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Effective Management of Semiconductor Obsolescence in Automotive ECU Manufacturers

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Abstract

The rapid evolution of semiconductor technology poses a significant challenge for the automotive industry, particularly in managing the lifecycle of electronic components used in Electronic Control Units (ECUs). While automotive products typically require a 15-year service life, semiconductor components often become obsolete within 7–10 years, creating a critical gap that threatens both supply chain stability and product sustainability. This issue is further exacerbated by the rising number of End-of-Life (EOL) notices from semiconductor manufacturers, along with ongoing geopolitical policies. Without effective lifecycle management, ECU manufacturers face production delays, costly redesigns, and compliance risks with stringent functional safety standards mandated by Original Equipment Manufacturers (OEMs). This paper examines proactive and mitigative strategies for addressing semiconductor obsolescence risks, including enhanced component lifecycle monitoring during the development phase, database enrichment, multi-sourcing component strategies, and risk-sharing agreements with suppliers and customers. By implementing these measures, ECU manufacturers can improve supply chain resilience, ensure compliance with safety and reliability standards, and reduce the financial impact of semiconductor obsolescence. The findings of this study highlight the importance of a structured approach to lifecycle management, which can significantly enhance the sustainability and reliability of automotive electronics.

Keywords: Automotive Semiconductor Shortage, Electronic Control Units**,** Obsolescence management, Functional Safety, Component Multisource.

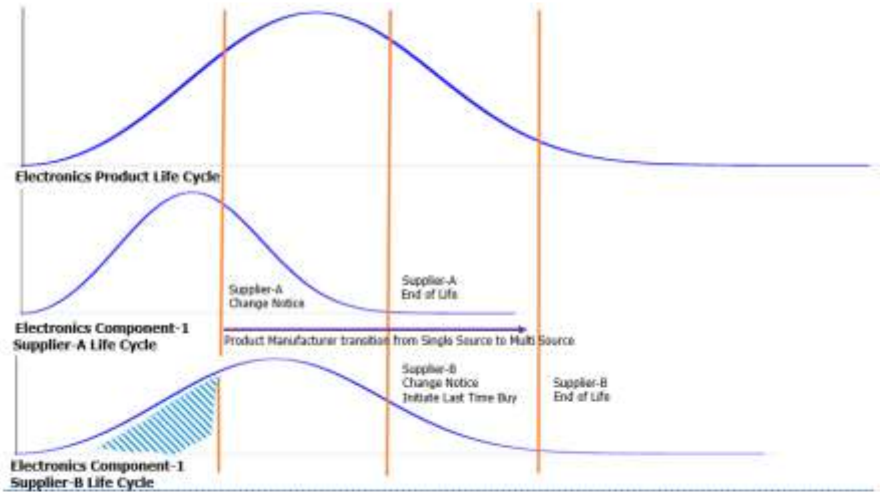
1. Introduction

The rapid evolution of semiconductor technology presents a critical challenge for the automotive industry, particularly in the lifecycle management of Electronic Control Units (ECUs). Unlike consumer electronics, where product cycles are relatively short, automotive manufacturers must ensure a reliable service life of 15 years or more. However, semiconductor components used in ECUs often reach the End of Their Life (EOL) within 7–10 years, creating significant supply chain risks, redesign burdens, and challenges to automotive standards compliance. The increasing frequency of semiconductor obsolescence, exacerbated by global shortages and shrinking supplier support, necessitates a proactive and structured approach to lifecycle management. For instance, the global semiconductor shortage in 2021 resulted in significant production delays and financial losses across the automotive industry, underscoring the urgent need for effective obsolescence management strategies [1]. Without effective mitigation strategies, ECU manufacturers face increased costs, production delays, and potential non-compliance with stringent safety and reliability standards set by Original Equipment Manufacturers (OEMs). Figure 1 illustrates the lifecycle misalignment between semiconductors and OEM requirements, which exposes ECU Manufacturers to End-of-Life Risk. Capital expenditure, scrapping costs, and redesign costs are the top three financial factors increasing End-of-Life risk, along with additional quality-related risks. This inherent discrepancy not only strains financial resources but also jeopardizes the long-term sustainability and performance of vehicles, demanding innovative solutions to bridge the gap between component lifespans and product service expectations. Furthermore, the inability to replace obsolete components can lead to vehicles being prematurely decommissioned, impacting consumer trust and potentially creating significant environmental waste. Therefore, a robust framework for managing semiconductor obsolescence is not merely a cost-saving measure but a fundamental requirement for the future viability and integrity of the automotive sector.

