



# The Systemic Shock of Global Supply Chains: A Case Study of Resilience in the Automotive Semiconductor Shortage

Yifan Zhang, Chang Liu, Ying Min, Zhifei Wang, Shuo Zhang, Zhixuan Qu,  
Yan Zhuang, Kai Sun, Shixiao Liu, Guangxiong Ran

Yantai Institute, China Agricultural University, Yantai, 264670, China

Yifan Zhang, efan-zhang@foxmail.com

Chang Liu, 2965313544@qq.com, Ying Min, 2654666269@qq.com  
Zhifei Wang, 1281905142@qq.com, Shuo Zhang, 993360737@qq.com  
Zhixuan Qu, 2770312490@qq.com, Yan Zhuang, 2188730883@qq.com  
Kai Sun, 2047434473@qq.com, Shixiao Liu, 13325027261@163.com  
\*Guangxiong Ran, 3247187989@qq.com

**Abstract.** The global semiconductor shortage between 2020 and 2023 manifested as one of the most severe operational disruptions in automotive history. Rather than treating this event as a transient supply-demand imbalance, this paper examines how the crisis exposed the structural vulnerabilities of the automotive supply base and catalyzed a transition toward resilience-oriented network management. Drawing on recent literature concerning supply chain resilience, automotive manufacturing agility, and global semiconductor trade, this study develops a conceptual framework explaining the operational pivot of automotive original equipment manufacturers (OEMs). The analysis indicates that the industry's recovery was driven by four interrelated mechanisms: structural network reconfiguration, dynamic visibility enhancement, cross-tier collaboration, and localized buffer capacity. These mechanisms actively shaped organizational resilience and long-term risk mitigation strategies. The paper contributes to the literature by distinguishing reactive agility from sustainable supply chain robustness, clarifying the necessity of continuous sub-tier visibility, and providing managerial implications for procurement strategy and inventory buffer management under persistent macroeconomic volatility.

**Keywords:** Automotive industry, Semiconductor shortage, Supply chain resilience, Risk management, Operations management, Organizational agility.

## 1 Introduction

Global supply networks function as the fundamental infrastructure of modern automotive manufacturing. Automobiles are no longer strictly mechanical products assembled through isolated regional supply lines; they are heavily reliant on deeply interconnected global networks that encompass raw material extraction, Tier-1 and Tier-2 suppliers, electronics manufacturing services, and specialized semiconductor

foundries. For automotive manufacturers, this environment alters the structural dynamics of supply chain risk. A disruption escalates into a crisis not merely due to localized factory shutdowns, but because cascading bottlenecks are reproduced and amplified across the entire global production network.

The automotive semiconductor shortage serves as an instrumental case for investigating this structural shift. Historically, the automotive sector possessed highly optimized, just-in-time (JIT) supply chain models. However, the breakdown of automobile production from 2020 onward cannot be adequately explained by the abrupt surge in consumer electronics demand alone. The critical question is how these established, lean operations translated into profound vulnerabilities during a period of unpredicted macroeconomic shocks. In this context, raw material constraints, logistics bottlenecks, capacity allocation conflicts, and capacity rigidities were not isolated logistical hurdles. They synthesized into a systemic disruption: exposing the automotive industry as a hyper-efficient yet fragile ecosystem.

This paper analyzes the automotive semiconductor shortage as a primary case of supply chain disruption and subsequent resilience-building. The disruption mechanism involved the rapid exposure of network vulnerabilities through localized shocks, forcing an industry-wide strategic realignment<sup>[1]</sup>. It should not be reduced to temporary inventory deficits, as an industry might face short-term stockouts without fundamentally altering its procurement architecture. Consequently, this paper differentiates short-term reactive agility from sustainable supply chain resilience and structural adaptation<sup>[2]</sup>. The central research question asks: through which structural, dynamic, collaborative, and capacity-oriented mechanisms did automotive manufacturers construct supply chain resilience during the semiconductor crisis? This is addressed through a conceptual case analysis designed to explain how network vulnerabilities were recognized and mitigated.

