# Assessing Sand and Gravel Demand in India: Trends, Forecast, and The Need for Alternatives

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**Abstract**

Sand and gravel are essential raw materials for infrastructure development, construction, and industrial applications in India. With rapid urbanization and economic growth, their demand has significantly increased, leading to extensive mining activities across riverbeds, floodplains, and coastal regions . Thus, there is a critical need to forecast the demand for sand and gravel in the future. This study analyzes historical data on sand and gravel extraction in India obtained from various sources. The correlation between this demand and other key economic parameters, such as GDP and population, is also established. Various time-series forecasting techniques are then employed to project the demand into the future. The findings indicate a continued rise in demand, which raises concerns about environmental degradation and river ecosystem disturbances. This highlights the need for industry to develop and adopt alternative materials to meet future needs.

## 1. Introduction

Sand and gravel (aggregates) are essential building blocks for concrete infrastructure, as they make up 70 - 85% by mass of concrete, the second most used material on Earth[1]. Rapid urbanization and economic expansion in India have prompted an unparalleled hike in demand for these resources[1][2]. Riverbeds, floodplains, and coastal areas are now flashpoints for large-scale sand mining operations, creating several environmental problems[1][7]. Sand plays a critical role as a buffer against tidal waves, a habitat for marine organisms, and a key component in construction materials[3]. Over-extraction of sand disturbs the ecosystem balance, destroys environments, and changes river systems, compromising biodiversity and water supply[1][6].

Even as river sand has a considerable market demand for use in construction, desert sands are unfit for the task owing to their fineness and smoothness [4]. Manufactured Sand (M-Sand) is potentially an alternative, but economic and technical constraints currently hinder widespread use[3][5]. The increasing need for sand has provoked over-mining and ecological degradation. Illegal sand mining is widespread in India due to poor governance, non-functional monitoring mechanisms, and corruption [1][6]. There is thus an urgent need to forecast, regulate, and plan for the use of both riverbed sand and M-Sand in India [2][7].

This research aims to examine historical trends of aggregate usage in India for the last two decades based on the extraction rates of the past, as well as socioeconomic factors such as GDP growth, population growth, and the growth of the construction sector[4]. From the historical data, time-series forecasting methods such as ARIMA, SARIMA, SARIMAX,and PROPHET are used to predict future sand demand[4][5]. These projections can be utilized to determine sustainable extraction limits and provide policymakers with data-driven policy interventions [2][7].

## 2. Assumptions

The following assumptions were considered for the forecasting of the aggregate demand in India:

- Cement production is mostly used for domestic purposes; imports and exports are excluded.
- Only naturally dredged (riverbed) sand is considered; other sand types are excluded.
- Sand consumption is driven by socio-economic factors such as GDP (construction sector), GDP growth, and population.
- For the SARIMAX model, fabricated exogenous data for GDP and population were used to simulate realistic growth patterns, assuming a constant annual GDP growth rate of 8%.
- "Factors" and "features" are used interchangeably to refer to these variables.

## 3. Methodology

### 3.1 Data Collection:

The data used in this study were mostly collected from publicly released reports by the U.S. Geological Survey (USGS) via its Mineral Commodity Summaries portal. The reports aggregate yearly data on a broad array of mineral commodities, including construction aggregates like sand and gravel, natural and manufactured. While the United States is the primary focus of the USGS data, it does contain important global measures, which enable the comparison of India's consumption trends in the international context. This study utilises data from 1994 to 2019, providing close to twenty years of historical data on sand and aggregate demand. For future projections, this study incorporates fabricated data for population and GDP growth based on trends observed in CEIC's population projections for India[8].

### 3.2 Forecasting Models:

We have used multiple time series models such as ARIMA, SARIMA, SARIMAX and Meta's pre-trained model PROPHET to predict sand demand through 2050 based on the historical data. These models are well suited for this study as it is time-series data. These models are used for handling Univariate and multivariate time series data with trends and seasonalities, which aligns with our sand and gravel data. A brief description of the models is provided below:

1. ARIMA (AutoRegressive Integrated Moving Average) was utilized as a baseline since it has strong ability to fit linear trends and autocorrelation in non-seasonal time series data. ARIMA is a stable model for stationary datasets or datasets that are stationary with the help of differencing.
2. SARIMA (Seasonal ARIMA) is an extension of the ARIMA model with the addition of seasonal factors. Because sand and aggregate demand frequently have periodic cycles—due to monsoon cycles, seasonality of construction, and yearly policy or budgetary cycles—SARIMA was especially effective for modeling these cyclical variations.
3. SARIMAX (Seasonal ARIMA with External Variables) is an extension of SARIMA which accommodates the use of external variables (for example, GDP, population growth, urbanization indices, etc.). It is particularly suitable for capturing extraneous influences that lie outside the time series, and was used to determine how extraneous socioeconomic drivers affect sand and aggregate demand.
4. PROPHET, developed by Facebook, is a pre-trained time-series forecasting model specifically designed to handle data with strong seasonal effects, holidays, and trend changes. It decomposes time series into trend, seasonality, and holiday components, and is robust to missing data and outliers. PROPHET was particularly suitable for modeling sand and aggregate demand due to its ability to automatically detect and adapt to shifts in trends, such as those caused by policy changes or infrastructure development phases. Its intuitive parameter tuning and flexibility made it suitable for capturing the yearly, weekly, and event-driven patterns in construction activity, making it a strong candidate for long-term forecasting alongside ARIMA-like models.

### 3.3 Model Evaluation:

In order to measure the performance of the forecasting models, we used Mean Absolute Error (MAE) as the primary performance metric. MAE is a standard measure of time-series forecasting error that approximates the average of the absolute differences between the forecasted and actual values. It can be mathematically represented as:

$$\mathrm{MAE} = \frac{1}{n} \sum_{t=1}^{n} \left| y_t - \hat{y}_t \right|$$

where $y_t$ is the actual value, and $\hat{y}_t$ is the predicted value at time t.

Mean Absolute Error (MAE) was selected because it is simple, easy to interpret, and best suited for datasets with few outliers. All the models of forecasting, i.e., ARIMA, SARIMA, SARIMAX, and PROPHET, were trained on the historical dataset of

1994–2015, and the predictive ability was tested using MAE on the last two years of data i.e., 2016-2019.

