Mortality Rate and Length of Stay Prediction with Machine Learning for Resource Management in Pediatric Intensive Care Units.

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Project Background : The difficulty in providing care for critically ill patients, insufficient bed resources, and the tools needed to handle emergency situations are inadequate.

"**The ability to admit** critically ill patients depends on the number of available ICU beds."

But what happens if it's not enough?

"**Refusing** a patient may mean **death**."

Wouldn't it be better if we could admit more patients?

"**Increasing the number of beds** beyond the essential capacity for emergency situations."

Is it a best solution? cost? space? and burden?

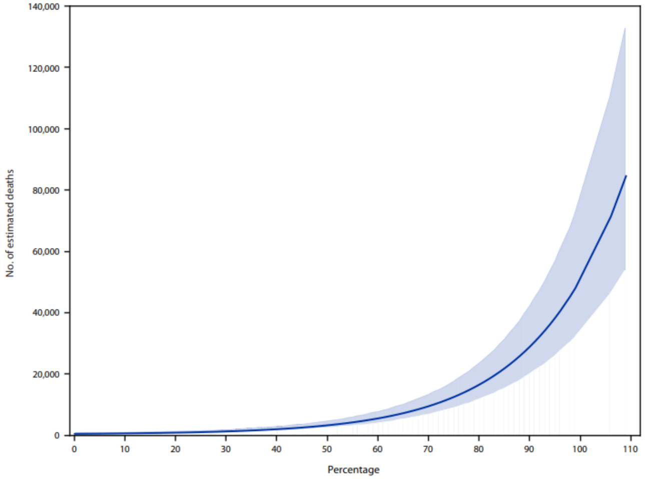
"Caring for patients in such critical situations demands **innovative approaches to ensure the safety and efficiency** of healthcare providers."

A model that assists in predicting length of stay and patient mortality rates.

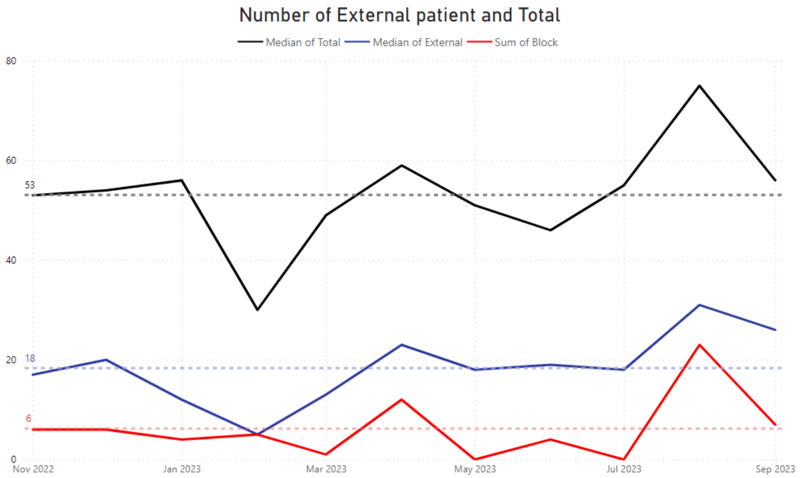
Project Background : Insufficient bed capacity in the pediatric intensive care unit.

There is a wealth of research and statistics demonstrating the relationship between the number of ICU beds and patient survival rates

- 1997 : Length of Stay (LOS) is an indicator of hospital performance and impacts patients.
- 2020-2021 : Impact of Hospital Strain on Excess Deaths During the COVID-19 Pandemic.
- 2022 : A systematic review of the prediction of hospital length of stay: Towards a unified framework
- etc.



