive market by volume producing over 5.8 million passenger vehicles in 2023–24 and targeting 7 million by 2030 India's automotive supply chains are simultaneously being transformed by two powerful and often conflicting forces: the relentless competitive pressure to reduce supply chain costs through lean efficiency practices, and the growing recognition that cost-optimised, lean supply chains are acutely vulnerable to the disruptions that have become a structural feature of global trade. The semiconductor shortage of 2021–22, which cost the Indian automobile industry an estimated 450,000–500,000 units of lost production, and the geopolitical supply disruptions of 2022–24 exposed the brittleness of efficiency-first supply chain strategies in an industry where 70–80% of component value is sourced externally.**

This dissertation investigates the resilience-efficiency trade-off in Indian automotive supply chains and develops the Resilience-Efficiency Integration (REI) Framework an empirically validated model linking supply chain resilience practices and supply chain efficiency practices to integrated supply chain performance, with digital capability as the critical mediating mechanism. The framework proposes that digital capability encompassing supply chain visibility technology, predictive analytics, digital twin deployment, and supplier digitisation integration serves as the mechanism through which resilience practices and efficiency practices are reconciled into superior overall supply chain performance. In organizations with high digital capability, resilience and efficiency become complementary rather than conflicting objectives; in organizations with low digital capability, the trade-off remains sharp and costly.

Using a mixed-method research design, primary data were collected from 90 supply chain professionals across Indian Original Equipment Manufacturers (OEMs), Tier-1 suppliers, Tier-2 suppliers, and automotive logistics service providers through a structured seven-section questionnaire employing a five-point Likert scale. Data were analyzed using descriptive statistics, Pearson correlation analysis, multiple regression analysis, and Baron and Kenny's (1986) mediation procedure.

Five hypotheses were tested. All five were supported. Supply chain resilience practices have a significant positive impact on supply chain performance (H1: β = 0.67, R^2 = 0.45). Supply chain efficiency practices have a significant positive impact on supply chain performance (H2: β = 0.71, R^2 = 0.50). Digital capability has the strongest positive impact on supply chain performance (H3: β = 0.78, R^2 = 0.61). Digital capability partially mediates the relationship between resilience practices and performance (H4: resilience β reduces from 0.67 to 0.29 when digital capability is included). H5 confirms the moderation effect: the resilience-efficiency trade-off is significantly less severe in organizations with high digital capability (45% reduction in trade-off intensity) compared to low digital capability organizations.

The study makes three principal contributions: the empirically validated REI Framework the first integrated model linking resilience practices, efficiency practices and digital capability to supply chain performance in the Indian automotive context; the first empirical test of digital capability's mediating role in the resilience-performance relationship in Indian manufacturing; and structured managerial recommendations for Indian automotive OEMs and suppliers calibrated to India's specific structural conditions including tier-city supplier fragmentation, semiconductor dependency, and the electric vehicle transition.

Keywords: ***Automotive supply chain, supply chain resilience, supply chain efficiency, digital capability, Indian automobile industry, REI Framework, resilience-efficiency trade-off, disruption management, semiconductor shortage, EV transition, Industry 4.0, supply chain visibility.***

I. INTRODUCTION

1.1 Background of the Study

The Indian automobile industry is one of the most strategically significant industrial sectors in the global economy. As the world's third-largest automotive market by volume accounting for 5.8 million passenger vehicle sales and over 21 million two-wheeler units in 2023–24 India represents a critical node in both regional and global automotive supply chains. The sector contributes approximately 7.1% of India's GDP, accounts for 49% of India's manufacturing GDP, employs directly and indirectly over 37 million people, and was responsible for exports worth USD 21.2 billion in 2023–24 (Society of Indian Automobile Manufacturers / SIAM, 2024).

Yet the very characteristics that make Indian automotive supply chains strategically important their complexity, their deep integration into global component networks, their high external sourcing ratios of 70–80% of vehicle value also make them acutely vulnerable to disruption. The semiconductor crisis of 2021–22 demonstrated this vulnerability in stark terms: Indian automobile manufacturers lost an estimated 450,000 to 500,000 units of production due to chip shortages, with the production loss valued at approximately Rs. 22,000 crore (SIAM, 2022). The crisis was not primarily a demand problem Indian automotive demand recovered strongly after the COVID-19 lockdowns but a supply chain problem: over-reliance on a small number of global semiconductor manufacturers, insufficient supplier diversification, and inadequate early-warning systems that would have enabled proactive inventory buffering ahead of the shortage.

This vulnerability is not unique to semiconductors. Indian automotive supply chains are exposed to a multi-dimensional disruption landscape: geopolitical risks affecting critical mineral supply chains for electric vehicle batteries (lithium, cobalt, nickel predominantly sourced from China, the Democratic Republic of Congo, and Australia); port and logistics disruptions affecting global component flows; domestic infrastructure constraints affecting just-in-time delivery from Tier-2 and Tier-3 suppliers in secondary industrial clusters; climate-related disruptions affecting both supplier operations and logistics networks; and the accelerating disruption of the industry's own product and technology base through electrification and software-defined vehicle development.

Against this disruption backdrop, the dominant supply chain management paradigm in the Indian automotive industry has historically been lean efficiency minimizing inventory, maximizing asset utilization, and relentlessly pursuing cost reduction through supplier rationalization, outsourcing, and just-in-time delivery. This approach delivered significant competitive benefits during periods of stable global supply chains but created systemic fragility that the disruptions of 2020–24 exposed comprehensively. The question facing Indian automotive supply chain leaders is no longer whether to invest in resilience the cost of insufficient resilience has been empirically demonstrated but how to build resilience without sacrificing the efficiency gains that competitive viability requires.

This dissertation addresses this question directly. It proposes and empirically tests the hypothesis that digital capability the organisation's ability to deploy supply chain visibility technology, predictive analytics, digital twin simulation, and supplier digitisation integration is the critical mechanism through which the resilience-efficiency trade-off can be resolved. Organizations with high digital capability can achieve supply chain resilience without the inventory, redundancy, and dual-sourcing costs that resilience typically imposes, because digital visibility enables proactive response rather than reactive buffering. The Resilience-Efficiency Integration (REI) Framework developed in this study provides a structured theoretical and empirical foundation for this proposition.

1.2 The Indian Automotive Supply Chain: Structure and Strategic Context

India's automotive supply chain is structured across five primary tiers. At the apex, Original Equipment Manufacturers (OEMs) Maruti Suzuki, Tata Motors, Hyundai India, Mahindra and Mahindra, Hero MotoCorp, Bajaj Auto, and the Indian operations of Honda, Toyota, Kia, Volkswagen, and Stellantis coordinate the final assembly of vehicles from approximately 3,000–4,000 components per vehicle. Tier-1 suppliers provide complete systems and modules engine assemblies, transmissions, braking systems, seating systems, electronic control units and number approximately 750 major entities in India. Tier-2 suppliers provide sub-components and sub-assemblies to Tier-1 suppliers, and are far more numerous estimated at 4,000–6,000 entities. Tier-3 and Tier-4 suppliers provide raw materials and basic components, and are often small and medium enterprises (SMEs) with limited digital capability and thin financial resilience.

This tiered structure creates compounding supply chain risks. A disruption at the Tier-3 level a single small casting or forging supplier in a secondary industrial cluster can cascade through Tier-2 to Tier-1 to OEM in a matter of days, halting final assembly lines that represent hundreds of crores of daily production value. The concentration of specific component manufacturing in specific geographies amplifies this risk: India's automotive casting and forging industry is concentrated in Rajkot and Coimbatore; sheet metal stamping in Pune and Chennai; electronic components heavily dependent on imports from Taiwan, South Korea, Japan, and China. This geographic and supplier concentration means that any disruption affecting a specific geography or import corridor disproportionately impacts multiple OEMs simultaneously.

The industry is simultaneously navigating the most significant technology transition in its history: the shift from internal combustion engine (ICE) vehicles to electric vehicles (EVs). India's EV ambitions driven by the FAME II scheme and the emerging FAME III policy are creating entirely new supply chain requirements: lithium-ion battery packs, electric motors, power electronics, and charging infrastructure. The supply chains for these components are largely undeveloped in India, creating new dependencies on China (which manufactures approximately 75% of global lithium-ion battery cells) and other international suppliers. The EV transition thus simultaneously disrupts the existing automotive supply chain and creates new vulnerability to supply chain disruption in the emerging one.

The 2020–24 period has also witnessed rapid digitalisation of the automotive supply chain, partly accelerated by the semiconductor crisis which demonstrated the catastrophic consequences of poor supply chain visibility. OEMs including Maruti Suzuki, Tata Motors, and Mahindra have accelerated investments in supply chain control towers, tier-deep visibility platforms, and predictive analytics for supply disruption early warning. These investments represent the empirical foundation for the REI Framework's proposition that digital capability enables the reconciliation of resilience and efficiency.

1.3 The Resilience-Efficiency Trade-Off in Automotive Supply Chains

The fundamental tension in automotive supply chain strategy is between efficiency the reduction of costs through lean inventory, high asset utilization, supplier rationalization, and just-in-time delivery and resilience the maintenance of operational continuity through inventory buffers, supplier redundancy, geographic diversification, and response capabilities. These objectives conflict because the practices that improve efficiency typically reduce the buffers and redundancies that enable resilience, and vice versa.

Christopher and Peck (2004) formalize this tension as a fundamental supply chain design trade-off: organizations can occupy positions on an efficiency-resilience frontier, but cannot simultaneously maximize both dimensions without incurring costs. Sheffi and Rice (2005) demonstrate empirically that organizations that invest in resilience prior to disruption achieve faster and more complete recovery, but that the investment imposes an ongoing cost premium of 3–5% of supply chain operating cost. For an industry as cost-competitive as automotive manufacturing, where OEM supply chain costs represent 70–80% of total vehicle cost, this premium is strategically significant.

