

Forecasting Monthly Birth Volumes and Its Impact on Emergency Healthcare Device Sales

Executive Summary

This report presents a comprehensive analysis aimed at forecasting monthly birth volumes using four time series forecasting methods: **ARIMA**, **SARIMA**, **Holt-Winters**, and **Prophet**. The primary objective is to assist the client in making data-driven decisions regarding strategic planning and inventory management for an emergency healthcare device, critical in 5% to 10% of birth deliveries. By leveraging historical national birth data, the report offers both an evaluation of model performance and actionable insights for managing stock levels.

Key Findings:

- **Prophet** emerged as the best-performing model, delivering the lowest Mean Absolute Error (MAE) and Root Mean Squared Error (RMSE).
 - **Seasonality:** All models indicate strong seasonal peaks in mid-summer, suggesting an increase in demand for emergency healthcare devices during these months.
 - **Actionable Insight:** The client should prioritize inventory increases for the summer months and plan for potential demand surges during peak periods, while reducing stock during the lower-demand months of January to March.
-

Introduction

The healthcare industry, particularly in emergency services, faces challenges in inventory management and demand forecasting. For devices used in emergency deliveries, such as the client's emergency healthcare product, anticipating demand is crucial for maintaining optimal inventory levels.

This report uses four forecasting methods—ARIMA, SARIMA, Holt-Winters, and Prophet—to predict monthly birth volumes. These insights are vital for planning inventory levels and ensuring adequate stock during periods of increased demand. The analysis highlights both model performance and key birth volume trends to support strategic decision-making for production and inventory management.

Methodology

The data for this analysis was sourced from the **CDC WONDER** database, covering monthly birth volumes from January 2016 to December 2022. The forecasting methods used in this report include:

1. **ARIMA (Auto-Regressive Integrated Moving Average):** Captures the trend and basic patterns in birth volumes.
2. **SARIMA (Seasonal Auto-Regressive Integrated Moving Average):** Extends ARIMA by modeling seasonal effects.
3. **Holt-Winters:** Incorporates trend and seasonality, suitable for short-term forecasts.

4. **Prophet:** Developed by Facebook, Prophet efficiently captures trends, seasonality, and holiday effects.

The models were applied to forecast birth volumes for the next 24 months (January 2023 to December 2024). While model performance was evaluated based on standard error metrics, the primary focus is on actionable insights derived from the forecasted trends.

Model Performance and Comparative Analysis

1. ARIMA Model:

- **Model Summary:** ARIMA(0,1,1)(0,1,1)[12]
- **Performance:**
 - MAE: 4260.78
 - RMSE: 6011.21
- **Insights:** ARIMA captured overall birth trends but did not explicitly model seasonality as effectively as Prophet. However, it still reflected expected birth volume increases during summer months and slight long-term growth.

2. SARIMA Model:

- **Model Summary:** SARIMA(0,1,1)(0,1,1)[12] (identical to ARIMA for this dataset)
- **Performance:**
 - MAE: 4260.78
 - RMSE: 6011.21
- **Insights:** Like ARIMA, SARIMA identified general birth volume patterns but added no significant advantage for this dataset. Both models pointed to higher birth volumes during the summer months.

3. Holt-Winters Method:

- **Model Performance:**
 - MAE: 159,658.42
 - RMSE: 219,980.81
- **Insights:** Holt-Winters significantly underperformed in comparison to the other models. The high error metrics suggest that this method is unsuitable for forecasting birth volumes in this context. However, it still reinforced the seasonal peaks observed in the summer months, aligning with the other models' findings.

4. Prophet:

- **Model Summary:** Prophet with monthly seasonality.
- **Performance:**
 - MAE: 3739.72
 - RMSE: 4743.94

- **Insights: Prophet outperformed all other models**, delivering the most accurate predictions for birth volumes. It captured both long-term growth trends and recurring seasonal patterns, particularly the **summer birth peak** in July-August, while showing lower birth volumes during the winter months (January-February). The model effectively accounted for the slight but consistent increase in birth volumes over the forecasted period, suggesting potential growth in demand for emergency healthcare devices.
-

Key Insights from Prophet and Overall Trends

1. Seasonality and Peak Demand

- **Insight:** All models, including Prophet, identified clear seasonal peaks in birth volumes during **July and August**. These months consistently show the highest birth volumes, driven by annual patterns.
- **Actionable Strategy:** The client should increase production and stock levels for their emergency healthcare device starting in **May**, peaking in the **July-August** period, to ensure readiness for increased demand.

