

Predictive Approaches to Obsolescence in Automotive Electronics Based on Life Cycle Concepts

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Abstract : An automotive electronics component typically progresses through seven distinct life cycle stages: Introduction, Growth, Maturity, Decline, Phase-out, Discontinuance and Obsolescence, and Special Cases. The obsolescence of Automobile electronic components significantly impacts the life cycle costs of long field-life systems such as automotive. These life cycle curves serve as critical tools for analyzing part longevity and forecasting availability trends. This paper presents a forecasting methodology that predicts both the time to obsolescence and the different stages of a part's life cycle. The approach incorporates both market dynamics and technological trends through a continuous analysis of sales data. The resulting models provide engineers with the ability to strategically plan for the deployment and maintenance of long life products, using forecasts of the life spans of their component parts. The methodology is specifically applied to integrated circuits, with obsolescence forecasts demonstrated for Advanced Driver Assistance Systems. The overarching objective is to minimize design revisions, reduce inventory and sustainment costs and lower the total life cycle expenses of the product. Manufacturers with strong market share and profitability tend to remain stable, lowering obsolescence risk. Overall, the current device/technology group remains supportable longer but requires ongoing risk monitoring due to sourcing constraints and evolving application demands.

Keywords: life cycle stages, parts obsolescence and Part life cycle.

I. INTRODUCTION

Automobile electronics in India cover a broad spectrum of products and technologies, ranging from in-car entertainment systems to advanced safety features such as parking sensors and rear-view cameras. Additionally, electronic components play a critical role in engine management, chassis control and various other vehicle subsystems. These systems are becoming more integrated and sophisticated, driven by rapid advancements in technologies such as Advanced Driver Assistance Systems (ADAS) and electric vehicle (EV) platforms. As the automotive industry in India evolves, the demand for intelligent, connected and efficient electronic systems continues to grow, supporting the shift toward smarter and more sustainable mobility solutions. The automotive market has experienced remarkable transformation in recent decades, largely driven by the rapid adoption of in-vehicle electronics. Today's vehicles are equipped with advanced systems for safety, security, infotainment and a wide range of comfort and convenience features—all designed to make driving safer, easier and more enjoyable. At the heart of these advancements lie semiconductors, which have played a vital role in enabling these essential functions.

Looking ahead, the industry is on the cusp of even greater change. Emerging technologies such as artificial intelligence, augmented reality, vehicle-to-everything (V2X) communication and autonomous driving are beginning to reshape the automotive landscape. These innovations promise to redefine mobility and usher in a new era of intelligent, connected and highly automated vehicles. This report provides revenue forecasts at the global, regional and country levels, offering a comprehensive analysis of industry trends across various sub-

segments from 2018 to 2030. For the purpose of this study, Grand View Research has segmented the automotive electronics market based on component, application, vehicle type, propulsion, sales channel and region. The current-carrying devices segment led the automotive electronics market in 2023, accounting for 40.2% of the total market share. These devices are critical components in vehicles, as they facilitate the transmission of electrical power and signals throughout the vehicle's electrical system. The strong demand in this segment is driven by the high cost and growing number of electronic components in modern vehicles, including switches, fuses, connectors and wiring harnesses.

The sensors segment is expected to register the highest growth rate over the forecast period. This growth is fueled by the increasing consumer preference for vehicles that offer enhanced safety, efficiency and connectivity. Sensors play a vital role in various automotive applications such as engine management, safety systems and infotainment, contributing significantly to vehicle performance and user experience. In 2023, the safety systems segment captured the largest revenue share in the market. This can be attributed to rising demand for safer, more efficient and more convenient driving experiences, along with stringent safety regulations. Leading manufacturers such as Continental AG, DENSO Corporation, Infineon Technologies AG and Robert Bosch GmbH are investing heavily in the development of advanced safety systems to meet the growing demand in both light and heavy commercial vehicles. The increasing focus on road safety and the rise in traffic accidents further support the expansion of this segment. For instance, in March 2023, Hyundai Motor India Limited launched the new Hyundai Verna, equipped with a Level 2 Advanced Driver Assistance System (ADAS) and 65 advanced safety features. The Verna also includes Hyundai's Smart Sense technology, which uses radar and camera-based sensing to detect obstacles and assist drivers through real-time warnings and corrective actions. The ADAS segment is expected to witness the highest compound annual growth rate (CAGR) during the forecast period. This rapid growth is driven by government mandates for safety features, increasing consumer awareness regarding passenger safety and comfort and the growing integration of cutting-edge technologies in vehicles. Features such as blind spot detection, lane-keeping assistance and collision warning are becoming key differentiators in purchasing decisions, as consumers increasingly favor vehicles with enhanced safety and driver-assistance capabilities.

Advances in electronics are reshaping the future of the automotive industry, with electronic components now playing an essential role across nearly every part of the vehicle—from the body and powertrain to infotainment and safety systems. As consumer expectations grow for enhanced innovation in safety, security, comfort and convenience features and as federal fuel economy and emissions standards continue to tighten, the demand for sophisticated electronic systems in next-generation vehicles is rapidly increasing. This trend is driving a significant rise in semiconductor content across a wide range of electronic modules and subsystems. Key application areas fueling automotive innovation and market growth include: Infotainment Systems, Advanced Driver Assistance Systems (ADAS), Powertrain Electronics and Body Electronics.