The critical question which this dissertation addresses is whether digital capability changes the shape of this trade-off frontier. The proposition, grounded in recent supply chain digitisation research, is that digital visibility tools, predictive analytics, and digital twin simulation allow organizations to achieve resilience through speed of response rather than size of buffers. An organization that detects a supply disruption ten days before it materializes through Tier-3 supplier financial health monitoring, geopolitical risk scoring, and predictive lead-time models can respond proactively at lower cost than one that detects the disruption when components fail to arrive. If this proposition is empirically confirmed, it has transformative implications for automotive supply chain strategy: digital investment becomes not just an operational improvement tool but a strategic mechanism for resolving the resilience-efficiency trade-off.

1.4 Problem Statement

Indian automotive OEMs and suppliers face a strategic supply chain management paradox: the efficiency-first supply chain practices that delivered competitive advantage during periods of stable global trade have proven dangerously fragile under the disruption conditions that now characterize the global automotive supply landscape. The semiconductor shortage of 2021–22 cost the Indian industry an estimated Rs. 22,000 crores in lost production. The 2022–24 geopolitical supply chain disruptions-imposed material cost increases averaging 15–25% on critical imported components. The EV transition is creating new supply chain dependencies that are not yet visible to most organizations operating below Tier-1.

Yet the response cannot simply be to abandon efficiency in favour of resilience. Indian automotive manufacturers operate in one of the most cost-competitive automotive markets globally average vehicle selling prices are substantially lower than in Western markets, raw material and component cost inflation has been persistent, and competitive pricing pressure from new entrants including BYD, SAIC, and JSW MG Motor is intensifying. Supply chain cost efficiency is not a strategic preference it is a competitive necessity.

The missing piece in Indian automotive supply chain strategy is an integrated framework that identifies the specific practices, investments, and organizational capabilities that allow organizations to achieve both resilience and efficiency simultaneously and that empirically tests whether and how digital capability serves as the mechanism that makes this integration possible. The absence of such a framework leaves automotive supply chain leaders making ad hoc, reactive investments in resilience following each disruption event, without a coherent strategic architecture for building durable resilience capability that is compatible with efficiency objectives.

1.5 Research Objectives

The primary objective of this study is to develop and empirically validate the Resilience-Efficiency Integration (REI) Framework, which proposes digital capability as the critical mediating mechanism through which supply chain resilience and efficiency practices can be integrated into superior supply chain performance in the Indian automotive context. The specific objectives are:

1. To analyze the impact of supply chain resilience practices on overall supply chain performance in Indian automotive OEMs and suppliers.
2. To assess the impact of supply chain efficiency practices on overall supply chain performance.
3. To examine the role of digital capability in determining supply chain performance outcomes, with particular emphasis on its ability to mediate the resilience-performance relationship.
4. To test the hypothesis that digital capability partially mediates the relationship between supply chain resilience practices and supply chain performance.
5. To develop the REI Framework and provide structured recommendations for integrating resilience and efficiency through digital capability investment across operational, tactical, and strategic horizons.

1.6 Research Questions

6. How do supply chain resilience practices influence overall supply chain performance in the Indian automotive industry?
7. How do supply chain efficiency practices influence supply chain performance?
8. What is the role of digital capability in determining supply chain performance, and does it mediate the resilience-performance relationship?
9. Is the resilience-efficiency trade-off significantly moderated by the level of digital capability in the organization?
10. How can Indian automotive supply chain leaders integrate resilience and efficiency through a structured strategic framework?

1.7 Scope of the Study

The study focuses on the Indian automotive sector, encompassing OEMs, Tier-1 and Tier-2 component suppliers, and automotive logistics service providers operating in India. The geographical scope is pan-Indian, with respondent concentration in the major automotive manufacturing clusters of Pune-Mumbai, Chennai, Gurugram-Manesar, Bengaluru, Rajasthan, and the emerging EV manufacturing hubs. The functional scope spans supply chain strategy, supplier relationship management, inventory management, logistics operations, and digital supply chain transformation. The temporal scope is cross-sectional, capturing the state of automotive supply chain management in 2025–26.

The study does not examine retail distribution networks, dealer-level supply chain management, consumer-side demand management, or the technical details of electric vehicle battery supply chains beyond their strategic supply chain implications.

1.8 Significance of the Study

Academic Significance

This study makes three academic contributions. First, it provides the first empirically validated integrated framework linking supply chain resilience practices, efficiency practices, and digital capability to supply chain performance in the Indian automotive context. Second, it tests the mediating role of digital capability in the resilience-performance relationship a mechanism proposed theoretically by Christopher (2016) and Ivanov (2020) but not empirically tested in Indian manufacturing. Third, the REI Framework extends supply chain resilience theory to incorporate digital capability as a trade-off moderator rather than simply a performance enhancer a theoretically significant repositioning of the role of digitisation in supply chain strategy.

Industry Significance

For Indian automotive supply chain practitioners supply chain directors at OEMs, procurement heads at Tier-1 suppliers, and supply chain strategy teams at automotive conglomerates such as the Tata Group, Mahindra Group, and Hero MotoCorp this study provides an empirically grounded strategic framework for navigating the resilience-efficiency trade-off. The recommendations are calibrated to Indian automotive structural conditions, making them directly applicable rather than adapted from North American or European frameworks developed under different cost structures, supplier ecosystem characteristics, and disruption profiles.

1.9 Structure of the Dissertation

- Chapter 1 Introduction: Establishes the Indian automotive supply chain context, the resilience-efficiency tension, problem statement, objectives, and significance.
- Chapter 2 Literature Review: Critically examines supply chain resilience, efficiency, and digital capability literature, culminating in the REI Framework and five testable hypotheses.
- Chapter 3 Research Methodology: Details the research design, sampling strategy, questionnaire architecture, and analytical procedures.
- Chapter 4 Data Analysis and Results: Presents findings from reliability testing, descriptive analysis, correlation, regression, and mediation testing.
- Chapter 5 Discussion and Implications: Interprets findings against prior literature and derives managerial and theoretical implications.
- Chapter 6 Conclusion and Recommendations: Presents the validated REI Framework and structured strategic recommendations.

1.10 Conceptual Overview the REI Framework

The Resilience-Efficiency Integration (REI) Framework proposes that supply chain performance in the Indian automotive industry is jointly determined by resilience practices, efficiency practices, and most critically digital capability. Digital capability is the mediating mechanism: it amplifies the performance benefit of resilience practices by replacing costly physical buffers with information-based early warning and proactive response capabilities. In organizations with high digital capability, resilience and efficiency become complementary dimensions of performance rather than conflicting objectives.

Independent Variables	Mediating Variable	Dependent Variable
Supply Chain Resilience Practices (SCR)	Digital Capability (DC)	Supply Chain Performance (SCP)
Supply Chain Efficiency Practices (SCE)	Supply chain visibility technology, Predictive analytics, Digital twin adoption, Supplier digitisation integration, Control tower deployment	On-Time-In-Full (OTIF), Cost per unit, Lead-time reliability, Production continuity, Customer service level, Supply chain resilience score
Supplier diversification, Safety stock strategy, Dual sourcing, Business continuity plans, Geographic redundancy		

Lean inventory, JIT delivery, Supplier rationalization, Asset utilization, Continuous improvement (Kaizen)		

Table 1.1: REI Framework Variable Structure and Key Indicators

II. REVIEW OF LITERATURE

2.1 Introduction
This chapter critically examines existing literature on supply chain resilience, supply chain efficiency, digital capability in supply chains, and the automotive supply chain management context, with the objective of establishing a rigorous theoretical foundation for the Resilience-Efficiency Integration (REI) Framework. The review is structured as an argument identifying established findings, contested propositions, and critical gaps culminating in five empirically testable hypotheses.

2.2 Supply Chain Resilience: Theory and Measurement
Supply chain resilience is defined as the adaptive capability of the supply chain to prepare for unexpected events, respond to disruptions, and recover from them by maintaining continuity of operations at the desired level of connectedness and control over structure and function (Christopher and Peck, 2004). This definition captures three critical temporal dimensions of resilience: preparation (building capabilities before disruption), response (activating those capabilities during disruption), and recovery (restoring normal operations after disruption).
Sheffi and Rice (2005) provide the foundational empirical evidence for resilience investment value, demonstrating through case analysis that organizations with higher pre-disruption resilience capability recover faster from major supply chain disruptions and sustain significantly less revenue and operational loss than less resilient peers. Their research established the concept of the 'resilience premium' the ongoing cost of maintaining resilience capability and showed that this premium is typically recovered within two to three disruption events at a rate that makes resilience investment economically rational even under uncertainty about disruption frequency.
Ivanov (2020) advances resilience theory significantly through the concept of the 'ripple effect' in supply chains the phenomenon whereby disruptions propagate through supply chain tiers in ways that amplify their initial impact. Ivanov demonstrates that the ripple effect is particularly severe in automotive supply chains, where the complexity of bill-of-materials structures (3,000–4,000 components per vehicle) and the just-in-time delivery architecture mean that a single component shortage can halt entire production lines with cascading cost implications. His work directly supports the research context of this study and provides theoretical grounding for the importance of resilience investment in the automotive sector.

Resilience practices in the automotive context can be categorized across four dimensions. Supply base resilience encompasses supplier diversification (maintaining multiple qualified sources for critical components), dual sourcing strategies (qualifying backup suppliers before they are needed), and geographic diversification of the supply base. Inventory resilience includes strategic safety stock buffer inventory above JIT requirements for high-risk or long-lead-time components and the identification of critical components that justify the carrying cost of safety stock. Process resilience includes business continuity planning, disruption simulation and drill exercises, and alternative routing and production flexibility. Information resilience includes supply chain visibility systems, early warning monitoring of supplier financial health and operational status, and crisis communication protocols.
The challenge for automotive supply chain managers is that each of these resilience practice categories imposes costs: dual sourcing increases per-unit procurement cost by reducing volume leverage; safety stock imposes working capital and storage costs; business continuity planning requires organisational investment; and visibility systems require technology investment and data governance infrastructure. These costs create the resilience-efficiency trade-off that is the central subject of this dissertation.

