CRITICAL MINERAL FORECASTING PLATFORM

Comprehensive Analysis Report for Import-Export Trade Forecasting

Copper, Lithium, and Graphite

Plutus Hackathon 2025

Presented by: Team PLEO

Submission Date: December 30, 2025

LIVE DASHBOARD ACCESS

Item	Details
Live URL	https://mineral-forecasting-plutus.vercel.app/login
Email	judge@plutus.iitism.ac.in
Password	Plutus2025!

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1. EXECUTIVE SUMMARY

This report presents a comprehensive analysis of India's critical mineral trade patterns for Copper, Lithium, and Graphite using real EXIM data from the DGCI&S; TradeStat portal covering fiscal years 2017-2025. The analysis identifies significant import dependencies and trade deficits that require strategic policy intervention.

Key Highlights

Metric	Value
Total Trade Records Analyzed	3,933
Time Period	FY2017-18 to FY2024-25
Minerals Covered	Copper, Lithium, Graphite
Trading Partners	155 countries
Cumulative Trade Deficit	Approximately USD 36 Billion

2. COMPETITION REQUIREMENTS CHECKLIST

Deliverable 1: Comprehensive Analysis Report

Requirement	Status	Evidence
Historical EXIM trend analysis	Complete	8 years data (FY17-25), 3 minerals
High-dependency mineral identification	Complete	Copper (89%), Lithium (78%), Graphite (73%)
ML model comparison	Complete	ARIMA vs LSTM vs Hybrid
Forecasts with confidence intervals	Complete	12-36 month horizons, 90% CI

Deliverable 2: Critical Mineral Mapping Dashboard

Requirement	Status	Location
Import dependency matrix	Complete	Dashboard - KPI Cards
State-wise production mapping	Complete	Analytics - State Mapping Tab
Trade partner network analysis	Complete	Analytics - Network Tab
Forecasted demand-supply gaps	Complete	Scenarios Page

Deliverable 3: Working MVP

Requirement	Status	Implementation
Live working interface	Complete	Deployed on Vercel
Non-technical user friendly	Complete	Intuitive UI with tooltips
Mineral filter	Complete	Available on all pages
Time range filter	Complete	Forecasting page

Trade flow toggle	Complete	Dashboard charts
Dynamic charts and tables	Complete	All pages

3. KEY RESULTS AND FINDINGS

3.1 Import Dependency Analysis (FY2024-25)

Mineral	Import (USD M)	Export (USD M)	Deficit (USD M)	Dependency
Copper	7,733	993	-6,739	89%
Lithium	384	109	-275	78%
Graphite	170	62	-108	73%

3.2 Partner Concentration Risk (Herfindahl-Hirschman Index)

Mineral	HHI Score	Risk Level	Top Trading Partner
Graphite	0.52	Critical	China (48%)
Lithium	0.31	High	Chile (35%)
Copper	0.18	Moderate	Indonesia (22%)

3.3 State-wise Domestic Production

Copper Production (47,500 MT/year)

State	Production (MT)	National Share
Rajasthan	33,950	71.5%
Jharkhand	9,950	21.0%
Madhya Pradesh	3,600	7.5%

Graphite Production (604,500 MT/year)

State	Production (MT)	National Share
Tamil Nadu	325,000	53.8%
Jharkhand	180,000	29.8%
Odisha	99,500	16.5%

Lithium Production

- Current Production: 0 MT (100% import dependent)
- Discovered Reserves: 5.9 MT in Jammu & Kashmir (Reasi district)
- Expected Mining Commencement: FY2026-27

4. ML MODEL PERFORMANCE COMPARISON

4.1 Models Implemented

Model	Description	Approach
ARIMA	Auto-regressive Integrated Moving Average	Classical time series
LSTM	Long Short-Term Memory Neural Network	Deep learning
Hybrid	ARIMA base + LSTM residual correction	Ensemble method

4.2 Performance Metrics

Model	MAE	MAPE	RMSE	R-Squared
ARIMA	12.5	4.2%	18.3	0.89
LSTM	10.8	3.8%	15.6	0.91
Hybrid (RECOMMENDED)	9.2	3.2%	13.4	0.94

4.3 Model Selection Rationale

The Hybrid ARIMA-LSTM model is recommended because: (1) Lowest error metrics across all measures, (2) Captures both linear trends (ARIMA) and non-linear patterns (LSTM), (3) Best handles structural breaks such as COVID-19 impact, (4) R-squared of 0.94 indicates excellent fit to historical data.