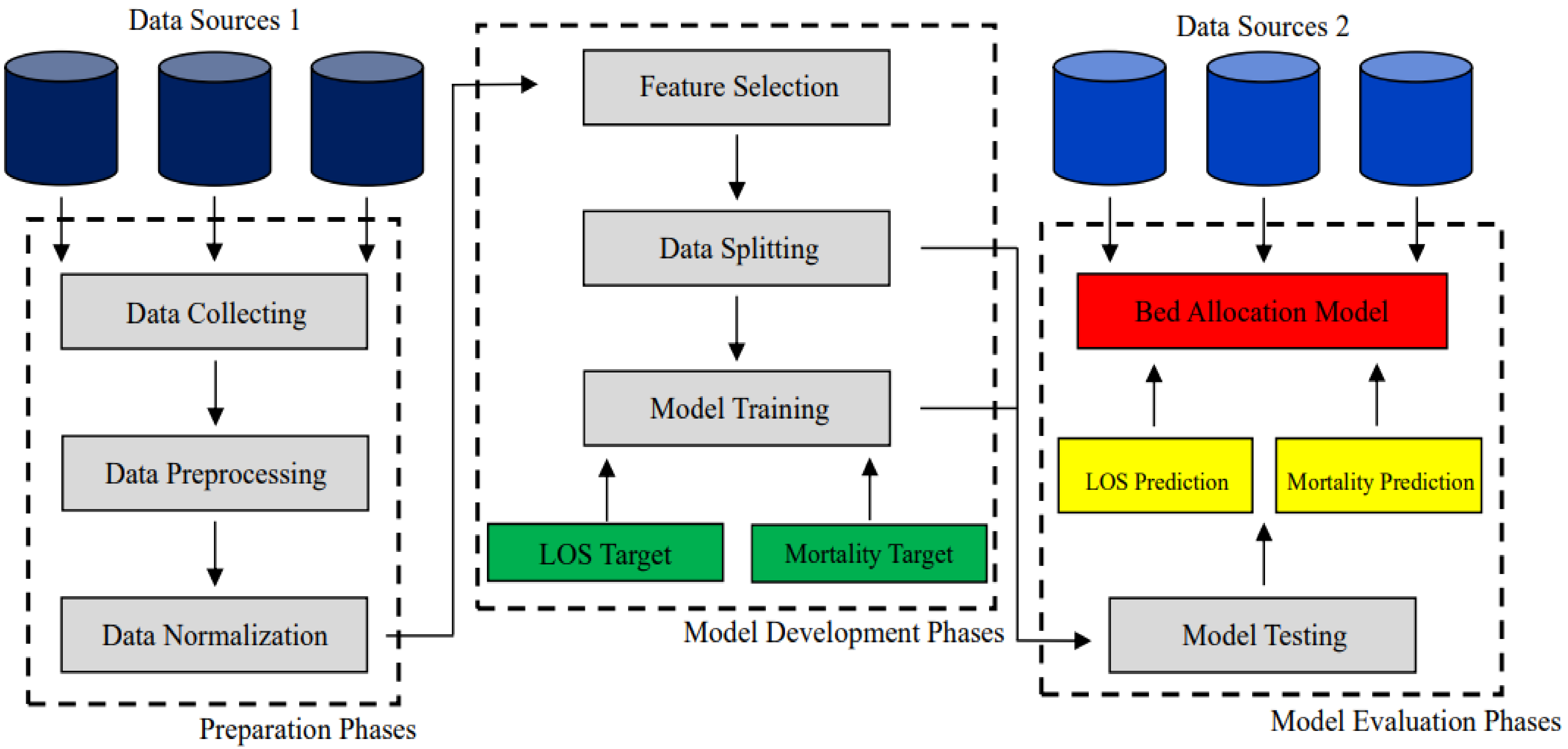
French, Geoffrey, et al. *Morbidity and Mortality Weekly Report Impact of Hospital Strain on Excess Deaths during the COVID-19 Pandemic*. 19 Nov. 2021.



Kritsaporn Sujjavorakul, Statistics on patient refusal for transfers from external hospitals, Critical Care Excellence Center. Oct. 2023.

We are focusing on integrating machine learning technology with queuing theory to efficiently allocate resources for maximum benefit.

