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RESEARCH ARTICLE

INDIA'S ELECTRONICS SECTOR: GROWTH TRENDS, E-WASTE PROJECTIONS, AND FUTURE OUTLOOK

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Abstract

The electronics industry in India has seen extraordinary growth over the last decade. While contributing positively to economic development, job creation, and technological innovations, the exponential expansion of the country's electronics industry has led to a significant increase in electronic waste (e - waste), presenting grave challenges for the environment, resource management, and public health. In the face of the rapid growth of the electronics sector and the surge in e-waste generation, a thorough understanding of the trends is crucial for evidence based policies and sustainable e -waste management initiatives. This study examines the growth trajectory of India's electronics sector and analyses its implications for the present and future e-waste generation. To provide a comprehensive understanding of the sector's trajectory, the study examines long-term trends in the growth and consumption of electronics, manufacturing, trade, and key policies shaping its development. The study further leverages forecasting models, implemented in RStudio using historical data, to forecast future e-waste generation, facilitating a deeper understanding of the magnitude and implications of the anticipated increase. Based on the outcome of the model evaluation, the Exponential Trend model has been adopted as the primary forecasting model for this study. The projection of the trend trends to offer valuable insights into the future trajectory of e-waste generation and underscores the need for stronger and more sustainable e-waste management systems. By intertwining the analysis of the sectoral growth with the e-waste generation forecast projections, the study provides actionable insights to aid in informed decision-making for attaining economic growth coupled with environmental sustainability and circular resource management in India's electronics sector.

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Introduction:-

In the last two decades, the world electronics industry has seen extraordinary growth, driven by consistent technological advancements, increasing digital transformation, innovation in telecommunication, and the adoption of electronic systems (Seif et al., 2023). The replacement of electronic devices has been accelerated by shorter product cycles, rapid model iterations, and intense market competition (Li et al., 2019) (Seif et al., 2023). As a result, rising demand for electronic equipment has drastically raised the quantity of e-waste products, exacerbating the global e-waste dilemma (Quinto et al., 2025). Therefore, while electronics have boosted productivity and improved quality of life, the growing number of discarded devices presents a dual challenge because these devices contain both hazardous materials and valuable secondary resources (Xavier et al., 2023).

In the midst of the rapid growth of the global electronics industry, India has emerged as the leading destination for electronics manufacturing. The rise of the electronics manufacturing sector has been coupled with a significant surge in the consumption of electronic products across India. The explosion in demand has been stimulated by population growth, increasing incomes, rapid digitalization, convenient access to affordable consumer electronics, and the proliferation of connected devices (Jaiswal et al., 2025). However, this growth has come at the price of a rapid increase in e-waste generation.

Improper management of e-waste can release heavy metals, persistent organic, and other toxic substances into the environment, significantly threatening the ecosystems and public health (Ahirwar & Tripathi, 2021). The risks are more significant in developing countries, where high volumes of e-waste are often handled through informal practices that include rudimentary dismantling, open burning, acid leaching, and informal disposal (Liu et al., 2023). However, literature acknowledges that e-waste is more than just a disposal problem. In addition to its environmental risks, e-waste has increasingly been recognized as an urban mine because it contains valuable resources, including gold, silver, copper, platinum group metals, and critical minerals such as lithium and cobalt, which can be recovered through recycling (Panchal et al., 2021).

This research contributes to the literature through three primary ways. First, the study analyses the evolution and recent development of India's electronics sector, integrating it with the broader technological and industrial transformation. Second, it estimates future e-waste generation using the available historical data to provide a foundation for strategic planning and infrastructure development. Finally, the study provides insights into the future trajectory of India's electronics sector to identify measures and strategies for sustainable resource management and long-term economic development. The findings will aid policymakers, industry practitioners, researchers, and environmental agencies to formulate effective strategies to balance industrial growth with environmental sustainability and efficiency in resource utilization.