2. Lower Demand in Early Months

- **Insight:** Birth volumes are consistently lowest during **January through March**. This pattern is reflected across all models, indicating that demand for the emergency healthcare device will be lower during this period.
- **Actionable Strategy:** The client can reduce inventory during these months to **minimize carrying costs** while maintaining sufficient stock to handle any unexpected surges.

3. Long-Term Growth

- **Insight:** Both **Prophet** and **ARIMA** showed a slight but steady upward trend in birth volumes over the next two years. This trend suggests a potential **increase in market size** for the client's emergency healthcare device over time.
- **Actionable Strategy:** The client should plan for **long-term production expansion**, particularly during high-demand months, while monitoring for market changes that may influence birth volumes.

4. High Demand During Summer

- **Insight:** All models strongly indicated that summer months, particularly **June through September**, are critical periods for high birth volumes. This seasonal spike aligns with historical trends and is expected to continue into the future.
 - **Actionable Strategy:** Inventory levels should be increased during **Q2**, with the highest stock levels maintained in **July and August**, to accommodate the peak in births.
-

Comparative Model Insights

While Prophet emerged as the best-performing model in terms of error metrics, the general insights from ARIMA and SARIMA also align with Prophet's forecast. All models pointed to:

- **Seasonal birth volume peaks** during summer.
- **Lower birth volumes in winter.**
- **Slight upward trend** in overall birth rates.

These recurring patterns reinforce the **robustness of the insights** derived from Prophet and validate the need for the client to strategically manage inventory, especially around the summer birth peaks.

Recommendations

1. Prioritize Summer Inventory:

- The client should ramp up production and increase inventory from **June through September**, with the highest stock levels in July and August to meet peak demand.

2. Reduce Inventory in Winter:

- Birth volumes are expected to be lowest in the **first quarter (January-March)**, allowing the client to reduce inventory during these months and minimize carrying costs.

3. Monitor Long-Term Growth:

- With the forecasted slight increase in birth volumes, the client should consider **expanding production capacity** and increasing stock levels incrementally over the next two years to accommodate long-term growth.
-

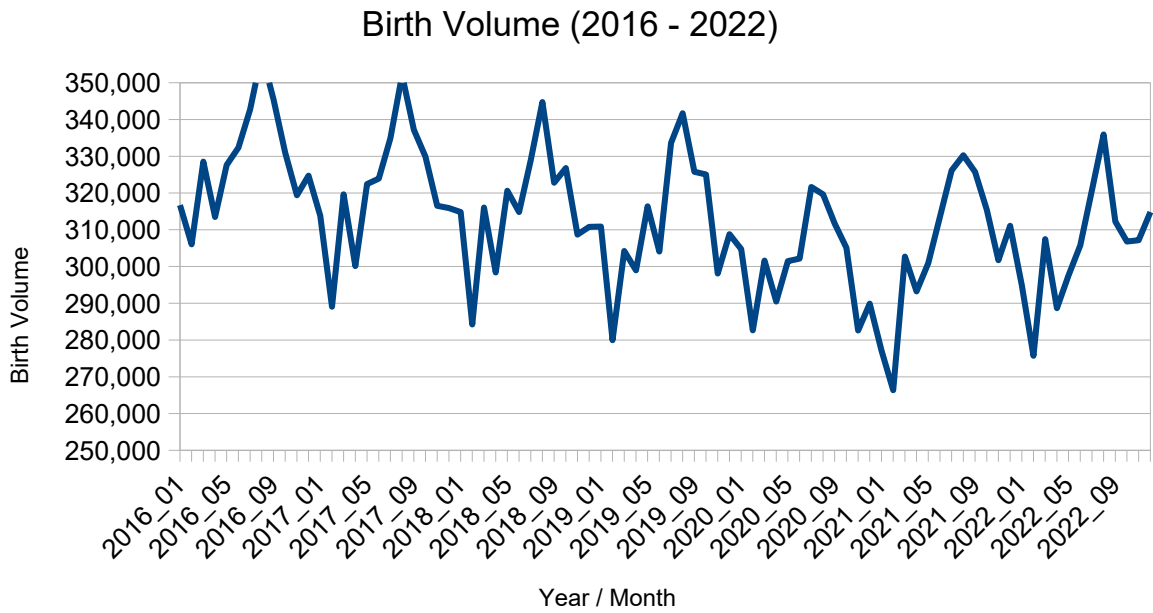
Conclusion

This report provides a comprehensive analysis of multiple time series forecasting methods, focusing on both model performance and actionable insights. **Prophet** emerged as the most accurate model, effectively capturing seasonality and long-term trends in birth volumes. The **seasonal birth peaks** during the summer months provide a clear opportunity for the client to align inventory and production strategies with market demand. By leveraging the insights provided, the client can optimize stock levels, prevent shortages during high-demand periods, and reduce costs during lower-demand months.