Proposed Method : Framework Methodology



Proposed Method : Architecture

Health Data

Admission data 24 hours

(For predicting mortality and length of stay, vital sign, laboratory test, etc.)

(From MIMIC-III (v1.4))

hospital resource utilization data

(For bed occupancy, number of bed, arrival rate, availability, etc.)

(From CCE Center.)

Preprocess

Imputation

(Use Interpolate, K-NN fill in the missing and Bootstrap for balancing classes)

Normalization

$$x' = a + \frac{(x - min(x))(b - a)}{max(x) - min(x)}$$

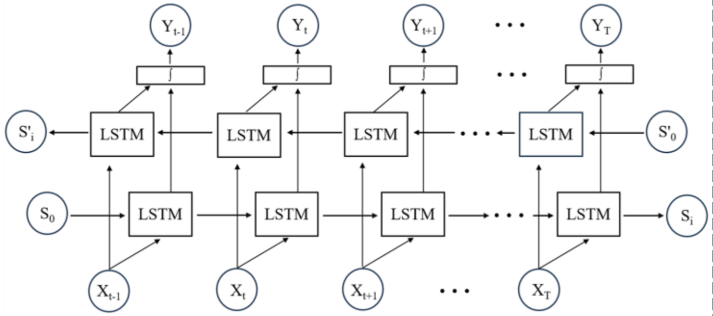
Feature Selection

(Use feature importance values obtained from Random Forest to select important features)

Machine Learning prediction

Model for prediction

(Ex. Bidirectional Long Short-Term Memory)



Analysis and Insight

Allocation Optimization

(For manage the most appropriate patient flow, Erlang loss Model - M/G/C/C - M/M/C/C)

Scenario Calculation

(Calculate the most efficient way to manage resources during normal and Emergency Scenario, arrival rate (λ), service level (%), Occupancy (%))

Data Delivery

Deliver Statistical Data

(Sending data to the medical team, healthcare personnel, and resource allocation personnel.)