In accordance with the product lifecycle concept, every product follows an estimated progression through four key stages: introduction, growth, maturity and decline. Similarly, a vehicle's lifecycle encompasses these phases, ultimately concluding when the car is sent to the scrap yard after the decline stage. Electric vehicles, especially when powered by low-carbon energy sources, present a promising opportunity to reduce greenhouse gas emissions. Vehicle sales also vary across these different lifecycle stages. This study explores the application of the product lifecycle framework specifically within the automotive sector, highlighting its relevance to understanding market dynamics and environmental impact. The life cycle mismatch issue demands that engineers carefully consider, during the design phase, which components will remain available and which may become obsolete throughout the product's manufacturing lifespan. This challenge is particularly common in avionics and military systems, where components can face obsolescence even before deployment and often continue to experience such issues throughout the system's operational life.

These challenges are further compounded by extended manufacturing timelines and the high costs associated with system qualification or certification, making design updates with newer components an exceptionally costly and complex process. Previous research has primarily focused on understanding the product life cycle through factors such as its various stages, overall product lifespan, strategies for extending

product life and marketing considerations. However, the issue of obsolescence has received less attention. The impact of obsolescence largely depends on how a product is defined. For instance, if a company's product is a sub-assembly, the obsolescence of a critical component within that sub-assembly can directly influence the lifespan of the final product. Between part obsolescence and product obsolescence, greater emphasis must be placed on part obsolescence, as it serves as the fundamental cause of obsolescence at any product level. This paper reviews the various stages of the product life cycle and introduces a methodology for forecasting the time until obsolescence for electronic components. Accurate prediction of obsolescence allows engineers to better manage both the introduction and ongoing use of long field-life products by anticipating the lifecycle of critical parts. This obsolescence forecasting methodology is a vital component of risk-informed parts selection and management strategies, helping to mitigate supply chain risks and ensure product reliability.

II. REVIEW OF LITERATURE

Julian Baehr et.al (2024) analysed that the methods performing uncertainty assessments is not exclusively reserved for Life Cycle Assessment practitioners, but multiple methods could be implemented into environmental product declarations disclosures with feasible effort. The digital product would be conceptionally sufficient to serve as added features of artificial neural networks based prediction models.

Yara Kayyali Elalem, Sebastian Maier and Ralf W Seifert (2023) provides a framework based on state of the art techniques that enables organizations to use quantitative methods to forecast sales of newly launched, short lived products that are parallel to previous products when there is limited availability of past sales data for the new product. In addition to exploiting past data using time series clustering, performed data consider two quantitative cluster assignment methods and augmentation to generate necessary sales data.

Rehim, Mostafa, and Adel (2021) performed that the illustrated the effect of changing the model parameters on the overall PLC shape. The result shows that the proposed model is furthestmost reliable and realistic in capturing the PLC of any product and performance further most exact forecasting of future values.

Haleh Ardebili, Jiawei Zhang and Michael G. Pecht (2019) presented that the Microelectronic devices, designs, packaging and materials have dramatically improved over the past decades. Integrated circuit chips are now much smaller, faster and the packaging is more efficient, reliable and cost effective. The trends and challenges for future microelectronic devices, plastic encapsulants and packaging are presented. Recent trends in applications of plastic packages for extreme Low and high temperatures are stated.

Rajeev Solomon, Peter Sandborn, and Michael Pecht (2000) presented the technological attributes and Captures market trends by identifying a set of quantifiable market, life cycle stage and Computes both years to obsolescence, data for the market, based on statistical analysis of sales and technology attributes for the technology group and Computes an overall risk factor associated with a specific part number by implementing market factors, manufacturer market share, such as component risk and PLC information.

Anderson, Rønning and Moncaster (2019) identifies the need for Environmental Product Declarations to provide End of Life and Module D data for products for use in building level Life Cycle Assessment.

III. AUTOMOBILE PRODUCT LIFE CYCLE STAGES

The product life cycle of an automobile typically progresses through seven distinct stages: Introduction Stage, Growth Stage, Maturity Stage, Decline Stage, Phase-out Stage, Discontinuance and Obsolescence and Special Cases of the Life Cycle Curve.

1. Introduction Stage

This phase marks the launch of a new automotive electronic product or technology, such as a novel sensor, connectivity module, or ADAS component. Development and testing dominate this stage, with high R&D costs and limited production volumes. Market adoption is slow as OEMs and suppliers validate performance, safety and reliability. Early adopters are cautious and pricing tends to be high due to low economies of scale.

2. Growth Stage

Once proven, the product enters rapid growth, gaining traction as it is integrated into a broader range of vehicle models. Production ramps up, driving down unit costs. Demand increases as consumer awareness

and regulatory pressures for safety, connectivity, or efficiency grow. Competition increases, pushing manufacturers to improve features and expand applications.

3. Maturity Stage

At maturity, automotive electronics become standard in most vehicle segments. Production stabilizes at high volumes and the focus shifts to cost optimization, incremental improvements and compliance with evolving industry standards. Innovation tends to be incremental, targeting power efficiency, size reduction and system integration. The market is highly competitive, often leading to price pressure and margin tightening.

4. Decline Stage

Emerging technologies or changing market requirements cause the decline of older electronic components or systems. Products may become less attractive due to newer, more capable alternatives, shifts in vehicle design, or obsolescence of critical parts. Demand decreases and manufacturers start to plan for phase-out.

5. Phase-out Stage

This stage involves the systematic withdrawal of the product from the market. Production volumes are reduced and efforts are made to fulfill remaining orders and support existing users. Suppliers manage inventory carefully to avoid excess stock, while transitioning customers to newer technologies or replacements.

6. Discontinuance and Obsolescence

Eventually, the product is discontinued and becomes obsolete. In automotive electronics, obsolescence is a critical challenge due to the long lifecycle of vehicles versus the faster pace of electronics innovation. Managing obsolescence involves forecasting part availability, redesigning to use current components, or providing lifecycle extensions to avoid supply chain disruptions and maintain vehicle support.