Evolution of the India's Electronics Sector and Growth Trends:-

India's electronics sector has shifted from an import-driven state-led industry to policy-driven manufacturing ecosystem, with robust growth in mobile phone production and export. The initial development of India's electronics sector was guided by planned development and self-reliance policy, marked by industrial licensing, technology controls, and public sector dominance (Verghese, 1986). While the paradigm enhanced domestic control over the sector, it limited private sector involvement, product innovation, and growth of domestic firms. Following the economic reforms of 1991, the sector adopted the policy of trade liberalization and foreign direct investment (FDI). However, domestic firms faced intensified competition from multinational giants prior to the establishment of a robust domestic component ecosystem (A. Dwivedi, 2012).

The industrial policy in the last decade has shifted its focus to expanding the scale and competitiveness of electronics manufacturing. The National Policy on Electronics 2012 aimed to create a globally competitive Electronics System Design and Manufacturing (ESDM) ecosystem for domestic and global markets (Raju & Saradhi, 2020). The 2019 policy revision, supplemented by PLI, SPECS, and EMC 2.0, encouraged domestic component manufacturing and extended the electronics manufacturing clusters signifying a strategic shift towards self-reliance (Raju & Saradhi, 2020). The launch of 'Make in India' in 2014 emphasized electronics manufacturing by stimulating investment, infrastructure development, and streamlining the approval process (Roy Chowdhury & Rastogi, 2021). Digital India and rapid development of telecommunication infrastructure fuelled demand and mobile phone manufacturing by raising the digital connectivity and expanding the consumer base (Mishra et al., 2024).

Recent studies highlight the swift expansion of India's electronics industry. According to a recent estimate, India's total production of electronics grew from ₹1.9 lakh crore in 2014–15 to ₹11.3 lakh crore in 2024–25 (S. Dwivedi

& Bhargava, 2026). Rapid growth in smartphone manufacturing has been a significant driver of the sector's expansion, with the industry reaching USD 44 billion (Rath & Das, 2024). Furthermore, the expansion has increased in recent years, with the electronics export reaching USD 12.41 billion in the first quarter of FY 2025–26 mainly driven by shipments of smartphones (S. Dwivedi & Bhargava, 2026). India has shifted from importing 98% of its mobile phones a decade ago to producing 99.2% of those used domestically, though component imports remain high (Rath & Das, 2024). Recent estimates show that the number of units involved in the production of mobile phones grew from just 2 in the year 2014 to 268 units in 2019, exceeding 300 by 2025 (Choudhury, 2021) (S. Dwivedi & Bhargava, 2026).

Overall, the India's electronics sector has moved from being a protected industry, to a liberalized market, to a phase of policy-driven expansion in manufacturing. Looking into the future, the critical challenge is to convert the manufacturing scale to higher domestic value addition, improved component capabilities, and sustained technological competitiveness across the electronics value chain.

Forecasting India's E-Waste Generation:-

E-waste has become one of India's fastest-growing waste streams, driven by rapid device replacement, shorter product lifecycles, and the expansion of digital consumption (Bagwan, 2024). Inadequate handling of e-waste can pollute the air, soil, and water, posing significant health risks to workers and surrounding communities through exposure to hazardous metals and toxic substances (Yadav et al., 2025).

Annual data on the generation of electronic waste for India for the years spanning the financial years 2017–18 to 2024–25 were collated from official reports. The data consist of eight annual observations on the total volume of e-waste generated (in metric tonnes), as presented in Table 1. The data were subsequently transformed to an annual time series object for the forecasting analysis in RStudio.

Table 1. Annual data of e-waste generation in India

Year	E-waste (Tonnes)
2017-18	708445
2018-19	771215
2019-20	1014961.21
2020-21	1346496.31
2021-22	1601155.36
2022-23	1609117
2023-24	1254286.55
2024-25	1397955.59

Source: Central Pollution Control Board (CPCB), as reported by the Press Information Bureau (PIB), Ministry of Environment, Forest and Climate Change, Government of India (2023).

Descriptive statistics, such as mean, median, minimum, maximum, standard deviation, variance, and coefficient of variation, were computed to provide a summary of the historical generation of e-waste. Additionally, the growth rates annually were computed to explore the inter-year fluctuations in the generation of e-waste. Trends in the historical data were visualized using the line graph as demonstrated in Figure 1 to provide an overview on the temporal pattern. The historical data showed an increase in the overall e-waste generation in India for the study period; however, significant inter-annual fluctuations were observed.

