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POPULATION PROJECTION OF AHMEDABAD DISTRICT USING STATISTICAL MODELS (2022–2027): A COMPARATIVE ANALYTICAL STUDY

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ABSTRACT

Rapid urbanization and demographic expansion have significantly transformed Ahmedabad District into one of the fastest-growing regions in Gujarat. Accurate population forecasting is therefore essential for effective planning, infrastructure development, and policy formulation. This study estimates the population of Ahmedabad District for the period 2022–2027 using both curve estimation models (quadratic, growth, exponential) and time-series analysis (ARIMA (1,2,0)). Statistical measures such as R^2, standard error, and significance levels are used to evaluate model performance. The quadratic model, with an R^2 value of 0.999, emerges as the most reliable model for medium-term projections, while ARIMA captures short-term fluctuations. The results highlight variations in projected growth patterns across models and emphasize the importance of selecting appropriate forecasting techniques for realistic demographic planning.

KEYWORDS: *Population Projection, Ahmedabad District, Quadratic Model, ARIMA, Time Series Analysis, Forecasting, Urban Growth*

1. INTRODUCTION

Ahmedabad District, located in the state of Gujarat, is one of India's most rapidly urbanizing and economically dynamic regions. Over the past century, the district has experienced sustained population growth driven by industrialization, migration, and expansion of urban infrastructure. As a major economic hub, Ahmedabad attracts a large inflow of population, leading to increasing pressure on housing, transportation, and public services.

Population projection is a critical component of regional planning as it provides a basis for estimating future demand for infrastructure and services. However, traditional linear methods often fail to capture the complex and nonlinear nature of demographic growth. In rapidly growing urban regions like Ahmedabad, population trends are influenced by multiple factors such as migration, economic opportunities, and demographic transitions.

This study aims to provide a scientifically robust estimation of population growth using advanced statistical techniques. By combining curve estimation models with time-series analysis, the research attempts to capture both long-term structural trends and short-term fluctuations. The objective is to identify the most suitable model for projecting population growth in Ahmedabad District for the period 2022–2027.

2. LITERATURE REVIEW

- In a study titled "Time Series Analysis of Monthly Birth Rate in Ghana" conducted by Buah Ahoba Masha in 2020, Ghana's birth rate was analyzed using the Box-Jenkins technique on a monthly basis. The research period considered for the study ranged from January 2014 to December 2019, during which monthly birth rate data was obtained from the Ghana Statistical Service. The paper tested several models, and from the results, it was discovered that the ARIMA (1, 1, 1) model had the best fit, with the lowest normalized Bayesian Information Criterion (BIC) and Akaike Information Criterion (AIC) values. This model was then applied to the 12-month birth rate for the year 2020, which revealed that the ARIMA (1, 1, 1) model was the best fit among the models tested, with the lowest BIC and AIC values. In conclusion, the study found a negative association between the dependent variable (birth rate) and the independent variable (time/months).
- Muhammad Zakria (2009), "Forecasting the population of Pakistan using ARIMA model". The goal of the study is to use a stochastic ARIMA model to anticipate Pakistan's population trend for the next 20 years based on historical trends. This empirical research uses the Box Jenkins ARIMA approach to estimate Pakistan's population from 1951 to 2007. He gathered population statistics for Pakistan from 1951 to 2007 for this purpose. A 20-year population estimate for Pakistan is also provided using the frugal ARIMA (1, 2, 0) model. He discovered that if Pakistan's population growth trajectory continues, there would be about 230.7 million people living there by 2027. The outcome of the sparse ARIMA model's population projection closely resembles Pakistan's various bureau's population projections. According to these bureaus, 229

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million population of Pakistan for the year 2025. He comes to the conclusion that the estimations offered in the study using the ARIMA (1,2,0) model are comparable to those of other researchers and are crucial for both the Government of Pakistan and Non-Governmental Organizations' upcoming plans and initiatives.

- Nishanth K P, Prof. Dr Ajay Massand, Prof. Dr Mrinmoy Roy (2023), PES University published a paper on "Forecasting Population in India." This study aims to explore how estimation methods can aid in understanding and predicting population trends. The data used for this study was obtained from Macrotrends.com, which provides simplified information on population-related factors. To estimate population growth, multiple linear regression models were used to build a predictive analysis model. The findings suggest that the predicted value of the population cannot be 100% accurate, as there are uncertainties that can affect population growth. For example, in 2019, the arrival of COVID-19 led to a decrease in population due to a rise in deaths caused by the disease.

