Department of Digital Medical Technologies

מכון טכנולוגי חולון
Holon Institute of Technology

# Anomaly Detection in Operating Room Performance and Bed Occupancy Forecasting


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# Project Purpose

## Predict Bed Occupancy

Develop accurate forecasting models to predict inpatient bed requirements 7 days in advance.

## Predict Surgery Duration

Build an accurate machine learning model to estimate surgery durations in advance, enabling smarter OR scheduling and reducing delays.

## Optimize OR Utilization

Detect anomalies in operating room performance and refine scheduling algorithms to maximize resource efficiency.

## Support Decision-Making

Create an interactive dashboard that provides real-time insights to hospital administrators and medical staff.

Goal:

Improve hospital efficiency through smart scheduling and predictive analytics.

# Theoretical Background

## The Operating Room Challenge

- Operating Rooms (OR) are high-cost, limited-capacity assets.
- Poor scheduling leads to delays, underuse, and long patient stays.
- ML techniques allow prediction, optimization, and real-time monitoring.
- At Assuta, the average yearly OR utilization during the years we analyzed was approximately 40–45%.

# Continued Background

## Tools and Techniques Applied in Our Project:

1 CatBoost

Used for predicting surgery durations.

2 BiLSTM

Used for forecasting inpatient bed occupancy.

3 Optimization

Applied with linear constraints and hospital-specific business rules.

4 Power BI Dashboard

Used to integrate results into real-time decision-support tools.

Together, these tools supported both the predictive and operational components of our solution.

# Project Workflow

1

## Data Acquisition & Analysis

Collected surgical and inpatient data from Assuta Hospital (2017–2024). Performed extensive data cleaning and exploratory analysis to identify patterns and anomalies.

2


## Duration Modeling & Optimization

Developed a CatBoost model to accurately predict surgery durations, enabling the creation of optimization algorithms for improved OR schedules.

3

## Bed Occupancy Forecasting

Implemented a BiLSTM neural network to forecast department-level inpatient bed requirements up to 7 days in advance.

4

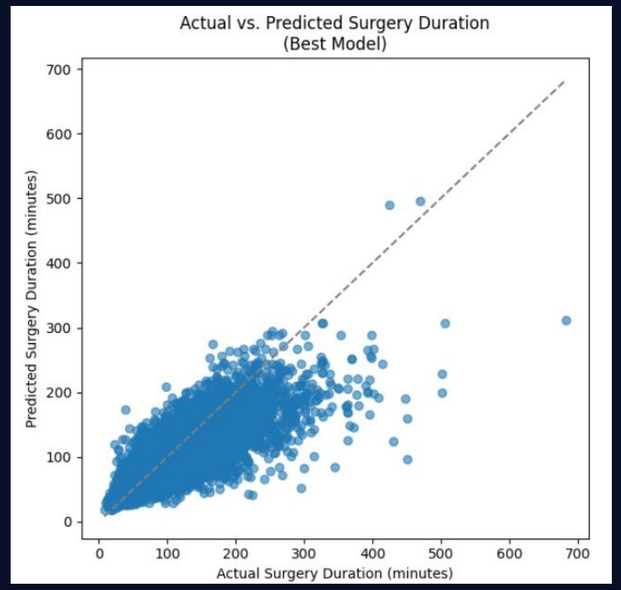

## Dashboard Development

An interactive Power BI dashboard was created to integrate predictions and actual performance metrics, providing real-time support for critical hospital decisions

