Department of Digital Medical Technologies

Research & Development - Final Projects

מכון טכנולוגי חולון
Holon Institute of Technology

Project Proposal form
Department of Digital Medical Technologies
Holon Institute of Technology HIT (41111)

Attention! The form must be filled out digitally. Do not change the form structure.
A scanned form or one with missing details will not be accepted.

The Project proposal will be submitted up to one month after the project starting day (see moodle for exact date on submission)
The proposal serves as the basis for project research and development process and must include Tasks, milestones and deliverables

Hebrew Year			
ה	פ	ש	ת

Semesters 1+2
Semesters 2+Summer

Date of submission (student): 22.12.2024

A. Student details:

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Student signature

Student signature

B. Project Name:

Anomaly Detection in Operating Room Performance Metrics and Development of a Bed Occupancy Prediction Model.

C. Supervisor's names:

Academic supervisor: Prof. Aviv Gibali, Head of Applied Mathematics Department and Dr. Yariv Marmor, Senior Lecturer, Department of Industrial Engineering and Management in Braude Academic College of Engineering, Karmiel.

External (clinical\industrial) supervisor: Dr. Royi Barnea, Principal Investigator, Assuta Institute for Health Services Research.

D. Background and rationale for the project, description of the problem

Please describe: (1) The background and rationale of the project. (2) Define the problem-what is the challenge the project will address, (3) the Aim of the project.

This section should contain at least 10 lines (note: background is neither the purpose of the project nor the description of the project).

One of the main challenges in hospitals today is the availability of surgical appointments. Patients expect fast and efficient treatment, but delays and long waiting times often lead to frustration. At Assuta Ramat HaHayal, which operates as a private hospital, there are 17 operating rooms. The scheduling system is based on time blocks allocated to each surgeon, which means that if there's an unexpected no-show or cancellation, valuable operating time might go unused. Filling these gaps isn't simple because calling another patient last-minute often requires preparation that can't always be done on the spot.

Another issue lies with hospital beds: recovery room beds and inpatient beds, which are essential for post-surgery recovery. Inpatient rooms have two beds per room and no hallway beds, limiting the number of surgeries that can be scheduled. This causes delays, as the patient "occupies a bed" while waiting to be transferred to the recovery room. Consequently, an operating room cannot be cleaned and prepared for next patient. Without a guaranteed bed, surgeries must be postponed, creating a bottleneck in the system.

In private hospitals like Assuta, the financial model depends on revenue from patients, often through insurance companies, rather than government funding like in public hospitals. Losing patients as clients because of long waiting times or inefficient management has a direct financial impact. Patients who experience delays may choose other hospitals with shorter wait times, which means lost revenue and missed opportunities to meet patient care goals.

This project aims to tackle these issues by analyzing the current scheduling and operational practices to identify bottlenecks, such as underused surgery time slots or recovery and hospitalization bed shortages. It will also explore ways to optimize patient flow, improve scheduling, and ensure better use of resources. Ultimately, the goal is to reduce waiting times, improve patient satisfaction, and help the hospital meet its financial and operational targets without compromising on the quality of care.

E. Project Goals and expected outcomes

Define the specific goals you plan to achieve in this project

The primary goal of this project is to improve the utilization of operating rooms at Assuta Ramat HaHayal. This includes minimizing unused time slots, ensuring a fully booked surgical schedule, avoiding unexpected gaps, and implementing a more effective queue management system. The aim is to create a smoother, more predictable surgical day that maximizes resources without compromising patient care or safety.

One of the key metrics for evaluating operating room efficiency is daily **utilization rate** (ρ), calculated as follows:

$$\rho = \frac{\sum_r \sum_p SU_p + \widetilde{S_p}}{\sum_r SH_r}$$

where SU_p is the set-up time of patient p in the room r, $\widetilde{S_p}$ is the surgery duration within the shift length and SH_r is the shift length of room r.

The Utilization Rate measures how much the operating room is occupied, including anesthesia, preparation and stitching, compared to the total available hours.