Figure 1 : Semiconductor Component Lifecycle vs. OEM Lifecycle

Figure 2 illustrates the life cycles of the automotive ECU compared to those of electronics component-1 from Supplier-A and Supplier-B. It's essential to note that an ECU comprises hundreds of components, as listed in its Bill of Materials (BOM), which significantly complicates supply chain coordination.

Figure 2 : ECU Life Cycle Vs Electronic Component Life Cycle (Supplier-A and Supplier-B)



This highlights the importance for ECU manufacturers to manage semiconductor design and development lifecycles efficiently. Given the complexity of cross-functional automotive electronic design, a streamlined yet robust process is essential within the current corporate framework, without disrupting present operations, databases, and their functionalities. Figure 3 illustrates the streamlined workflow of automotive electronic design, from Computer-Aided Design (CAD) creation to ECU development.

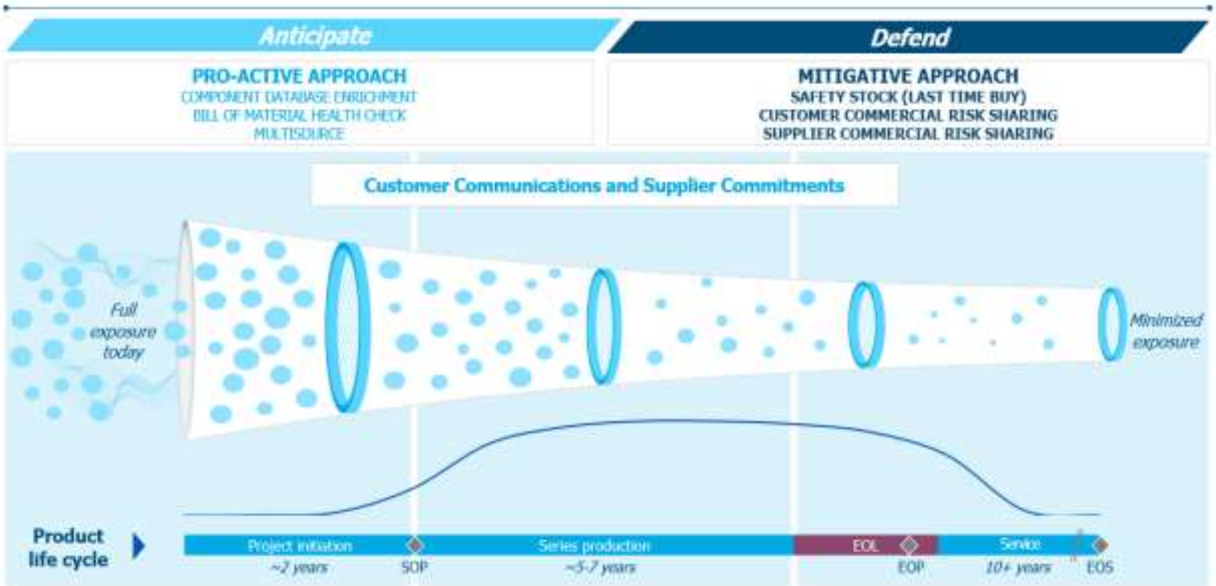
Figure 3 :Workflow process of automotive electronic design