7. Special Cases of the Life Cycle Curve

Certain automotive electronic products may not follow the traditional life cycle curve due to rapid innovation cycles or regulatory changes. For example, cutting-edge ADAS modules or EV battery management systems may experience shortened cycles with frequent upgrades or sudden obsolescence triggered by safety regulations or technological breakthroughs. Additionally, legacy components in long-life vehicles may require extended support well beyond typical lifecycle expectations, necessitating special lifecycle management strategies.

Table 1: India Automotive Electronics Market Size & Lifecycle Trends

Market Size & Trend	Lifecycle Stage	Key Drivers in India
2018–20 (USD 6B baseline)	Introduction	Launch of components like ADAS, EV electronics in premium vehicles; early innovations
2020–27, accelerating towards USD 18B	Growth	Enabled by FAME-II, PLI incentives and EV/ADAS policies; growing middle-class demand
2027–33, plateauing towards USD 18.6B	Maturity	Standardization in mid-tier vehicles; focus on cost efficiency and compliance with Bharat NCAP and CAFE-II
Post-2030	Decline to Phase-out	Older ECUs/sensors phased out in favor of next-gen modules and AI/AV components
Ongoing past-phase-out	Discontinuance & Obsolescence	Legacy components in ICE vehicles need long-term support; obsolescence risks due to imports and long vehicle lifespans
EV and ADAS electronics	Special Cases	Rapid cycles for battery management systems (BMS), telematics, fast chargers (especially in Tamil Nadu)

The lifecycle of India's automotive electronics sector reflects a dynamic evolution shaped by both policy and technological shifts. The Introduction phase (2018–2020), with a market baseline of USD 6 billion, was characterized by the early rollout of ADAS and EV components in premium vehicles. The sector entered an aggressive Growth phase from 2020 to 2027, driven by government schemes like FAME-II and PLI, growing consumer demand, and expanding EV and ADAS penetration—pushing the market towards USD 18 billion. From 2027 onward, the industry enters Maturity, marked by a plateauing growth curve (~USD 18.6B), increased standardization, and compliance with Bharat NCAP and CAFE-II norms. Post-2030, a Decline to Phase-out phase begins as legacy ECUs and sensors are replaced by AI-enabled and autonomous components.

Table 2: India Automotive Electronics Market (2018–2033)

Year	Lifecycle Stage	Market Size (USD Billion)	Key Developments
2018	Introduction	5.5	Early adoption of infotainment, basic ECUs and sensors in mid-to-high-end vehicles
2019	Introduction	6.0	Initial rollout of ADAS (rear cameras, sensors) and EV pilot projects
2020	Introduction → Growth	6.8	Rise in in-car infotainment; localization starts for EV electronics
2021	Growth	7.4	Government pushes FAME-II and PLI schemes
2022	Growth	8.3	Launch of connected car platforms, higher adoption of safety electronics
2023	Growth	9.7	Semiconductor demand surges; tier-1 expansion
2024	Growth	11.2	ADAS becomes more common; market consolidation begins
2025	Growth	12.3 (est.)	Wider EV rollout; Bharat NCAP influence begins
2026	Growth	13.5 (est.)	High demand for battery management, telematics, in-cabin tech
2027	Growth → Maturity	15.0 (est.)	ADAS Level 2 features in mid-range cars; digital clusters common
2028	Maturity	16.2 (est.)	Regulatory compliance drives upgrades over innovation
2029	Maturity	17.4 (est.)	Focus shifts to integration, standardization and cost reduction
2030	Maturity	18.4 (est.)	Plateauing adoption curve; peak penetration in ICE platforms
2031	Decline → Phase-out	18.5 (est.)	Older ECUs/sensors being replaced by AI-driven electronics
2032	Phase-out	18.6 (est.)	Discontinuation planning for legacy components begins
2033	Obsolescence / Special Case	18.6 (est.)	EV & ADAS tech evolve rapidly; legacy ICE support remains essential

Beyond that, Obsolescence becomes a concern as older ICE-based electronics persist due to long vehicle lifespans and dependence on imported spares. Notably, special cases like battery management systems and telematics for EVs have accelerated innovation cycles—especially in fast-growing hubs like Tamil Nadu. Between 2018 - 33, the India automotive electronics market has evolved significantly, growing from USD 5.5 billion to an estimated USD 18.6 billion. The Introduction stage (2018–2019) saw the rollout of basic ECUs, infotainment systems, and the first steps toward ADAS and electric vehicles. This set the stage for a rapid shift into the Growth phase (2020–26), driven by increasing consumer demand, localization efforts, and strong government support through initiatives like FAME-II and PLI. During this period, technological advancements such as connected car platforms, ADAS integration, and rising EV adoption reshaped the market. From 2027 - 30, the sector enters a Maturity phase, with widespread implementation of advanced features like ADAS Level 2 and digital instrument clusters, alongside a plateauing of innovation and rising standardization.

By 2031, the market transitions into Decline and Phase-out, as legacy components are phased out and replaced by AI-centric and more integrated systems. Finally, Obsolescence is reached by 2033, with traditional

ICE electronics becoming outdated amid the dominance of EVs and next-gen technologies. This progression highlights a clear lifecycle arc, underscoring the need for strategic foresight and agile adaptation across the value chain.

IV. AUTOMOBILE PRODUCT LIFE CYCLE FORECASTING METHODOLOGY

Life cycle forecasting in the automotive electronics sector focuses on examining the stages of adoption, expansion, maturity and eventual decline of key vehicle technologies like infotainment systems, Advanced Driver Assistance Systems, sensors and electric vehicle components. This approach estimates future market size, technology uptake and critical transition phases by leveraging past data, industry trends and mathematical curve fitting models.