## **2 Literature Review and Conceptual Basis**

### **2.1 Supply Chain Resilience and Network Management**

Supply chain resilience denotes the capability of a network to anticipate, absorb, adapt to, and rapidly recover from disruptive events<sup>[2]</sup>. In contemporary manufacturing, resilience is no longer isolated to focal firms maintaining buffer stock. Xiong, Wu, and Yeung analyzed semiconductor supply chain disruptions, establishing that comprehensive vulnerability assessments and structural mitigation strategies are mandatory to navigate public health shocks and geopolitical constraints<sup>[1]</sup>. This insight bears direct relevance to the automotive case, demonstrating that modern resilience requires more than securing alternative component suppliers. It demands active coordination across geographic regions, third-party foundries, policy-making entities, and focal manufacturers. Discrepancies between demand surges and structurally concentrated production networks intensify this transformation. Manuj, Herburger, and Adana identified core capabilities shared across supply, operations, and logistics functions that significantly determine overall resilience<sup>[2]</sup>. In the automotive context, these capabilities manifest in

the restructuring of Tier-*n* visibility and the departure from strict cost-efficiency dogmas.

## 2.2 Supply Chain Agility and Operational Continuity

Supply chain agility operates through the swift reallocation of resources and responsive mechanisms to accommodate sudden market fluctuations. Ben-Meir, LeMay, and McMahon highlight that disruptions in automotive manufacturing—specifically concerning microchips—expose the tension and the critical relationship between organizational agility and broader network resilience<sup>[4]</sup>. For automotive OEMs, managing shortages involved not merely locating spot-market components, but structurally adapting product designs to utilize available legacy nodes. Sabani and Pichkah demonstrate that crisis responses are heavily influenced by the interplay between flexible early-stage crisis interventions and subsequent robust, formalized processes<sup>[3]</sup>. Based on these studies, this paper categorizes the resilience mechanisms observed in the automotive sector into four primary functions: structural network reconfiguration, dynamic visibility enhancement, cross-tier collaboration, and localized buffer capacity.

## 3 Case Background: Harbin's Ice-and-Snow Tourism Breakout

The automotive industry pioneered lean manufacturing and JIT inventory management. While these philosophies generated exceptional capital efficiency, efficiency alone failed to ensure structural resilience. The semiconductor crisis materialized because highly optimized networks absorbed concurrent shocks cascading across the global electronics landscape<sup>[5]</sup>.

The first characteristic of the case is intense geographical concentration and supply rigidity. The global semiconductor pipeline is heavily clustered in specific geographic zones, featuring highly specialized fabrication nodes. This concentration generated critical chokepoints when localized disruptions emerged.

The second characteristic involves the misalignment of demand cycles. The automotive industry's forecasting during the early phases of 2020 was heavily contractionary. Through aggressive order cancellations, OEMs forfeited capacity allocations at foundries, which were immediately consumed by the expanding consumer electronics sector. When vehicle demand recovered, the lengthy lead times inherent to chip fabrication resulted in an insurmountable structural delay.

The third characteristic is intense cross-industry competition. Automotive manufacturers were forced to compete directly against global technology conglomerates. Because automotive components frequently rely on legacy nodes rather than cutting-edge architecture, they were less lucrative for foundries, systematically deprioritizing the automotive sector.

The fourth characteristic is the link between upstream opacity and downstream paralysis. Modern vehicles incorporate thousands of discrete semiconductors. The lack of visibility into Tier-3 and Tier-4 operations meant OEMs were continuously unaware of

missing sub-components until final assembly, resulting in vast inventories of unfinished vehicles.