Traditional approaches to managing semiconductor obsolescence rely heavily on reactive strategies, such as Last Time Buy (LTB) purchases, emergency redesigns, or supplier-driven replacements. However, these methods are often costly, inefficient, and fail to address the root cause of lifecycle misalignment [2]. Existing solutions also lack data-driven decision-making, leading to ineffective forecasting and suboptimal supply chain resilience. This paper presents a novel, proactive approach by integrating lifecycle monitoring, multi-sourcing strategies, enriched electronic component databases, and risk-sharing mechanisms with suppliers and customers. Unlike conventional reactive methods, this strategy enables ECU manufacturers to anticipate obsolescence risks early, optimize sourcing decisions, and implement structured mitigation plans. The methodology consists of two parts: 1) The development of a framework for component database enrichment and multi-sourcing classification. 2) The implementation of this framework in a case study at a Tier-1 automotive supplier. The impact was measured by tracking key performance indicators (KPIs), including the Inventory Turnover Ratio and the number of End of Line (EOL) driven redesigns, over 24 months.

2. Pro-Active Approach to Electronics Component Obsolescence

To manage semiconductor obsolescence in automotive ECUs, manufacturers should first adopt a proactive strategy, followed by a mitigative strategy. As supplier commitment and customer communication are crucial, they must be maintained throughout all stages of semiconductor obsolescence management. This strategy fosters clear communication, provides timely updates, and ensures stakeholder alignment. Figure 4 presents a comparison of proactive (long-term planning, multi-sourcing, lifecycle monitoring) and mitigative (LTM, component requalification, redesign) approaches for mitigating semiconductor obsolescence risks in automotive applications. Advanced analytical methods, such as the Decision-Making Trial and Evaluation Laboratory (DEMATEL) method with Interpretive Structure Modeling (ISM) approach, can be used to thoroughly evaluate the interdependencies and effectiveness of these strategies in complex automotive supply chains [5].

Figure 4 : Pro-active vs. Reactive Obsolescence Management Strategies



A proactive strategy involves enriching electronic component databases, continuously monitoring component attributes throughout the product development lifecycle, and enforcing a multi-sourcing strategy to reduce risk.

2.1.Electronics Component Database Enrichment

ECU manufacturers rely on Electronic Database Management (EDM) systems to link component attributes to CAD schematics and PCB footprints. However, EDM systems often lack comprehensive component attributes essential for effective lifecycle management. The proposed approach enriches the existing database with additional attributes, categorized as supplier attributes, technology attributes, and environmental attributes, which are managed by cross-functional teams, as illustrated in Figure 5. Among these, the semiconductor lifecycle and manufacturer sourcing attributes are particularly critical in solving the challenges related to lifecycle management and ensuring the sustainability of ECUs. Only critical attributes are analyzed to maintain focus. By integrating these crucial data points, such as detailed EOL forecasts from suppliers, alternative component availability, and potential geopolitical impacts, the EDM system transforms into a more intelligent tool. This enhanced database enables proactive identification of obsolescence risks much earlier in the design and production cycles, facilitating timely strategic decisions. Moreover, such detailed data enrichment is critical not only for mitigating obsolescence but also for bolstering the overall security and resilience of the supply chain against various threats [4].

Figure 5 : Proposed new attributes to enrich existing EDM

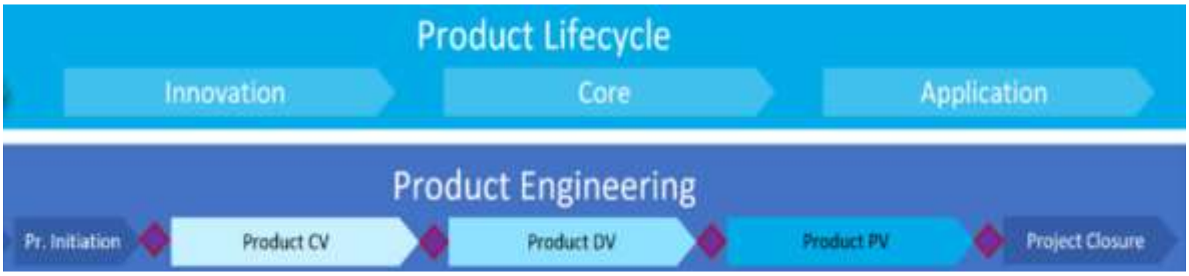
2.2.Monitor all component attributes throughout the ECU Life Cycle

