

Optimizing Hospital Bed Management Through Digital Innovation: Improving Resource Allocation and Patient-Centered Care in Health-Promoting Hospitals

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INTRODUCTION

Effective bed management is hindered by stochastic patient inflows and structural constraints, often resulting in ED crowding and operational delays. While traditional methods struggle with such volatility—a challenge exacerbated by the COVID-19 pandemic—data-driven Decision Support Systems (DSS) offer a transformative solution. This study developed and evaluated an integrated DSS at National Taiwan University Hospital (NTUH) to enhance real-time bed allocation. By leveraging digital health analytics, the system aims to optimize inpatient capacity and align hospital operations with patient-centered care principles.

METHODS

This longitudinal mixed-methods study was conducted at National Taiwan University Hospital (2,600 beds). Using an Experience-Based Co-Design (EBCD) framework, a multidisciplinary team developed a Power BI-based DSS utilizing SQL Server 2022 and automated ETL pipelines. The three-layer architecture (Data Management, Model, and UI) integrated ER, inpatient, and outpatient data for real-time analytics. System impact was assessed by comparing pre-implementation (2022) and post-implementation (2024–2025) KPIs, including Bed Occupancy Rate (BOR), Turnover Rate (BTR), Turnover Interval (BTI), and ED boarding times.

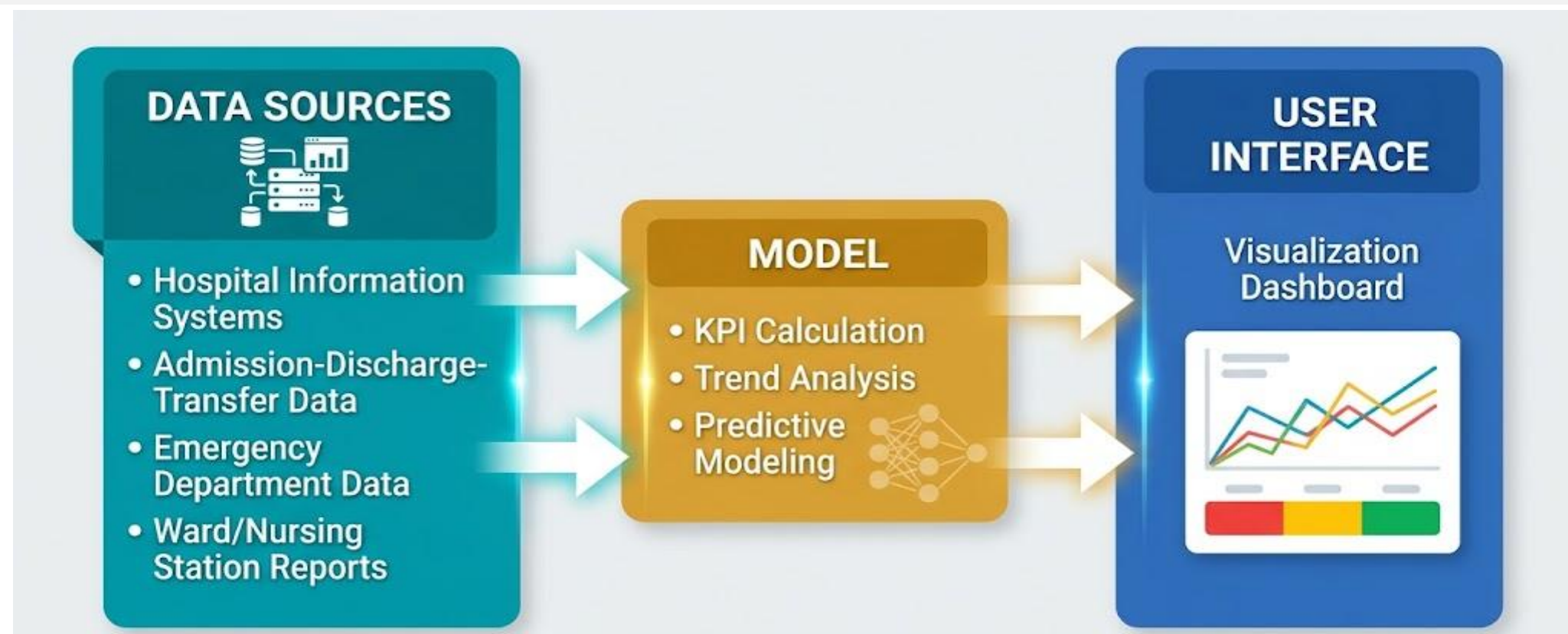


Figure 1. This figure illustrates the systemic framework, encompassing database integration, data preparation phases, and the application of data mining techniques to support the decision-making process.