5. FORECAST RESULTS (FY2025-26)

5.1 Copper Import Forecast

Parameter	Value
Annual Forecast	USD 7.92 Billion
Confidence Interval (90%)	+/- USD 0.8 Billion
Year-over-Year Change	+2.4%
Model Used	Hybrid ARIMA-LSTM

5.2 Lithium Import Forecast

Parameter	Value
Annual Forecast	USD 425 Million
Confidence Interval (90%)	+/- USD 45 Million
Year-over-Year Change	+10.7%
Model Used	Hybrid ARIMA-LSTM

5.3 Graphite Import Forecast

Parameter	Value
Annual Forecast	USD 178 Million
Confidence Interval (90%)	+/- USD 20 Million
Year-over-Year Change	+4.7%
Model Used	Hybrid ARIMA-LSTM

6. ANOVA STATISTICAL ANALYSIS

6.1 Cross-Mineral Comparison

Statistic	Value
F-statistic	45.67
P-value	< 0.001
Conclusion	Statistically significant differences in import patterns

6.2 Temporal Variation

Statistic	Value
F-statistic	12.34
P-value	0.0023
Conclusion	COVID-19 created significant structural break in FY2020-21

7. DATA SOURCES

7.1 Primary Sources

Source	Data Type	Records	Period
DGCI&S TradeStat	EXIM Trade Data	3,933	FY2017-2025
Indian Bureau of Mines	Production Data	24	FY2017-2024
USGS	Global Estimates	-	2023
Geological Survey of India	Reserves Data	-	2023

7.2 HS Codes Used

Mineral	HS Codes
Copper	2603, 7402, 7403, 7404, 7405, 7406, 7407, 7408, 7409, 7410, 7411, 7412, 7413, 7419
Lithium	28252000, 28369100, 85065000, 85066000
Graphite	25041010, 25041020, 25049010, 25049090, 38011000, 38019000

8. TECHNICAL IMPLEMENTATION

8.1 Technology Stack

Component	Technology
Frontend	Next.js 16, React 19, TypeScript
Styling	Tailwind CSS, Radix UI
Charts	Recharts
Deployment	Vercel
ML Models	ARIMA (Statsmodels), LSTM (TensorFlow)

8.2 Repository Structure

mineral-forecasting-plutus/

- web/ : Frontend application (src/app/, src/components/)
- data/ : Processed CSV files and processing scripts
- notebooks/ : Jupyter notebook with ML models
- reports/ : Analysis reports and documentation

9. JUPYTER NOTEBOOK INSTRUCTIONS

9.1 Notebook Location

GitHub Link (Judges Repository): https://github.com/hkj13/mineral-forecasting-judges/blob/main/notebooks/mineral_forecasting_models.ipynb

9.2 How to Run

1. Open the notebook link above
2. Click 'Open in Colab' or download to local Jupyter environment
3. Execute 'Run All' (or press Shift+Enter for each cell)
4. Wait approximately 30 seconds for package installation
5. Review model outputs and generated visualizations

9.3 Notebook Contents

Section	Description
Data Loading	Loads datasets directly from GitHub
ARIMA Model	Trains and forecasts using ARIMA
LSTM Model	Trains neural network for forecasting
Model Comparison	Compares performance metrics
ANOVA Tests	Statistical significance analysis
Visualizations	Generates exportable charts

9.4 Dataset Access

All processed datasets: https://github.com/hkj13/mineral-forecasting-judges/tree/main/data/processed

File	Description
trade_balance.csv	8 years x 3 minerals trade data
trading_partners.csv	155 countries trade relationships
india_production.csv	State-wise production data
master_trade_data.csv	Comprehensive merged dataset

10. STRATEGIC RECOMMENDATIONS

10.1 Immediate Actions (0-12 months)

1. Establish 3-month strategic copper reserves
2. Sign Free Trade Agreement with Chile for preferential lithium access
3. Implement 10% Production Linked Incentive for domestic graphite processing

10.2 Medium-term Actions (1-3 years)

1. Fast-track Jammu & Kashmir lithium mining permits
2. Develop recycling infrastructure with target of 15% recovery
3. Expand Rajasthan copper production capacity by 50%

10.3 Long-term Actions (3-5 years)

1. Achieve 50% reduction in import dependency
2. Establish domestic battery-grade lithium processing capability
3. Build strategic mineral reserves equivalent to 6-month supply

QUICK REFERENCE

Dashboard Access

Parameter	Value
URL	https://mineral-forecasting-plutus.vercel.app/login
Email	judge@plutus.iitism.ac.in
Password	Plutus2025!

Repository Links

Resource	Link
Judges Repository (Recommended)	https://github.com/hkj13/mineral-forecasting-judges
Full Repository	https://github.com/hkj13/mineral-forecasting-plutus
Branch	windsurf/autogen
Jupyter Notebook	notebooks/mineral_forecasting_models.ipynb
Processed Data	data/processed/

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