2.3 Supply Chain Efficiency Practices in Automotive Manufacturing
Supply chain efficiency in automotive manufacturing is the application of lean production philosophy

originated by Taiichi Ohno and the Toyota Production System to the entire supply chain rather than only the manufacturing floor. The lean supply chain eliminates waste (muda) in the form of excess inventory, unnecessary transportation, over-processing, waiting time, and defects across all supply chain tiers. In practice, automotive lean supply chain practices include just-in-time delivery scheduling (components delivered to the assembly line in the sequence and at the time they are needed), vendor-managed inventory (VMI) arrangements with Tier-1 suppliers, kanban-based replenishment systems, supplier development programs to extend lean practices into the supply base, and relentless focus on reducing total supply chain cost.

Womack, Jones, and Roos (1990) established in their landmark study The Machine That Changed the World that lean automotive manufacturing as practiced by Toyota, Honda, and Nissan achieved dramatically superior quality and productivity compared to mass production systems. Their research has been replicated and extended extensively; the lean supply chain literature overwhelmingly confirms that lean practices deliver significant efficiency and quality benefits under stable supply conditions. Chopra and Meindl (2019) note that lean automotive supply chains typically achieve 20–30% lower inventory levels, 15–25% lower logistics costs, and 10–20% higher asset utilization compared to non-lean equivalents.

The vulnerability of lean automotive supply chains to disruption is equally well-documented. The 2011 Tōhoku earthquake and tsunami which disrupted production at Renesas Electronics, a critical automotive semiconductor supplier caused global automotive production losses estimated at 400,000 units over six months, demonstrating that even infrequent, high-impact disruptions can impose costs that dwarf the efficiency savings of lean systems. The COVID-19 pandemic and the subsequent semiconductor shortage provided an even more comprehensive demonstration: lean supply chains with minimal safety stock for semiconductor components had essentially no buffer when component flows were disrupted, while those with strategic safety stock maintained production continuity.

This pattern lean efficiency delivering ongoing savings but creating catastrophic vulnerability to disruption is the empirical foundation for the resilience-efficiency trade-off in automotive supply chains. The critical research question is whether digital capability changes the economics of this trade-off by enabling resilience without the physical buffer costs that traditional resilience strategies impose.

2.4 Digital Capability in Supply Chains

2.4.1 Definition and Components

Digital capability in supply chains is defined as the organisation's ability to leverage digital technologies including IoT-enabled tracking, supply chain visibility platforms, predictive analytics, artificial intelligence, digital twins, and blockchain-based provenance tracking to improve supply chain decision-making, enhance visibility across supply chain tiers, and enable proactive management of supply chain risks and opportunities. This definition distinguishes digital capability from technology adoption: an organisation may have implemented visibility technology without developing the analytical capability, governance structures, and organisational processes to derive decision value from the data it generates.

Quayson, Bals, and Venugopal (2020) identify four primary dimensions of supply chain digital capability: visibility (the ability to monitor supply chain status in real time across multiple tiers), analytics (the ability to convert supply chain data into actionable insights), agility (the ability to act quickly on supply chain intelligence), and integration (the degree to which digital systems are connected across supply chain partners). Their framework provides the conceptual basis for the digital capability construct operationalized in this study.

2.4.2 Industry 4.0 Technologies in Automotive Supply Chains

The automotive industry has been at the forefront of Industry 4.0 technology adoption in manufacturing, though supply chain digitisation has lagged behind factory automation. Key technologies include: IoT-based tracking devices embedded in components and shipments, enabling real-time location and condition monitoring; AI-powered demand forecasting and supply disruption prediction systems; digital twin platforms that create virtual replicas of supply chain networks to enable scenario simulation and risk assessment; blockchain-based provenance tracking for critical materials and components, particularly relevant for the electric vehicle battery supply chain where material provenance documentation is increasingly required by regulatory frameworks; and control tower systems that aggregate supply chain intelligence from multiple sources into unified decision-support dashboards.

Wang et al. (2024) provide empirical evidence from the Chinese automotive sector that digital twin adoption reduces supply chain disruption recovery time by 35–40% and decreases buffer inventory requirements by 18–22%, directly supporting the proposition that digital capability enables resilience without full buffer costs. Ivanov and Dolgui (2021) demonstrate that AI-powered supply chain risk scoring can provide an average of 12–15 days early warning of supply disruptions sufficient time for proactive mitigation actions that are substantially less costly than reactive crisis management.

2.4.3 Digital Capability as a Trade-Off Resolver

The theoretical argument for digital capability as a resilience-efficiency trade-off resolver operates through three mechanisms. First, information substitution for inventory: real-time supply chain visibility enables organizations to reduce safety stock requirements by replacing physical buffers with information-based assurance. An organization that can monitor its Tier-2 and Tier-3 supplier production status in real time can maintain lower safety stock while achieving equivalent service levels, because it detects supply problems earlier and can initiate responses before they become production stoppages. Second, prediction-based proactive resilience: predictive analytics and AI-powered risk scoring enable organizations to anticipate disruptions and activate resilience responses before disruptions materialize at a fraction of the cost of reactive crisis management. Third, virtual scenario testing: digital twin simulation allows organizations to stress-test supply chain configurations against disruption scenarios without incurring the cost of physical redundancy, enabling more targeted and cost-efficient resilience investment.

Pettit, Fiksel, and Croxton (2010) provide the theoretical framework for resilience-capability investment, arguing that organizations should invest in capabilities that improve response speed rather than buffer stocks wherever possible, as response speed investments are more economically efficient per unit of resilience achieved. Digital capability investments fit this criterion precisely: they improve response speed (through earlier disruption detection and faster decision activation) without imposing the ongoing carrying costs of physical inventory buffers.

2.5 The Indian Automotive Supply Chain: Specific Challenges

India's automotive supply chain presents four structural conditions that differentiate it from the Western and Japanese contexts in which most automotive supply chain management theory has been developed. These conditions shape the specific form of the resilience-efficiency trade-off in India and inform the design of the REI Framework.

First, semiconductor dependency and domestic production absence: India has essentially no domestic semiconductor manufacturing capability, making its automotive supply chain entirely dependent on imported chips. The fabrication facilities of Taiwan Semiconductor Manufacturing Company (TSMC), Samsung Electronics, and Intel collectively supply the vast majority of automotive-grade semiconductors consumed by Indian OEMs. This creates a structurally high vulnerability that cannot be resolved through domestic supplier development the only available mitigation strategies are strategic safety stock maintenance, design diversification across multiple chip architectures, and early-warning monitoring of global semiconductor supply conditions. Digital capability investments that provide better visibility into global semiconductor supply dynamics directly address this structural vulnerability.

Second, tier-city supplier fragmentation: India's automotive component supply base is geographically fragmented across hundreds of industrial clusters Rajkot, Coimbatore, Ludhiana, Agra, Kanpur, Faridabad that developed historically around specific component categories. These clusters contain thousands of SME suppliers with limited financial resilience, limited digital capability, and limited visibility into their own upstream supply chains. A disruption affecting a tier-city cluster through flooding (Rajkot during monsoon), power outages, or labour disputes can simultaneously affect dozens of Tier-2 and Tier-3 suppliers for multiple OEMs, creating correlated supply risks that are not visible through traditional supplier management approaches. Digital capability investments that extend visibility into Tier-2 and Tier-3 supplier operations are particularly valuable in this context.

Third, the EV transition supply chain disruption: India's government has set an ambitious target of 30% EV penetration in passenger vehicles by 2030 (National Electric Mobility Mission Plan). This transition requires automotive supply chains to simultaneously manage declining ICE component volumes and growing EV component volumes, with fundamentally different supplier bases, component specifications, and geographic sourcing patterns. The EV battery supply chain heavily dependent on Chinese cell manufacturers introduces a new class of geopolitical supply risk that existing supply chain risk management frameworks are not designed to address. Digital capability investments that enable dynamic supply chain network reconfiguration are essential for managing this transition.

Fourth, infrastructure variability and logistics reliability: India's road, rail, and port infrastructure, while improving rapidly, still exhibits significantly higher variability in transit times and freight reliability than comparable infrastructure in China, Japan, or Western Europe. Just-in-time delivery systems that assume predictable transit times face systematic failures during monsoon disruptions, port congestion events, and urban freight delivery challenges. Digital capability investments in real-time logistics tracking and dynamic routing enable supply chains to absorb this infrastructure variability without maintaining the large inventory buffers that would otherwise be required.

2.6 Research Gaps

The literature review identifies five gaps that justify the present study:

11. No integrated empirical framework: Existing research examines supply chain resilience, efficiency, and digital capability as separate constructs. No study has formally modelled digital capability as a mediating variable between resilience practices and supply chain performance in the Indian automotive context.
12. Untested digital mediation mechanism: The proposition that digital capability mediates the resilience-performance relationship is theoretically supported but has not been empirically tested through formal mediation analysis in any automotive supply chain context.
13. India-specific research deficit: The majority of automotive supply chain management research is based on US, European, or Japanese data. India's structural conditions semiconductor dependency, tier-city supplier fragmentation, EV transition disruption, and infrastructure variability require context-specific empirical investigation.
14. EV transition supply chain implications: The academic literature on automotive supply chain management has not yet fully incorporated the supply chain management implications of the EV transition, particularly the new geopolitical risk dimensions created by China's dominance of battery cell manufacturing.
15. Digital capability as trade-off resolver: The theoretical proposition that digital capability changes the shape of the resilience-efficiency trade-off frontier has not been empirically tested in any automotive supply chain study.

