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Childbirth Rate Prediction System Based on Time Series Analysis

Abdullahi Yusuf Umar[1], Dr. Adamu Abdullahi Garba[2], , Dr. Audu Musa MABU[3], Mr. Ibrahim Bukar Dauba[4]

[1,2,3,4,] Department of Computer Science Yobe State University, Nigeria
E-mail id – adamugaidam@gmail.com

ABSTRACT:

Prediction of childbirth rate using time series analysis is a tedious and repetitive task, which requires a lot of skill. It will be so interesting that a computerized system is developed to alleviate the problems encountered in predicting childbirth rate using time series analysis. In this regard, this project work is taken up to developed a software package that computerized the prediction of childbirth rate using time series analysis with waterfall development of software life cycle and the records of childbirths at the Yobe State specialist Hospital Damaturu for the period of five years, from 2020 to 2024. ARIMA model was implemented using c sharp programming language and SQLite for the database for prediction based on collected data, result show consistence increase in childbirth for years upward with the corresponding values, 2025: 2659, 2026: 2709 and 2027: 2721. So, it would be value to health personal, policy marker in decision making to control childbirth in a given vicinity.

Keywords*:* Time Series, ARIMA, Prediction, Childbirth, Rate, C sharp.

1. INTRODUCTION

The childbirth rate is a crucial indicator of a country's demographic and economic growth. According to Wikipedia (2018) demography is the statistical study of populations, especially human beings. It is a measure of the number of births per 1000 women of reproductive age. Birth rate data is an important factor in healthcare planning and resource allocation for maternal and child health programs. Ebuokehme (2000) explained that records on birth and death are important set of data for studying the dynamics of a country's population. Accurate prediction of the childbirth rate can help policymakers and healthcare providers to plan and allocate resources accordingly. Therefore, developing a childbirth rate prediction system based on time series analysis can be a valuable tool for healthcare professionals and policymakers.

According to the World Health Organization (WHO), approximately 303,000 women died from childbirth related complications globally in 2015 (WHO, 2019). Most of these deaths occurred in low and middle-income countries. Mobesheri et al (2013) explained that the rapid decline in fertility rate and disassembling in the balance of age pyramid can exert irreparable damages to the country's economic and social structures.

Therefore forecasting these rates, hospitals can allocate resources such as staff, medical equipment, and beds more efficiently. However, traditional methods of predicting childbirth rates using manual time series analysis can be repetitive and prone to human error. This project aims to develop a computerized system that automates the childbirth rate prediction process using time series analysis, specifically utilizing the ARIMA model. This system, designed with C# and SQLite, will offer accurate predictions based on historical childbirth data from Specialist Hospital Damaturu over a five-year period (2020–2024). The predicted values for the upcoming years are intended to support hospital staff, health policy makers, and other stakeholders in making informed decisions regarding resource allocation and maternal healthcare services.

2. LITERATURE REVIEW

Time series analysis is a statistical technique used to analyze time-ordered data, which can help to identify patterns and trends in data over time (Tapha, A. 2010). In this research the techniques of time series analysis will be used to analyze numbers of babies delivered monthly is the numbers of babies born a live a women of child Bering age monthly for the period of five years, after collecting data it was organized into a table for simplicity and easy analysis. Time series analysis is among method of prediction, it can be efficiently used to predict increase or decrease in population due child maternal birth hence useful decision can be taken. Time series is set of observation taken as a specific time usually at equal interval (Tapha, A. 2010) Time series analysis can be applied to real-valued, continuous data, discrete numeric data, or discrete symbolic data (i.e. sequences of characters, such as letters and words in the English language). The traditional statistical methods may not capture the non-linear trends and seasonality effects present in the data. Hence, there is a need for a robust and efficient prediction system based on time series analysis to provide reliable estimates of childbirth rate (smith & Lee, 2022).