Automotive product lifecycles are categorized into three major phases: Innovation, Core, and Application. The product engineering process includes key validation stages:

- Project Initiation: Feasibility, cost estimation, and customer requirements assessment
- Concept Validation (CV): Prototype development and basic functional testing
- Design Validation (DV): Rigorous design testing for compliance
- Process Validation (PV): Ensuring manufacturability and high-quality production
- Project Closure: Final testing, documentation, and mass production readiness

Figure 4 illustrates the integration of multi-stage gate reviews into the product engineering workflow.

Figure 6 : Monitoring Component Attributes Across All Validation Phases



This article proposes a solution to track all components by incorporating newly added attributes, such as lifecycle management and component sourcing. This multi-stage gate review process will involve ensuring that the lifecycle stage for every element is consistent with the production and service duties of the entire product. Each validation phase requires thorough planning with multiple technical review stages.

For a case example, Concept Validation should review the design and components chosen to assess their feasibility in meeting both performance and lifespan demands. Similarly, in Design Validation, the design must be tested intensively to identify potential issues, such as component obsolescence or life cycle incompatibility, that could result in product difficulties during subsequent production or servicing. Lastly, in Production Validation, every component, material, and design should be thoroughly tested to prove they perform as required under actual operating conditions and meet both quality and safety standards.

During this process, any deviations or inconsistencies from the anticipated component lifecycle or performance criteria should be raised for additional examination, a practice that is increasingly vital for identifying not only obsolescence risks but also potential security vulnerabilities throughout the

component's lifespan [4]. Whenever such deviations occur, the Product Engineering Team should examine the issue and make adjustments as necessary. This may involve identifying replacement parts, redesigning components, or implementing risk management steps. The engineering team would then create a mitigation plan to offset the risks and ensure that the product continues to meet the required specifications and functional safety standards.
Lastly, integrating these gate reviews and validation processes ensures that every electronic component used in an auto product will be dependable for its entire life cycle, from design to long-term service. Through the integration of thorough checks, audits, and validation procedures, the auto company can mitigate the risks of component failure, prevent delays, and ensure that the product remains in compliance with safety and operational standards throughout its entire life cycle.

2.3.Electronic Component Multisource

Most electronic components, including passive components like resistors, capacitors, and Metal Oxide Semiconductor Field Effect Transistor (MOSFET)s, can be sourced from multiple vendors. Within the ECU design and development centres, the electronic database typically uses a single ordering code to normalize purchasing across the various global locations. The current electronic database system has been structured to support dual sourcing of components. The new sourcing strategy, as planned, will further enhance this system by linking multiple manufacturer sources (order codes) to a single part number, thereby strengthening the robustness of the supply chain, a critical move not only for mitigating obsolescence but also for enhancing national and economic security against supply chain disruptions [4]. The multi-sourcing strategy will be divided into two groups: Equivalent and Alternatives. Equivalents include passive components, such as resistors and capacitors, while Alternatives include active components, including inductors, MOSFETs, Bi-Polar Junction Transistors (BJTs), diodes, timing devices, and Controller Area Network (CAN) transmitters. Both types of parts need to be "drop-in replacements" so that they are footprint-compatible and have the identical package orientation to avoid manufacturing equipment being modified when switching between sources. More complex ICs, such as controllers and processors, are often proprietary, making a multisource approach impractical.