# Results: Prediction Models

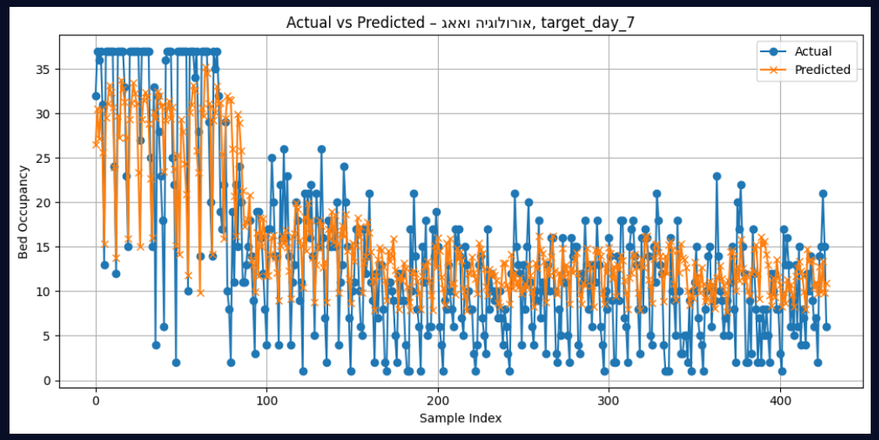
## Surgery Duration Prediction

- CatBoost model achieved MAE of 19 minutes
- $R^2$ score of approximately 0.72
- Key features: procedure type, surgeon, anesthesia method




## Bed Occupancy Forecasting

- BiLSTM achieved $R^2$ up to 0.61 for 7-day forecasts
- Accuracy decreases with prediction horizon
- The model learns from past occupancy trends, including weekly and seasonal patterns, to make accurate short-term predictions




## Challenges:

- Missing or inaccurate timestamps for surgical events.
- Surgeon estimates often inconsistent and biased.
- For bed occupancy: incomplete hospitalization records and delayed discharges.
- Capturing department-specific patterns required tailored preprocessing and input engineering.
- Trade-off between accuracy and forecast horizon (short-term more accurate).

# Dashboard Demo

## Real-Time Monitoring

Real-time tracking of bed availability and occupancy rates, with automated anomaly detection and customizable admin alerts

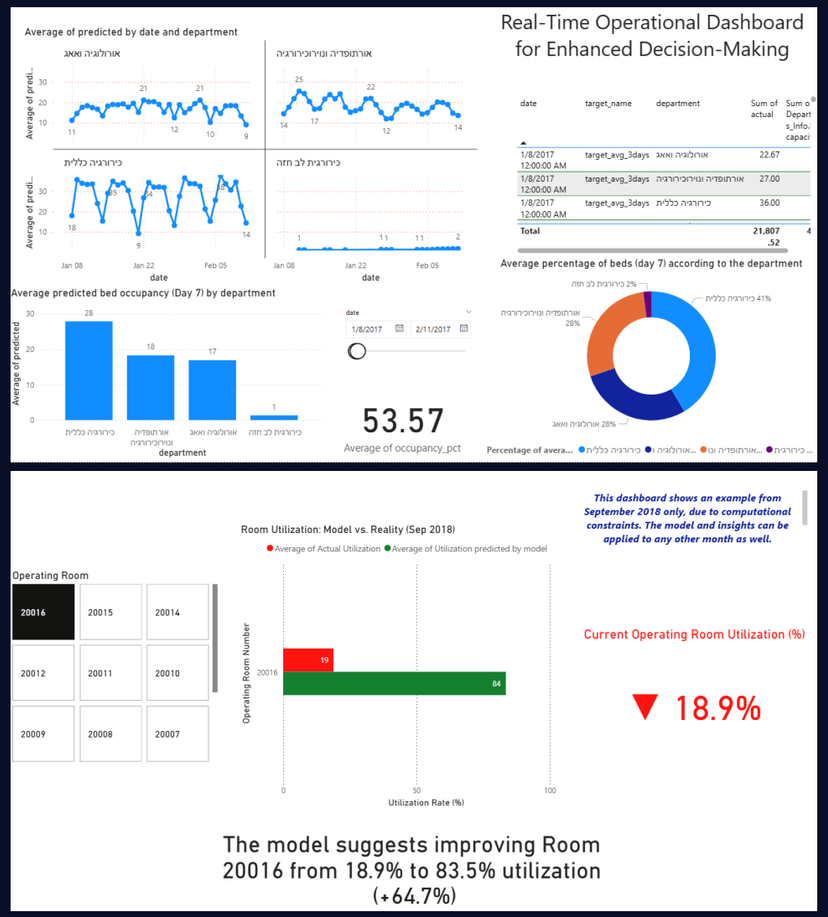
## Forecasting Visualization

Interactive bed occupancy predictions by department with confidence intervals and historical comparison features.