Data Collection:

The first step involves compiling historical data on sales figures, market size and adoption rates for various

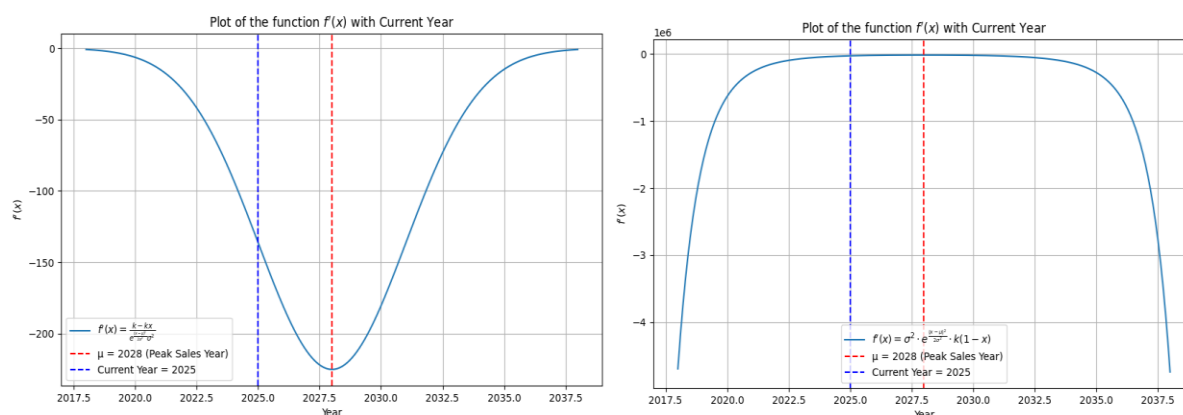


Fig. 1. Life cycle curve of a Automotive Electronic Product. The dashed line marks the current date assumed for this example analysis

automotive electronic technologies. Additionally, qualitative factors such as government initiatives, technological innovations and regulatory changes are gathered to provide context and influence on market dynamics. Forecasts and projections from industry reports are also incorporated to anticipate future trends and developments.

Define Key Parameters:

This step involves determining critical parameters that characterize the life cycle of automotive electronic technologies. The peak sales year (μ) is identified for each technology or market segment, representing the point of maximum market adoption. The spread (σ) quantifies the rate at which the market grows before and declines after this peak, capturing the duration of different phases. Using these parameters and market data, lifecycle stages—such as Introduction, Growth, Maturity, Decline, Phase-out and Obsolescence—are assigned to describe the technology’s evolution and adoption over time.

Curve Fitting:

In this phase, mathematical models such as Gaussian or logistic growth functions are applied to fit the historical sales and market data of automotive electronic technologies. A common approach uses the Gaussian function defined by:

$$f(x) = \exp\left(-\frac{(x-\mu)^2}{2\sigma^2}\right) \tag{1}$$

Where, x , represents the year, μ is the year corresponding to peak sales and σ , determines the spread or duration of the life cycle stages around the peak. By fitting this curve to the data, it becomes possible to estimate the market behavior over time. Additionally, derivatives or modified versions of this function can be calculated to analyze growth rates and refine forecasts for different lifecycle stages.

$$f(x) = \sigma^2 \cdot \exp\left(\frac{(x-\mu)^2}{2\sigma^2}\right) \cdot k(1-x) \quad (2)$$

Defines this function, Plots it for a range of x , adjust, μ , σ , and k as needed.

Stage Classification:

Lifecycle stages for automotive electronics are determined based on the year x in relation to the peak year μ and the spread σ . These stages reflect the typical trajectory of product and technology adoption. The Introduction stage occurs before significant growth, representing early market entry and limited adoption. As adoption accelerates, the Growth phase is marked by a rapid rise in market share and technological penetration. Once the market reaches its highest adoption rate, it enters the Maturity phase, where growth slows and stabilizes. Eventually, the Decline phase sets in as the market becomes saturated or newer technologies emerge. Following this is the Phase-out, where products are deliberately retired or replaced. Finally, Discontinuance and Obsolescence occurs, characterized by the complete withdrawal of products from the market, ending support and shifting to legacy system maintenance. These stages help forecast product transitions and inform strategic planning.

Forecasting:

Forecasting in automotive electronics involves utilizing the fitted life cycle curves and defined stage classifications to estimate future trends in market size and technology adoption. By analyzing historical patterns and applying statistical models such as Gaussian or logistic functions, projections are made for upcoming years. These forecasts are refined by integrating external influences like government policies, changes in the global and local supply chain and technological advancements such as increased EV penetration or the integration of AI in ADAS. The methodology is iterative forecasts are continuously updated with new data and market feedback to enhance precision and relevance, supporting better decision-making for product development, resource allocation and lifecycle management.

Visualization & Reporting

Visualization and reporting are essential for interpreting life cycle forecasts in automotive electronics. Life cycle curves are plotted to display the trajectory of technology adoption over time, with key stages: Introduction, Growth, Maturity, Decline, Phase-out and Obsolescence clearly marked. Highlighting the current year on these curves helps stakeholders quickly assess the present market position of each technology or product category. These visual tools, combined with narrative reports, offer actionable insights into when market transitions are likely to occur, guiding strategic decisions on R&D investments, product updates, or phase-out planning. This enables manufacturers, suppliers, and policymakers to align their objectives with the anticipated evolution of automotive electronic systems.

V. FORECAST RESULTS

Define a Device/Technology Group

A device or technology group refers to a collection of products that perform similar functions and are built on comparable technological principles, although they may be developed or manufactured by different companies. These products typically serve the same purpose within a system or application domain.

Identify Primary and Secondary Attributes

A primary attribute is a defining feature that fundamentally characterizes a device or technology group. In contrast, a secondary attribute influences or adjusts how long the device remains relevant affecting its estimated years to obsolescence and its position within the life cycle. These secondary traits may not define the group, but they significantly shape its longevity and stage progression.