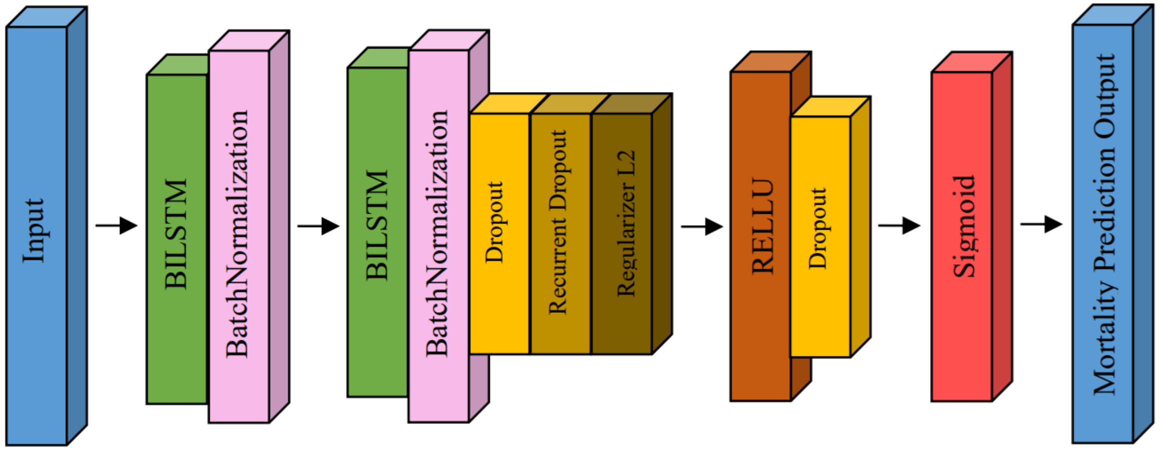
Decision making system

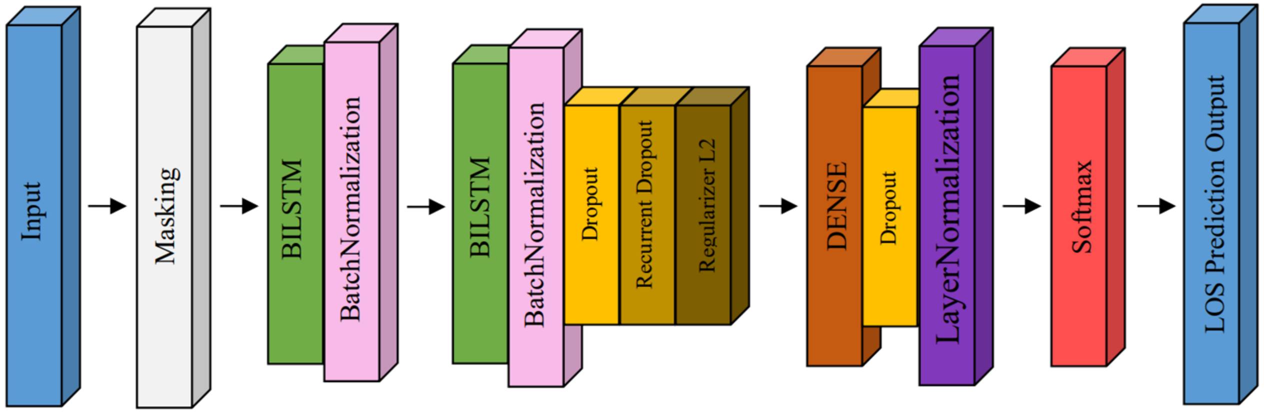
(In the future…)

Model Tuning and Evaluating

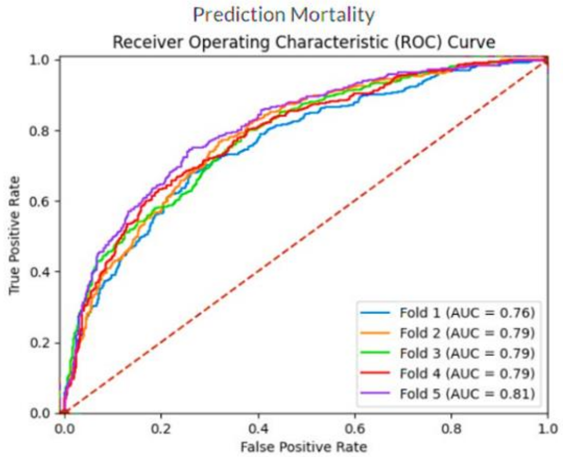
Train | Validation | Tuning | Deploy

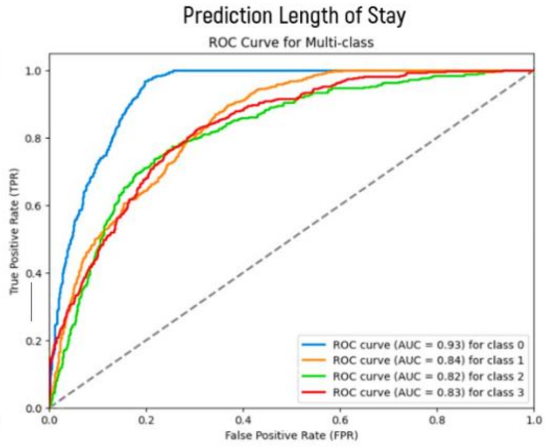
Proposed Method : Experiments including field testing





- **Preliminary AUCROC results of mortality and LOS**





- **Comparison results of the LOS models**

We evaluate the performance of all 7 models to find the best-performing model within a rigorous and parameter-tuned environment to ensure that each model has its best parameter settings.