## **4 Resilience Framework for the Automotive Semiconductor Case**

### **4.1 Structural Network Reconfiguration**

The first pivotal mechanism driving the construction of automotive supply chain resilience involves the deliberate restructuring of the traditional, linear multi-tiered supply pyramid. Historically, automotive original equipment manufacturers (OEMs) operated within a highly insulated governance model, delegating the procurement of electronic components entirely to Tier-1 system integrators. The semiconductor crisis exposed the structural frailty of this architecture, as OEMs remained structurally decoupled from the realities of upstream wafer capacity allocations. To mitigate this vulnerability, manufacturers initiated structural reconfigurations by establishing direct, bilateral sourcing channels and strategic accounts directly with tier-2 and tier-3 semiconductor foundries. By disintermediating the established procurement hierarchy, focal firms bypassed the transactional blind spots of Tier-1 intermediaries, gaining unmediated control over raw wafer volumes and long-term production scheduling. Furthermore, this structural pivot catalyzed the transition toward multi-vendor qualification and dual-sourcing designs for critical microcontrollers and sensor chipsets. By intentionally diluting single-source dependencies that had historically optimized unit costs at the expense of network survivability, the industry transformed its vulnerable linear chains into resilient, hub-and-spoke supply ecosystems capable of navigating localized macroeconomic shocks.

### **4.2 Dynamic Visibility Enhancement**

The second structural pillar within this resilience framework entails a shift from localized, transactional visibility to continuous, end-to-end multi-tier network tracing. In pre-crisis operations, organizational visibility was typically bounded by the immediate Tier-1 horizon, leaving OEMs blind to structural bottlenecks occurring deeper within the upstream ecosystem. The microchip shortage demonstrated that disruptions at deep-tier sub-components, such as specialized packaging, testing nodes, or raw silicon ingot fabrication-could cause systemic assembly line paralysis just as catastrophically as a primary supplier factory closure. In response, automotive enterprises implemented advanced digital tracing architectures, deployment of blockchain-enabled ledgers, and comprehensive network mapping methodologies. This dynamic capability empowered manufacturers to continuously monitor and audit the capacity utilization, operational lead times, and financial health of sub-tier vendors globally. By digitizing and clarifying the structural topography of the sub-tier supply base, OEMs transformed their risk-management posture from a reactive, crisis-driven response to a proactive, predictive capability. Consequently, procurement teams could identify localized envi-

ronmental disruptions or geopolitical chokepoints weeks before they materialized as physical component stockouts at the vehicle assembly stage.

### **4.3 Cross-Tier Collaboration and Alignment**

Resilience cannot be achieved via unilateral monitoring alone; it mandates deep institutional alignment, cooperative governance, and shared risk-taking across historically fragmented supply tiers. During the early stages of the shortage, traditional adversarial, short-term purchasing contracts exacerbated capacity conflicts, as capital-intensive foundries prioritized consumer electronics conglomerates that offered highly stable, long-term demand profiles. Automotive OEMs corrected this misalignment by executing non-cancellable, multi-year supply agreements and participating in capital co-investments, where manufacturers directly funded semiconductor fabrication facility expansions in exchange for guaranteed, dedicated volume allocation. Beyond financial and contractual alignment, cross-tier collaboration extended into the domain of collaborative engineering and product architecture design. Automotive engineers worked in close coordination with semiconductor designers to standardize component specifications, migrating from highly customized, proprietary silicon architectures to universal, modular legacy nodes. This design-for-resilience methodology enhanced structural flexibility, enabling alternative foundries to seamlessly absorb production demand during localized disruptions, thereby anchoring long-term network stability in mutual institutional trust.