Currently, the utilization rate is around 80-82%, but it should not exceed 89%, as going beyond this threshold negatively impacts both the quality of treatment for patients and the performance of surgeons. Overloading the system can also compromise safety standards.

In addition to this metric, a combination of other variables will be explored in later stages to further optimize the process. As part of the solution, we aim to develop a **dynamic prediction model** that considers inpatient bed occupancy and factors such as patient age, underlying health conditions, and other variables that may extend surgery or recovery time. This model will provide accurate predictions of bed availability and surgical timelines.

The final deliverable of the project will be a **visual dashboard** that offers a clear and actionable overview of bed availability, surgical efficiency, and potential scheduling solutions for addressing issues such as "no-shows" for surgeries. This tool will help optimize bed occupancy and improve overall resource management.

The prediction model is expected to forecast inpatient bed occupancy 5-7 days in advance, allowing better planning and scheduling of surgeries. The proposed solution will be tailored for all hospital departments at Assuta Ramat HaHayal, focusing on the unique needs of each discipline. By considering the specific characteristics of different departments, the solution will ensure optimal and department-specific outcomes.

F. The Proposed solution; methods and performance indicators

What is the proposed solution? Please explain how you will achieve the project goals. Please provide detailed methods and performance indicators in which the project will be evaluated, to ensure that the project successfully met the goals

The proposed solution focuses on improving operating room utilization and developing a dynamic prediction model for inpatient bed occupancy. To achieve this, we will implement a combination of data-driven methods and performance metrics to monitor, predict, and optimize hospital resources. The solution includes real-time surgical monitoring, anomaly detection, and the identification of trends to enhance decision-making processes.

Methods and Proposed Steps:

1. **Analysis of Length of Stay (LOS):**
   We will improve the forecast of LOS by reducing the variance for each patient to identify unexpected patterns, such as prolonged hospital stays. Anomalies in LOS may

indicate inefficiencies in treatment or resource allocation. By addressing these inefficiencies, we can improve bed turnover and ensure better resource availability.

2. **Monitoring Hospital-Acquired Infection Rates:**
   Tracking infection rates will provide insights into patient safety and care quality. High infection rates often result in extended LOS, reducing bed availability. By identifying and mitigating these risks, we aim to improve overall hospital efficiency.
3. **Integration of Patient Safety Indicators (PSI):**
   We will use PSI, developed by AHRQ, to identify safety events like postoperative complications or adverse drug reactions. Addressing these issues will enhance care quality and reduce unexpected delays in patient discharge.
4. **Optimization of Turnover Time:**
   Turnover time, the duration required to prepare the operating room between surgeries, will be monitored and optimized. Reducing this time will allow for more surgeries within the same operating hours, improving utilization rates without compromising safety by using data mining and machine learning methods in order to predict bed occupancy time and track bed turnover, and by mining data we can learn about relationships in the data and trends that cause LOS to be extended.
5. **Dynamic Prediction Model for Bed Occupancy:**
   Using big data analysis tools, we will develop a dynamic prediction model capable of forecasting inpatient bed occupancy 5-7 days in advance by using computational methods. This model will incorporate variables such as patient demographics, comorbidities, and surgery types to provide accurate predictions and improve scheduling.
6. **Identification of Anomalies and Trends in Data:**
   Through database analysis, we will identify key metrics and outliers, enabling better understanding and management of resources. By detecting trends, we can make proactive adjustments to improve operating room efficiency and optimize bed usage.

Expected Deliverables:

1. **Improved Utilization Rates:**
   By addressing inefficiencies and enhancing data-driven decision-making, the proposed solution aims to increase operating room utilization to an optimal level (between 81-89%) and improve inpatient bed turnover.
2. **Real-Time Monitoring Dashboard:**
   A visual dashboard will display real-time metrics, including LOS, infection rates, turnover time and bed availability. This tool will help hospital staff make informed decisions and quickly respond to unexpected situations.
3. **Predictive Model and Insights:**
   The prediction model will allow hospital management to anticipate resource needs, such as bed availability, and schedule surgeries accordingly. It will be tailored to the specific needs of each department within Assuta Ramat HaHayal, considering the unique characteristics of different disciplines.