2.7 Conceptual Framework The REI Framework

The Resilience-Efficiency Integration (REI) Framework synthesizes the literature reviewed above into a formal mediation model:

Construct	Role	Key Indicators / Dimensions
Supply Chain Resilience (SCR)	Independent Variable 1	Supplier diversification index, Dual sourcing adoption, Safety stock strategy, Business continuity plan quality, Geographic diversification, Disruption recovery capability
Supply Chain Efficiency (SCE)	Independent Variable 2	Lean inventory index, JIT delivery adoption, Supplier rationalization, Asset utilization rate, Kaizen/CI program maturity, Total supply chain cost as % revenue
Digital Capability (DC)	Mediating Variable	Supply chain visibility coverage (Tier depth), Predictive analytics adoption, Digital twin deployment, Supplier digitization integration, Control tower functionality, AI/ML-based risk scoring

Supply Chain Performance (SCP)	Dependent Variable	OTIF rate, Production continuity score, Lead-time reliability, Cost per unit (relative to benchmark), Disruption recovery speed, Overall supply chain resilience score

Table 2.1: REI Framework Construct Structure

2.8 Hypotheses Development

H1: Supply chain resilience practices (SCR) have a significant positive impact on supply chain performance (SCP). *Supplier diversification, dual sourcing, strategic safety stock, and business continuity capabilities directly improve production continuity, OTIF rates, and disruption recovery speed. Supported by Sheffi and Rice (2005), Ivanov (2020), Christopher and Peck (2004).*

H2: Supply chain efficiency practices (SCE) have a significant positive impact on supply chain performance (SCP). *Lean inventory, JIT delivery, supplier rationalization, and continuous improvement programs reduce supply chain costs and improve asset utilization, directly improving performance metrics. Supported by Womack et al. (1990), Chopra and Meindl (2019).*

H3: Digital capability (DC) has a significant positive impact on supply chain performance (SCP). *Supply chain visibility, predictive analytics, and digital twin adoption improve decision quality, reduce disruption response time, and enable proactive risk management all of which directly improve performance outcomes. Supported by Quayson et al. (2020), Ivanov and Dolgui (2021), Wang et al. (2024).*

H4: Digital capability (DC) partially mediates the relationship between supply chain resilience practices (SCR) and supply chain performance (SCP). *Resilience practices improve performance both directly (through physical buffers and redundancy) and indirectly through digital capability which enables information-based resilience that is less costly than physical resilience. Partial mediation is predicted.*

H5: The resilience-efficiency trade-off is significantly moderated by the level of digital capability, with the trade-off being less severe in high digital capability organizations. *High digital capability organizations achieve resilience through information and response speed rather than physical buffers, allowing them to simultaneously maintain high efficiency. Supported by Pettit et al. (2010), Christopher (2016).*

2.9 Key Literature Summary

Author	Year	Key Contribution	Link to REI Framework
Christopher & Peck	2004	Foundational resilience framework; four principles: flexibility, redundancy, agility, culture	SCR construct; H1; trade-off framing
Sheffi & Rice	2005	Resilience premium; disruption recovery speed correlated with pre-disruption investment	SCR → SCP; H1 quantification
Womack, Jones & Roos	1990	Lean production system; Toyota Production System efficiency evidence	SCE construct; H2 foundation
Chopra & Meindl	2019	Supply chain trade-offs; efficiency-responsiveness frontier	Trade-off framework; H5
Ivanov, D.	2020	Ripple effect in supply chains; automotive disruption amplification	SCR importance; Indian context

Ivanov & Dolgui	2021	AI-powered disruption early warning; 12–15 days advance notice	DC value; H3, H4
Pettit, Fiksel & Croxton	2010	Resilience-capability investment framework; response speed vs. buffer stock	H4 mediation logic; H5 moderation
Quayson, Bals & Venugopal	2020	Digital supply chain capability dimensions: visibility, analytics, agility, integration	DC construct operationalization
Wang et al.	2024	Digital twin in auto supply chains: 35–40% faster recovery, 18–22% less buffer stock	H3, H4 empirical support
SIAM	2024	Indian automotive industry data: production, exports, EV targets	Indian context; structural conditions
Christopher, M.	2016	Agile supply chain; demand-driven logistics; resilience through agility	H4 mediation logic
World Bank LPI	2023	India logistics performance; infrastructure gaps impacting automotive supply chains	Indian context; reliability challenge

Table 2.2: Key Literature Summary

III. RESEARCH METHODOLOGY

3.1 Introduction

This chapter presents the methodological architecture of the study, justifying every design choice by reference to the research questions and the nature of the constructs being measured. The chapter covers research philosophy, approach and design, population and sampling, questionnaire design, construct operationalization, data collection, analysis techniques, and methodological limitations.

3.2 Research Philosophy

This study adopts a positivist research philosophy, which holds that supply chain phenomena including the practices, capabilities, and performance outcomes of automotive supply chains can be objectively measured and that causal relationships between them can be investigated through systematic empirical methods. Positivism is appropriate because the constructs of interest are operationalizable through measurable indicators (OTIF rates, dual sourcing adoption, digital visibility coverage, disruption recovery time); the research questions seek to establish quantified directional relationships; and the study aims for generalizable findings applicable beyond the specific sample.

3.3 Research Approach and Design

The study adopts a deductive approach testing theory-derived hypotheses rather than inductively generating theory. The five hypotheses were derived from established theoretical frameworks and prior empirical findings, then tested against primary survey data. The research design is both descriptive (characterizing the current state of automotive supply chain resilience, efficiency, and digital capability in India) and explanatory (testing the relationships between constructs and examining the mediating mechanism of digital capability).

A cross-sectional design is adopted, collecting data at a single point in time during 2025–26. A mixed-method approach is employed: quantitative primary data from a structured questionnaire provides the basis for hypothesis testing, while secondary data from automotive industry reports (SIAM, McKinsey, Deloitte, World Bank), case studies of Indian OEM supply chain transformations, and academic literature contextualizes and validates the primary findings.

3.4 Sampling Design

3.4.1 Target Population

The target population comprises supply chain professionals in the Indian automotive sector with direct experience of supply chain strategy, procurement, logistics, or supplier management. Inclusion criteria: current or recent role in automotive supply chain management, supplier development, procurement, logistics, or supply chain strategy; minimum two years of experience in the automotive sector; direct familiarity with at least one of the study's core constructs supply chain resilience, efficiency, or digital capability. The population spans OEMs, Tier-1 and Tier-2 component suppliers, and automotive logistics service providers.

3.4.2 Sampling Technique and Size

A purposive and snowball sampling approach was adopted, accessing respondents through LinkedIn automotive supply chain professional networks, Society of Indian Automobile Manufacturers (SIAM) member contacts, Automotive Component Manufacturers Association (ACMA) professional networks, and direct outreach to supply chain functions at automotive organizations. A total of 90 complete, usable responses were collected exceeding the minimum of n = 74 required for regression analysis with three predictors at $\alpha = 0.05$ and power = 0.80, per Green's (1991) formula. Of 112 total responses received, 22 were excluded for incompleteness or non-qualification.

3.5 Questionnaire Design

Sec.	Content	Items	Scale
A	Respondent Profile: Organisation type, Role, Experience, Company size, Primary automotive segment served	5 items	Categorical / multiple choice
B	Supply Chain Resilience Practices (SCR): Supplier diversification, dual sourcing, safety stock, BCP, disruption recovery	8 items	Likert 1–5
C	Supply Chain Efficiency Practices (SCE): Lean inventory, JIT adoption, supplier rationalization, kaizen maturity	7 items	Likert 1–5
D	Digital Capability (DC): Visibility coverage, predictive analytics, digital twin, supplier digitisation, control tower	8 items	Likert 1–5
E	Supply Chain Performance (SCP): OTIF, production continuity, lead-time reliability, cost efficiency, disruption recovery	7 items	Likert 1–5
F	Resilience-Efficiency Trade-off Perceptions: Perceived trade-off intensity, digital impact on trade-off	5 items	Likert 1–5
G	Open-ended qualitative insights: Key supply chain challenges, digital investment priorities, lessons from disruptions	3 items	Free text

Table 3.1: Questionnaire Structure

Items were adapted from validated academic scales: Supply Chain Resilience items adapted from Pettit et al. (2010) and Christopher and Peck (2004). Supply Chain Efficiency items adapted from Chopra and Meindl (2019) and Womack et al. (1990). Digital Capability items adapted from Quayson et al. (2020) and Ivanov and Dolgui (2021). Supply Chain Performance items adapted from the SCOR model and Gunasekaran et al. (2004). A pilot test with seven automotive supply chain professionals resulted in revision of five items identified as ambiguous or insufficiently specific to the Indian automotive context.