Determine the Number of Sources

Assess how many sources are available for the device. If no sources are identified, it suggests that the device is either already obsolete or has not yet entered production.

Collect Sales Data for the Primary Attribute of the Device/Technology Group

Sales figures provide key insights into the life cycle stage of a device or technology group. These figures can include the number of units shipped, total revenue, or market share percentages. If unit level data is

unavailable, dollar-based sales or market share data may be used especially when overall market size remains relatively stable. This information is typically sourced from industry market research reports or analytical databases.

Develop a Life Cycle Profile and Identify Key Parameters

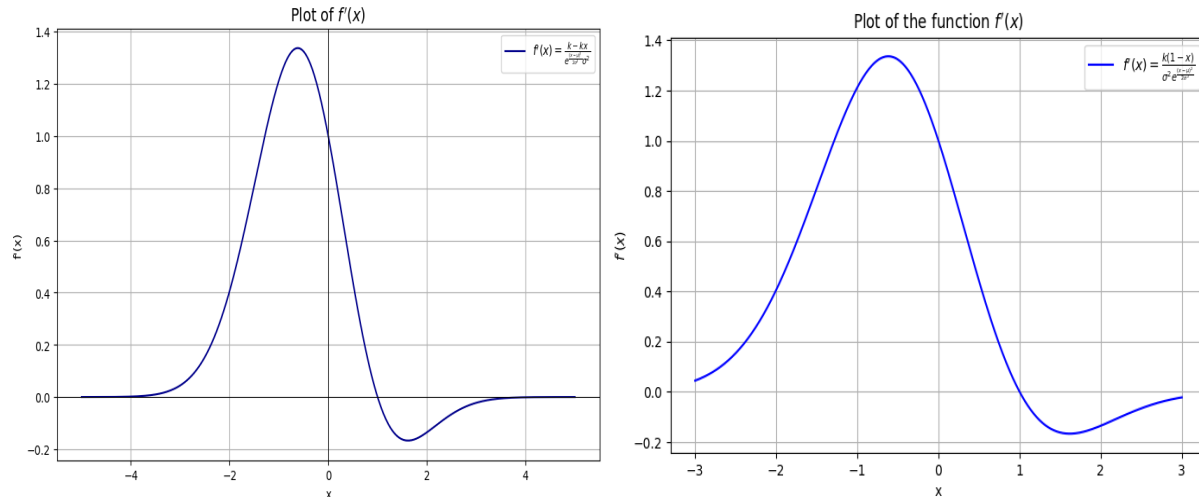


Fig. 2. Life cycle curve of a Automotive Electronic Product dashed line marks the current date assumed for this example analysis

A life cycle profile represents the shipment volume of a device or technology group over time. This profile is modeled using a Gaussian (normal) distribution, where each phase of the product life cycle is defined in terms of its deviation from the mean year of peak activity (μ), using standard deviation (σ) as a scaling factor. The obsolescence period is expressed as the interval $(\mu + 2.5\sigma - p, \mu + 3.5\sigma - p)$ ($\mu + 2.5\sigma - p, \mu + 3.5\sigma - p$), where p is the current year. This interval reflects how far, in years, the product is from entering and completing its obsolescence phase. To construct the profile, sales data corresponding to the device’s primary attribute the defining feature of the technology group—is used to fit the Gaussian life cycle model and estimate the timing of each stage.

Use of Gaussian Models for Life Cycle Forecasting

The Gaussian (normal) distribution has been widely adopted by the Electronic Industries Association as the standardized representation of a product life cycle curve. This makes it a familiar modeling tool among equipment vendors and suppliers. The mathematical form of the life cycle curve is:

$$f(x) = k \cdot \exp\left(-\frac{(x-\mu)^2}{2\sigma^2}\right) \tag{3}$$

In this equation, $f(x)$ represents the projected sales revenue, unit shipments, or market demand at time x , where μ is the mean year corresponding to peak sales, and σ is the standard deviation reflecting the spread or duration of the life cycle. The constant k denotes the magnitude of the peak typically the highest value of sales, demand or units shipped for the technology or product group being evaluated.

$$\begin{aligned} f(2024) &= 16.2 \cdot \exp\left(-\frac{(2024-2028)^2}{2.4^2}\right) \\ &= 16.2 \cdot \exp\left(-\frac{(-4)^2}{2.4^2}\right) \\ &= 16.2 \cdot \exp\left(-\frac{16}{32}\right) \\ &= 16.2 \cdot \exp(-0.5) \\ &= 16.2 \cdot 0.6065 \\ &\approx 9.83 \text{ USD Billion} \end{aligned} \tag{4}$$

Table 3: The Years to Obsolescence from Modifying Attributes

Inequality	Equation	Modified zone of obsolescence (a,b)	Equation
$\mu + 3.5\sigma - p < \mu_j + 2.5\sigma_j - p$	(A1)	$\min[\mu + 2.5\sigma - p, \mu_j + 2.5\sigma_j - p], \mu_j + 3.5\sigma_j - p$	(A2)
$\mu_j + 2.5\sigma_j - p \leq \mu + 3.5\sigma - p$ $\leq \mu_j + 3.5\sigma_j - p$	(B1)	$[\mu_j + 2.5\sigma_j - p, \mu + 2.5\sigma - p]$ $\min[\mu_j + 3.5\sigma_j - p, \mu + 3.5\sigma - p]$	(B2)
$\mu + 3.5\sigma - p > \mu_j + 3.5\sigma_j - p$	(C1)	$(\min[\mu + 2.5\sigma - p, \mu_j + 2.5\sigma_j - p], \mu_j + 3.5\sigma_j - p)$	(C2)