## Strategic Planning

What-if scenario planning capabilities allowing schedulers to evaluate different allocation strategies and their impacts.

Preview of the dashboard:




## Challenges:

- Integration issues due to lack of real-time hospital APIs.
- Limited granularity due to privacy constraints.

## Functionality:

- Real-time monitoring of bed availability and occupancy rates
- Department-level bed occupancy forecasts (e.g. 7-day ahead)
- Anomaly detection and seasonal trend analysis
- Automated alerts for occupancy thresholds and irregularities

# Results: Operating Room Utilization

## Findings:

### Target Utilization

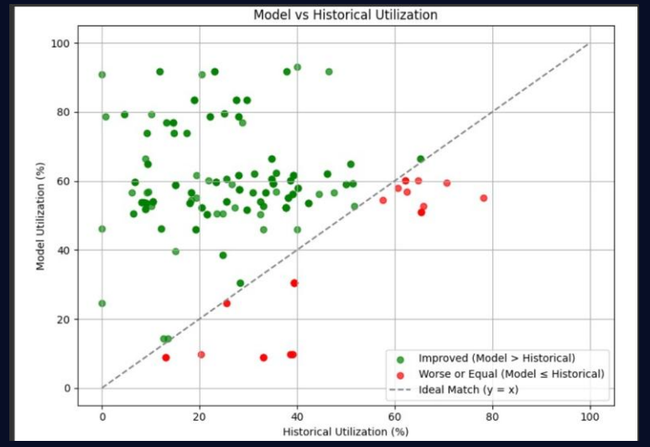
Defined and calculated a daily utilization metric per room, measuring the percentage of available OR time that was actively used.

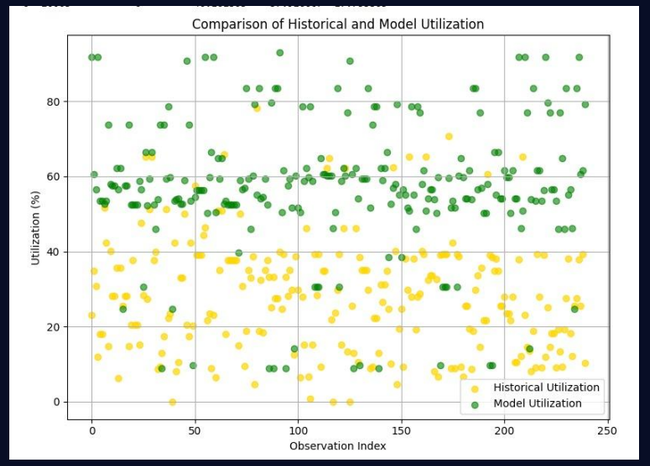
### Utilization Improvement

Optimization model nearly doubled average utilization, from 28.4% (historical) to 57.2% (model) in the rolling horizon evaluation.

### Framework for Deployment

The scheduling framework was implemented using a rolling horizon strategy, simulating real-world weekly constraints and enabling modular hospital planning.




### Challenges:

- Lack of existing daily OR utilization metric in raw data.
- Significant variation in utilization between rooms and departments.
- Difficulty identifying whether low utilization was due to cancellations, scheduling errors, or early finishes.
- Absence of unified benchmark to compare performance over time.
- Heavy model constraints led to memory issues – MILP crashed even with 50GB RAM, and CP required strict time limits.