Performance Indicators:

- Improved operating room utilization within safe limits (81-89%) by optimizing surgeons' time blocks, reducing unused gaps, and improving scheduling efficiency to minimize cancellations.
- Observe better performance accuracy in average LOS when implementing the model.

- Reduction in turnover bedtime.
- Decrease in hospital-acquired infection rates.
- Improved forecast accuracy for bed occupancy (measured in days).

G. The research and development plan

List the main tasks to achieve the goals of project.

Research and Development Plan

1. **Data Collection, Preprocessing, and Visualization:**
   Before performing analysis and building predictive models, we will first collect and preprocess the data, including handling missing or outlier values (EDA). We will then create visualizations to identify patterns and trends in the data, which will help in understanding key insights and preparing the data for accurate forecasting.
   To forecast surgical duration, we will use statistical and machine learning techniques, starting with exploratory data analysis (EDA) using Python libraries like Pandas and Matplotlib to identify patterns and trends in the data. Based on the data structure and availability, we plan to implement regression models, such as Linear Regression or Decision Trees, using Scikit-learn to predict surgery durations. These models will incorporate variables such as patient demographics, surgery type, and historical trends.
   The model's performance will be evaluated using metrics like Mean Absolute Error (MAE) and R-squared (R^2), and cross-validation techniques will be applied to ensure robustness. For handling uncertainty and variability in predictions, we will consider robust optimization methods to improve scheduling efficiency. For further validation and testing, libraries like NumPy and SciPy will be utilized to fine-tune the model and improve accuracy.
2. **Analyzing Existing Trends in Operating Rooms by analyzing the database:**
   We will perform database analysis to evaluate surgical duration, inpatient length of stay (LOS), operating room utilization, and turnover numbers as key outcome measures. Additionally, we will identify and compare trends across different departments in the Assuta network, including orthopedics, gynecology, ENT, and others. These findings will be used to highlight operational efficiencies and discrepancies specific to each medical discipline.
3. **Developing a Predictive Model for Bed Occupancy (5 Days in Advance) by tools for analyzing big data:**
   We will utilize advanced big data analysis tools to create a predictive model for inpatient bed occupancy based on the scheduled surgical plans. The model will incorporate variables such as the type and duration of surgeries, as well as department-specific characteristics, to ensure accurate forecasting. These insights will help optimize bed allocation and improve surgical scheduling efficiency.

H. References

1. Dexter, F., & Traub, R. D. (2007). Operating room efficiency and hospital capacity: Factors affecting operating room turnover and utilization. *Journal of the American College of Surgeons, 204*(5), 845–852. https://doi.org/10.1016/j.jamcollsurg.2007.01.030

2. Marmor, Y. N., Rohleder, T. R., Huschka, T., Cook, D., & Thompson, J. (2011). A simulation tool to support recovery bed planning for surgical patients. *Proceedings of the 2011 Winter Simulation Conference*, 1338–1344. https://citeseerx.ist.psu.edu/document?repid=rep1&type=pdf&doi=16ba94de21edc49d85136d465c6fb15719a80bb8

3. Dulskas, A., Samalavicius, N. E., & Urbanavicius, R. (2023). Operating Room Performance Optimization Metrics: A Systematic Review. *Journal of Medical Systems, 47*(2), Article 19. https://doi.org/10.1007/s10916-023-01912-9

4. Tumin, D., & Tobias, J. D. (2022). Operating Room Relay Strategy for Turnover Time Improvement: A Quality Improvement Initiative. *BMJ Open Quality, 11*(3), e001957. https://doi.org/10.1136/bmjoq-2022-001957

I. Risk analysis table

List main tasks as well as development risks (if any) and how you will overcome these risks

Description of risk (Severity: Minor, Severe, Critical; Likelihood: Low/Medium/High)	Proposed risk-mitigation measures
Data quality issues: Missing or incomplete data from hospital records (Severity: Severe; Likelihood: Medium)	**Conduct thorough data validation and cleaning processes. Implement algorithms to handle missing data (e.g., imputation methods).**
Model accuracy: Predictive model may not achieve high accuracy due to insufficient training data, or overfitting the model to the data (Severity: Severe; Likelihood: Medium)	**Collect additional data and use advanced machine learning techniques. Validate the model with cross-validation and external datasets.**