$$f(x) = 4^2 \cdot \exp\left(\frac{(2024-2028)^2}{2 \cdot 16^2}\right) \cdot 16.2(1 - 2024)$$

$$f(2024) = 16 \cdot 0.5 \left(\frac{4^2}{32}\right) \cdot 16.2(-2023)$$

$$f(2024) = 16 \cdot 0.5 \left(\frac{16}{32}\right) \cdot 16.2(-2023)$$

$$f(2024) = 16 \times 1.6487 \times (-32776.6)$$

$$= 16 \times (-54064.7)$$

$$= -865035.2$$

$$f(2024) \approx -865,035.2 \tag{5}$$

- μ = 2028: the year at which market demand peaks
- σ = 4 the spread or standard deviation of the curve
- k = 16.2k the peak market size in USD Billion
- x = 2024: the year for which we want to estimate the market size

Table 3 depicts the application of the algorithm presented in evaluate the zone of obsolescence.

A1. Inequality

$$\mu = 2028 \quad \sigma = 4 \quad \mu_j = 2032$$

$$\sigma_j = 2 \quad p = 2024$$

Left side:

$$\mu + 3.5\sigma - p = 2028 + 3.5 \times 4 - 2024 = 2028 + 14 - 2024 = 18$$

Right side

$$\mu_j + 2.5\sigma_j - p = 2032 + 2.5 \times 2 - 2024 = 2032 + 5 - 2024 = 13$$

Check the inequality

$$8 < 13 \text{ (This is ** false **)} \tag{6}$$

$\mu + 3.5\sigma - p < \mu j + 2.5\sigma j - p$ is ****not true**** under the given parameters.

A2. Modified zone of obsolescence (a,b)

$$\begin{aligned} \mu + 2.5\sigma - p &= 2028 + 2.5 \times 4 - 2024 = 2028 + 10 - 2024 = 14 \\ &= 2028 + 10 - 2024 = 14 \\ &= 2028 + 10 - 2024 = 14 \\ \mu j + 2.5\sigma j - p &= 2032 + 2.5 \times 2 - 2024 = 2032 + 5 - 2024 = 13 \\ &= 13 \\ &= 2032 + 5 - 2024 = 13 \end{aligned}$$

Take the minimum:

$$\text{Min}(14, 13) = 13 \tag{7}$$

$$\begin{aligned} \mu j + 3.5\sigma j - p &= 2032 + 3.5 \times 2 - 2024 = 2032 + 7 - 2024 = 15 \\ &= 15 \\ &= 2032 + 3.5 \times 2 - 2024 = 15 \\ &= 15 \end{aligned}$$

$$(\min[\mu + 2.5\sigma - p, \mu j + 2.5\sigma j - p], \mu j + 3.5\sigma j - p) = (13, 15)$$

This means the modified zone of obsolescence begins 13 years from now and ends 15 years from now.

B1. Inequality

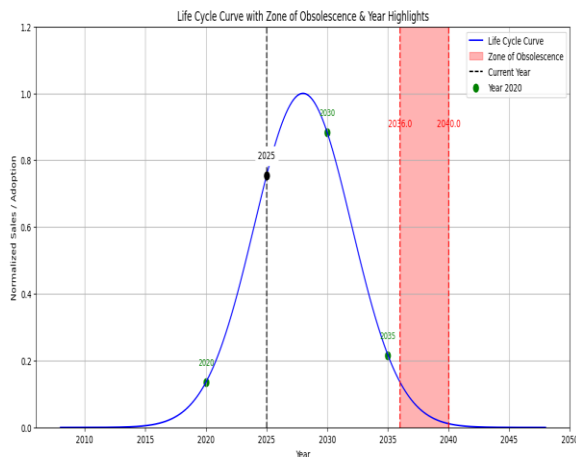


Fig. 3. Condition (A1)

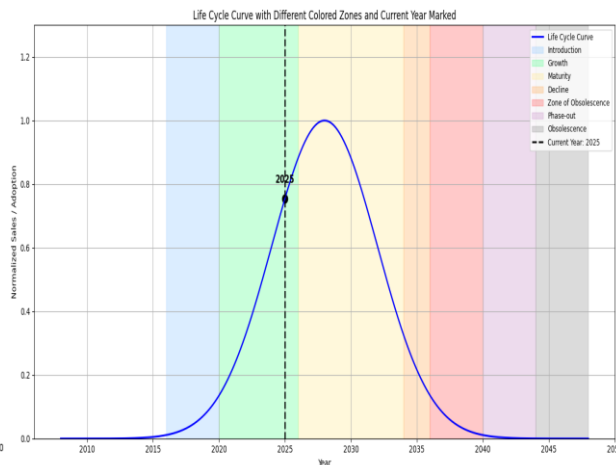


Fig. 4. Modified zone of obsolescence (a,b) (A2)

Left side of inequality

$$\mu j + 2.5\sigma j - p = 2032 + 2.5 \times 2 - 2024 = 2032 + 5 - 2024 = 13$$

Middle term

$$\mu + 3.5\sigma - p = 2028 + 3.5 \times 4 - 2024 = 2028 + 14 - 2024 = 18$$

Right side

$$\mu j + 3.5\sigma j - p = 2032 + 3.5 \times 2 - 2024 = 2032 + 7 - 2024 = 15$$

Full Inequality

$$13 \leq 18 \leq 15$$

(8)

First part: $13 \leq 18 \rightarrow \text{True}$

Second part: $18 \leq 15 \rightarrow \text{False}$

B2. Modified zone of obsolescence (a,b)