Models	Accuracy		Precision		Recall		Specificity		F1 Score	
	μ(%)	σ(±)	μ	σ(±)	μ	σ(±)	μ	σ(±)	μ	σ(±)
GRU	79.705	0.0150	0.788	0.0003	0.813	0.0008	0.922	0.0002	0.794	0.0001
GRU wo masking	80.745	0.2550	0.811	0.0027	0.829	0.0011	0.931	0.0010	0.817	0.0020
LSTM	79.556	1.2963	0.789	0.0134	0.848	0.0311	0.926	0.0067	0.788	0.0144
LSTM wo masking	79.540	1.9199	0.799	0.0198	0.867	0.0158	0.930	0.0093	0.800	0.0179
BILSTM	82.112	0.3975	0.821	0.0116	0.865	0.0057	0.938	0.0042	0.820	0.0123
LSTM+CNN	82.210	-	0.827	-	0.827	-	0.939	-	0.827	-
TRANSFORMER	80.160	-	0.807	-	0.823	-	0.930	-	0.806	-

Impact : Scientific and Technological

- **Scientific Advancement** - Our innovative approach signifies a pioneering step in the integration of AI technology within the field of medicine in Thailand. By employing cutting-edge AI techniques, including deep learning models tailored for medical applications, we tackle the intricate task of predicting mortality rates and length of stays in Pediatric Intensive Care Units (PICUs). This scientific spearheads the effective utilization of AI technology for healthcare within Thailand. It paves the way for advancements in healthcare analytics and data-driven decision-making, with the ultimate aim of enhancing resource allocation and patient care in the country.

- **Technological Innovation** - From a technological standpoint, our approach represents a substantial leap in the field of healthcare resource management in PICUs. By integrating state-of-the-art machine learning algorithms and predictive modeling, it harnesses cutting-edge technologies to analyze patient data and predict outcomes. This technological advancement has the potential to revolutionize resource allocation practices in pediatric intensive care, ultimately leading to improved patient care and hospital efficiency.

Impact : Societal

- **Improving Healthcare Access -** Our innovative approach to mortality rate and length of stay prediction with machine learning holds significant promise for the Thai healthcare system. By accurately forecasting patient outcomes, it enables healthcare providers to allocate resources more efficiently and make well-informed decisions. This ultimately results in improved healthcare access for the people of Thailand, ensuring that medical services are available when needed and reducing waiting times for critical care.

- **Economic Benefits and Resource Allocation -** The societal impact of our method extends to the economic realm. By predicting mortality rates and length of stays, healthcare facilities can optimize resource allocation, reducing the strain on the healthcare budget. This not only leads to economic benefits by utilizing resources more effectively but also ensures that funds are available for other healthcare needs, ultimately benefitting the broader society.