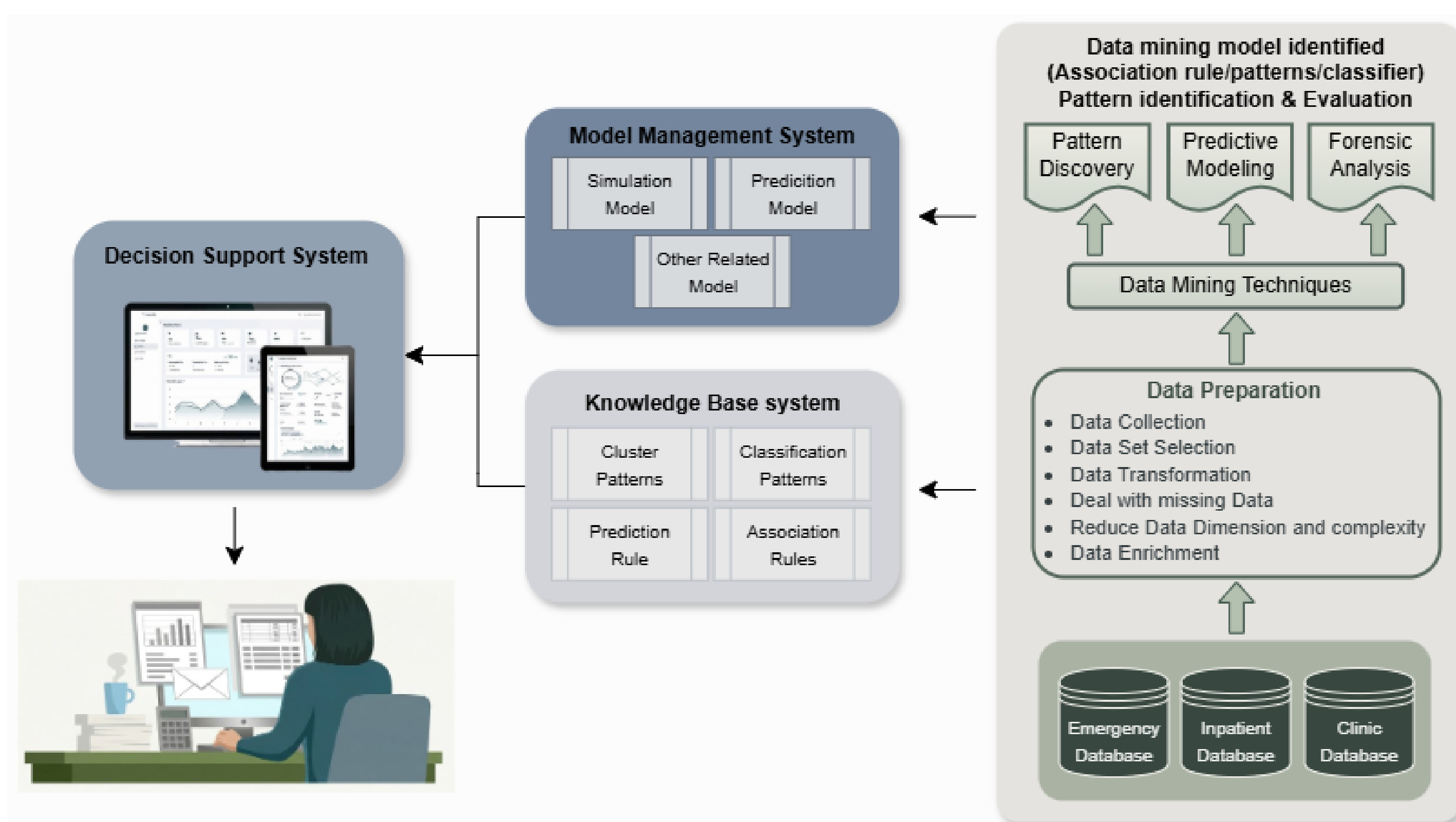


Figure 2 Workflow of the proposed DSS: From clinical data preparation and pattern identification to decision-making support.



Figure 3-5. The Real-time Bed Management Decision Support Interface, illustrating institutional occupancy trends and departmental bed status.

RESULTS

NTUH's Power BI-based DSS automated manual reporting and improved operational efficiency significantly:

- ED Boarding: Reduced by 34%.
- Turnover Efficiency: Increased by 23%.
- Reporting Accuracy: Improved from 89% to 98%.
- Communication Delays: Dropped by over 70%.