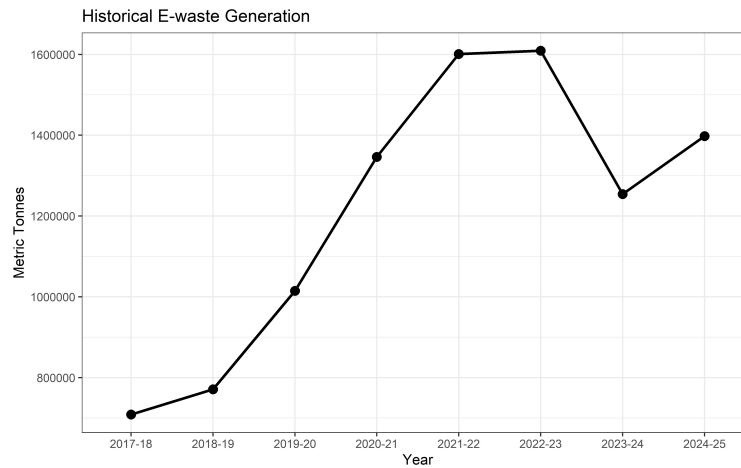


Figure 1. Historical E-waste generation trend

The descriptive statistics reveal average fluctuations in annual generation of e-waste, which reflect the evolving dynamics of electronic consumption, cycles of electronic product replacement, and waste management practices. The descriptive statistics of the e-waste data are presented in Table 2. Furthermore, the annual rate of growth analysis further demonstrates that generation of e-waste has not proceeded strictly on a perfectly linear path suggesting that economic and behaviour factors are interrelated in the inter-annual variability.

Table 2. Descriptive statistics of e-waste generation data

Statistic	Value
Mean	1212954
Median	1300391
SD	348522.8
Min	708445
Max	1609117
CV (%)	28.73339

The stationarity of the annual time series was evaluated with the Augmented Dickey–Fuller (ADF) test and the Kwiatkowski–Phillips–Schmidt–Shin (KPSS) test. The ADF test evaluates the null hypothesis that the series contains a unit root, whereas the KPSS test considers stationarity as the null hypothesis. While the KPSS test did not provide enough proof to reject the null hypothesis, the differenced series satisfied the ADF stationarity assumption. The statistical data consisted only of eight annual observations. Therefore, the findings of these statistical tests were interpreted with caution and supplemented with the graphical inspection. The limited volume of the data does not have a greater statistical power of formal unit root tests; therefore, the forecasting models were directly estimated on the original annual series. To compare the forecasting alternatives, four forecasting models, encompassing different philosophies of model, were estimated.

The Linear Trend Regression was used as a benchmark model to capture constant rate of change on the generation of e-waste over time. The Exponential Trend Regression was estimated by fitting a linear regression on the natural logarithm of the generation of e-waste. This model assumes a constant percentage rate of growth in the generation of e-waste which is particularly suitable for rapidly growing indicators. ETS models for Exponential Smoothing State Space were estimated based on the automatic model selection procedure as provided by the package. The best model specification is ETS model selected using Akaike Information Criterion. Auto-Regressive Integrated Moving Average (Auto-ARIMA) models were estimated using the automatic model selection algorithm, which finds the optimal ARIMA specification by the minimization of the corrected Akaike Information (AICc). The forecasting models were assessed in terms of various statistical performance measures, including Root Mean Square Error (RMSE), Mean Absolute Error (MAE), Mean Absolute Percentage Error (MAPE), the Akaike Information Criterion (AIC) and the Bayesian Information Criterion (BIC) as depicted in Table 3. The lower the values for these statistics,

the better the performance of the model. The comparison indicates that the Linear Trend model achieved the lowest RMSE, suggesting the highest forecasting accuracy by minimizing the average squared differences between the forecasted and observed values. Conversely, the Auto-ARIMA model achieved the lowest MAE and MAPE, implying a relatively smaller error in forecasts.