Table 1 : Multisource – Proposed Equivalent and Alternate Component Categories

Multisource Category	Components	Drop-in Replacement	Form-Fit-Function	Part Approval
Equivalent	Resistor and MLCC	Yes	Same	Purchasing Team
Alternative	Diode, BJT, MOSFET, Inductor, Timing Device, CAN ICs	Yes	Similar	Engineering Team

Equivalents enable multi-sourcing of simple components without separate validation for each manufacturer. This is possible if the component performance, electrical requirements of the product, environment, and the process are all within the limits defined in the relevant Umbrella Specification Guidelines. Alternatives enable the multi-sourcing of complex components, with tailor-made validation to ensure that the product's functional safety is not compromised. Note: Refer to the purple line in Figure

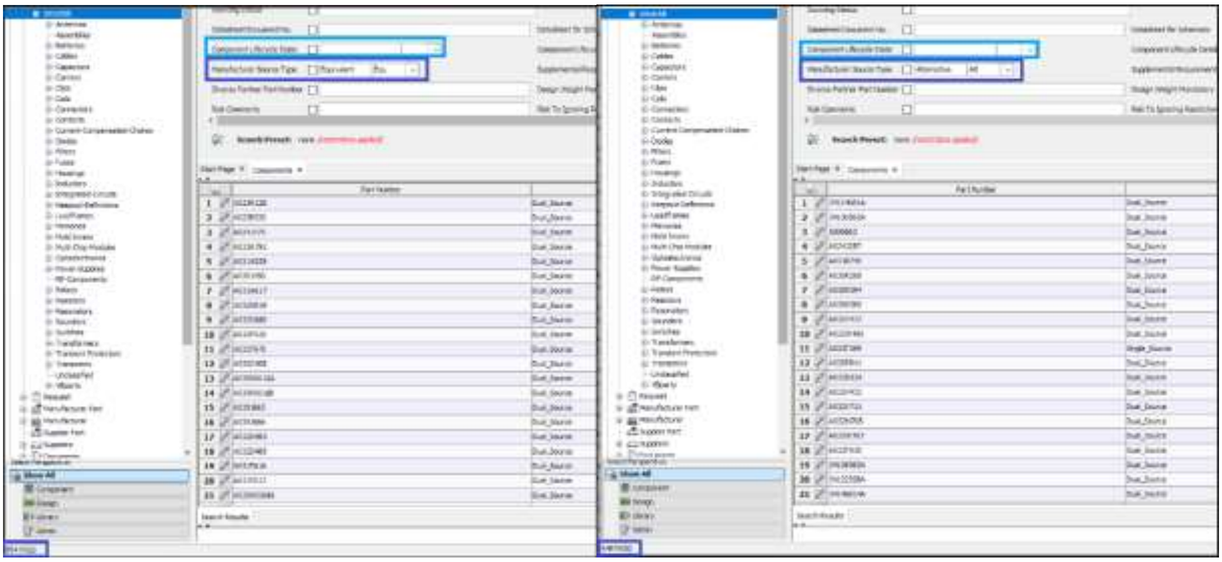
2 above, which depicts how ECU manufacturers migrate from Supplier-A to Supplier-B over the period of the ECU development life cycle.

3. Pro-Active Approach - Case Study

One of the top Tier-1 Automotive component suppliers was selected for a case study. Supplier Requested Changes (SRC) and Product Change Notice (PCN) with Electronic Component End-of-Life was skyrocketing post-covid, which causes Inventory Turn-Over Ratio (ITR) to decrease from 14% to 7%, LTB stock to increase from 5% to 20% of total inventory stock, and slow turn over aftermarket (Service) stock was doubled than fast turn over production stock. The proactive approach described in this article was adopted and implemented to address the rising cash-flow shortage problem. Figure 7 shows that 'Component Life Cycle' and 'Manufacturer Source Type' have been added to the Electronic Component Database. Classification of Equivalent and Alternate source types is incorporated in the Electronic Component Database system.