We now evaluate these metrics across High, Middle, Low, and Emergency turnover categories to further analyze hospital bed efficiency.

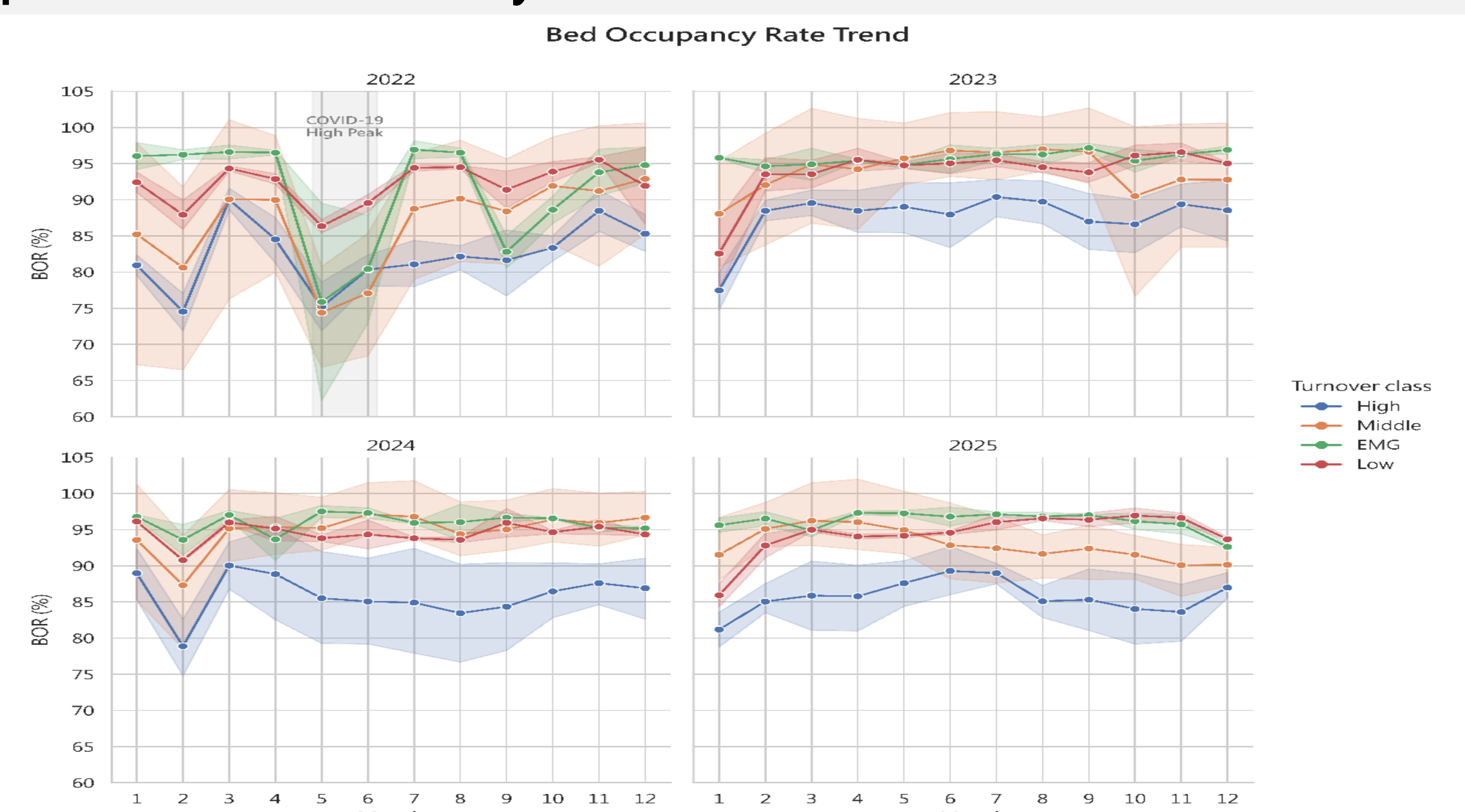


Figure 6. Longitudinal Trends of Bed Occupancy Rate (BOR) by Ward Category (2022–2025). Note the convergence of data lines and narrowed variance post-2023, reflecting improved management stability.

