ICUConnect: A Machine Learning-Powered Dashboard for ICU Bed Coordination and Forecasting in Public Hospitals in Kenya.

Kathrine Ganda Samiratu Ntohsi

African Leadership University

Introduction

Critical illness management in Kenya's public hospitals is crippled by severe ICU bed shortages and a reliance on manual, reactive referral processes [1]. This systemic lack of real-time visibility across facilities leads to delayed patient transfers, poor resource utilization, and preventable loss of life [2].

The core challenge is **reactivity**: clinical decisions and resource allocations are made only after overcrowding has occurred, severely limiting effective response during patient surges [3].

ICUConnect addresses this gap through a **closed-loop, AI-driven platform** that transforms critical care coordination from reactive to proactive. By combining a centralized referral system with real-time ICU occupancy monitoring, the platform's embedded **machine learning model** analyzes admission and discharge patterns to forecast bed demand up to a week in advance. This predictive capability triggers early surge alerts (e.g., at 80% occupancy), enabling healthcare teams to anticipate crises, optimize resource allocation, and coordinate life-saving transfers more efficiently across the hospital network.

Objectives

- Develop a centralized web dashboard for real-time ICU bed tracking and referral management.
- Apply and evaluate machine learning models (ARIMA, Prophet, LSTM, Attention-LSTM) for forecasting ICU bed demand to enable proactive surge preparedness.
- Improve inter-hospital coordination and reduce referral delays.
- Support data-driven decision-making in critical care by integrating AI-powered insights into existing hospital management workflows.

Methodology

This study adopted a mixed-methods design combining user-centered co-design with machine learning evaluation to ensure both usability and predictive accuracy.

1. User-Centered Co-Design (Platform Development)
   - **Stakeholders:** Engaged clinical staff and hospital administrators to define centralized referral logic and dashboard requirements.
   - **Outcome:** Development of the ICUConnect dashboard for real-time ICU occupancy and referral management, aligned with clinical workflows.
2. Machine Learning Evaluation (Predictive Demand Forecasting)
   - **Data Proxy:** Ontario ICU occupancy dataset (open-source) used for time-series model validation to simulate Kenya's ICU public health context.
   - **Models Compared:** ARIMA, Prophet, and Attention-LSTM, benchmarking traditional vs. deep learning approaches.
   - **Evaluation Metrics:** Mean Absolute Error (MAE), Root Mean Square Error (RMSE), and Mean Absolute Percentage Error (MAPE).

System Architecture and Design

The ICUConnect system follows a three-layer architecture integrating the web interface, business logic, and machine learning engine. It was developed using Flask (backend), PostgreSQL (database), and ARIMA-based forecasting.

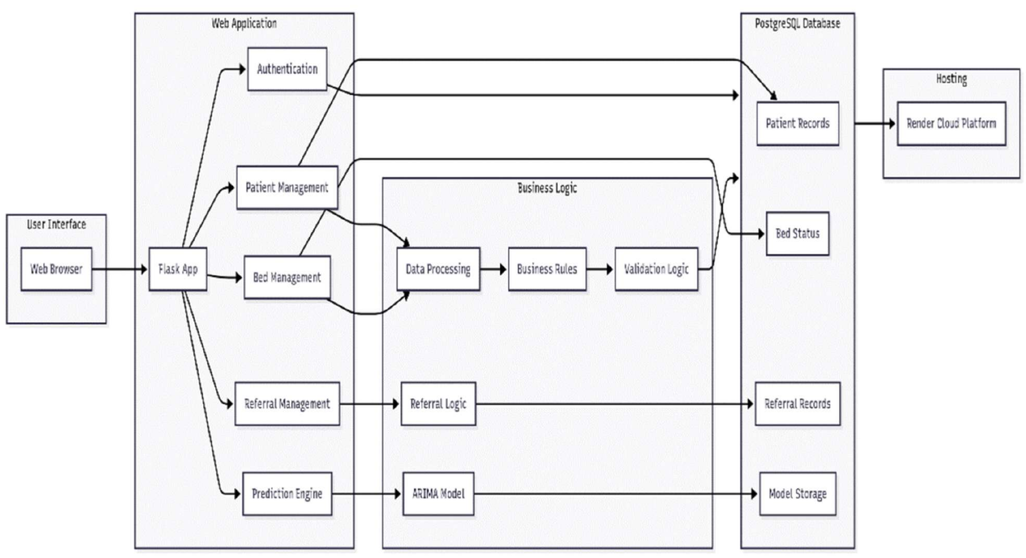

Figure 1. System Architecture of ICUConnect.