3.6 Construct Operationalization

Variable	Sample Questionnaire Items	Academic Source
Supply Chain Resilience (SCR)	We maintain qualified backup suppliers for all critical components; Strategic safety stock covers 30+ days for high-risk components; Our business continuity plan is tested annually; We actively monitor Tier-2 and Tier-3 supplier health; Our supply chain recovered from the semiconductor shortage within 60 days	Pettit et al. (2010); Christopher & Peck (2004); Sheffi & Rice (2005)
Supply Chain Efficiency (SCE)	Our inventory turns exceed industry benchmarks; JIT delivery is adopted for 70%+ of component volumes; We have rationalised our supplier base over the past three years; Kaizen programs are active across our supply chain; Our total supply chain cost as a % of revenue has improved over three years	Chopra & Meindl (2019); Womack et al. (1990)
Digital Capability (DC)	We have real-time visibility into Tier-1 supplier operations; Our predictive analytics identify supply risks 10+ days in advance; We use digital twin simulation for supply chain scenario planning; 60%+ of our Tier-1 suppliers share data digitally with us; Our control tower provides a unified view of supply chain status	Quayson et al. (2020); Ivanov & Dolgui (2021); Wang et al. (2024)
Supply Chain Performance (SCP)	Our OTIF rate meets or exceeds 95% target; Production line stoppages due to supply issues are fewer than 3 per quarter; Lead times are predictable within ±10% variance; Supply chain cost per unit has improved versus prior year; Recovery from the last major disruption took fewer than 30 days	SCOR Model; Gunasekaran et al. (2004); SIAM (2024)

Table 3.2: Construct Operationalization

3.7 Data Collection

Data collection was conducted over seven weeks during 2025–26 using Google Forms distributed through SIAM and ACMA member networks, LinkedIn automotive supply chain professional groups, and direct outreach to supply chain functions at major Indian automotive organizations including OEMs in the passenger vehicle, commercial vehicle, and two-wheeler segments, and Tier-1 suppliers. Of 112 responses received, 22 were excluded 15 for incomplete responses and 7 for failure to meet minimum experience criteria yielding a final usable sample of 90.

Ethical protocols were observed throughout: participation was voluntary and anonymous, informed consent was obtained, no organizational-level competitive data was requested, and data was used solely for academic research purposes.

3.8 Data Analysis Plan

16. Descriptive Statistics: Mean, standard deviation, and frequency distributions for all constructs and demographic variables.
17. Reliability Analysis: Cronbach's Alpha for each construct (threshold $\alpha \geq 0.70$, Nunnally, 1978).
18. Correlation Analysis: Pearson correlation matrix to assess bivariate relationships and screen for multicollinearity.
19. Multiple Regression Analysis: Four regression models testing H1 (SCR → SCP), H2 (SCE → SCP), H3 (DC → SCP), and H4 pre-test (SCR → DC). Full standardized Beta (β), R^2, and F-statistic reported.
20. Mediation Analysis: Baron and Kenny's (1986) four-step procedure to test H4 whether Digital Capability mediates the SCR-to-SCP relationship.
21. Moderation Analysis (H5): Subgroup comparison of organizations classified as high vs. low digital capability; comparison of SCR-SCE trade-off intensity across subgroups.

3.9 Validity, Reliability, and Limitations

Content validity was ensured by grounding items in established academic instruments. Face validity was confirmed through pilot testing with seven automotive supply chain professionals. Internal reliability was tested through Cronbach's Alpha. Common method bias was addressed through anonymous survey design and Harman's single-factor test, which indicated no single factor explained more than 34% of variance, suggesting common method bias is not a major threat.

Four limitations are acknowledged. First, purposive sampling may over-represent larger, more structured organizations with more developed supply chain management practices, potentially overstating adoption of resilience and digital practices relative to the full SME-inclusive supply base. Second, self-reported performance data may reflect organizational aspiration rather than audited operational performance. Third, the cross-sectional design limits causal inference. Fourth, the sample of n = 90, while adequate for primary analyses, limits the power of organisation-type (OEM vs. Tier-1 vs. Tier-2) subgroup analyses.

IV. DATA ANALYSIS AND RESULTS

4.1 Introduction

This chapter presents the statistical analysis of data collected from 90 supply chain professionals in the Indian automotive sector. Analysis follows the six-step procedure established in Chapter 3. All five hypotheses are formally tested. Results are presented objectively; interpretation and implications are reserved for Chapter 5.

4.2 Respondent Profile

4.2.1 Organisation Type Distribution

Organisation Type	Frequency (n)	Percentage (%)
Original Equipment Manufacturer (OEM) Passenger Vehicle	18	20.0%
Original Equipment Manufacturer Commercial Vehicle / Two-Wheeler	12	13.3%
Tier-1 Component Supplier	26	28.9%
Tier-2 Component Supplier	18	20.0%
Automotive Logistics Service Provider (3PL/4PL)	11	12.2%
Automotive Supply Chain Consulting / Strategy	5	5.6%
Total	90	100%

Table 4.1: Organisation Type Distribution

4.2.2 Experience Level and Automotive Cluster Distribution

Experience Level	Frequency (n)	Percentage (%)
2–4 years	11	12.2%
5–8 years	28	31.1%
9–14 years	30	33.3%
15+ years	21	23.3%

Table 4.2: Experience Level Distribution

The sample has a strong seniority profile: 56.7% of respondents have nine or more years of automotive supply chain experience, indicating that responses reflect deep operational and strategic knowledge rather than entry-level familiarity. The cluster representation is balanced across India's major automotive manufacturing hubs: Pune-Mumbai (29%), Chennai (24%), Gurugram-Manesar (22%), Bengaluru (14%), and other locations including Rajasthan, Uttarakhand, and Gujarat (11%).

4.3 Reliability Analysis

Construct	No. of Items	Cronbach's Alpha	Interpretation
Supply Chain Resilience (SCR)	8	0.87	Good reliability
Supply Chain Efficiency (SCE)	7	0.83	Good reliability
Digital Capability (DC)	8	0.89	Good reliability
Supply Chain Performance (SCP)	7	0.85	Good reliability
Resilience-Efficiency Trade-off (RET)	5	0.81	Good reliability

Table 4.3: Cronbach's Alpha Internal Consistency by Construct

All constructs exceed the threshold of $\alpha = 0.70$, with digital capability ($\alpha = 0.89$) and supply chain resilience ($\alpha = 0.87$) achieving particularly strong internal consistency. No items required deletion. Harman's single-factor test indicated that no single factor explained more than 34% of total variance, confirming that common method bias is not a significant threat to validity.

4.4 Descriptive Statistics

Construct	Mean	Std. Dev.	Interpretation
Supply Chain Resilience Practices (SCR)	3.58	0.72	Moderate adoption
Supply Chain Efficiency Practices (SCE)	4.05	0.61	High adoption
Digital Capability (DC)	3.31	0.78	Moderate significant gap
Supply Chain Performance (SCP)	3.62	0.68	Moderate performance
Resilience-Efficiency Trade-off Perception	4.18	0.57	Trade-off strongly perceived

Table 4.4: Descriptive Statistics Construct-Level Means

The descriptive findings reveal three strategically important patterns. First, supply chain efficiency practices score substantially higher (M = 4.05) than resilience practices (M = 3.58), confirming that the Indian automotive industry's historical efficiency bias persists: organizations are more mature in lean efficiency practices than in resilience capability development. Second, digital capability scores the lowest of the supply chain management constructs (M = 3.31), indicating that the digital capability gap identified in the literature is empirically confirmed: Indian automotive organizations have not yet developed the digital capabilities required to enable information-based resilience. Third, the resilience-efficiency trade-off is strongly perceived (M = 4.18, the highest-scoring construct), confirming that supply chain professionals experience this tension acutely in their operational decisions.

4.5 Correlation Analysis

Variable	SCR	SCE	DC	SCP
Supply Chain Resilience (SCR)	1.00	0.38**	0.59**	0.67**
Supply Chain Efficiency (SCE)	0.38**	1.00	0.44**	0.71**
Digital Capability (DC)	0.59**	0.44**	1.00	0.78**
Supply Chain Performance (SCP)	0.67**	0.71**	0.78**	1.00

*Table 4.5: Pearson Correlation Matrix (** p < 0.01, two-tailed)*

The correlation matrix reveals four key patterns. Digital capability has the strongest positive correlation with supply chain performance ($r = 0.78$) stronger than either resilience ($r = 0.67$) or efficiency ($r = 0.71$) alone providing preliminary support for H3 and H4. SCR and SCE are positively correlated ($r = 0.38$), suggesting a moderate positive relationship rather than a pure trade-off: organizations with stronger resilience practices also tend to have somewhat stronger efficiency practices, consistent with the proposition that digital capability enables both simultaneously. SCR and DC are strongly correlated ($r = 0.59$), supporting the H4 pathway that digital capability enhances the value of resilience investments. All correlations are below $r = 0.80$, confirming acceptable multicollinearity levels.

4.6 Regression Analysis

Model 1: SCR → Supply Chain Performance (H1)

Predictor	β	t-value	p-value
Supply Chain Resilience Practices	0.67	8.44	< 0.001
$R^2 = 0.45$ | Adjusted $R^2 = 0.44$ | $F(1,88) = 71.2$, $p < 0.001$			

Table 4.6: Model 1 SCR → SCP (H1)

Supply chain resilience practices significantly predict supply chain performance ($\beta = 0.67$, $p < 0.001$), explaining 45% of variance. H1 is supported.

Model 2: SCE → Supply Chain Performance (H2)

Predictor	β	t-value	p-value
Supply Chain Efficiency Practices	0.71	9.28	< 0.001
$R^2 = 0.50$ | Adjusted $R^2 = 0.50$ | $F(1,88) = 86.0$, $p < 0.001$			

Table 4.7: Model 2 SCE → SCP (H2)

Supply chain efficiency practices significantly predict supply chain performance ($\beta = 0.71$, $p < 0.001$), explaining 50% of variance. H2 is supported. Notably, efficiency practices have a slightly stronger direct effect on performance than resilience practices, consistent with the industry's greater maturity in efficiency relative to resilience.

Model 3: Digital Capability → Supply Chain Performance (H3)

Predictor	β	t-value	p-value
Digital Capability	0.78	11.54	< 0.001
$R^2 = 0.61$ | Adjusted $R^2 = 0.61$ | $F(1,88) = 133.2$, $p < 0.001$			

Table 4.8: Model 3 DC → SCP (H3)

Digital capability is the strongest single predictor of supply chain performance ($\beta = 0.78$, $p < 0.001$), explaining 61% of variance substantially more than either resilience (45%) or efficiency (50%) alone. H3 is strongly supported. This is the study's most significant bivariate finding: digital capability is a more powerful performance driver than either of the traditional supply chain management orientations.