While the ideal solution would be to cleanse all components in the Electronic Component Database, this process is time-consuming and cost-prohibitive. As explained in Table 1, all Resistors and Multi-layer Ceramic Capacitors (MLCCs) are identified as faster targets, as they satisfy Drop-in Replacement, Form-Fit-Function compatibility, and the Purchasing Team can make an independent, faster decision without Engineering Team Approval. All Resistors and MLCCs used in active products have been identified and considered for Source Type classification, out of which 80% are complete, as shown in Figure VII. Gate Reviews have been enforced to monitor these two attributes in all product developments.

Figure 7 : Implementation of Source Type (Equivalent and Alternate) in one of the Tier-1 Supplier Databases



70% of Components have Life-Cycle and Sourcing attributes updates in the production bill of materials. Eighty % of resistors and Multi Layer Ceramic Capacitor (MLCC) used in production bill of materials have a second source identified, which enables the purchasing team to make a buying decision based on the cost advantage between Source-A and Source-B.

Table 2 : Case study – Improvement metrics

Metric	Pre-Implementation	Post-Implementation	Improvement
Inventory Turn-Over Ratio (ITR)	7%	11%	+57%
LTB Inventory as % of Total Inventory	20%	12%	-40%
EOL Notices Requiring Redesign	45 per year	8 per year	-82%
% of BOM with Approved Multi-Source	< 10%	74%	+650%
Purchasing Decisions (LTB vs. Bridge)	N/A (Reactive)	90% Data-Driven	-

4. Mitigating Approach to Electronics Component Obsolescence – Safety Stock

When a component supplier announces the End-of-Life of an automobile electronic component and issues a LTB announcement, reconsidering proactive lifecycle management measures becomes imperative. This includes verifying whether substitute or equivalent parts can be sourced and used as a drop-in replacement without disrupting production. Suppose no alternatives are available that meet the required specifications. In that case, the LTB option serves as the final safeguard in managing the obsolescence of the component, ensuring the production line operates without significant delays or quality issues.

Precise forecasting is required when managing LTB purchase orders. This involves forecasting both production and future service volume with customers. This is particularly important because service parts in the automotive industry often need to be ordered long after production has stopped and may be difficult to predict. Incorrect calculations in forecasting, such as overestimating or underestimating levels, can have life-or-death financial consequences. Overstocking of electronic parts can tie up cash unnecessarily, and understocking may lead to production delays or inability to fulfil service commitments, both of which can negatively impact profitability.

Historical trends help estimate the demand for service parts, but uncertainty remains. Service parts requirements are likely to change due to unforeseen factors, such as customer requirements, vehicle usage patterns, or weather conditions, which can complicate forecasting and planning. Thus, despite attempts, the process is inherently risky and requires a vigilant eye and flexibility to realign with changing situations.

5. Stakeholder Engagement

In the automotive industry, especially when managing the lifecycle of ECUs, shifting from a risk-bearing model to a risk-sharing model is a strategic approach to mitigate the financial strain caused by component obsolescence and other disruptions, a recommendation echoed in analyses of semiconductor supply chain resilience [3]. Risk-bearing refers to a situation where one party (typically the ECU manufacturer) takes on all the risks associated with supply chain volatility, component obsolescence, and unforeseen circumstances. This often results in a significant financial burden, especially when suppliers discontinue parts unexpectedly or when there is a sudden increase in the need for components (such as when an ECU enters its final production run). On the other hand, risk-sharing allows the burden of these risks to be distributed more evenly across the entire value chain, including suppliers and customers. This collaborative approach is essential for the long-term sustainability of ECU manufacturers, as it helps to smooth out financial impacts and ensures continuity in production and service without overwhelming any single party. Such strategic partnerships and risk-sharing mechanisms are increasingly recognized as vital components of a resilient and secure semiconductor supply chain [4].

5.1. Commercial Risk Sharing (Customer) And Contract Adjustments

For customers, an EOL Dashboard enables proactive communication of End-of-Life status, production volume, and service volume to ECU manufacturers. This transparency allows for early obsolescence warnings, cost-sharing for storage, and guaranteed purchasing contracts, thereby reducing supply chain disruptions. Customer pre-payment contact to secure advance payments from customers for EOL components to mitigate financial risk.