3. OBJECTIVES OF THE STUDY

The study aims to analyse the population growth pattern of Ahmedabad District and to project its population for the period 2022–2027 using statistical models. It also seeks to compare curve estimation and time-series techniques in order to identify the most suitable method based on statistical accuracy and realistic demographic trends.

4. METHODOLOGY

4.1 Research Design

The study adopts a quantitative and analytical research design, focusing on statistical modeling and forecasting techniques. It is based entirely on secondary data and aims to estimate future population trends using both deterministic and stochastic approaches.

4.2 Data Sources

The study is based on historical population data of Ahmedabad District from 1901 to 2021. The long-time span allows for capturing both linear and nonlinear growth trends.

4.3 Tools and Technique

The population of Ahmedabad District for the years 2022 to 2027 was estimated using curve estimation techniques. Various models, including linear, logarithmic, exponential, growth curve, quadratic, and ARIMA, were applied in the analysis. SPSS software and R-Studio were used to compute the values of R and R^2 for these models.

5. RESULTS AND FINDING

(I) Curve Estimation

Table-1: Model Summary of Curve Estimation for Ahmedabad District Population

Model	Model Summary					
	R Square	St. Error	F value	df1	df2	Sig./P-value
Quadratic	0.999	109.406	3483.658	2	10	0.001
Growth	0.982	0.130	591.219	1	11	0.001
Exponential	0.982	0.130	591.219	1	11	0.001
Dependent Variable: Population						

Table-2: Model Parameter Estimation for Ahmedabad District Population

Model	Parameter Estimation					
	Constant	Sig/P-value	β1	Sig/P-value	β2& (sig.)	Sig/P-value
Quadratic	1021.797	0.001	-320.058	0.000	68.415	0.001
Growth	6.026	0.000	0.234	0.000		
Exponential	413.987	0.000	0.234	0.000		
Dependent Variable: Population						

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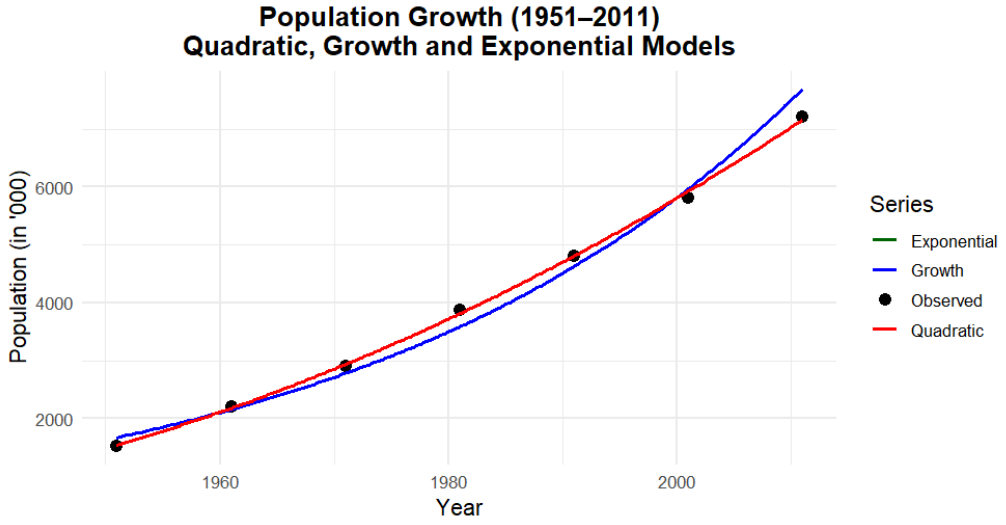


Figure: 1 Curve fitting Population of Ahmedabad district (1901 to 2021).

Table-1 shows that the quadratic model has the highest R^2 value (0.999), which means it explains almost the entire variation in the population data of Ahmedabad District. The growth and exponential models also perform well, but their R^2 values (0.982) are slightly lower. The standard error of the quadratic model is higher, but this is mainly because it is based on the original population scale. All the models are statistically significant, yet the quadratic model clearly provides a better fit. From Table-2, it is observed that all the parameters of the quadratic model (constant, β_1, and β_2) are statistically significant. This indicates that the model is able to capture the changing pattern of population growth over time. In contrast, the growth and exponential models assume a constant rate of increase, which may not fully reflect the actual trend. Figure 1 also shows that the quadratic curve closely follows the observed data points.

Therefore, considering both statistical results and the pattern of growth, the quadratic model is the best fitted model. It is more suitable and reliable for forecasting, as it represents the nonlinear nature of population growth more accurately than the other models.