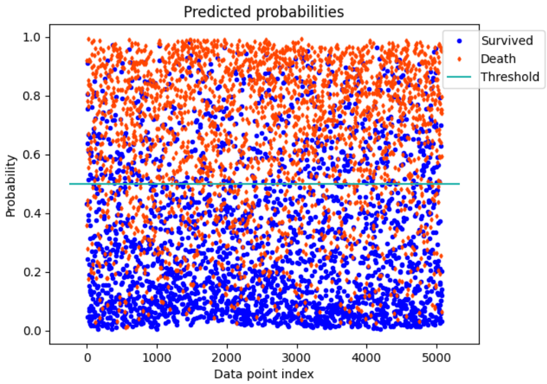
Impact : Collaborative

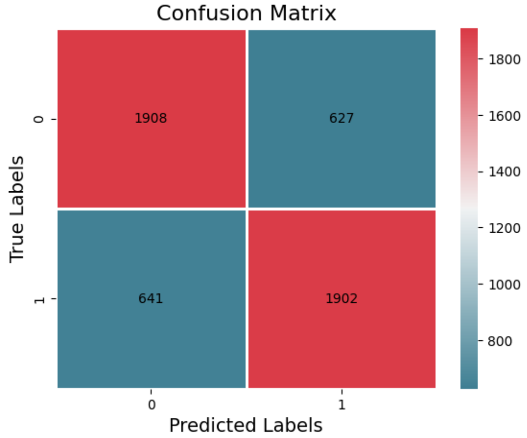
- **Promoting Interdisciplinary Collaboration -** Our methodology emphasizes the importance of interdisciplinary collaboration between healthcare professionals, data scientists, and technology experts. This collaboration drives the development and application of advanced healthcare analytics, allowing for better resource management, enhanced patient care, and the advancement of medical research. By fostering cooperation among these diverse fields, we contribute to the betterment of the Thai healthcare system, bringing about improvements in healthcare access and patient outcomes.

- **Enhancing Quality of Life** - Our emphasis on interdisciplinary collaboration is driven by the shared goal of enhancing the quality of life for the humankind. This collaborative effort aims to bring about advancements that positively impact people's lives, ensuring access to better healthcare and promoting healthier living.

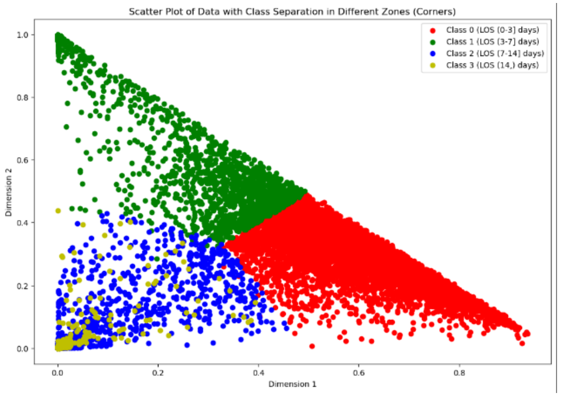
Outcome :