Main group

$$\mu + 3.5\sigma - p = 2028 + 3.5 \times 4 - 2024 = 2028 + 14 - 2024 = 18$$

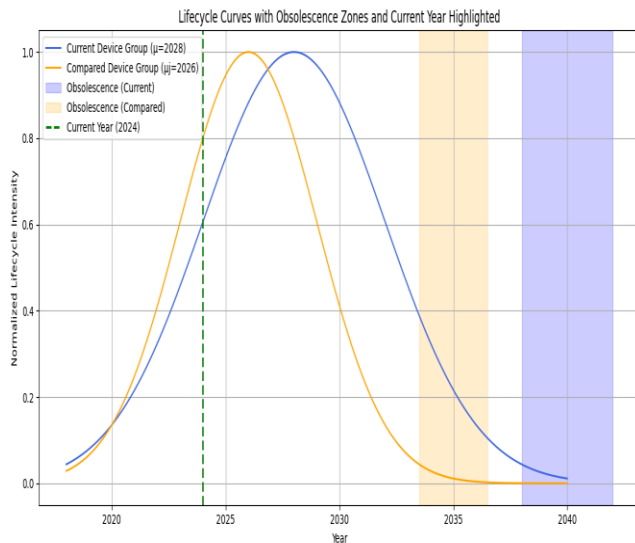


Fig. 7. Condition (C1)

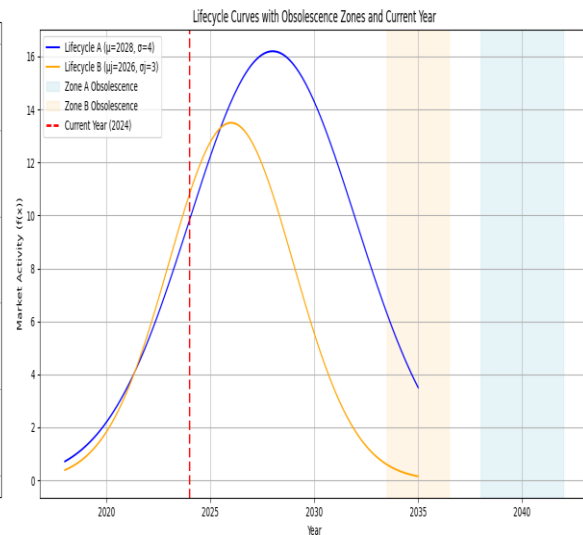


Fig. 8. Modified zone of obsolescence (a,b) (C2)

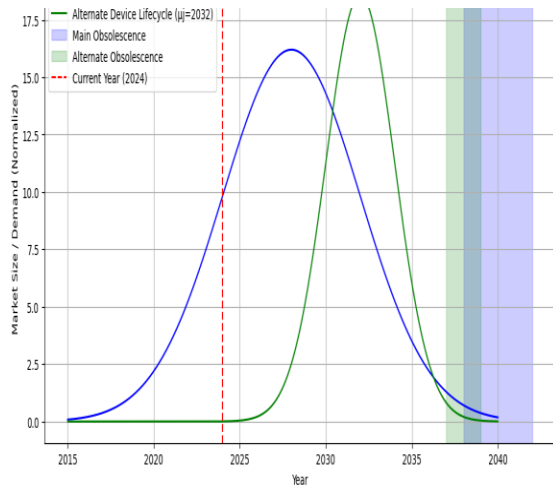


Fig. 5. Condition (B1)

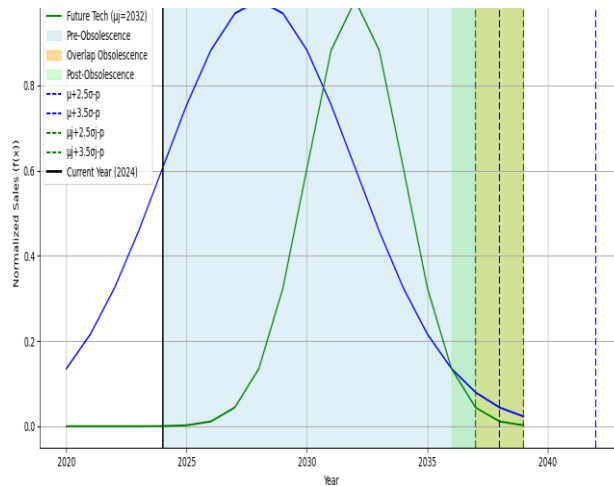


Fig. 6. Modified zone of obsolescence (a,b) (B2)

Alternate group

$$\mu j + 3.5\sigma j - p = 2032 + 3.5 \times 2 - 2024 = 2032 + 7 - 2024 = 15$$

Final Result

$$\min[15, 18] = 15$$

(9)

C1. Inequality

μ	=	2028 (peak of current device group)	σ	=	4
μj	=	2026 (peak of another device group, for example)	σj	=	3

$$\begin{aligned}
2028 + 3.5 \cdot 4 &= 2028 + 14 = 2042 \\
2026 + 3.5 \cdot 3 &= 2026 + 10.5 = 2036.5 \\
\mu + 3.5\sigma - p &> \mu_j + 3.5\sigma_j - p \Rightarrow 2042 > 2036.5
\end{aligned} \tag{10}$$

C2. Modified zone of obsolescence (a,b)

$$\begin{aligned}
\mu &= 2028 & \sigma &= 4 & \mu_j &= 2026 & \sigma_j &= 3 & p &= 2024 \\
\text{Compute } \mu + 2.5\sigma - p & & & & & & & & & = 2028 + 2.5 \times 4 - 2024 = 2028 + 10 - 2024 = 14 \\
\text{Compute } \mu_j + 2.5\sigma_j - p & & & & & & & & & = 2026 + 2.5 \times 3 - 2024 = 2026 + 7.5 - 2024 = 9.5 \\
\text{Minimum of those two} & & & & & & & & & \min[14, 9.5] = 9.5 \\
\text{Compute } \mu_j + 3.5\sigma_j - p & & & & & & & & & = 2026 + 3.5 \times 3 - 2024 = 2026 + 10.5 - 2024 = 12.5 \\
\text{Final Result:} & & & & & & & & & \\
& & & & & & & & & (9.5, 12.5)
\end{aligned} \tag{11}$$