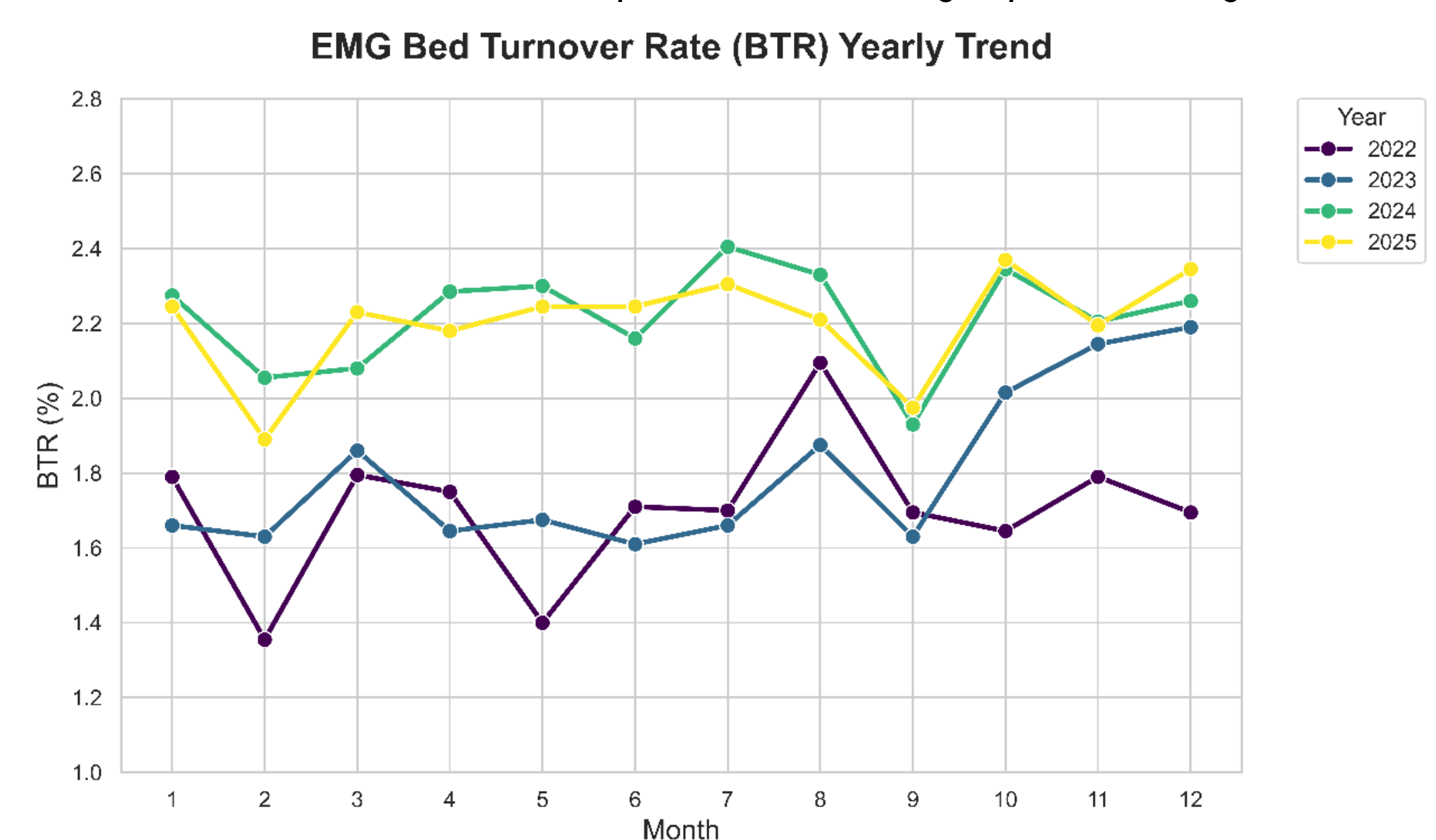


Figure 7. Annual Comparison of EMG Bed Turnover Rate (BTR). The upward staircase progression from 2022 to 2025 highlights the cumulative efficiency gains following DSS implementation.

CONCLUSION

NTUH's transition to real-time bed management shifted hospital operations from reactive to proactive, patient-centered care. While data visualization significantly reduced ED boarding and improved turnover, BTR and ALOS outliers reveal persistent non-clinical bottlenecks, such as discharge and coordination delays. This demonstrates that while digital tools provide essential transparency, technology alone is insufficient. Achieving optimal patient flow requires targeted administrative interventions to resolve underlying operational friction.

DISCUSSION

NTUH's Power BI-based DSS shifted bed management from reactive to proactive, improving patient throughput. To further enhance efficiency, the system will evolve into an **AI-driven IDSS**, integrating predictive analytics and workload data to optimize resource allocation and ensure sustainable, patient-centered care.

Keywords : Bed Management, Digital Innovation, Patient Flow, Patient-Centered Care, Real-Time Monitoring, Emergency Department Congestion