## 4. Results

### 4.1 Overview of Historical Data

As shown in **Figure 1**, the historical sand and gravel mining data for India indicates a relatively stagnant trend from the early 1990s up until approximately 2013, with the quantity mined consistently hovering just above 1 million metric tons per year. During this period, only minor fluctuations are observed, potentially due to regional construction activities or intermittent regulatory interventions. A notable shift occurs around 2014–2015, where the data reflects a significant inflection point in demand. The quantity mined increases sharply—nearly quadrupling by 2016—and continues to rise steadily through to 2020, eventually exceeding 12 million metric tons. This surge in extraction volume is likely associated with intensified infrastructure development, rapid urbanization, and pro-growth policy initiatives introduced during this period.

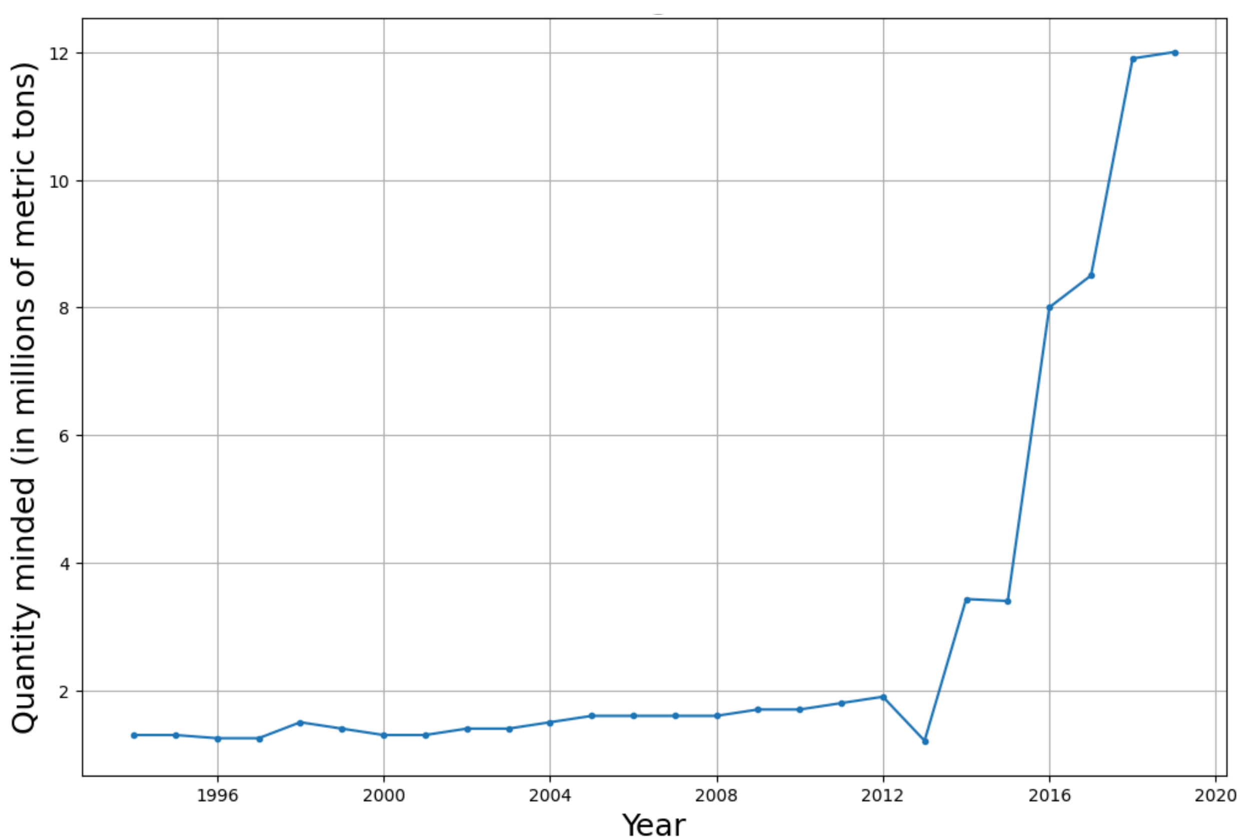


**Figure 1: Annual Sand and Gravel Mining in India (1994–2020).**

### 4.2 Factors contributing to the annual sand consumption

Four external factors were considered in trying to predict sand mining in India: GDP, GDP growth rate, population, and population growth rate. These are shown in Figures 2-5, respectively.