The traditional or manual method of conducting the survey and prediction of childbirth has the following problems, time delay and problem of updating, error during manipulation, lack of portability and labor intensive. Besides, other researchers indicated that the ARIMA models had been widely used in modelling and forecasting population variables since 1970, showing high efficiency in many different knowledge fields in demography. They suggested

that many studies used the ARIMA models to calculate future fertility rates, which contributes to predicting future populations (Audu et al., 2017). The paper reported that they examined the birth rate data in the US by using the ARIMA model since ARIMA methods could reveal the intricate structures of momentary interdependence in time series. They suggested that the ARIMA models succeeded in analyzing the patterns of seasonal interdependence in the birth rate series, which provides a basis for developing an alternative method of seasonal modification of dynamic demographic statistics (Land et al., 1983). According to the article, modelling and forecasting the changes in the birth rate over time are crucial since they offer crucial information for decisions on birth control, family planning, and welfare policies. They argued that finding effective models for demographic statistics, like the birth rate of a developing country, can be challenging due to the complexity of factors involved.

The ARIMA models make use of the autocorrelations of the data, while exponential smoothing or the ETS models make use of the weighted averages of past observations. They recommended using the ARIMA and exponential smoothing models for fertility rate prediction since these two models are the most frequently employed in time series forecasting (Hyndman, et al., 2018). Some researchers indicate that the major area of interest of demographers is modelling birth rate curves to understand the fertility pattern. To anticipate the future fertility rate, people typically use prediction models, including the ARIMA and exponential smoothing models.

The ARIMA models are the most commonly used forecast models because of their simplicity. They argue that the ARIMA models are usually utilized for time series prediction, which aims to identify the stochastic process and forecast future values. The ETS models minimize historical birth rates by assigning an exponentially decreasing birth rate compared to the historical data. The multiplicative trend analysis gives exponential trend analysis, while the additive trend analysis provides linear trend analysis. They suggested that the ARIMA and ETS models had low marginal error rates in the long-term fertility prediction. However, the ARIMA models have been proven to be more accurate in fertility prediction since it has a lower accuracy measure error (Anuj, et al., 2023).

3. METHODOLOGY

3.1 Data Collection

The childbirth record data were collected from Department of Health Information Management Monitoring and Evaluation/Statistic Unit Yobe State Specialist Hospital Damaturu for a period of five years (2020-2024). The data included the number of monthly childbirths, also data obtained were captured in Microsoft Excel 2013 and preprocessed to handle missing value and ensure consistency

Table 1: Birth Statistics for Specialist Hospital Damaturu over January, 2020 to December, 2024

YEARS	JAN	FEB	MAR	APRIL	MAY	JUN	JUL	AUG	SEPT	OCT	NOV	DEC
2020	216	211	211	247	239	207	185	211	200	231	223	263
2021	183	204	212	211	164	179	189	195	189	199	233	172
2022	188	157	229	166	267	211	245	236	255	280	254	249
2023	262	234	230	258	211	234	210	276	263	314	274	306
2024	171	221	276	261	255	171	164	195	210	199	233	187

3.2 Software Development Methodology

The waterfall model of the software development life cycle was adopted for this project. Waterfall development, analysts and users proceed sequentially from one phase to the next. . Once the work produced in one phase is approved, the phase ends and the next phase begins. As the project progresses from phase to phase, it moves forward in the same manner as a waterfall. While it is possible to go backward through the phases (Dennis 2018). The phases are:

- Requirement Analysis: Determining the requirement for the childbirth rate prediction system.
- System Design: Designing the structure of the application and database
- Implementation: Developing the system using C-Sharp and SQLite for the database
- Testing: Ensuring the system function correctly and meets the requirements.
- Deployment: Installing the system in the hospital environment for use.

Waterfall development methodologies have the advantages of identifying requirements long before programming begins and limiting changes to the requirements as the project proceeds (Dennis 2012).