(II) ARIMA Model Fitting

In this model, population projection for Ahmedabad District for the period 2022 to 2027 was conducted using time series analysis. Various ARIMA models were applied during the analysis. SPSS software was used to compute the values of R and R^2 for these models.

Stationarity Test in Data

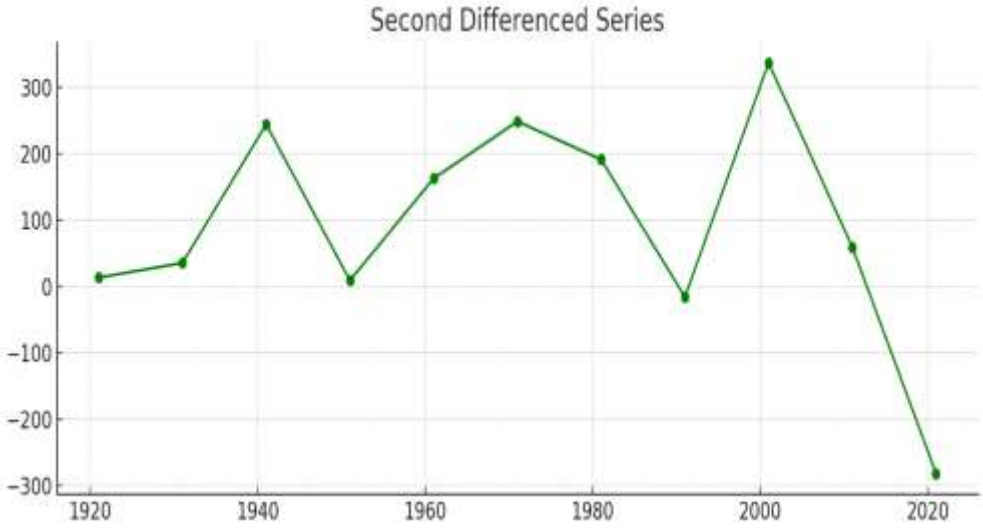


Figure: 2 Stationarity in Population of Ahmedabad District

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In Figure 2, A 2-lag difference was applied to achieve stationarity in the population data series of Ahmedabad District. After applying the 2-lag difference, the data series was found to be stationary.

Unit Root Test (KPSS)

Table-3: Kwiatkowski-Phillips-Schmidt-Shin (KPSS) test for Population of Ahmedabad District

KPSS Test		t-Statistic	Prob.*
		0.4947	0.1070
Test critical values:	Level of 1%	0.7390	
	Level of 5%	0.4630	
	Level of 10%	0.3470	

The KPSS test statistic is 0.4947, which is slightly above the 5 percent critical value (0.4630) but still below the 1 percent level (0.7390). Since the null hypothesis assumes that the series is stationary, this result does not provide strong enough evidence to reject it at the 5 percent level. Therefore, the population series of Ahmedabad District can be treated as approximately stationary for further analysis.

Detecting of Auto-Correlation

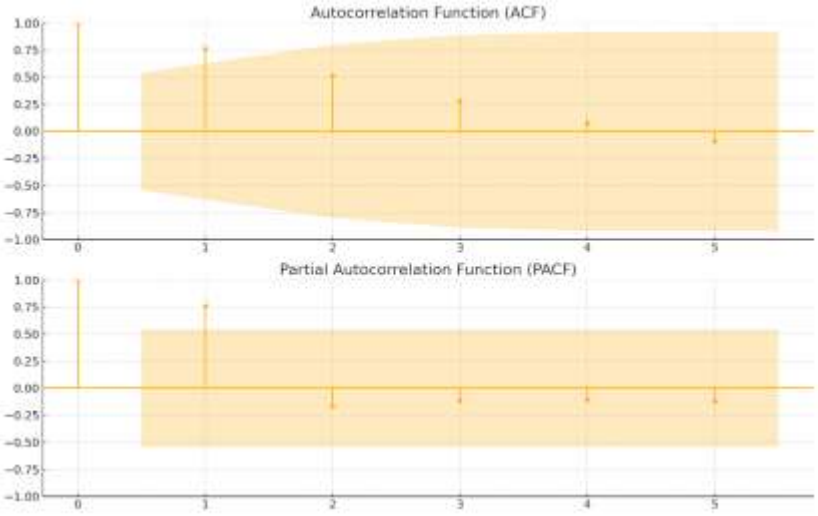


Figure 3: ACF and PACF Plot for the Ahmedabad District Population

The ACF and PACF plots indicate that the series is not stationary. This is evident from the strong positive autocorrelation at the first lag and the gradual decline in the ACF values. The PACF shows a sharp cut-off after lag 1, suggesting that an AR (1) process may be appropriate. This pattern implies that the current year's population is largely influenced by the immediate previous year, with little effect from earlier periods. To ensure proper modeling, the series needs to be differenced so that stationarity can be achieved before applying ARIMA techniques.