Description of risk (Severity: Minor, Severe, Critical; Likelihood: Low/Medium/High)	Proposed risk-mitigation measures
It is difficult to increase utilization without adding new beds under the constraints of adjacent waiting times for surgery and the restrictions discussed in the previous sections. (Severity: Severe; Likelihood: Medium)	• Prolonged setup times between surgeries: Use a Linear Programming optimization algorithm to group surgeries requiring similar equipment and preparation, minimizing transition/setup times. • Idle time caused by suboptimal scheduling: Develop a predictive model using historical data (e.g., surgery duration, equipment needs) to optimize scheduling and fill idle gaps with shorter procedures. • Variability in surgery durations: Implement Random Forest Regression to accurately predict surgery durations, accounting for procedure type, equipment, and team experience.
Resistance to change: Staff may be reluctant to adopt new tools and workflows (Severity: Minor; Likelihood: High)	Provide training sessions and clear documentation. Highlight benefits of the system to encourage adoption.

Name of academic supervisor	Date	Signature
Prof. Aviv Gibali	22/12/24	
Dr. Yariv Marmor	22/12/2024	

Gantt Project Activities

This table will be updated during the project by the student(s) according to the development of the project,
Both the students and the supervisor will hold a copy of this table

**** The student must complete two additional milestones according to the nature of the project and in coordination with the supervisor, for example: learning the platforms, developing a prototype, submitting for testing by stages, etc.**

		Month								
Task	Detail / Format	Milest one	1	2	3	4	5	6	7	8
Project proposal form, submitted	PDF file and Word file.	1	X							
Data collection	Collect data from the hospital's records.		X	X	X					
Data Cleaning, and Preparation (Basic EDA): • Organize and clean the data to make it ready for analysis. • Find trends and key metrics to identify areas for improvement.	Python code: • Handle missing values and outliers. • Organize the data into a structured format. • Create simple visualizations to identify initial patterns. Format: clean dataset in CSV format and a short report (Word/PDF). Analyzing Trends and Patterns (Advanced EDA): • Analyze surgery durations, inpatient length of stay (LOS), and operating room utilization. • Identify patterns and trends across different departments (e.g., orthopedics, gynecology). • Highlight inefficiencies, such as long waiting times or underutilized operating rooms. Format: Report of the visualizations (Word/PDF).		X	X	X					
Building a Model to Predict Surgery Duration	Python code: • ML methods like Linear Regression or Decision Trees.			X	X	X	X	X		

• **Develop a model to predict surgery durations based on patient and surgery data.**	• **Evaluate model performance with metrics like MAE and R^2.** • **Apply cross-validation and optimize the model for better accuracy.** **Format: Python script along with a summary of results in Word/PDF.**									
Submitting an Interim Report	**PDF file and Word file.** **will be submitted by the supervisor according to the submission date indicated in the box found on Moodle**	2			**X**					
Developing a Predictive Model for Bed Occupancy (5 Days in Advance) • **Build a dynamic model to forecast inpatient bed usage to improve scheduling.**	**Python code:** • **big data tools to predict bed occupancy based on surgery plans.** • **Variables like surgery type, duration, and department characteristics.** • **Predictions to optimize resource allocation.** **Format: Python script with the model, along with a report in Word/PDF.**					**X**	**X**	**X**		
Real-Time Dashboard • **Develop a dashboard to display live data for better decision-making.**	**Dashboard in Power BI:** • **Include key metrics like surgery times, bed availability, and infection rates.** • **Integrate the predictive models into the dashboard.** • **Allow interactive use for quick adjustments based on real-time data.**					**X**	**X**	**X**	**X**	
Project book submission and results	● **Project Book** ● **Project Poster** ● **Project video** ● **The product (algorithm/code/predictive model/software/ article)**	3							**X**	
Oral Exam	● **Oral-Exam Presentation**	4								**X**