**GDP:**

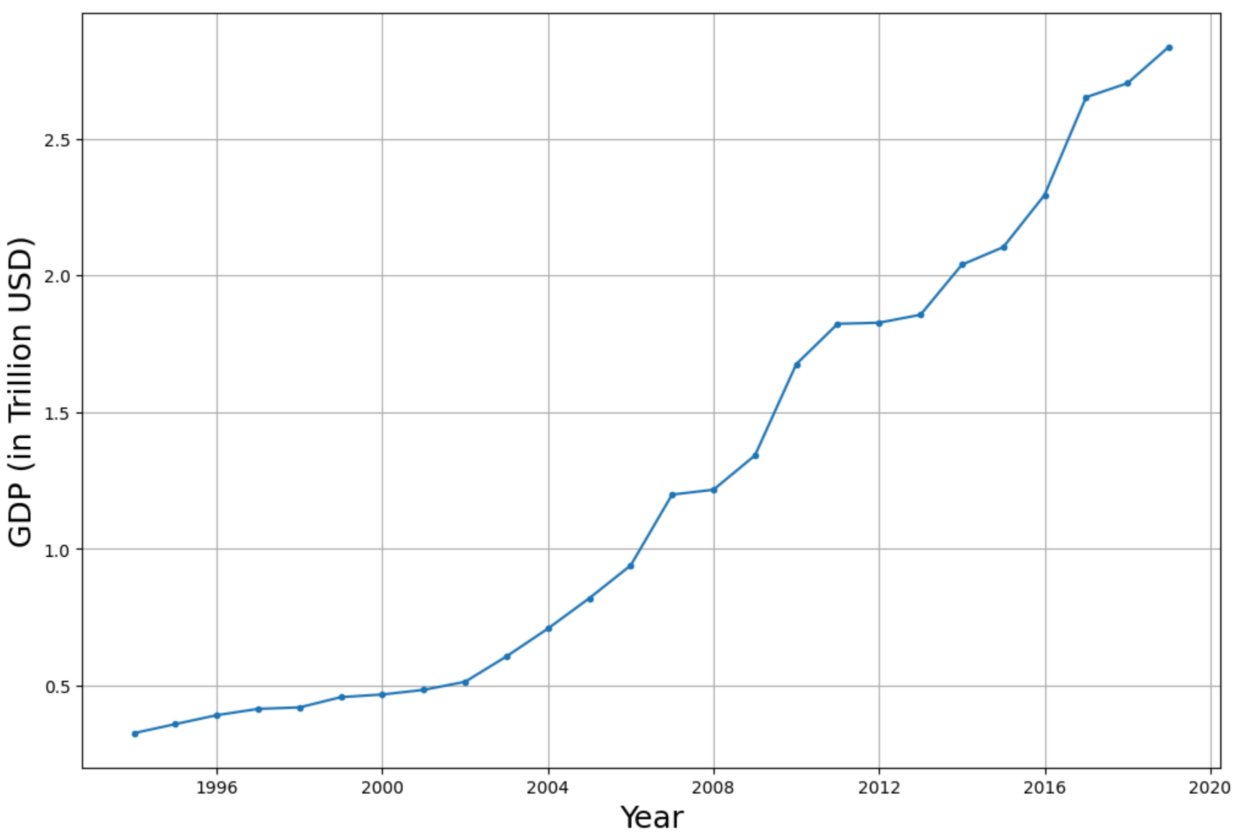


**Figure 2: Annual data of GDP of India (1994–2019).**

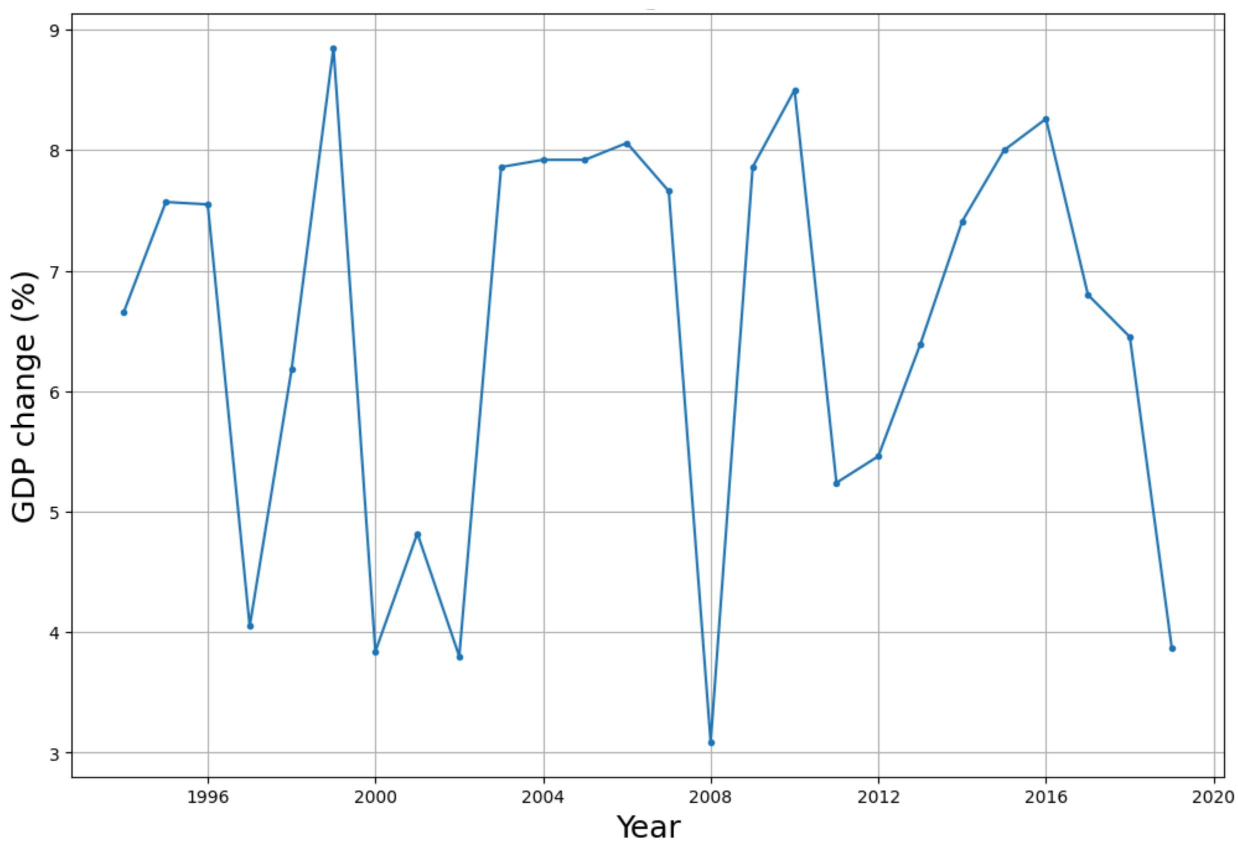


**Figure 3: Annual data of change in GDP of India (1994–2019).**

**Population:**

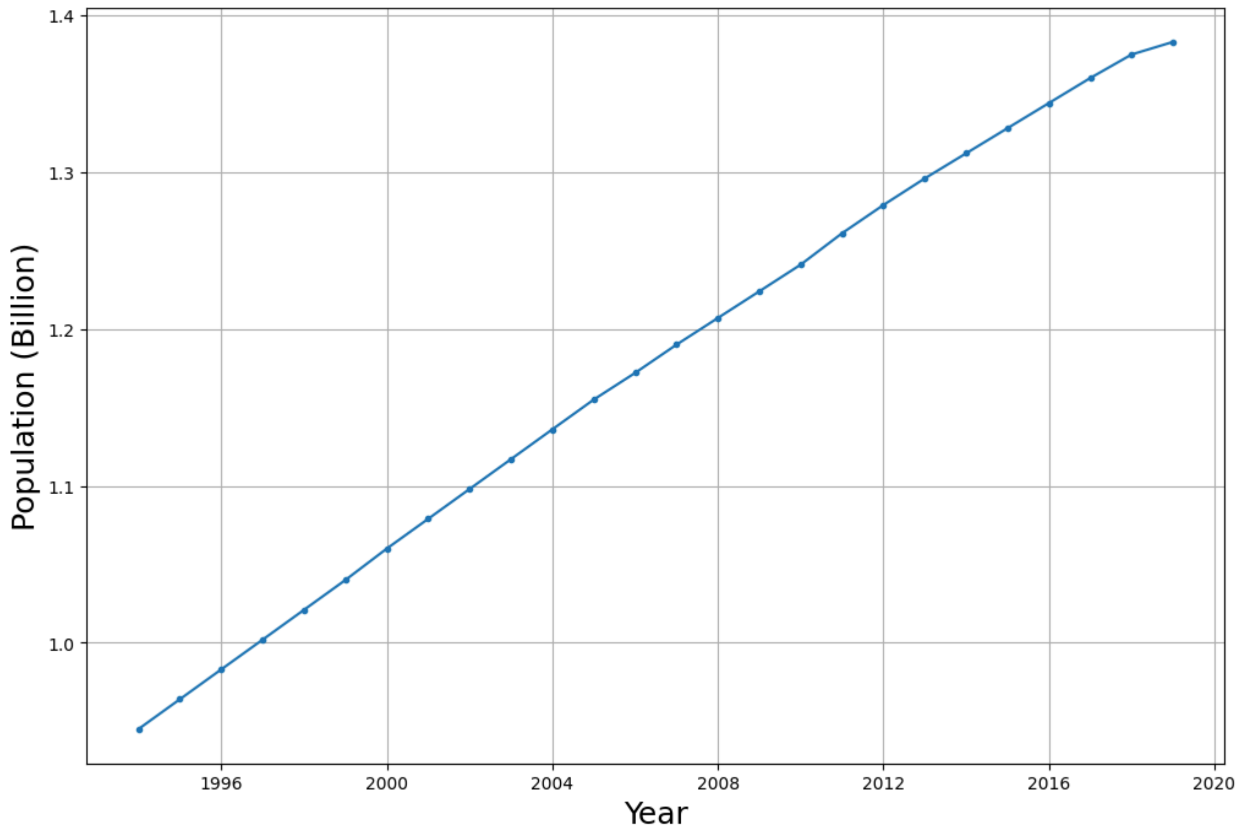