Table 3. Comparison of forecasting models

Model	RMSE	MAE	MAPE	AIC	BIC
Linear	205478.5	188052.3	15.44673	224.4326	224.6709
Exponential	231696.6	205478.4	16.17972	0.861455	1.099779
ETS	282682.6	237960.3	22.86911	223.4072	223.6455
ARIMA	219296.7	174985	13.98031	194.9744	194.9203

In addition, the coefficient of determination (R^2) and the adjusted R^2 were computed for the regression-based models to measure the proportion of variance explained by the fitted trend models. The regression-based models exhibited a good explanatory performance as demonstrated in Table 4. The Linear Trend model returned an adjusted R^2 value of 0.537, while the Exponential Trend model achieved a slightly higher adjusted R^2 value of 0.590, which suggests better results in capturing the long-term trajectory of growth.

Table 4. Comparison of R^2 and adjusted R^2 values of regression-based models

Model	R-Squared	Adjusted R-Squared
Linear Trend	0.60275	0.53654
Exponential Trend	0.64881	0.59028

Residual diagnostics were performed for the ETS and ARIMA models using the Ljung–Box test to assess whether the residuals constituted white noise, as presented in Figure 2. A non-significant Ljung–Box statistic suggests that the underlying temporal dependence is adequately represented by the fitted model. Residual diagnostics suggest that both the ETS and Auto-ARIMA models adequately captured the underlying temporal dependence in the series. The results from the Ljung–Box test produced non-significant p-values for both models ($p > 0.05$), suggesting the residuals were independently distributed without statistically significant autocorrelation.

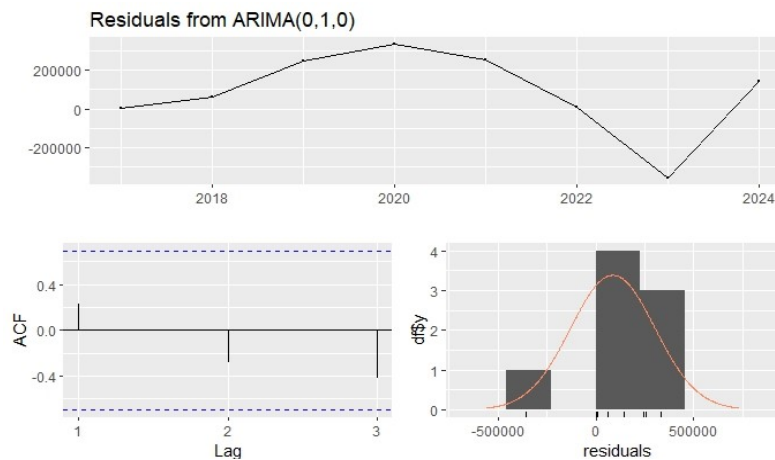


Figure 2. Residual diagnostics for ETS and ARIMA model.

Five-year forecasts for the time span of 2025–26 to 2029–30 were generated for each of the forecasting model. The prediction intervals for the future forecasts to measure the uncertainty of the forecasting estimates was quantified using the 95% prediction interval. Comparative plots of the forecasts were created to compare the differences between the forecasting alternatives as represented in Figure 3. The Linear Trend model forecasted a gradual rise in the generation of e-waste for the forecast period. The Exponential Trend model estimated a relatively faster rate of

increase, capturing a sustained pattern of percentage growth. Conversely, the ETS (M, N, N) model and the selected ARIMA (0,1,0) model produced forecasts that are nearly constant for the five-year period.