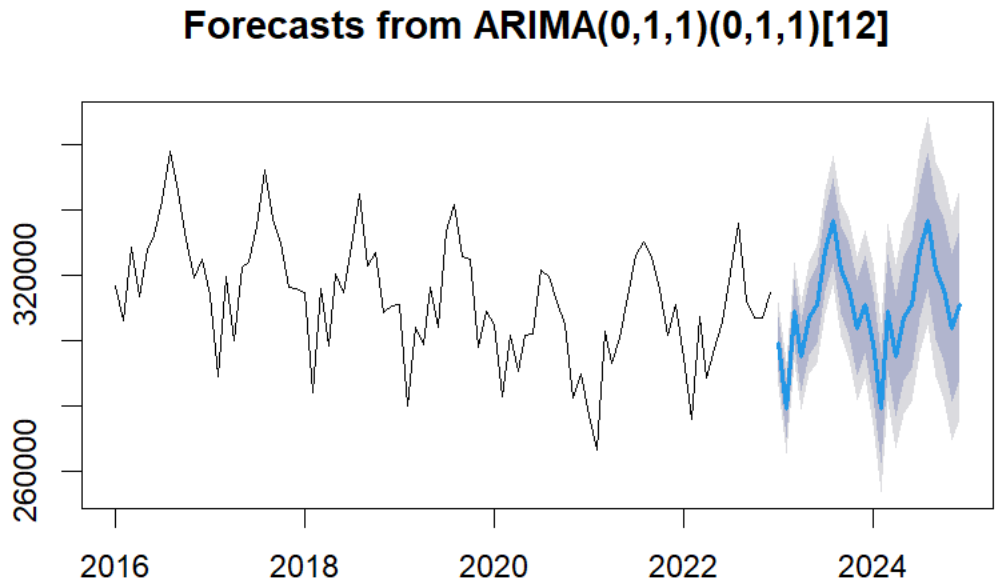
References

- CDC WONDER Database, Natality Data, 2016-2022.
- Hyndman, R. J., & Athanasopoulos, G. (2018). Forecasting: Principles and Practice.
- Taylor, S., & Letham, B. (2018). Prophet: Forecasting at Scale.

Appendix

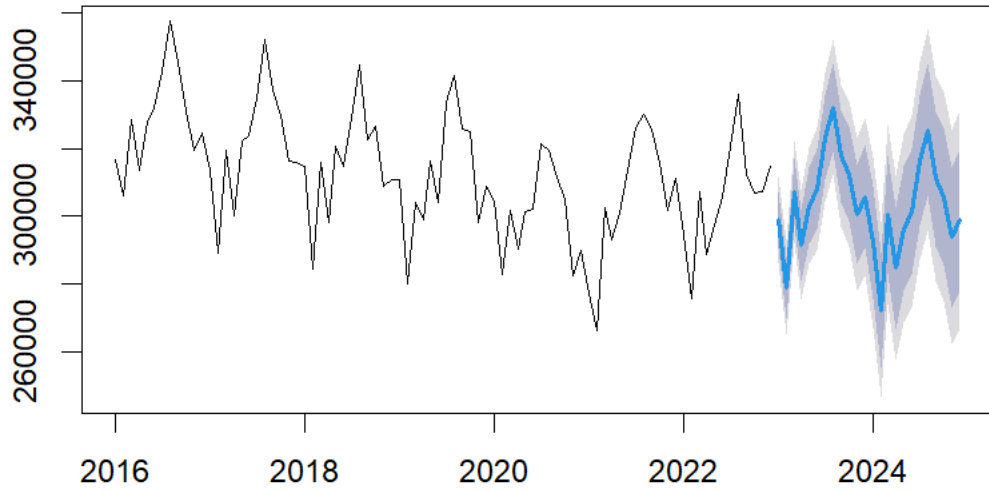


Arima Forecast
Holt-



Winters Forecast

Forecasts from HoltWinters



Prophet Forecast