**Figure 4: Population of India (1994–2019).**

**Population growth:**

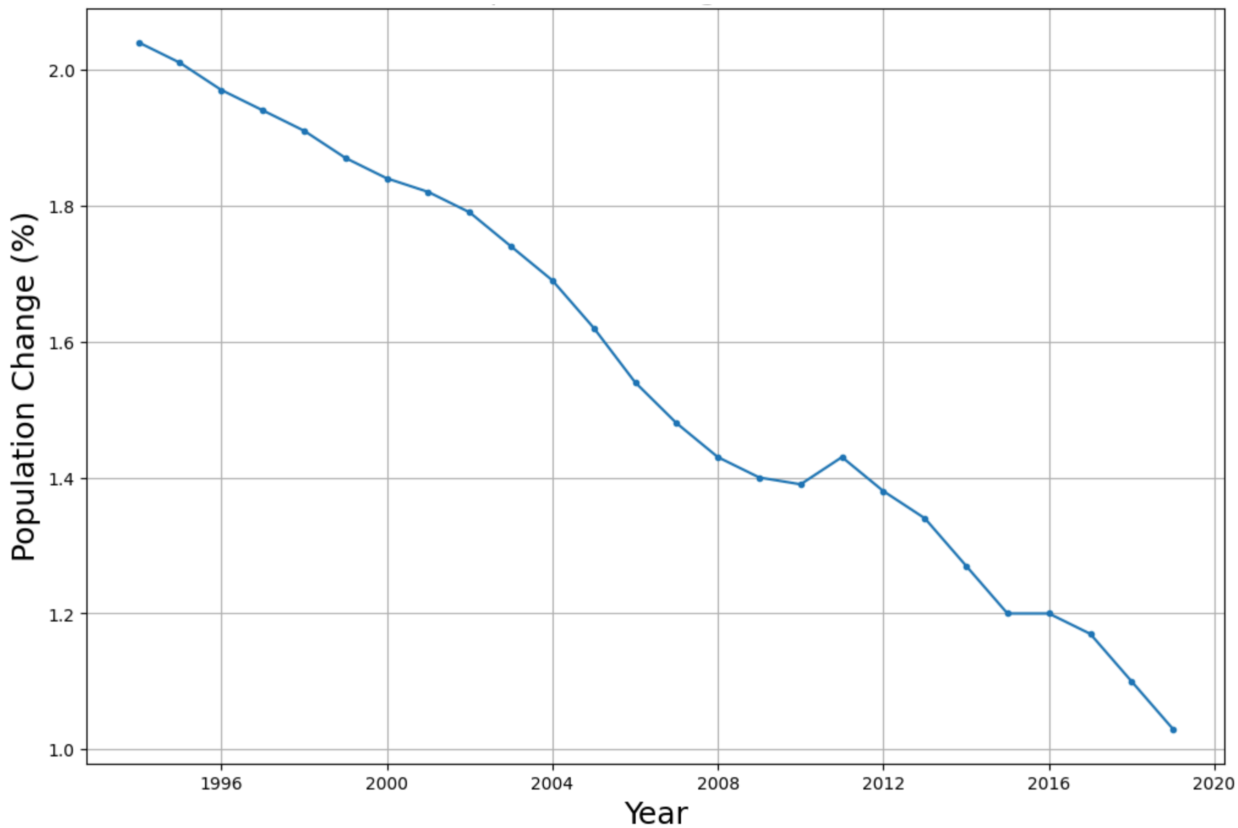


**Figure 5: Population growth rate of India (1994–2019).**

And as seen in **Figure 6** that only 2 factors can be used for exogenous factors as they are highly correlated with sand and mining data.