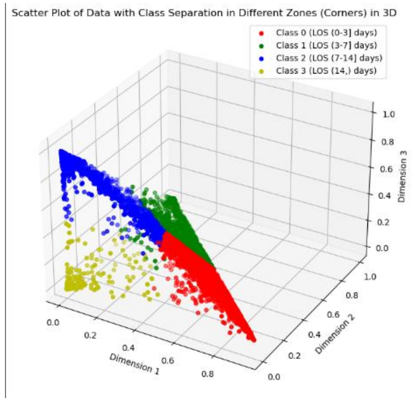
- **Mortality Prediction Model**

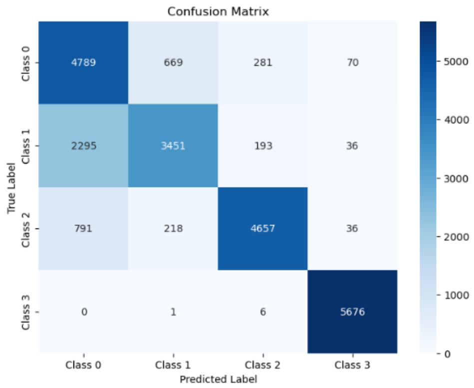




- **Length of Stay Prediction Model**

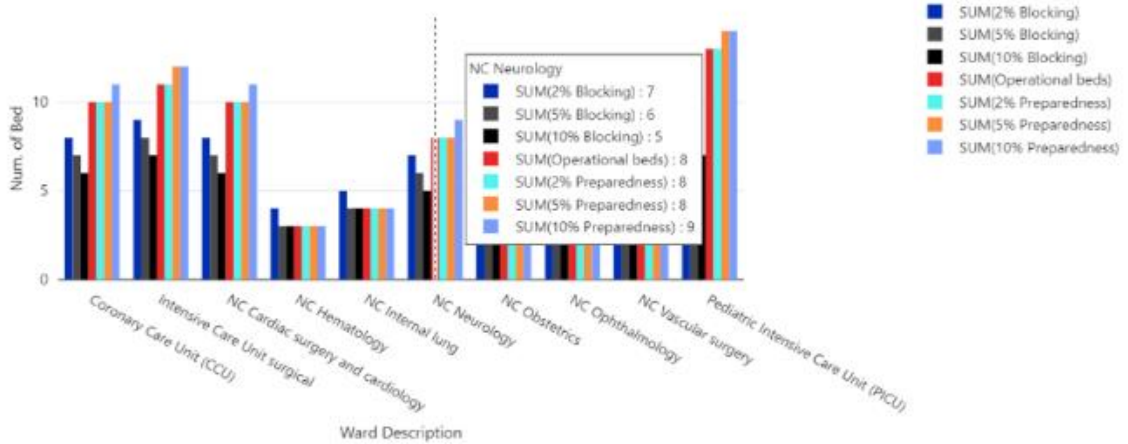






- **Mortality Prediction Model** and **Length of Stay Prediction Model:** The method will provide a prediction probabilities plot, showing the predicted probabilities for the Mortality Prediction Model have 2 classes "Death" and "Survived" and the Length of Stay Model has 4 classes, distinguishes patients' stays as follows: Class 0 for LOS 0-3 days, Class 1 for LOS 3-7 days, Class 2 for LOS 7-14 days, and Class 3 for LOS exceeding 14 days. and the Confusion matrix quantifies the accuracy and error rates of the model's predictions.

- **Bed Allocation Model**



- **Bed Allocation Model:** representation of the appropriate allocation of bed resources in a hospital to maintain the quality of service (QoS) within the range of 90-98% in normal situations and to prepare for potential congestion scenarios, which could range from 102-110%.
- **Data-Driven Pediatric Care:** The utilization of machine learning for mortality rate and length of stay predictions introduces data-driven decision-making in pediatric intensive care. Healthcare providers can make more informed choices about resource allocation, leading to better patient outcomes and ultimately saving lives.
- **Proactive Resource Allocation and Reduced Patient Rejection:** The methodology significantly improves proactive resource allocation within pediatric intensive care units. This proactive approach not only enhances the unit's ability to respond effectively but also plays a crucial role in reducing patient rejection due to insufficient bed availability. Every life saved is a testament to the potential for this approach to save even more lives in the future.

Conclusion : Future Direction

- **Future Research Endeavors**

Healthcare Resource Allocation and Efficiency: Future research will focus on investigating innovative and distinct approaches to enhance the efficiency and effectiveness of resource allocation in healthcare systems. These novel methods aim to ensure that healthcare facilities can better manage resources to epidemic or emergencies situation, ultimately leading to improved patient care and healthcare system resilience.

- **Future Project Plan**

Integrated Healthcare Decision Support System: Our future project plan are dedicated to creating an integrated healthcare decision support system, focusing on both comprehensive medical decision-making and resource allocation. This system will incorporate predictive models for mortality rates, length of stay (LOS), and other pivotal medical parameters. It empowers healthcare professionals with the tools needed to make informed decisions that optimize patient care and enhance healthcare outcomes. This integrated approach ensures the efficient allocation of resources while promoting excellence in medical decision-making.

Conclusion : Key Takeaways

- Our proposed method introduces **Mortality prediction**, **Length of Stay**, and **Bed allocation**.
- The method offers outputs such as prediction probabilities, confusion matrix, Scatter point, and Optimal Bed Allocation Chart
- Scientific by employing deep learning models (Bidirectional LSTM) and Queuing theory tailored for medical applications.
- **Technological Innovation** to analyze patient data and predict outcomes, ultimately leading to **improved patient care and hospital efficiency**.
- Healthcare Access enables healthcare providers to allocate resources more efficiently and make well-informed decisions.
- Economic Benefits **reduced the strain on the healthcare budget** and **healthcare facilities can optimize resource allocation**.
- Promoting Interdisciplinary Collaboration drives the development and application of healthcare analytics, allowing for better resource management, enhanced patient care, and the advancement of medical research.
- **Enhancing Quality of Life** ensured everyone access to better healthcare and promoting healthier living.