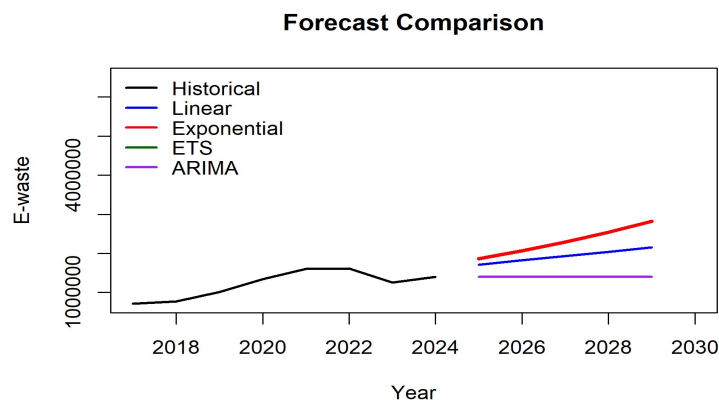


Figure 3. Five-year forecast comparison of models

The constant forecasts generated by the ETS and ARIMA models indicate that the available data on observations are insufficient to offer sufficient statistical evidence for the presence of a persistent stochastic trend. The selection of the ARIMA (0,1,0) and ETS (M, N, N) suggests that the fluctuations observed in the series are predominantly interpreted as fluctuations around an approximately stable level rather as continuing dynamic growth. Although the Auto-ARIMA model obtained the lowest information criteria and forecasting error measures, it produced constant forecasts for future years because the selected model did not contain autoregressive, moving average, or drift components. Similarly, the ETS model found a specification that lacks a trend leading to flat future projections.

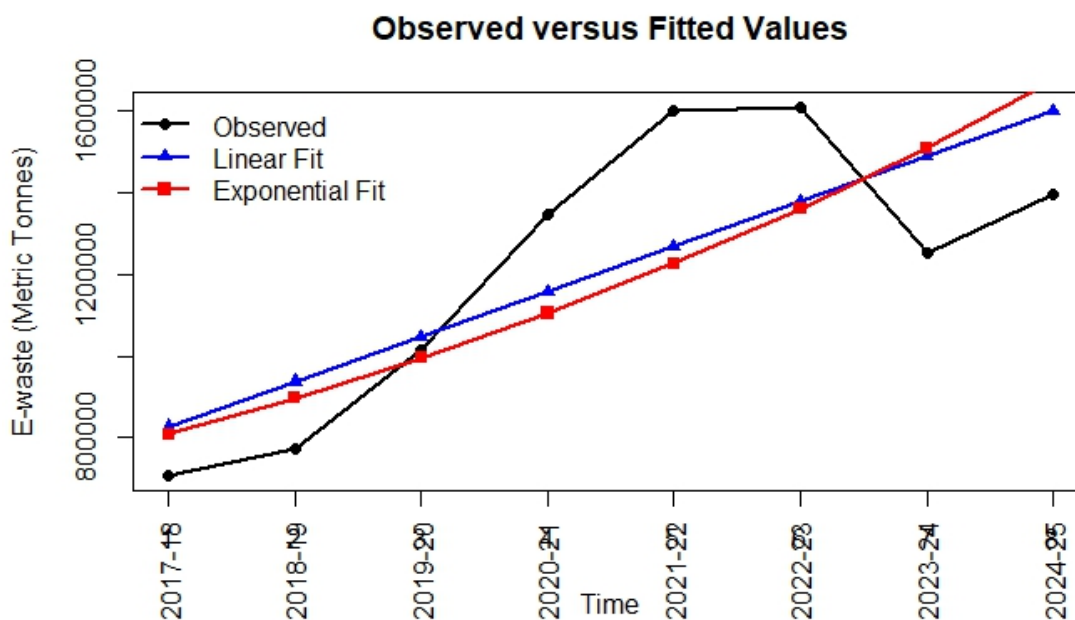


Figure 4. Observed vs. Fitted values for Linear and Exponential Trend models

The objective of forecasting future e-waste generation to support strategic planning necessitated the selection of the Exponential Trend model as the primary forecasting model. Figure 4 depicts the line chart of observed vs. fitted values for Linear and Exponential Trend Models. As compared to the statistical time-series models, the exponential

model better captures the long-term rising growth trend observed in the India's electronics industry and allows a more realistic growth scenario to be analysed for policy decision-making. The Linear Trend model was kept as a benchmark, while ETS and Auto-ARIMA were used as a conservative comparison models. The five -year e-waste forecast generated by Exponential Trend Model is presented in Table 5.