### 4.3 Socio-Economic Factors Influencing Sand and Gravel Mining:

Correlation analysis, shown in Figure 6, reveals key socio-economic factors influencing India's sand and gravel mining activities over time. A strong positive correlation (0.79) between the GDP (in Trillion USD) and mining output indicates that economic growth significantly drives extraction levels[4]. This suggests that more significant economic activity within the nation comes with greater demand for building materials like sand and gravel as infrastructure, urbanization, and industrialization expand[1][2].

Population (Billion) also shows a highly positive correlation (0.67) with mining volumes. An increasing population fuels more housing, transportation, and public infrastructure requirements and hence fuels more raw materials like sand and gravel extraction[4].

Population Change (%) is moderately negatively correlated with mining (-0.70). This may indicate that while the overall population is biased towards expanding mining, the population growth rate per se has no direct correlation with mining quantity, possibly due to lag effects in policy, urban planning, or infrastructure enactment[5].
GDP Change (%) weakly and negatively correlates with mining (-0.08), which means short-run GDP movement has no or negligible short-term effect on sand and gravel mining. Long-term economic growth tendencies are more pertinent[4][7].
Finally, the analysis shows that absolute economic and population growth are the major socio-economic drivers of Indian mining activity and not short-term growth rates[4][5].

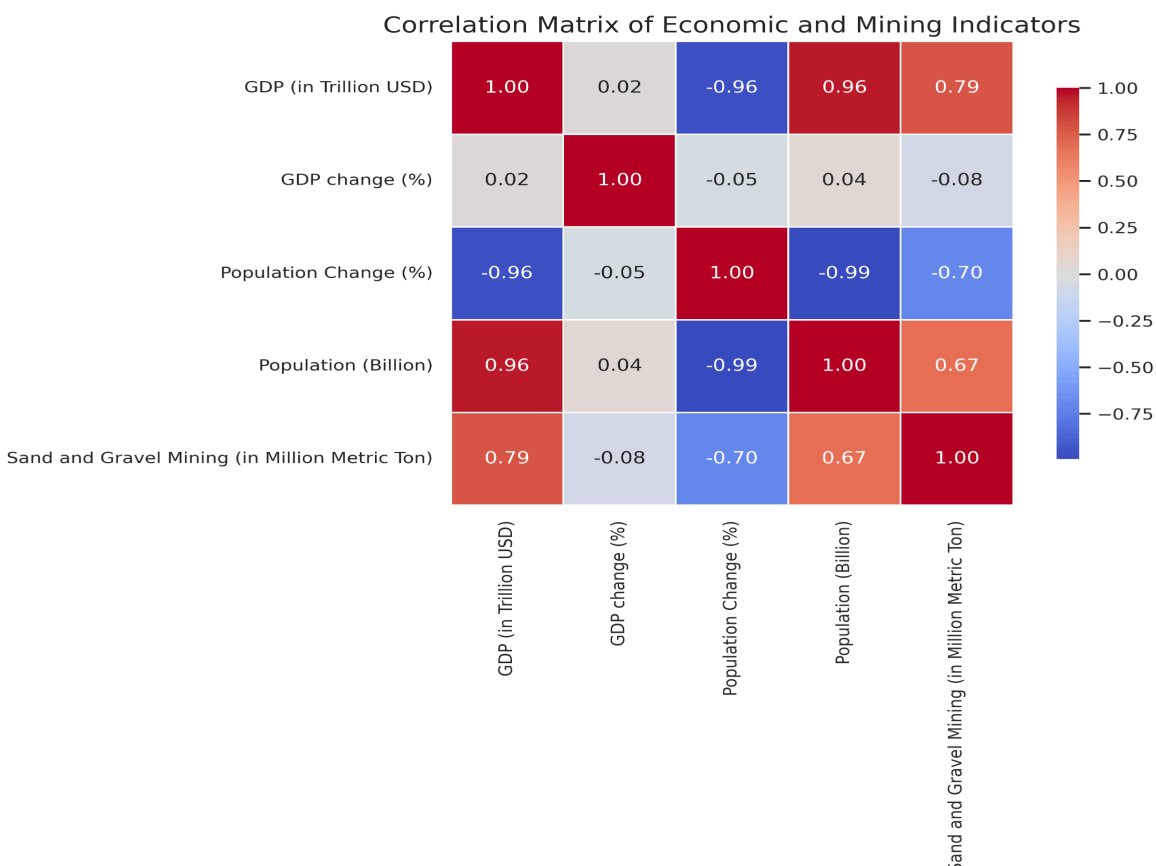


**Figure 6: Socio-Economic Factors affecting mining.**

### 4.4 Predictions Using Time-Series Models

For each model, we performed a train-test split, training on historical data and evaluating predictions on the test set. The resulting plots below illustrate the actual versus predicted values for each model on the test data. To rigorously evaluate the predictive performance of different time-series models, we implemented ARIMA, SARIMA, and SARIMAX, each subjected to systematic hyperparameter tuning using grid search[4][5]. The results for the optimized hyperparameters are shown below.