# Conclusions

1. ## Improved OR Efficiency

   Achieved better alignment between scheduled and actual surgery times, reducing idle periods and delays.

2. ## Developed Robust Predictive Models

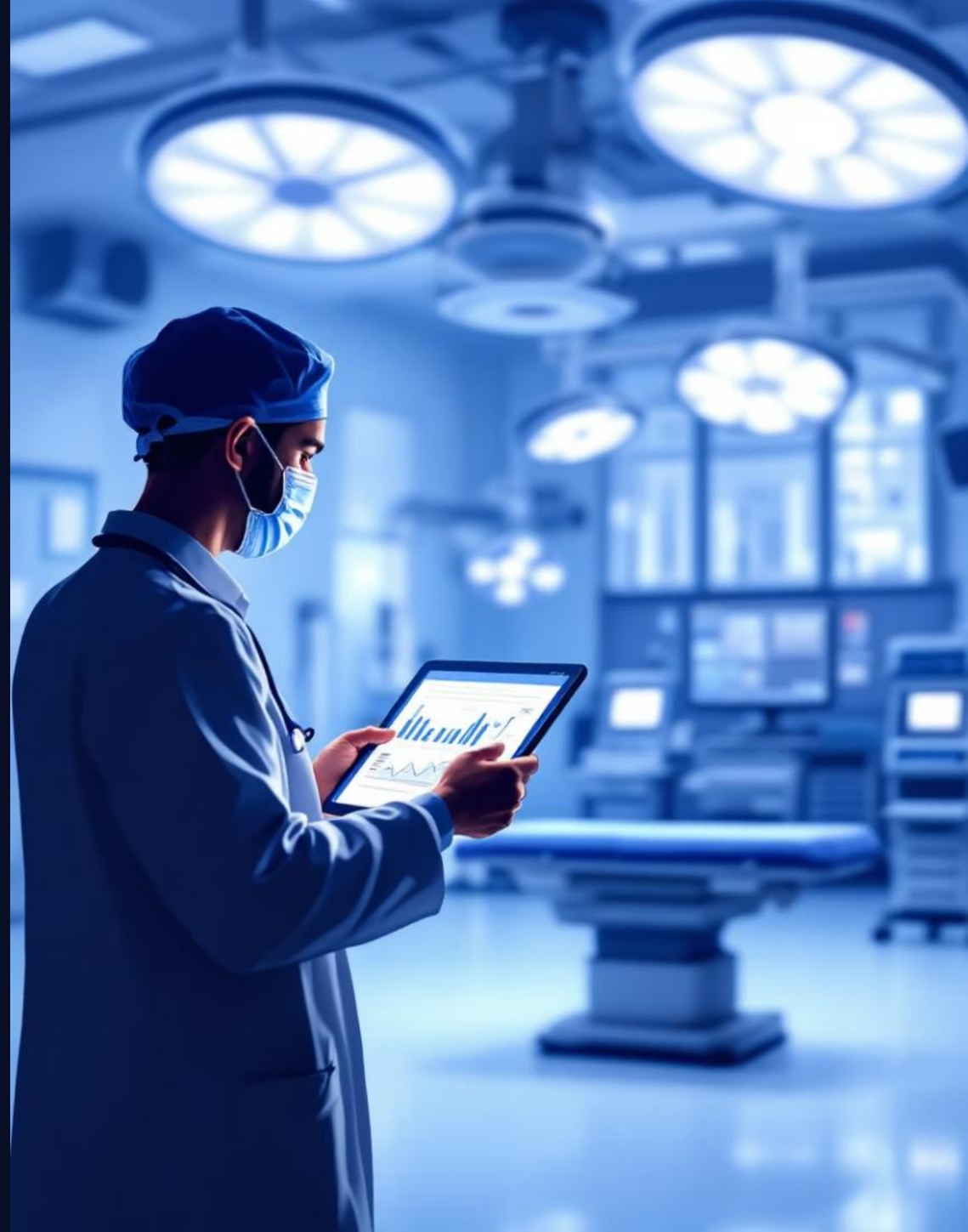
   Built accurate models for forecasting surgery durations and inpatient bed requirements, outperforming manual estimates.