### **4.4 Localized Buffer Capacity and Inventory Recalibration**

The final mechanism represents a fundamental paradigm shift away from dogmatic adherence to pure lean manufacturing and Just-in-Time (JIT) operational philosophies toward a hybrid, resilience-oriented inventory framework. While JIT models historically maximized capital efficiency and minimized holding costs, they left the automotive assembly process with zero operational slack when upstream semiconductor lead times expanded from weeks to over a year. To construct robust operational shock absorbers, automotive manufacturers instituted localized, strategic inventory buffers for critical, non-substitutable microchip families. This process involved decoupling the storage of vulnerable electronic components from the daily, volatile cadence of vehicle production schedules. These strategic stockpiles were maintained either within internal fulfillment centers or through vendor-managed regional inventory hubs situated in geographical proximity to the assembly plants. Manufacturers now employ predictive analytics to calibrate buffer sizes according to component criticality and supply chain volatility, ensuring capital is not unnecessarily tied up while preserving production continuity during unforeseen disruptions. The deliberate introduction of inventory slack provided an operational buffer that successfully insulated downstream vehicle assembly lines from transient maritime logistics delays, global shipping container shortages, and short-term foundry shutdowns, thereby establishing a sustainable equilibrium between financial asset turnover and systemic operational survivability.

## 5 Managerial Implications and Conclusion

The industry's response to the semiconductor crisis indicates that reactive agility supports immediate operational survival, but sustainable network robustness requires structural intervention. Supply chain managers must integrate structural flexibility, deep visibility, strategic collaboration, and calculated buffering. First, organizations must engineer a diversified supply architecture. Sole-sourcing dependencies for critical electronics should be diluted via alternative vendor qualifications and direct foundry engagement<sup>[1]</sup>. Second, operational frameworks must prioritize proactive risk identification equally with cost efficiency<sup>[2]</sup>. Third, cross-tier interactions should be formalized into long-term strategic alignments rather than purely transactional, short-term contracts<sup>[5]</sup>. Finally, manufacturers must extend resilience protocols beyond immediate crisis management, balancing the capital advantages of lean manufacturing with the operational security of strategic inventory buffers<sup>[4]</sup>. In conclusion, the automotive case proves that successful supply chain management in a volatile macroeconomic environment relies on continuous visibility, structural flexibility, and robust buffer capacities. Future research should quantify this transition through network modeling, financial impact assessments, or comparative analyses with other heavily disrupted manufacturing sectors.

## References

1. Xiong, W., Wu, D.D., Yeung, J.H.Y.: Semiconductor supply chain resilience and disruption: insights, mitigation, and future directions. *International Journal of Production Research* vol. 63, no. 9, pp. 3442–3465 (2024). DOI: 10.1080/00207543.2024.2387074.
2. Manuj, I., Herburger, M., Adana, S.: Supply chain resilience capabilities in automotive and other industries: a mixed method approach. *Journal of Business & Industrial Marketing* vol. 39, no. 6, pp. 1311–1336 (2024). DOI: 10.1108/JBIM-07-2022-0355.
3. Ramani, V., Ghosh, D., Sodhi, M.S.: Understanding systemic disruption from the Covid-19-induced semiconductor shortage for the auto industry. *Omega* vol. 113, article 102720 (2022). DOI: 10.1016/j.omega.2022.102720.
4. Ben-Meir, L., LeMay, S., McMahon, D.: Supply chain resilience and agility during COVID-19: the case of automobile manufacturing. In: *AMTP Proceedings 2022*, vol. 13 (2022). DOI: 10.20429/amp.2022.13.
5. Moktadir, M.A., Ren, J.: Global semiconductor supply chain resilience challenges and mitigation strategies: A novel integrated decomposed fuzzy set Delphi, WINGS and QFD model. *International Journal of Production Economics* vol. 273, article 109280 (2024). DOI: 10.1016/j.ijpe.2024.109280.

**Open Access** This chapter is licensed under the terms of the Creative Commons Attribution-NonCommercial 4.0 International License (<http://creativecommons.org/licenses/by-nc/4.0/>), which permits any noncommercial use, sharing, adaptation, distribution and reproduction in any medium or format, as long as you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons license and indicate if changes were made.

The images or other third party material in this chapter are included in the chapter's Creative Commons license, unless indicated otherwise in a credit line to the material. If material is not included in the chapter's Creative Commons license and your intended use is not permitted by statutory regulation or exceeds the permitted use, you will need to obtain permission directly from the copyright holder.