3.3 ARIMA Model Implementation

ARIMA models are widely used for time series forecasting due to their ability to handle various data patterns, including trends and seasonality (Ljung, 2015). They consist of three components: autoregression, differencing to achieve stationarity, and moving averages. The parameters are (p, d, and q), where:

- P: is the number of autoregressive terms (AR)
- d: how many non-seasonal difference are needed to achieve stationarity (I)
- q: number of lagged forecast error in the prediction equation (MA)

Auto-Regressive Model: An auto-regressive model is a simple model that predicts future performance based on past performance. It is mainly used for forecasting when there is some correlation between values in a given time series and those that precede and succeed (back and forth). An AR is a Linear Regression model that uses lagged variables as input. By indicating the input, the Linear Regression model can be easily built using the scikit-learn library. Creating the model AutoReg () Call t() to train it on our dataset. Returns an AutoRegResults object. Once t, make a prediction by calling the predict () function the equation for the AR model (Y=mX+c)

$$yt = C + b1\ Yt - 1 + b2\ Yt - 2 + \ldots\ldots\ldots\ldots .+bp\ Yt - p + Ert - - - - - x$$

Key Parameters

p=past values

YT=Function of different past values

Ert = errors in time

C=intercept.

Moving Average Methodology: The Simple Moving Average (SMA) calculates the unweight mean of the previous M or N points. We prefer selecting sliding window data points based on the amount of smoothing, as increasing the value of M or N improves smoothing but reduces accuracy.

$$\textbf{SM At} = \frac{Xi + Xi - 1 + Xi - \cdots\ldots\ldots\ldots\ldots + Xm - (t-1)}{M} + \cdots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots ix$$

4. RESULTS AND DISSCUSION

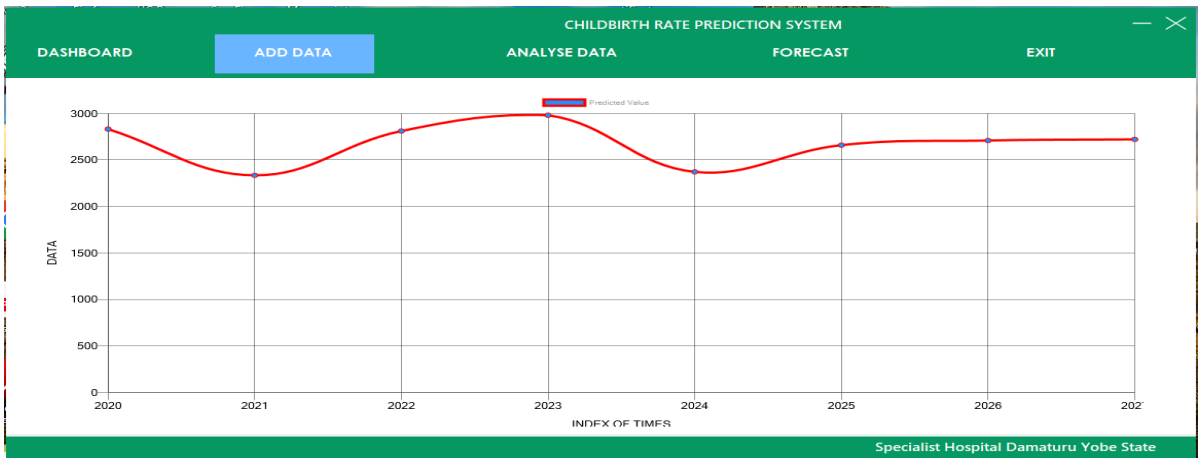
4.1 ARIMA Model Performance

The ARIMA model provided accurate predictions, capturing both the overall upward trend and seasonal fluctuations in childbirth rates at Specialist Hospital Damaturu. As seen in Table 2, the model predicted childbirth rates of 2,659 for 2025, 2,709 for 2026, and 2,721 for 2027. These predictions were consistent with the upward trend observed during the training period.

Table 2: Predicted Values for Upcoming Three Years.