Model 4: SCR → Digital Capability (H4 pre-test)

Predictor	β	t-value	p-value
Supply Chain Resilience Practices	0.59	6.84	< 0.001
$R^2 = 0.35$ | Adjusted $R^2 = 0.34$ | $F(1,88) = 46.8$, $p < 0.001$			

Table 4.9: Model 4 SCR → DC (H4 pre-condition)

Supply chain resilience practices significantly predict digital capability ($\beta = 0.59$, $p < 0.001$), explaining 35% of variance. This confirms the pre-condition for mediation analysis: the IV (SCR) significantly predicts the MV (DC). Organizations with stronger resilience practices also tend to have higher digital capability a finding with important strategic implications explored in Chapter 5.

4.7 Mediation Analysis H4

Baron and Kenny's (1986) four-step mediation procedure was applied to test whether digital capability mediates the SCR-to-SCP relationship.

Step	Relationship Tested	β	p-value	Met?
1	SCR → Supply Chain Performance (direct, without DC)	0.67	< 0.001	Yes
2	SCR → Digital Capability	0.59	< 0.001	Yes
3	Digital Capability → Supply Chain Performance	0.78	< 0.001	Yes
4	SCR → SCP with Digital Capability in model (direct effect)	0.29	< 0.01	Yes reduced
RESULT: PARTIAL MEDIATION CONFIRMED SCR direct effect reduces from $\beta = 0.67$ to $\beta = 0.29$ (57% reduction). DC $\beta = 0.62$ in full model. Both significant. H4 SUPPORTED.				

Table 4.10: Mediation Analysis Baron and Kenny Four-Step Results

All four conditions are satisfied. The direct effect of supply chain resilience practices on performance reduces from $\beta = 0.67$ to $\beta = 0.29$ a 57% reduction when digital capability is included in the model.

Digital capability remains a strong significant predictor (β = 0.62) alongside resilience practices. This confirms partial mediation: resilience practices improve performance both directly (through physical buffers and supplier redundancy) and indirectly by enabling organizations to develop higher digital capability, which in turn drives substantially stronger performance. H4 is supported.

4.8 Trade-off Moderation Analysis H5

H5 was examined through comparison of high digital capability (DC score ≥ 4.0, n = 36) versus low digital capability (DC score < 3.0, n = 31) subgroups on the perceived intensity of the resilience-efficiency trade-off and the correlation between SCR and SCE.

Metric	Low DC Group (DC < 3.0)	High DC Group (DC ≥ 4.0)
Mean Trade-off Perception Score	4.52 (strongly perceived)	2.48 (weakly perceived)
SCR × SCE correlation within group	−0.28 (negative trade-off present)	+0.61 (positive complementary)
Mean SCR score	3.12	4.14
Mean SCE score	3.81	4.38
Mean SCP score	3.28	4.22

Table 4.11: Subgroup Analysis High vs. Low Digital Capability

The subgroup analysis provides striking evidence for H5. In low digital capability organizations, the resilience-efficiency trade-off is strongly perceived (M = 4.52) and is reflected in a negative SCR-SCE within-group correlation (r = −0.28): organizations that score higher on resilience within this group tend to score lower on efficiency, confirming that the trade-off is real and binding in the absence of digital capability. In high digital capability organizations, the trade-off perception is substantially weaker (M = 2.48) and the SCR-SCE correlation becomes strongly positive (r = +0.61): organizations that score higher on resilience also score higher on efficiency, confirming that digital capability enables both to be achieved simultaneously. The mean SCP score is 28.7% higher in the high digital capability group (4.22 vs. 3.28). H5 is supported.

4.9 Hypothesis Testing Summary

H	Hypothesis Statement	Key Statistic	Result
H1	SCR has a significant positive impact on supply chain performance	$\beta = 0.67$, $R^2 = 0.45$, $p < 0.001$	Supported
H2	SCE has a significant positive impact on supply chain performance	$\beta = 0.71$, $R^2 = 0.50$, $p < 0.001$	Supported
H3	Digital capability has a significant positive impact on SCP	$\beta = 0.78$, $R^2 = 0.61$, $p < 0.001$	Supported strongest effect
H4	Digital capability partially mediates the SCR → SCP relationship	SCR β: 0.67 → 0.29 (57%); DC β = 0.62	Supported (Partial)
H5	The SCR-SCE trade-off is moderated by digital capability level	Trade-off score: 4.52 vs. 2.48 (high vs. low DC)	Supported

Table 4.12: Hypothesis Testing Summary

V. DISCUSSION AND IMPLICATIONS

5.1 Introduction

This chapter interprets the empirical findings of Chapter 4 in the context of the theoretical framework and literature reviewed in Chapter 2. The discussion addresses each hypothesis, explains the mechanisms behind the observed patterns, identifies the managerial implications for Indian automotive supply chain strategy, and derives the theoretical contributions of the study.

5.2 Resilience and Efficiency Both Drive Performance (H1 and H2)

The confirmation of both H1 (SCR: β = 0.67, R^2 = 0.45) and H2 (SCE: β = 0.71, R^2 = 0.50) establishes that both resilience and efficiency practices independently contribute to supply chain performance in the Indian automotive context. This is consistent with Sheffi and Rice (2005) for resilience and Womack et al. (1990) for efficiency, confirming the theoretical predictions of both streams of literature.

The slightly stronger direct effect of efficiency practices (β = 0.71) relative to resilience practices (β = 0.67) is consistent with the descriptive finding that efficiency adoption (M = 4.05) significantly outpaces resilience adoption (M = 3.58) in Indian automotive organizations. This performance differential reflects the industry's decades-long investment in lean manufacturing and supply chain efficiency: more mature practices produce stronger performance effects. It does not imply that resilience is less important the semiconductor shortage demonstrated that resilience failures can impose catastrophic one-time costs that far exceed the cumulative efficiency gains of multiple improvement years.

The positive SCR-SCE correlation (r = 0.38) across the full sample is an important finding that initially appears to contradict the trade-off framing. This overall positive correlation is explained by the H5 subgroup finding: in high digital capability organizations, SCR and SCE are strongly positively correlated (r = +0.61), which dominates the full-sample correlation. In low digital capability organizations, the correlation is negative (r = −0.28), confirming the trade-off. The full-sample positive correlation masks the moderating role of digital capability further underlining why digital capability is the critical variable in understanding the resilience-efficiency dynamics of the Indian automotive industry.

5.3 Digital Capability as the Primary Performance Driver (H3)

H3's confirmation as the strongest relationship in the model (β = 0.78, R^2 = 0.61) is the most striking finding of the study. Digital capability explains 61% of supply chain performance variance more than either resilience (45%) or efficiency (50%) individually, and consistent with the theoretical proposition advanced by Quayson et al. (2020) and Wang et al. (2024) that digital capability is the highest-leverage supply chain investment available to organizations operating in high-uncertainty environments.

The descriptive finding that digital capability has the lowest mean score (M = 3.31) relative to resilience (M = 3.58) and efficiency (M = 4.05) is therefore doubly concerning: not only is digital capability the most powerful performance driver, but it is the most underdeveloped capability in the sample. This combination highest performance impact, lowest current adoption implies that digital capability investment represents the highest-return opportunity available to Indian automotive supply chain organisations. An organisation that improves from a DC score of 3.31 to 4.0 a realistic one-to-two-year improvement horizon would, on the basis of the study's regression model, achieve a performance improvement of approximately 0.54 standard deviations, equivalent to moving from the 50th to approximately the 70th performance percentile in the sample.

The interpretation of why digital capability has such a strong performance effect draws on three mechanisms identified in Chapter 2. Supply chain visibility enables proactive disruption management the 12–15 days early warning demonstrated by Ivanov and Dolgui (2021) transforms supply disruption from a crisis into a manageable operational event. Predictive analytics enables demand and supply variability management, reducing the inventory and capacity buffer requirements that are the primary source of supply chain cost. Digital twin simulation enables supply chain configuration optimization and scenario planning, identifying efficiency improvements that manual analysis cannot detect. Together, these mechanisms explain why digital capability generates performance benefits that exceed either resilience or efficiency practices in isolation.

5.4 Digital Capability as Resilience Mediator (H4)

The partial mediation confirmed in H4 SCR's direct effect reducing from β = 0.67 to β = 0.29 (57% reduction) when digital capability is included, with digital capability retaining β = 0.62 is the study's primary theoretical contribution. It establishes that supply chain resilience practices generate their performance benefits through two pathways: a direct physical pathway (through supplier redundancy, safety stock, and business continuity plans that directly reduce production stoppages) and an indirect digital pathway (through the digital capabilities that resilience-oriented organizations tend to develop, which provide superior supply chain performance through visibility, analytics, and agility).

The magnitude of the indirect pathway capturing 57% of resilience's performance effect has direct strategic implications. It suggests that organisations can achieve a substantial portion of resilience's performance benefit through digital investment alone, without incurring the full cost of physical resilience buffers. An organization that cannot afford full dual sourcing for all critical components, or that has limited balance sheet capacity for strategic safety stock, can partially substitute digital capability investment earlier disruption detection, faster response activation, digital supplier health monitoring for physical resilience investment. This is the economic logic of information-based resilience: faster response at lower buffer cost.

The residual direct effect of resilience ($\beta = 0.29$) confirms that physical resilience investment supplier diversification, safety stock for genuinely critical components, business continuity planning retains value that digital capability cannot fully replace. The practical implication is that digital capability and physical resilience are complements, not substitutes: organisations should invest in digital capability to amplify the value of physical resilience investment and to reduce the total physical buffer required for a given performance level, rather than choosing between them.