VI. DISCUSSION

Certain market dynamics are tied specifically to manufacturers, applications and should be included as part of a broader risk assessment when evaluating a component. When an end-use application sees increasing adoption, it can lead to heightened demand for its associated components, thereby introducing potential market risks. Manufacturers that hold a large market share and maintain profitability are generally less likely to exit the market. Conversely, the number of available sources for a device or technology group can pose a risk particularly when considering alternative suppliers or replacement options. However: The inequality $\mu + 3.5\sigma - p < \mu_j + 2.5\sigma_j - p$ is false with the given values. This means the modified zone of obsolescence begins 13 years from now and ends 15 years from now. The inequality $\mu_j + 2.5\sigma_j - p \leq \mu + 3.5\sigma - p \leq \mu_j + 3.5\sigma_j - p$ is not satisfied under the given parameters. The middle term (18) lies outside the defined obsolescence window (13 to 15). This means the earliest estimated "zone of obsolescence" threshold—based on the two Gaussian life cycle curves will begin in 15 years from the current year (2024), For example: around the year 2039. True : This inequality holds, which means the current group has a longer obsolescence tail than the compared group. This means the modified zone of obsolescence for this case begins in 9.5 years, ends in 12.5 years from the current year (2024), for example from mid-2033 to mid-2036.

VII. CONCLUSION

An automotive electronics component typically progresses through seven distinct life cycle stages: Introduction, Growth, Maturity, Decline, Phase-out, Discontinuance and Obsolescence, and Special Cases. These life cycle curves serve as critical tools for analyzing part longevity and forecasting availability trends. By modeling part sales over time, engineers and manufacturers can better predict when parts may become obsolete, allowing for timely system redesigns and upgrades. Ignoring these life cycles can result in products built around unavailable components, leading to increased costs, functional limitations, or maintenance challenges. The forecasting model described captures the trajectory of device and technology groups by linking measurable market and technological factors to their respective growth and decline phases. This allows stakeholders to assess both the expected time to obsolescence and the part's current life cycle stage using statistical analysis of sales and market data. Additionally, the model calculates a comprehensive risk factor for a specific part number by incorporating market share, component vulnerability, and manufacturer status. Although aftermarket support can extend a part's practical availability beyond official obsolescence, this pertains more to sourcing than true lifecycle extension. Relationships with sunset distributors, aftermarket manufacturers, and long term suppliers often help bridge the gap between obsolescence and availability, ensuring support for critical automotive systems beyond the part's primary production lifecycle. Certain market dynamics, such as manufacturer dominance and application-specific growth, significantly influence component lifecycle risks. As end-use applications expand, component demand rises, potentially increasing market vulnerability and especially if sources are limited.

REFERENCES

Julian Baehr, Anish Koyamparambath, Steffi Wey and Carsten Binnig, Eduardo Dos Reis, Liselotte Schebek and Guido Sonnemann (2024), “Predicting product life cycle environmental impacts with machine learning: Uncertainties and implications for future reporting requirements”, *Sustainable Production and Consumption*, Vol. 52, pp.511–526.

Yara Kayyali Elalem, Sebastian Maier and Ralf W. Seifert (2023), “A machine learning-based framework for forecasting sales of new products with short life cycles using deep neural networks”, *International Journal of Forecasting*, Volume 39, Issue 4, Pages 1874-1894, ISSN 0169-2070,

Abdel Rehim, Seif El Din & Mostafa and Noha & Mohamed and Tamer (2021), “Adjusting the Logistic Function to Develop a more Realistic Product Life Cycle Model”, *International Journal of Product Lifecycle Management*, Vol. 13. 205. 10.1504/IJPLM.2021.118039.

Haleh Ardebili, Jiawei Zhang and Michael G. Pecht (2019), “Encapsulation Technologies for Electronic Applications (Second Edition)” *Materials and Processes for Electronic Applications*, pp. 431-479.

Anderson, Rønning and Moncaster (2019), “The Reporting of End of Life and Module D Data and Scenarios in EPD for Building level Life Cycle Assessment” *IOP Conf. Series: Earth and Environmental Science 323 (2019)* 012051, doi:10.1088/1755-1315/323/1/012051

Won-Joon Kim, Jeong-Dong Lee and Tai-Yoo Kim (2005), “Demand forecasting for multigenerational products combining discrete choice and dynamics of diffusion under technological trajectories” *Technological Forecasting and Social Change*, Vol. 72, Issue 7, pp. 825-849

Rajeev Solomon, Peter Sandborn, and Michael Pecht (2000), “Electronic Part Life Cycle Concepts and Obsolescence Forecasting” *IEEE Trans. on Components and Packaging Technologies*, pp. 707-717.

Wright, Humphrey and McCluskey (1997), “Upgrading electronic components for use outside their temperature specification limits,” *IEEE Trans on Components, Packaging, and Manufacturing Technology*, vol. 20, No. 2, pp. 252-256.

WEB REFERENCES

- <https://www.broadcom.com/solutions/industry/industrial-automotive/automotive-solutions>
- <https://docs.broadcom.com/doc/12379559>
- <https://www.grandviewresearch.com/industry-analysis/automotive-electronics-industry>
- <https://www.marklines.com/en/statistics/>
- <https://www.data.gov.in/>
- <https://www.sciencedirect.com/topics/engineering/automotive-electronics>