Table 5. Five-year e-waste generation forecast as per Exponential Trend Model

Year	E-Waste Forecast (Tonnes)
2025-26	18,59,831
2026-27	20,63,899
2027-28	22,90,358
2028-29	25,41,666
2029-30	28,20,548

Future Outlook:-

The literature can be categorized around three themes: circularity, technology, and governance & investment. Across these dimensions, sustainable advancement will require the integration of urban mining, AI-driven material recovery, and strengthened Extended Producer Responsibility (EPR) mechanisms within formal waste management systems. In the context of circularity, e-waste is characterized as a resource rather than a waste, with emphasis put on the reuse, repair, remanufacturing, and high-quality recycling to ensure the maximum material recovery (Xavier et al., 2021). The shift is particularly applicable to the electronics sector as the e-waste includes both hazardous and high-value materials which can be recovered using circularity principles, thus lowering the reliance on virgin resources but also generating employment opportunities and minimizing environmental impacts (Pan et al., 2022). The urban mining concept plays a pivotal role in circular supply chains by enabling the recovery of critical metals from e-waste while minimizing the need for primary resource extraction (Xavier et al., 2021). The case studies of several cities indicate that repair and remanufacture can help reduce the needed material for new products by a significant percentage of up to 80% (Ghisellini et al., 2022). By encouraging the recovery and reusing of rare materials such as the rare earth elements, circular supply chains help maintain a stable material value and minimize reliance on virgin resources (Quinto et al., 2025).

Urban mining has been established as a priority strategy in terms of resource recovery while the AI and digital technologies mainly focus on improving the operational efficiency of the e-waste management and material recovery processes. The literature identifies e-waste as a crucial secondary source of critical raw materials but highlights that efficient recovery requires coordinated collection systems, suitable recycling technologies and enhanced data throughout the value chain (Xavier et al., 2023). Literature identifies Extended Producer Responsibility (EPR) as the core e-waste governance mechanism while highlighting that its success depends on the effective enforcement, reliable traceability systems and inclusion of the informal sector. The reviews stress the importance of the EPR mechanisms and producer responsibility organizations, the licensing and effective legal frameworks for the future circular economy (CE) systems (Murthy & Ramakrishna, 2022). Studies on India reveal that Extended Producer Responsibility (EPR), the polluter-pays principle, and the formal integration of the informal sector are key to accelerating the transition to a CE (Arya & Kumar, 2020). The strengthening of the traceability and accountability throughout the recycling value chain should be prioritized as the future policy framework. Harmonized policy frameworks should target the both social and technical aspects, including the involvement of informal workers and consumers (Xavier et al., 2023).

The investment opportunities have been mostly focused on the formal recycling infrastructure, urban mining, smart sorting technologies, reverse logistics, and circular business models. The literature identifies e-waste as a valuable secondary resource, with one review estimating the total global recoverable material value at USD 62.5 billion, while other studies highlight the economic and livelihood opportunities associated with urban mining (Mudali et al., 2021). Emerging opportunities are reaching for more advanced recovery technologies, the development of the formal recycling infrastructure and the development of circular business models to integrate the collection, dismantling, recovery and remanufacturing (Murthy & Ramakrishna, 2022). A successful investment should focus on education, infrastructure, recycling innovation, and technological development together, rather than solely on technology itself. Scenario-based forecasting allows the policymakers and industry to make an informed, long-term decisions for future e-waste management.

Conclusion:-

The transformational growth of India's electronics sector has generated substantial industrial opportunities but has also contributed to the growing challenge of e-waste generation. The evidence suggests that the e-waste is no more a side effect of modernization but has evolved as a primary concern with consequences for resource management, public health, and industrial policy, that is impacting the long-term sustainability of electronics-led growth in India. The future growth in e-waste production highlights the need of a significant extension of collection systems, recycling capacity, reverse logistics infrastructure and resource recovery facilities throughout the country. The forecasts further emphasize the importance of strengthening CE practices, enhancing producer responsibility mechanisms, improving material recovery efficiency, and promoting investment in sustainable e-waste management technologies. A prominent theme emerging from the literature is the shift in perspective that recognizes e-waste not only as a disposal challenge but also as a valuable resource within the CE. The future challenge is to establish an efficient collection, recycling and governance system that would be able to keep up with the expansion of electronics sector in India while facilitating a safe and circular transition.

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