1. ARIMA
   The predictions from ARIMA are shown in Figure 7.

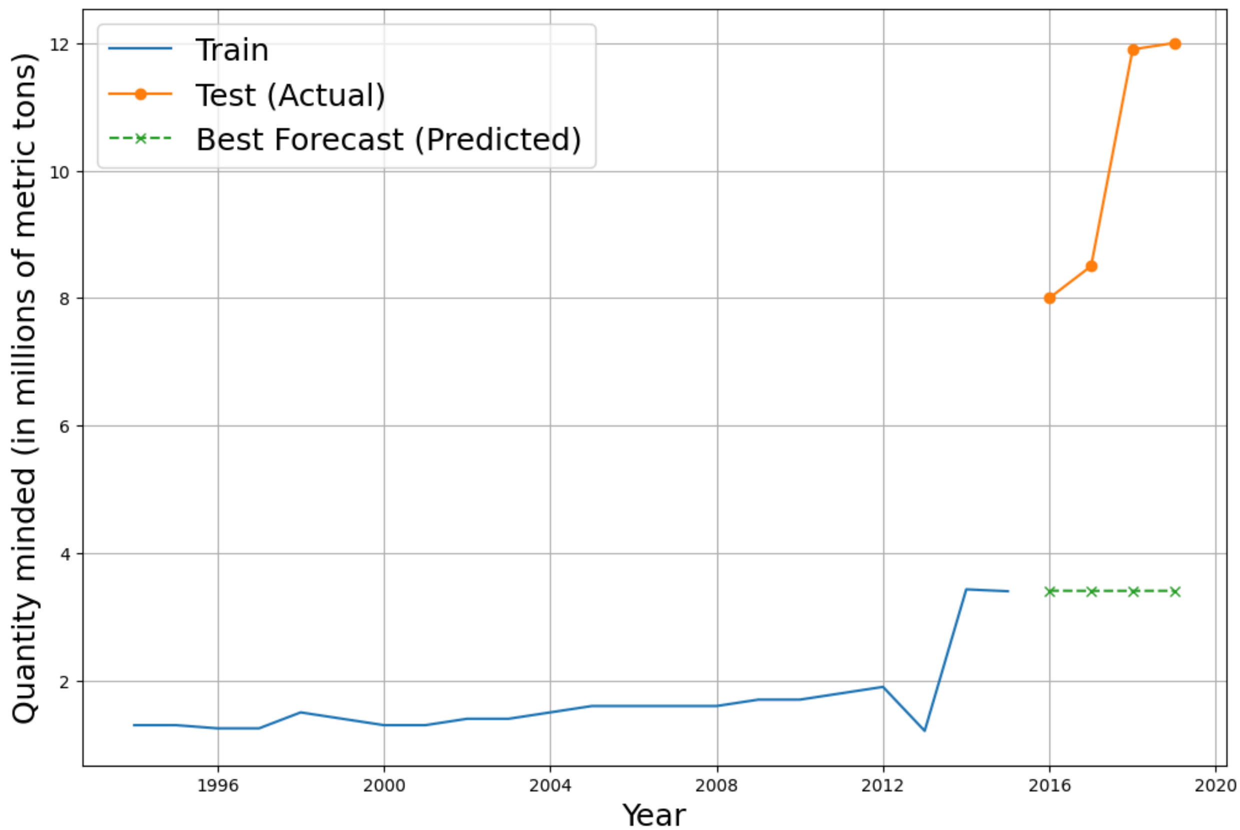


**Figure 7: ARIMA (Hyperparameter-Tuned): Actual vs. Predicted Demand (1994–2020)**

2. SARIMA
   The predictions from SARIMA are shown in Figure 8.

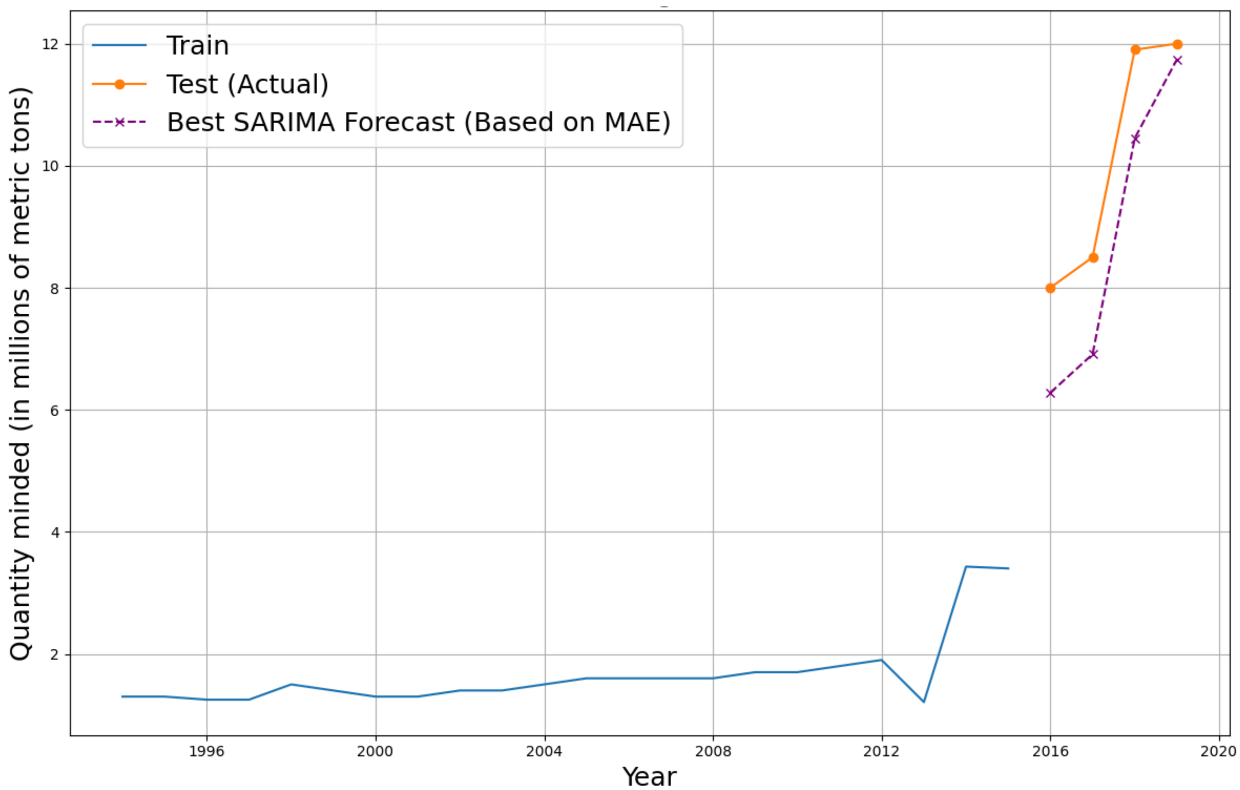


**Figure 8: SARIMA (Hyperparameter-Tuned): Actual vs. Predicted Demand (1994–2020)**

3. SARIMAX
   The predictions from SARIMAX are shown in Figure 9.

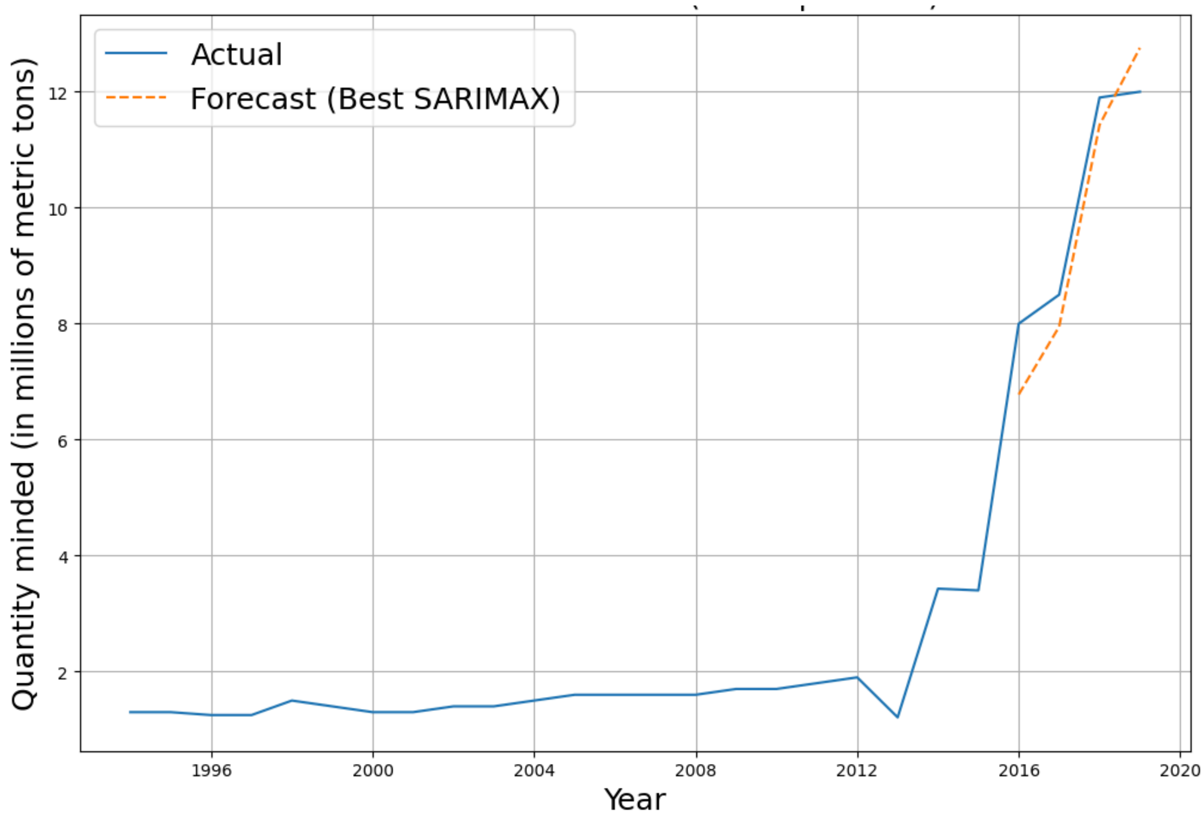


**Figure 9: SARIMAX (Hyperparameter-Tuned): Actual vs. Predicted Demand (1994–2020)**

4. PROPHET
   The predictions from PROPHET are shown in Figure 10.

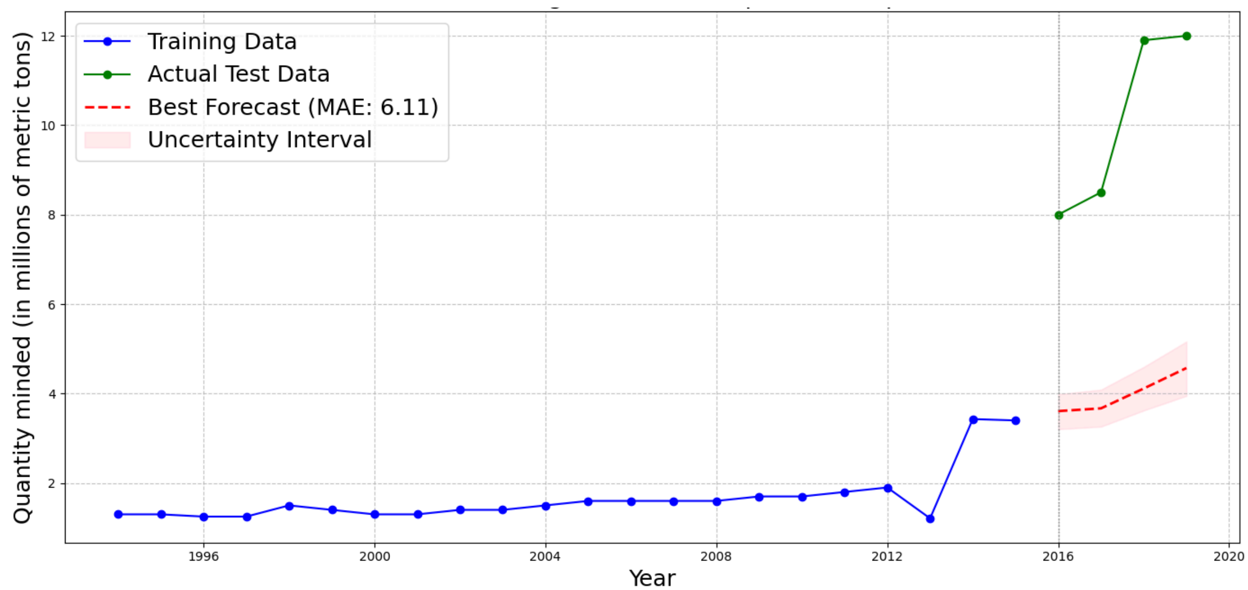


**Figure 10: PROPHET (Hyperparameter-Tuned): Actual vs. Predicted Demand (1994–2020)**

The results of the hyperparameter optimization and MAE are shown below:

ARIMA: Best order (1, 1, 0), MAE: 6.693
SARIMA: Best order (0, 2, 0), Best seasonal order (0, 1, 0, 2), MAE: 1.255
SARIMAX: Best order (0, 2, 1), Best seasonal order (0, 1, 1, 2), MAE: 0.75

### 4.5 Forecasting Sand and Aggregate Demand in India Until 2050

After selecting the best-performing model based on historical data (SARIMAX), we extended the forecast horizon to project sand demand in India from 2021 to 2050. This long-term forecast provides valuable insights into how extraction rates may evolve if current socio-economic trends continue. The forecasted demand is shown in Figure 11.