5.5 Digital Capability Resolves the Trade-off (H5)

The H5 subgroup finding trade-off perception of 4.52 in low DC organizations versus 2.48 in high DC organizations, with SCR-SCE correlation shifting from −0.28 to +0.61 provides the most practically actionable finding of the study. It demonstrates empirically that the resilience-efficiency trade-off is not a fixed structural feature of automotive supply chains but a contingent outcome that depends on the organisation's level of digital capability.

This finding resolves the strategic dilemma described in Chapter 1: Indian automotive organizations do not have to choose between resilience and efficiency. They can achieve both, but only if they develop the digital capability that makes simultaneous achievement possible. The pathway from trade-off to integration is not a strategic insight that any individual organization can implement through willpower or organizational redesign it requires specific technology investments, data governance infrastructure, analytical capability development, and supplier digitisation integration. The REI Framework provides the architectural blueprint for this pathway.

The 28.7% performance gap between high and low digital capability organizations (mean SCP 4.22 vs. 3.28) quantifies the competitive cost of the digital capability gap. In an industry as cost-competitive as Indian automotive manufacturing, a 28.7% supply chain performance deficit represents a material competitive disadvantage. The practical urgency of digital capability investment is therefore not simply strategic it is a competitive necessity, analogous to the urgency of lean adoption thirty years earlier.

5.6 The Semiconductor Shortage and EV Transition: Specific Implications

The semiconductor shortage of 2021–22 which provides the most vivid recent illustration of resilience failure in Indian automotive supply chains is interpreted through the REI Framework as a predictable consequence of the combination of low digital capability and low resilience investment. Organizations with high digital capability would have detected the global semiconductor supply tightening through Tier-3 supplier monitoring and geopolitical risk scoring 8–12 weeks before shortages materialized, enabling strategic safety stock building, alternative source qualification, and production sequencing adjustments that would have substantially reduced production losses. The Rs. 22,000 crore production loss estimated by SIAM (2022) is the cost of operating in the bottom-left quadrant of the REI Framework low resilience, low digital capability.

The EV transition creates new supply chain challenges that the REI Framework directly addresses. Battery supply chains have unprecedented geopolitical concentration risk (approximately 75% of lithium-ion cell capacity in China) and critical mineral supply risks (lithium, cobalt, nickel with contested geographic provenance). These risks require both physical resilience investment (strategic mineral inventory, supply source diversification) and digital capability investment (provenance tracking through blockchain, supply risk scoring for battery material sources, digital twin simulation of EV supply chain configurations). The REI Framework's prediction that digital capability amplifies the performance benefit of resilience investment is particularly relevant for EV supply chain development, where the supply risk profile is more complex and the cost of supply disruption is higher than in ICE component supply chains.

5.7 Managerial Implications

Operational Level Immediate Priorities (0–6 months)

- Implement Tier-2 and Tier-3 supplier health monitoring: Deploy digital supplier monitoring platforms that track financial health indicators, operational capacity utilization, and order book status for critical Tier-2 and Tier-3 suppliers. The semiconductor shortage demonstrated that production stoppages originate at Tier-3 level; visibility must extend to this depth.
- Establish semiconductor and critical component safety stock policy: Define SKU-specific safety stock targets for semiconductor components and other single-source, long-lead-time components based on geopolitical risk scoring and supply base concentration analysis. Target a minimum of 8–12 weeks safety stock for A-class semiconductor SKUs.
- Activate supply chain control tower functionality: For organizations that have implemented control tower technology without activating its decision-support functionality, prioritise integration of existing ERP, TMS, and supplier data feeds into unified real-time dashboards. Control tower value comes from decision integration, not technology installation.
- Conduct disruption scenario mapping: Map the top 10 supply disruption scenarios (by probability × impact) and develop response playbooks specifying activation triggers, decision authority, and execution steps for each scenario. Pre-registered response plans reduce time-to-action during actual disruptions.

Tactical Level Medium-Term Priorities (6–18 months)

- Dual source qualification for critical components: Identify the top 20% of components by supply risk score (combining single-source concentration, geographic concentration, and lead time) and complete alternate source qualification for each. Target dual-source capability for 100% of A-class components within 18 months.
- Predictive analytics for supply risk scoring: Implement AI/ML-based supply risk scoring that ingests supplier financial data, geopolitical risk signals, logistics performance metrics, and commodity price movements to generate predictive risk scores for the critical supply base. Target 10+ days advance warning capability for 80% of supply risk events.
- EV supply chain visibility roadmap: Develop a battery supply chain visibility roadmap that extends digital tracking to lithium, cobalt, and nickel provenance both for emerging regulatory compliance requirements (EU Battery Regulation, CBAM) and for internal supply risk management. Engage cell suppliers to establish data-sharing protocols.
- Supplier digital capability development program: Many Tier-2 and Tier-3 SME suppliers lack the digital infrastructure to participate in supply chain visibility systems. OEMs and large Tier-1 suppliers should establish structured programs to co-fund and co-implement basic digital capability at critical SME suppliers, building the data-sharing infrastructure on which OEM control towers depend.

Strategic Level Long-Term Priorities (18+ months)

- Digital twin deployment for supply chain network optimization: Develop a digital twin of the full supply chain network encompassing supplier locations, transport links, inventory positions, and production capacities to enable continuous scenario simulation. The digital twin enables both resilience testing (stress-testing the network against disruption scenarios) and efficiency optimization (identifying structural cost reduction opportunities invisible to traditional analysis).
- Resilience-by-design in EV supply chain architecture: As EV production volumes scale, design the EV supply chain with explicit resilience architecture geographic diversification of battery cell suppliers across China, Korea, and emerging Indian cell manufacturers (Tata, Amara Raja, Exide); strategic mineral inventory; and supplier financial resilience support programs for critical component suppliers.

- ACMA-SIAM collective digital infrastructure investment: Given that digital capability development requires data-sharing infrastructure that is partly industry-level (shared logistics platforms, industry-wide supply risk databases), ACMA and SIAM should coordinate industry-level investments in shared digital infrastructure, reducing the per-organisation cost of digital capability development and enabling smaller suppliers to participate in the automotive digital ecosystem.
- Integrate REI Framework into supply chain strategy review: Formally incorporate the resilience-efficiency-digital capability integration logic into annual supply chain strategy reviews, using the REI diagnostic framework to assess current quadrant position (high/low DC × high/low resilience) and target quadrant for the planning period.

5.8 Theoretical Implications

This study makes three theoretical contributions. First, it provides empirical validation of digital capability's mediating role between supply chain resilience practices and supply chain performance in the Indian automotive context. The 57% mediation effect size establishes that the indirect digital pathway accounts for the majority of resilience's performance benefit a finding that repositions digital capability from a performance enhancement tool to a fundamental mechanism in resilience-to-performance causation.

Second, the REI Framework advances supply chain resilience theory by formally modelling digital capability as a trade-off moderator an organizational capability that changes the shape of the efficiency-resilience trade-off frontier rather than simply improving performance along it. The H5 empirical evidence negative SCR-SCE correlation in low DC organizations, positive correlation in high DC organizations provides the first empirical demonstration of this trade-off resolution mechanism in the automotive supply chain context.

Third, the study contributes India-specific empirical data to a global automotive supply chain literature that has been primarily developed from Japanese, US, and European data. India's structural conditions semiconductor dependency, tier-city supplier fragmentation, infrastructure variability, and EV transition dynamics produce supply chain management challenges and digital capability requirements that are quantitatively and qualitatively different from those in developed automotive markets.

5.9 Limitations

Five limitations are acknowledged. First, purposive sampling of professionals accessible through SIAM and ACMA networks may over-represent larger, more formally managed organizations, understating the digital capability gap in the SME supply base. Second, self-reported performance data may reflect aspiration rather than audited metrics particularly for OTIF and production continuity scores, which vary in definition and measurement across organizations. Third, the cross-sectional design cannot confirm causal ordering; longitudinal data would provide stronger evidence that digital capability investment leads to improved performance. Fourth, the n = 90 sample limits the statistical power of OEM-vs-supplier subgroup analyses. Fifth, the study does not capture the dynamics of the ongoing EV transition the performance implications of EV supply chain management are likely to become substantially more important as EV production volumes scale toward the 2030 targets.

VI. CONCLUSION AND RECOMMENDATIONS

6.1 Introduction

This chapter synthesizes the study's key findings, presents the validated Resilience-Efficiency Integration (REI) Framework with confirmed empirical coefficients, provides structured strategic recommendations for Indian automotive supply chain practitioners across operational, tactical, and strategic time horizons, identifies policy implications for industry bodies and government, proposes directions for future research, and closes with a final statement on the future of automotive supply chain strategy in India.

6.2 Summary of the Study

This dissertation investigated the resilience-efficiency trade-off in Indian automotive supply chains and developed the Resilience-Efficiency Integration (REI) Framework a model proposing digital capability as the critical mediating mechanism through which supply chain resilience and efficiency can be integrated into superior supply chain performance. The study was motivated by the empirical evidence of resilience failure in Indian automotive supply chains most acutely the Rs. 22,000 crore production loss from the semiconductor shortage of 2021–22 and the strategic imperative to develop supply chain architectures that are simultaneously resilient, efficient, and competitive. Using a structured questionnaire survey of 90 automotive supply chain professionals across OEMs, Tier-1, Tier-2, and logistics service providers, supplemented by secondary industry data, the study tested five hypotheses through descriptive statistics, correlation analysis, regression analysis, and Baron and Kenny's (1986) mediation procedure. All five hypotheses were supported. The most critical findings are: digital capability is the strongest supply chain performance driver ($\beta = 0.78$, $R^2 = 0.61$); digital capability partially mediates the resilience-performance relationship (57% mediation effect); and the resilience-efficiency trade-off virtually disappears in high digital capability organizations (trade-off perception 2.48 vs. 4.52 in low DC organizations).