Results and Discussion

Key Findings: ICUConnect demonstrates strong potential to enhance operational visibility and improve predictive accuracy within ICU referral workflows.

Objective / Question	What Was Measured	Result / Insight
Evaluate current ICU referral challenges (Obj. 1 / Q1)	Literature review (40+ sources)	Manual processes, phone-based referrals, and poor coordination.
Compare ARIMA, LSTM, Prophet (Obj. 2 / Q3)	Forecasting accuracy (RMSE/MAE)	ARIMA showed the best performance (RMSE: 5.11).
Build dashboard with ML forecasting (Obj. 3 / Q2)	End-to-end referral + forecast integration	Functional prototype successfully developed and tested.
Assess usability by healthcare workers (Obj. 4 / Q2, Q3)	Avg. referral completion time	Average completion time: 10 seconds; User satisfaction rating: 4.5 / 5 (15 participants).

Table 1. **Summary of Evaluation Outcomes.**

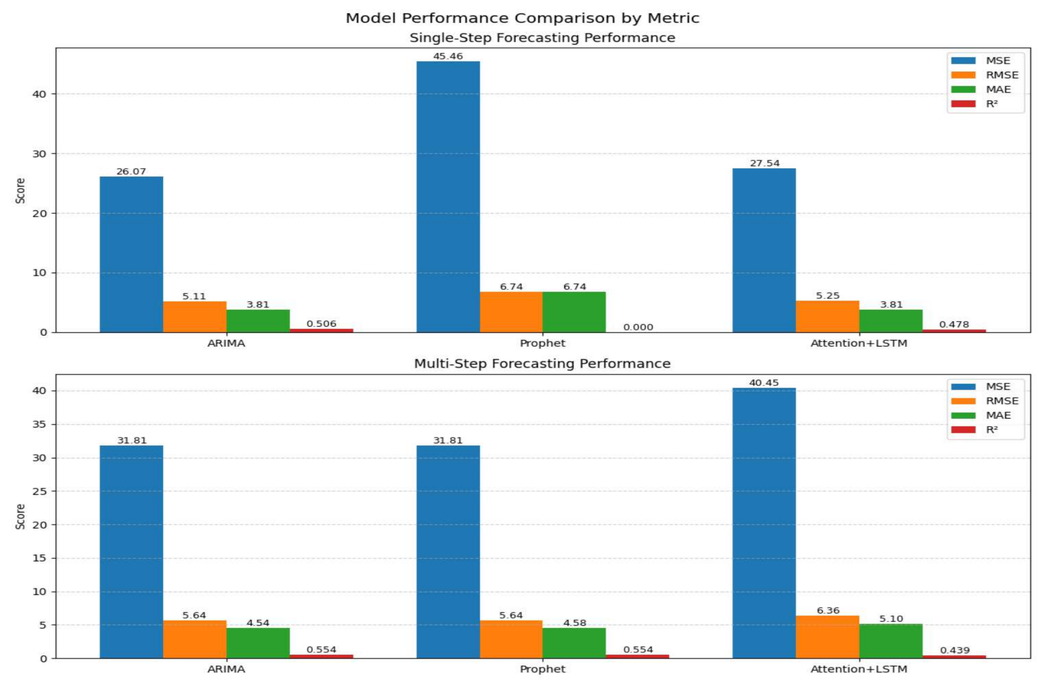

Figure 2. Forecasting Model Comparison (ARIMA, Prophet, LSTM, Attention-LSTM).

Impact and Conclusion

- **ICUConnect** enhances visibility and coordination among Kenyan public hospitals.
- Predictive analytics supports proactive ICU capacity management.
- Demonstrates the feasibility of AI integration into Kenya's digital health systems.
- Represents a scalable, low-cost model for data-driven healthcare innovation in Africa.

Future Work and Recommendations

- Integrate real hospital datasets under ethical data governance frameworks.
- Add offline functionality for low-connectivity hospital environments.
- Incorporate customizable surge alert thresholds to reduce clinician fatigue.
- Expand deployment to counties and integrate ambulance dispatch modules.

Next Step: Position ICUConnect as a national AI-driven ICU coordination platform.

References

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