The SARIMAX model incorporates both temporal patterns and key exogenous factors such as GDP and population, which were found to be highly correlated with sand consumption[4][5]. By including these variables, the model generates a more robust and realistic long-term prediction[7].

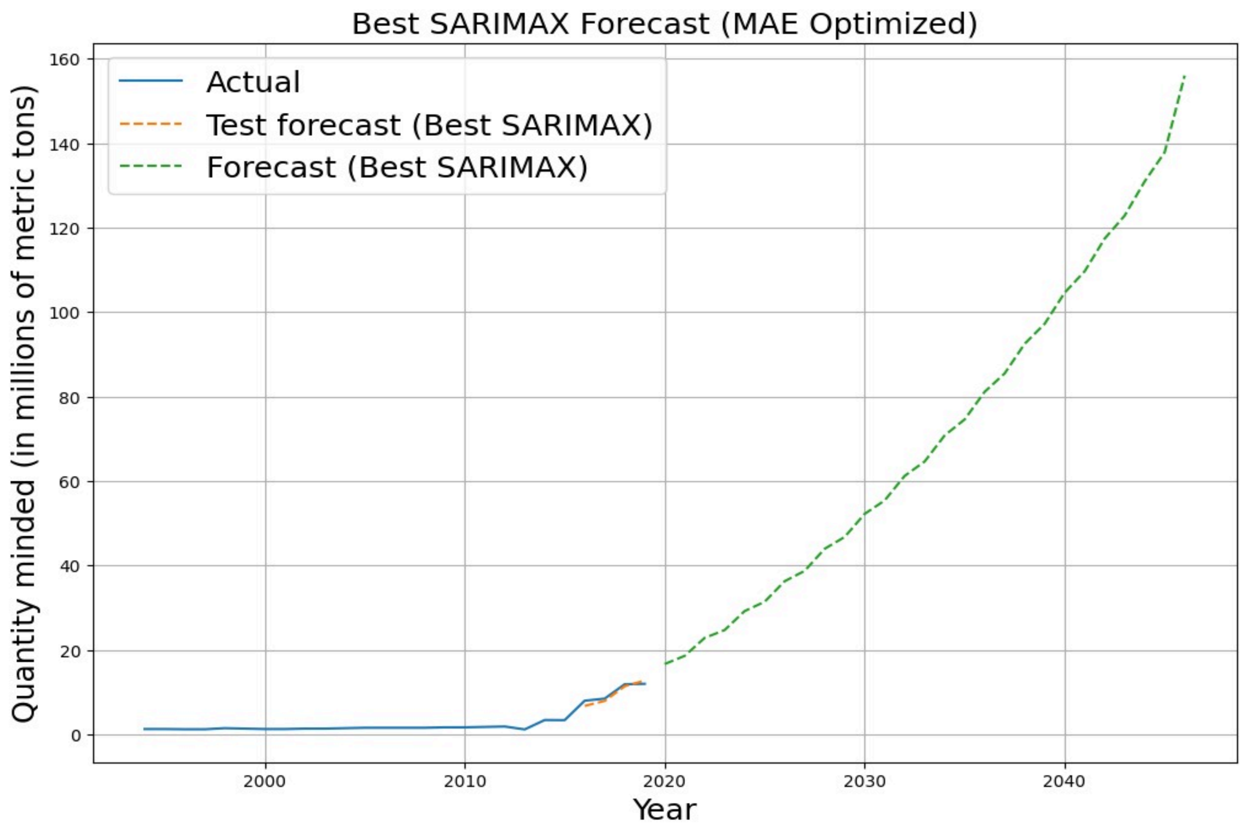


**Figure 11: Forecasted Sand and Gravel Demand in India (2021–2050) using SARIMAX**

As seen in Figure 11, the demand for sand and gravel mining is projected to rise steadily over the next three decades, with the quantity mined potentially exceeding 90 million metric tons annually by 2050. This represents a significant increase from 2020 levels (approximately 12 million metric tons), driven primarily by continued economic development and population growth[4][7].

These forecasts emphasize the urgent need to explore sustainable alternatives like M-Sand and recycled aggregates [3][5], Implement stringent regulatory frameworks to curb illegal mining[2][6] and develop policies for sustainable extraction limits based on projected demand[2][7].

This forward-looking analysis aims to aid policymakers, urban planners, and industry stakeholders in making informed decisions to balance infrastructure growth with environmental sustainability.

## 5. Conclusion

The exponential rise in sand and aggregate demand in India, projected to exceed 100 million metric tons annually by 2050, underscores the urgent need for sustainable resource management. SARIMAX model, incorporating exogenous variables like GDP and population,

provides a robust framework for forecasting demand, with a low MAE of 0.75. This model's superiority over ARIMA (MAE: 6.693) and SARIMA (MAE: 1.255) highlights the critical role of socio-economic drivers and seasonal trends in shaping extraction patterns[4][5].
However, unchecked sand mining poses severe environmental risks, including riverbed erosion, habitat destruction, and groundwater depletion, as evidenced by the degradation of rivers. Regulatory frameworks, such as the Sustainable Sand Mining Guidelines (2016) and Enforcement & Monitoring Guidelines (2020), remain under-enforced due to governance gaps and illegal practices.
Manufactured Sand (M-Sand) emerges as a viable alternative, offering higher masonry strength and cost savings compared to river sand. Despite challenges like inconsistent quality and initial infrastructure costs, state-led initiatives in Rajasthan and Kerala demonstrate its potential to mitigate ecological harm while meeting construction needs.

**References:**


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