Model Fitting

Table-4: Model Statistics for ARIMA (1,2,0)

Model	Number of Predictors	Model Fit statistics			Ljung-Box Q (18)		
		Stationary R-squared	R-squared	Normalized BIC	Statistics	DF	Sig.
Ahmedabad District Population	1	0.862	0.992	10.06	11.875	10	0.294

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Table-5: ARIMA (1,2,0) Model Parameters					
		Estimate	SE	t	Sig.
Ahmedabad District Population	Constant	0.9285	0.114	8.134	0.000
	AR (1)	25.5581	9.358	2.732	0.019

The population of Ahmedabad District was modeled using the ARIMA (1,2,0) approach, and the results indicate a strong model fit. As shown in Table-4, the model has a high R^2 value of 0.992, meaning it explains most of the variation in the population data. The Stationary R^2 (0.862) also suggests a good fit after differencing. The BIC value of 10.06 further supports the suitability of the model. The Ljung-Box test (p = 0.294) shows that there is no significant autocorrelation in the residuals, indicating that the model is statistically adequate.

From Table-5, both the AR (1) term and the constant are statistically significant. This confirms that the model captures the pattern of population growth effectively and provides reliable estimates for forecasting.

Forecast Ahmedabad District Population for 2022 to 2027

Quadratic Model: $Y_t = 1021.797 - 320.058t + 68.415t^2 + \varepsilon_t$

Growth Model: $Y_t = e^{6.026+0.234t} + \varepsilon_t$

Exponential Model: $Y_t = 413.987 \cdot e^{0.234t} + \varepsilon_t$

ARIMA Model: $Y_t = 2Y_{t-1} - Y_{t-2} + 0.9285(Y_{t-1} - 2Y_{t-2} + Y_{t-3}) + 25.5581 + \varepsilon_t$

Table-6 Forecasted Value with Different Models for Ahmedabad District Population in thousand from 2022 to 2027				
Years	Quadratic	Growth	Exponential	ARIMA (1,2,0)
2022	8569.74	8878.61	8877.14	**9211.36**
2023	8717.66	9088.82	9087.31	**10146.81**
2024	8866.95	9304.00	9302.46	**11075.75**
2025	9017.62	9524.28	9522.71	**12002.82**
2026	9169.65	9749.78	9748.17	**12929.36**
2027	9323.05	9980.62	9978.96	**13855.76**

Table-6 presents the projected population of Ahmedabad District for the years 2022 to 2027 using four models—Quadratic, Growth, Exponential, and ARIMA (1,2,0). The results clearly show differences in the pattern of growth across these models. The ARIMA model gives the highest estimates, rising sharply from 9,211 in 2022 to 13,856 in 2027, which reflects a strong upward trend based on recent changes. In contrast, the Quadratic model gives the lowest estimates, with a steady increase from 8,569 to 9,323 over the same period. The Growth and Exponential models fall in between and show almost similar, moderate increases.

The ARIMA model captures recent trends well, which explains its rapid rise, but this can also lead to higher estimates over time. The Quadratic model, on the other hand, shows a smoother and more stable pattern and also has the strongest statistical support, with the highest R^2 and significant parameters.

Considering both the statistical results and the nature of population growth, the Quadratic model appears more suitable for forecasting. It provides a balanced and realistic estimate, avoiding the risk of overestimation seen in the ARIMA model, while also offering a better fit than the Growth and Exponential models.

6. CONCLUSION

This study examined the population growth of Ahmedabad District using both curve estimation methods and time series analysis. Different models were applied and compared to understand which one gives more suitable results for future projections.

The findings show that although all models are statistically significant, the quadratic model fits the data best. It explains almost all variation in the population series and also reflects the changing pattern of growth over time. The ARIMA (1,2,0) model also performs well and is useful for understanding short-term trends, but its forecasts increase rapidly and may not be realistic for longer periods.

When the forecast values are compared, it is clear that the quadratic model provides a more stable and gradual increase in population. The growth and exponential models give moderate results, but they assume a constant rate of increase, which may not match actual population behaviour.

Therefore, considering both the statistical results and the nature of population growth, the quadratic model is more suitable for forecasting the population of Ahmedabad District for the period 2022–2027. It gives more balanced and realistic estimates and can be useful for planning and policy purposes.

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