PREDICTED DATA	
YEAR	**Value**
2024	2659
2025	2709
2026	2721

Figure 1: The childbirth Predicted Values



4.2 The trend analysis and interpretation:

Direction of Trend: From 2020 to 2024, there seems to be a general fluctuation in the data, with both increases and decreases in child birth rates. However, from 2025 to 2027, the predicted values 2024: 2659, 2025: 2709, 2026: 2721 show a consistent increase.
Magnitude of Change: Between 2020 and 2024, the child birth rates have experienced fluctuations in the range of approximately 648 births (from 2335 to 2981). In contrast, the predicted values for 2025 to 2027 indicate a more gradual increase of around 62 births over the three years.
Validation with Historical Data: The predicted values for 2025 to 2027 seem to be in line with the historical trend of fluctuations. However, the predicted upward trend for 2025 to 2027 is relatively modest compared to the historical fluctuations in earlier years.
Potential Drivers: To explain the predicted upward trend, consider examining factors that might contribute to increased child birth rates during this period. Economic conditions, social policies, cultural changes, and healthcare advancements could all be potential drivers of this trend.
Long-Term vs. Short-Term Trend: The predicted trend appears to be a short- to medium-term increase, spanning from 2025 to 2027. It's important to consider whether this trend aligns with broader demographic trends and societal shifts.