5.2. Commercial Risk Sharing (Supplier) And Contract Adjustments

For suppliers, Long-Term Service Agreements (LTSA) help mitigate sudden cash flow. Instead of making bulk purchases in a single fiscal year, LTSAs distribute LTB orders over multiple years, reducing financial strain and ensuring smoother cash flow management. This approach enhances budget flexibility while securing long-term component availability. A few examples from the ON-SEMI website will be cited regarding ON-SEMI and Zeekr's long-term supply agreement, as well as ON-SEMI and Magna's collaboration on silicon carbide in the Electric Vehicle Market [6, 7]. Supplier buyback agreements negotiate contracts where suppliers agree to repurchase unused EOL inventory, and Consignment Inventory agreements help retain ownership of EOL stock. At the same time, manufacturers only pay when components are used.

A key aspect of risk-sharing is revisiting supplier contracts to ensure a 24-month notice period for component EOL. This advance notice allows manufacturers to source alternatives, revalidate parts, and adjust production plans, reducing last-minute disruptions and excessive stockpiling. By incorporating this clause, both manufacturers and suppliers mitigate financial and operational risks, ensuring a smoother transition when components are discontinued. To maintain effective risk-sharing, ECU manufacturers should regularly assess supplier performance in lifecycle management. Quarterly evaluations based on KPIs—such as reliability, adherence to notice periods, and lifecycle management efficiency—enable manufacturers to track trends, identify risks early, and refine strategies. This approach ensures partnerships with reliable suppliers who can effectively mitigate component obsolescence risks.

6. Conclusion

The automotive industry faces significant challenges in managing semiconductor component life cycles due to shorter life spans of electronic components compared to the long production and service timelines required by Automotive ECUs. The strategies discussed in this paper, including proactive approaches such as enriching the Electronics Component Database, monitoring all component attributes throughout the ECU Life Cycle, and utilizing multisource information, are critical in ensuring a stable and resilient supply chain for ECU manufacturers. Additionally, reactive measures such as LTB and commercial risk-sharing can help mitigate the impact of component obsolescence. As the industry evolves, collaboration between suppliers, customers, and ECU manufacturers will be key to navigating future challenges. Effective lifecycle management, early identification of risks, and adaptability will be essential to ensure that ECUs meet the stringent safety and reliability standards required by OEMs while maintaining sustainability and cost efficiency. Future research could explore the integration of AI-based predictive analytics in semiconductor lifecycle management, as well as the development of more sophisticated risk-sharing models to enhance supply chain resilience further.

While individual strategies, such as multisource and LTB, are known, this paper demonstrates the synergistic effect of an integrated framework. The primary contribution is the quantifiable evidence that linking proactive component database management directly to supplier and customer risk-sharing agreements can dramatically reduce financial liability and engineering workload.

References

1. Harald Bauer, et al., “Coronavirus: Implications for the semiconductor industry”, Semi.org, 2020.
2. Young Carter, “The Semiconductor Shortage: An Analysis of Potential and Ongoing Remediation Efforts and their Implications on the Industry & Macroeconomy”, University Honors Theses Paper, 2021, 1162.
3. Wassen Mohammad, et al., “The Global Semiconductor Chip Shortage: Causes, Implications, and Potential Remedies”, IFAC Papers online, 2022, 55 (10) - 476–483.
4. Heather Wishart-Smith, “The Semiconductor Crisis: Addressing Chip Shortages and Security”, Forbes, 2024.
5. Nishi Panchal, et al., “Evaluation of Semiconductor Risk Mitigation Strategies in the Electric Vehicle Supply Chain”, MDPI Eng. Proc. 2024, 76 (30).
6. ONSEMI Website, ONSEMI and ZEEKR Sign Long-Term Supply Agreement for Silicon Carbide Power Devices, 2023.
7. ONSEMI Website, ONSEMI and Magna Sign Strategic Agreements to Invest in Silicon Carbide for the Growing Electric Vehicle Market, 2023.