6.3 Key Conclusions

Conclusion 1 Both resilience and efficiency matter, but differently: *SCR (β=0.67) and SCE (β=0.71) both significantly drive performance. The industry's historical efficiency bias has delivered real performance benefits, but the residual resilience gap evidenced by the semiconductor shortage represents an unmanaged performance risk that efficiency practices cannot protect against.*

Conclusion 2 Digital capability is the primary supply chain performance driver: *DC (β=0.78, R²=0.61) outperforms both resilience and efficiency as a standalone performance driver, yet scores the lowest mean of all constructs (M=3.31). The combination of highest performance impact and lowest current adoption defines the single most important supply chain investment priority for Indian automotive organizations.*

Conclusion 3 Digital capability mediates resilience's performance benefit: *57% of resilience's performance benefit operates through the digital capability pathway. Resilience investment without digital capability investment captures less than half its available value. Physical resilience and digital capability are complements: digital capability amplifies physical resilience investment.*

Conclusion 4 Digital capability resolves the resilience-efficiency trade-off: *In high DC organizations, the trade-off virtually disappears: SCR and SCE are positively correlated (+0.61) and mean SCP is 28.7% higher than in low DC organizations. The trade-off is not a fixed structural constraint it is a symptom of digital capability deficit.*

Conclusion 5 India-specific structural challenges amplify both the trade-off and the digital opportunity: *Semiconductor dependency, tier-city supplier fragmentation, EV transition dynamics, and infrastructure variability make the resilience-efficiency trade-off more acute in India than in comparable automotive markets and make digital capability investment more valuable as a trade-off resolver.*

6.4 The Validated REI Framework

Layer 1: Supply Chain Practices (IVs)	Layer 2: Digital Capability (Mediator)	Layer 3: Performance (DV)
Supply Chain Resilience (SCR)	Digital Capability (DC)	Supply Chain Performance (SCP)
Supplier diversification, Dual sourcing, Safety stock, BCP, Geographic redundancy	Visibility (Tier-deep), Predictive analytics, Digital twin, Supplier digitisation, Control tower	OTIF, Production continuity, Lead-time reliability, Cost efficiency, Disruption recovery speed
Supply Chain Efficiency (SCE)		

Lean inventory, JIT delivery, Supplier rationalization, Kaizen, Asset utilization	Confirmed: SCR → DC: β=0.59 | DC → SCP: β=0.78 | SCR direct (with DC): β=0.29 | Trade-off resolution confirmed (H5)	SCP gap (high vs. low DC): +28.7%. Trade-off: r=−0.28 (low DC) vs. r=+0.61 (high DC)

Figure 6.1: Validated REI Framework Confirmed Beta Coefficients and Trade-off Resolution

6.5 Strategic Recommendations

Horizon	Recommendation	Target KPI	Audience
Operational (0–6 months)	Deploy Tier-2/Tier-3 supplier digital health monitoring	Supply disruption early-warning lead time	SCM directors, Procurement
	Establish semiconductor safety stock policy (8–12 weeks A-class)	Production continuity score	Supply chain planners
	Activate control tower decision-support functionality	Disruption response time	Digital/IT + SC ops teams
	Conduct disruption scenario mapping and response playbook development	Response time per scenario	Risk management teams
Tactical (6–18 months)	Complete dual-source qualification for top-20% highest-risk components	Single-source exposure index	Procurement directors
	Implement AI/ML predictive supply risk scoring for critical supply base	Days of advance warning (target 10+)	Analytics + digital teams
	EV battery supply chain visibility roadmap: provenance tracking to mineral level	Supply risk score for battery materials	EV SCM teams
	SME supplier digital capability co-investment program	Tier-2 digital visibility coverage %	OEM + large Tier-1 leadership
Strategic (18+ months)	Deploy digital twin of full supply chain network for scenario simulation	Scenario coverage; scenario recovery accuracy	C-suite; SCM leadership
	Design EV supply chain with explicit resilience architecture	EV supply risk score vs. ICE baseline	Group strategy teams
	Engage ACMA/SIAM for industry-level shared digital infrastructure investment	Industry DC index improvement	Industry bodies; Policy engagement

Table 6.1: Structured Recommendation Matrix Horizon, KPI, and Audience

6.6 Policy Implications

Four policy priorities are identified for government and industry bodies. First, the Production Linked Incentive (PLI) scheme for Advanced Chemistry Cell batteries should incorporate explicit supply chain resilience and digital capability requirements linking PLI disbursements to evidence of Tier-2 supplier diversity, critical material inventory standards, and supply chain visibility system deployment. This would accelerate both the EV supply chain transition and the digital capability development that the REI Framework identifies as critical to supply chain performance.

Second, ACMA should develop and maintain a centralised Automotive Supply Chain Risk Registry an industry-shared database of component-level supply risk scores, geopolitical risk assessments for critical import dependencies, and disruption probability estimates that member organizations can access to inform their resilience investment decisions. The collective benefit of shared intelligence far exceeds what any individual organization can generate independently.

Third, the Ministry of Heavy Industries should establish a Semiconductor Strategic Reserve strategic government-held inventory of critical automotive-grade semiconductor types that can be released to domestic OEMs during global shortage events, providing a systemic backstop against the production disruption cost that the 2021–22 shortage demonstrated. This is analogous to strategic petroleum reserves and is justified by the semiconductor's similar criticality to economic activity.

Fourth, the National Logistics Policy's digital infrastructure initiatives the Logistics Data Bank (LDB) and Unified Logistics Interface Platform (ULIP) should be extended to include automotive-specific supply chain visibility modules that connect OEM ERP systems with Tier-2 and Tier-3 supplier operational data, enabling the tier-deep visibility that the REI Framework identifies as the foundation of digital capability.

6.7 Directions for Future Research

Six directions for future research are identified. First, a longitudinal study tracking the same automotive organizations across a complete disruption cycle before disruption, during disruption, and in recovery would provide stronger causal evidence for the REI Framework's propositions and would quantify the performance improvement attributable to specific digital capability investments. Second, an OEM-vs-Tier-1-vs-Tier-2 comparative study with adequate sample sizes would test whether the REI Framework relationships hold equally across supply chain tiers particularly important given the digital capability gap between large OEMs and SME suppliers. Third, a study specifically focused on EV supply chain management in India would extend the REI Framework to the battery, electric motor, and power electronics supply chains that are rapidly becoming the dominant strategic supply chain challenge. Fourth, an examination of the industry-level collective action problem how industry bodies, government, and individual organizations can coordinate to build the shared digital infrastructure on which individual digital capability development depends would address a gap in the current study's recommendations. Fifth, extending the REI Framework to incorporate sustainability and carbon emissions as a fourth performance dimension would address the growing regulatory and competitive pressure on automotive supply chains. Sixth, comparative research contrasting India with other high-growth automotive markets Brazil, Mexico, Indonesia, Vietnam that share structural similarities (SME supplier fragmentation, import dependency, infrastructure variability) would test the geographic generalizability of the REI Framework.

6.8 Contributions of the Study

Contribution	Type	Chapter(s)
First empirical mediation test of digital capability between SCR and SCP in Indian automotive supply chains	Academic	Ch. 2, 4, 5
Resilience-Efficiency Integration (REI) Framework named, validated, India-specific, with confirmed coefficients	Academic + Managerial	Ch. 2, 6
First empirical demonstration of digital capability resolving the resilience-efficiency trade-off (H5)	Academic	Ch. 4, 5

India-specific automotive supply chain data semiconductor dependency, EV transition, tier-city fragmentation	Academic + Managerial	Ch. 1, 2, 5
Structured 3-horizon recommendation matrix for automotive SCM digital transformation	Managerial	Ch. 5, 6
Policy framework: Semiconductor Strategic Reserve, ACMA Risk Registry, PLI-linked resilience requirements	Policy	Ch. 6

Table 6.2: Study Contributions Summary

6.9 Final Conclusion

The Indian automobile industry's supply chain leadership faces a defining strategic choice. The semiconductor shortage of 2021–22 cost Rs. 22,000 crore in lost production and demonstrated conclusively that the efficiency-first supply chain strategy that built India's automotive industry cannot, by itself, deliver the operational continuity that a global, disruption-prone supply chain environment demands. The EV transition is creating new supply dependencies and new disruption vulnerabilities that will compound this challenge. The question is not whether to invest in supply chain resilience the cost of insufficient resilience has been quantified beyond reasonable dispute but how to do so without sacrificing the cost competitiveness on which the industry's competitive viability depends.

The Resilience-Efficiency Integration (REI) Framework, developed and empirically validated in this study, provides the answer. The trade-off between resilience and efficiency is not a fixed structural constraint it is a consequence of insufficient digital capability. Organizations that invest in supply chain visibility, predictive analytics, and digital twin capability achieve resilience through information and response speed rather than physical buffers, enabling them to maintain lean efficiency simultaneously. The 28.7% supply chain performance gap between high and low digital capability organizations in this study quantifies the competitive cost of failing to make this investment.

The automobile industry's history offers a precise parallel. Thirty years ago, lean manufacturing was a competitive differentiator that separated Toyota and Honda from their rivals. Within a decade, it became a competitive necessity organizations that had not adopted lean were not competitive. Digital supply chain capability is at the same inflection point in 2025. The organizations that invest now will define the performance frontier of Indian automotive supply chains. Those that do not will increasingly find themselves unable to match the performance, resilience, and cost efficiency of their digitally capable competitors both domestic and international. The future of Indian automotive supply chains does not belong to the most efficient, nor to the most resilient. It belongs to those that are intelligently both using digital capability to dissolve the trade-off rather than manage it.

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