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

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 offer 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 growth economic growth coupled with environmental sustainability and circular resource management in India's electronics sector.

Keywords:- Electronics, Growth, Trends, Forecast

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). Accompanied by shorter product cycles, rapid model iterations, and fierce market competition have expedited the replacement of electronic devices (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, it is apparent that while electronics have boosted productivity and improved quality of life, the increase in the number of discarded devices presents a dual challenge, containing 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 highvolumes 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 with its valuable collection of such as gold, silver, copper, platinum group metals, critical minerals such as lithium, cobalt, and other strategically important resources that can be salvaged by 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 offers insights into the trajectory of the India's electronics sector into the future 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) investments. However, domestic firms faced intensified competition from multinational giants prior the establishment of a robust domestic component ecosystem (A. Dwivedi, 2012).

The industrial policy for 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 fueled 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 expansion in manufacturing smartphone growth has been a significant driver of the sector's growth, with the industry reaching USD 44 billion (Rath & Das, 2024). Furthermore, the expansion hasincreased 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 grown into one of India's fastest-growing waste streams, attributed to rapid device replacement, reduced product lifecycles, and the expansion of digital consumption (Bagwan, 2024). Inadequate handling of e-waste can pollute the air, soil, and water, significantly threatening the health of workers and the surrounding community to exposure to the presence of hazardous metals and toxic substances (Yadav et al., 2025).

Annual data on the generation of electronic waste for India were for the years spanning the financial years 2017–18 to 2024–25 collated from official reports. The data consist of eight observations annually covering the total volume of e-waste generated in metric tonnes as depicted 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 show an increase overall e-waste generation in India for the study period; however, significant inter-annually fluctuations were observed.

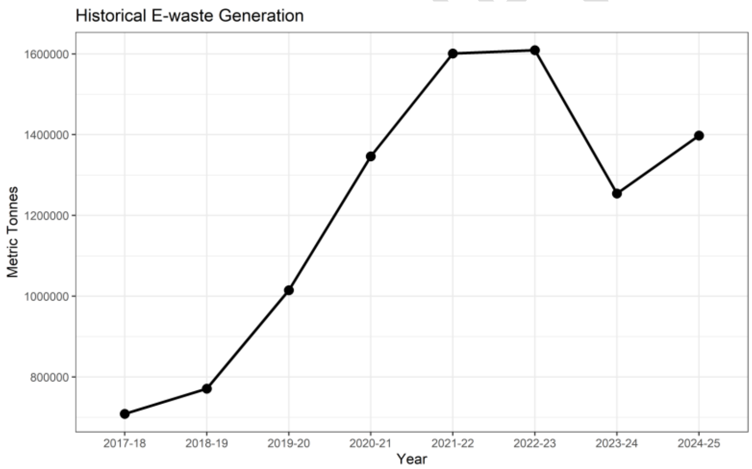

Figure 1. Historical E-waste generation trend

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 tests the null hypothesis of the presence of a unit root in the series, 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 a minimum mean square error of forecasts in terms of average square error between the forecasts and the forecasts obtained from the compared the forecasting alternatives. 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

The coefficient of determination (R^2) and the adjusted R^2 were computed in addition for the regression-based models to measure the proportion of variation accounted 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**	**AdjustedR-Squared**
Linear Trend	0.602751387	0.536543285
Exponential Trend	0.648815217	0.59028442

Residual diagnostics were conducted on the ETS and ARIMA models using the Ljung–Box test to check whether the residuals represented as 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 captured adequately represented the underlying temporal dependence of 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.

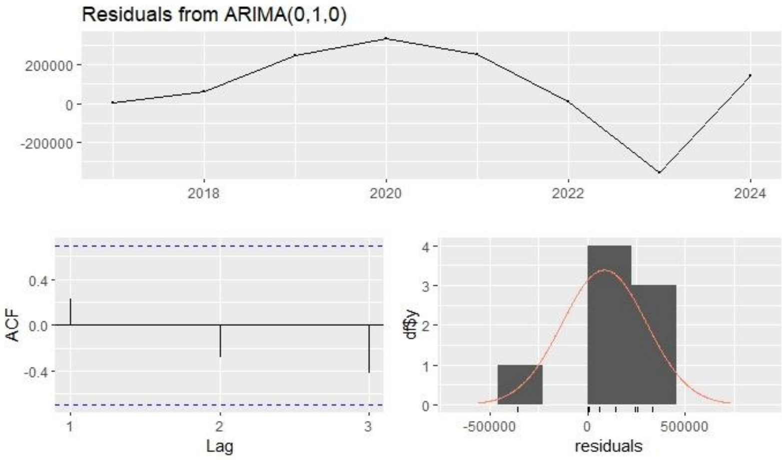

Figure 2. Residual diagnostics for ETS and ARIMA model.

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.