3. ## Delivered Real-Time Insights via Dashboard

   Provided planners with real-time access to key performance indicators and forecasts, enabling faster, data-driven decisions.

4. ## Advanced Hospital Resource Optimization

   Our results directly support strategic resource planning and optimization across departments.



# Challenges & Solutions

## Challenges

- Incomplete or inaccurate timestamp data
- Non-standardized procedure naming across departments
- Difficulty modeling rare and high-impact events (e.g., prolonged surgeries, ICU transitions)
- Missing ICU admission data, limiting model confidence in critical cases

## Solutions

- Rule-based imputation logic tailored to surgical workflows
- Standardization and mapping of procedure codes
- Use of ensemble models to improve predictions on rare events

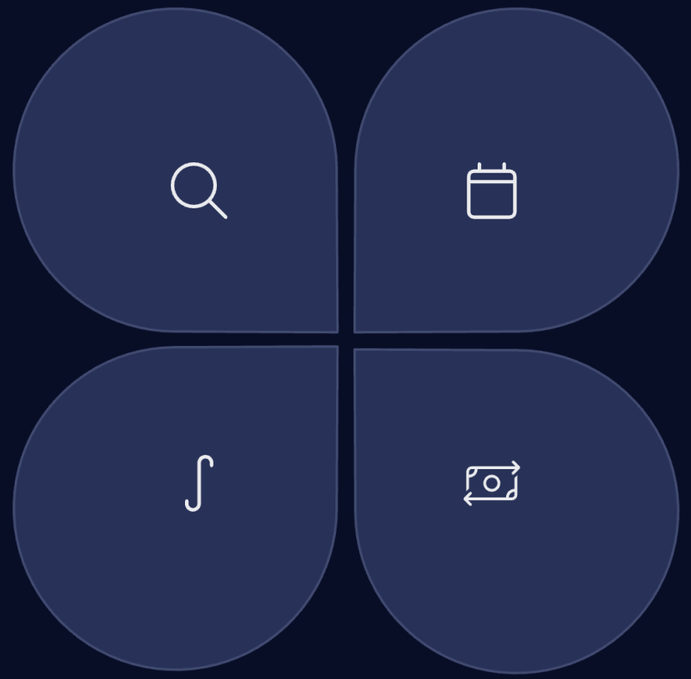
# Technical Innovations

## Custom Anomaly Detection

Developed specialized algorithms to detect outliers in surgical durations, leveraging contextual features (e.g., procedure type, department, weekday) instead of relying solely on static statistical thresholds.

## Dynamic Scheduling

Designed an adaptive scheduling mechanism that learns from historical patterns and continuously refines parameters to optimize future planning.



## API Integration Layer

Built a secure, real-time data pipeline that connects hospital systems with our predictive engines and dashboards.

## Cross-Department Transfer Prediction

Introduced a novel model to forecast patient transfers between departments, improving the accuracy of downstream bed occupancy predictions.

# Summary & Future Roadmap

You can explore the source code, models, and scripts via the following link:

Link to the Drive folder

## Key Achievements

- Significantly improved OR efficiency and scheduling precision through data-driven insights
- Built robust machine learning models for predicting surgery durations and inpatient bed occupancy
- Delivered an intuitive, real-time dashboard for surgical and operational decision-making
- Successfully integrated advanced data science techniques into real-world hospital workflows under clinical constraints

## Future Directions

- Expand model scope to emergency surgeries and unplanned admissions
- Develop mobile tools for real-time updates and alerts for clinicians and managers
- Generalize the solution across diverse hospitals and specialties for scalable impact

Thank you for your attention. Questions?