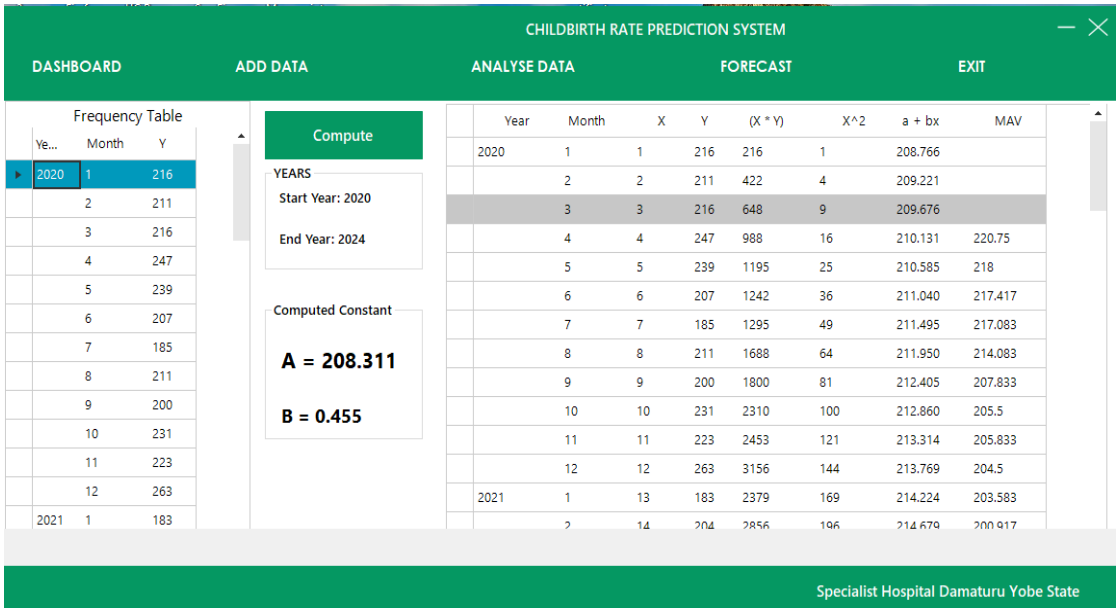


Figure 2: Analyze data for childbirth

Figure 1: Time series plot for the historical and predicted values of childbirth

Figure 2: the analyze data

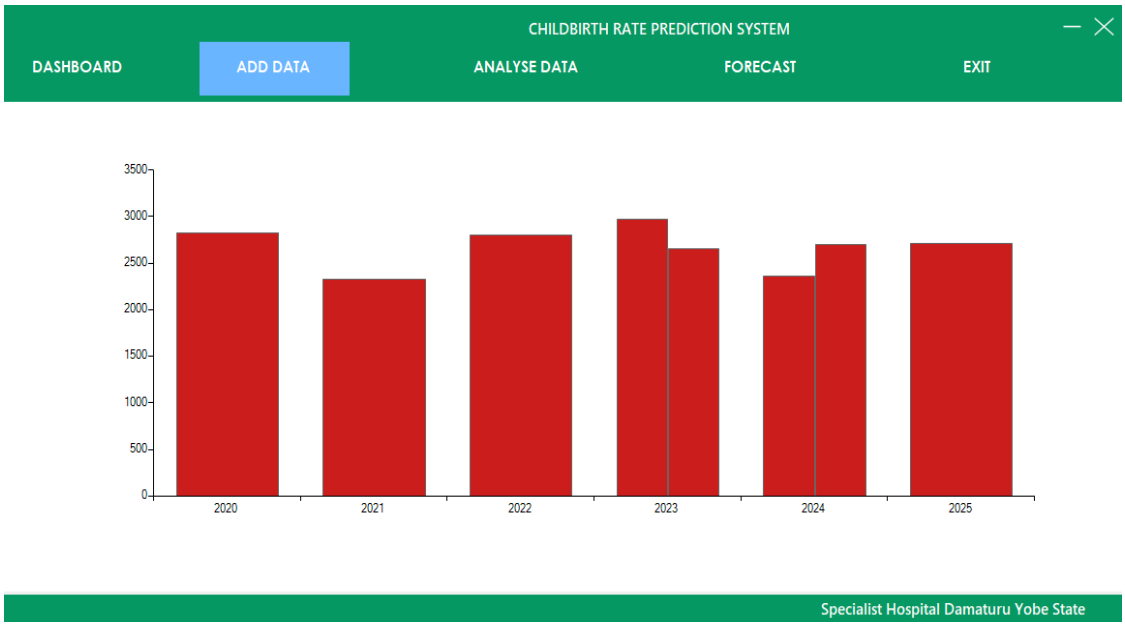


Figure 3: Time series plot for historical and predicted values

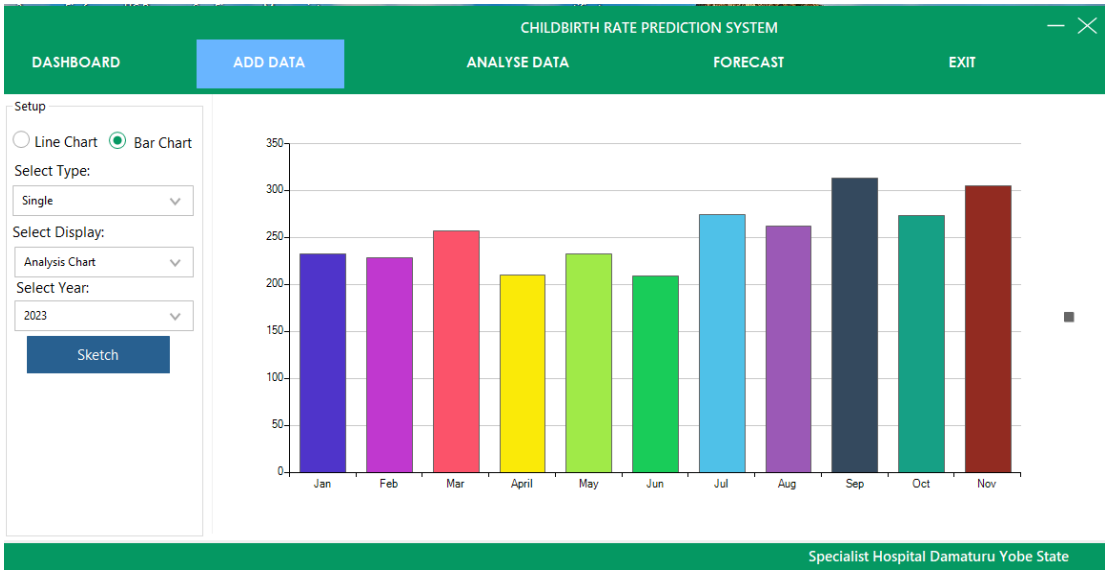


Figure 4: the analyzed of 2023 historical data

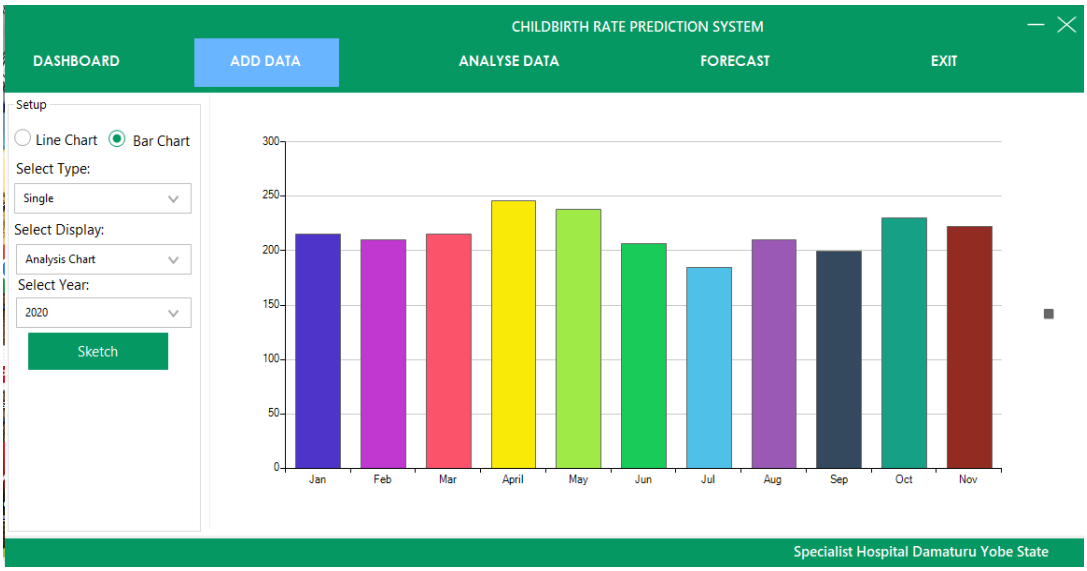


Figure 5: The Analyzed of 2020 Historical Data

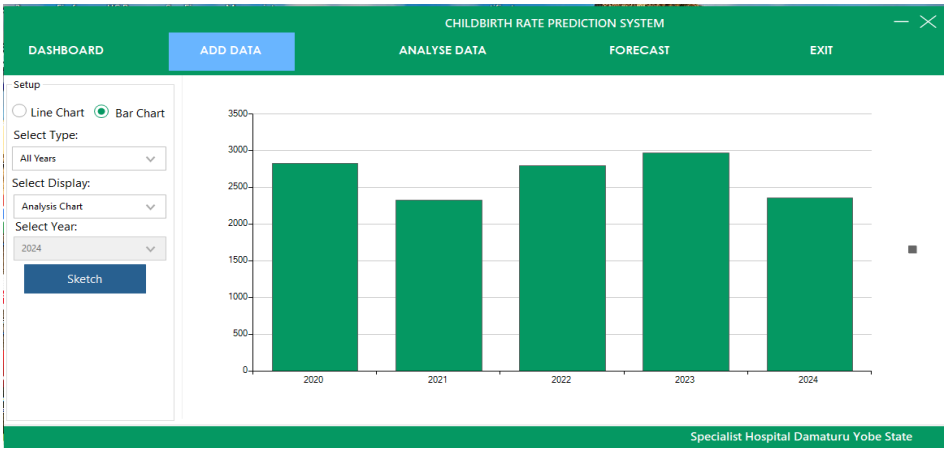


Figure 6: Time Series Plot for Historical

4.3 Practical Implications

These predictions offer valuable insights for hospital management. By anticipating the rise in childbirth rates, the hospital can better plan for staffing, bed space, and medical supplies. Additionally, policymakers can use these forecasts to inform resource allocation and public health strategies aimed at managing population growth.

4.4 Challenges and Limitations

One of the challenges faced during the study was the presence of outliers in the dataset, which affected model performance initially. However, through careful data preprocessing, these issues were mitigated. Additionally, the ARIMA model, while effective for short-term predictions, may need adjustments for long-term forecasting where other factors, such as policy changes, could impact childbirth rates.

5. CONCLUSION

This project successfully developed a childbirth rate prediction system for Specialist Hospital Damaturu using the ARIMA model. The system provides accurate predictions that can assist healthcare providers and policymakers in making informed decisions regarding resource allocation and maternal care services. By leveraging time series analysis, the hospital can now forecast childbirth rates with greater confidence, improving overall operational efficiency.

Future research could involve integrating external variables like economic or social factors to further refine the predictions. Expanding the system to include other departments, such as patient admissions or emergency services, could provide a more comprehensive hospital management tool.

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