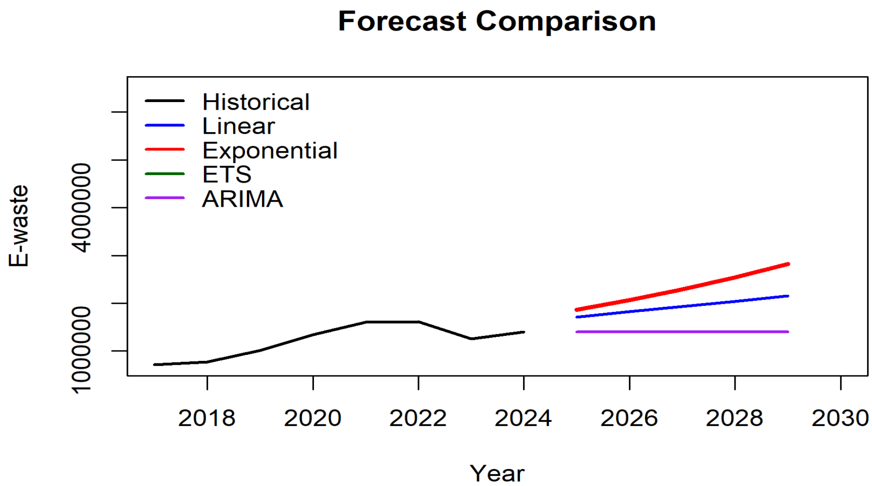

Figure 3. Five-year forecast comparison of models

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.

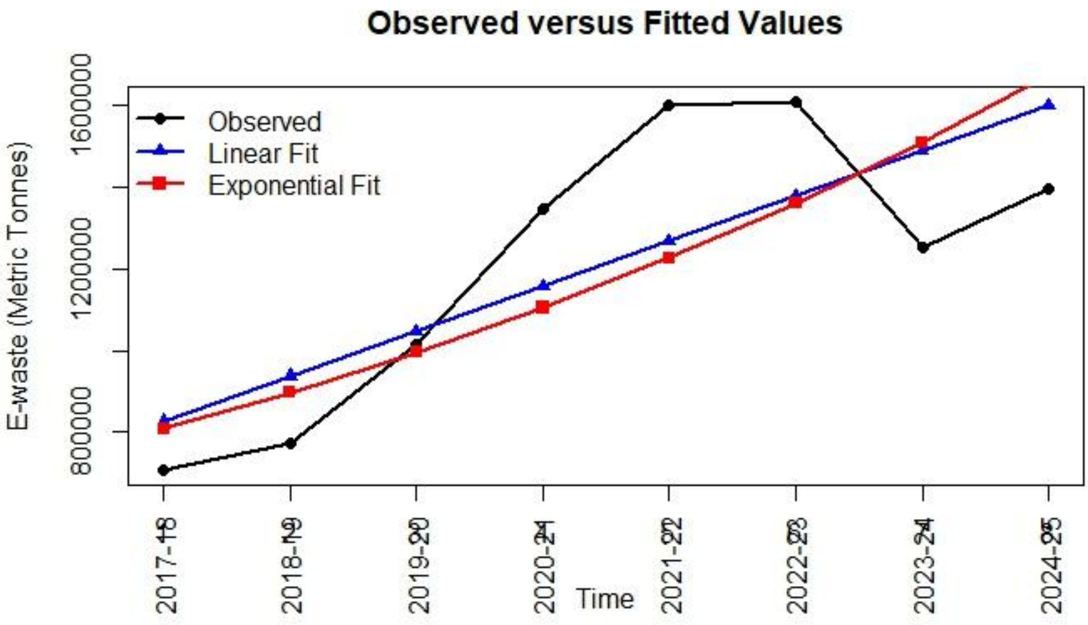

Figure 4. Observed vs. Fitted values for Linear and Exponential Trend models

The goal of forecasting the future generation of e-waste to inform strategic planning for developing recycling infrastructure and reverse-logistics and circular economy initiatives 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 and investment. It evident that across these dimensions, sustainable advancement will require the integration of urban mining, AI-driven material recovery, and the strengthening of Extended Producer Responsibility (EPR) mechanisms within official 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 within circular supply chains as it allows the extraction of critical metals from e-wastes with minimizing the primary extraction of resources (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, circularity 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 resources 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 with 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 systems (Murthy & Ramakrishna, 2022). The studies on India reveal that Extended Producer Responsibility (EPR) and the polluter-pays principle to be the key in the acceleration of the transition to a circular economy, in addition to the formal inclusion of the informal sector (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 the e-waste as a valuable secondary resource, with one review stating that the total global recoverable material value is estimated at USD 62.5 billion and others highlight the economic and livelihood opportunities of 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 in the electronics sector in India has had generated huge industrial opportunities but has led to a growing e-waste problem. 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 on the importance of the strengthening of the circularity practices, enhancing producer responsibility mechanisms, the enhancing of the material recovery efficiency, and the promotion of investment in sustainable e-waste management technologies. A prominent theme emerging from the literature is a shift of perspective that recognizes the e-waste not only as an only as a disposal challenge but as a valuable resource under a circular economy. The future challenge is that 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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