IMPROVE OPERATION THEATRE SCHEDULING TO OPTIMISE RESOURCE UTILISATIOM

IE 3100M System Design Project (AY2020/2021)
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Overview

Company Background

Founded in 1985, National University Hospital (NUH) was Singapore's first restructured hospital.

Currently, NUH is a tertiary hospital and major referral centre with over 50 medical, surgical and dental specialities. The hospital attends to more than one million patients every year.

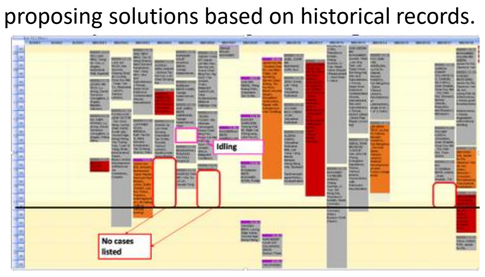
As of 2020, the hospital has over 1200 beds and 33 Operation Theatres (OTs) to accommodate the high demand of surgeries.

Problem Description

The MBOT has 18 Operation Rooms (ORs), and the scheduling is currently done by a management system OOTS. The OR slots are allocated by different departments and within the department, the HODs will then decide on how to allocate the given slots amongst its sub-specialties or their surgeons.

The problem lies in scheduling of surgery cases is not always the optimal. There are idling periods for the ORs in between some surgery.

To increase current utilisation rate of 0.8, industrial supervisors advised on exploring different assignment of Free-for-all (FFA) slots on scheduling system's performance, and proposing solutions based on historical records.



Red: No cases listed

Pink: Idling status

Objective

Develop a simulation model for MBOT scheduling system to test proposed ideas and to assist future analysis

Recommend and provide NUH actionable allocation plans to improve utilisation rate of ORs

Methodology Stages

Data Processing
- Identify discrepancies between allocated slots for disciplines and their actual demand
- Select potential ORs that can be selected as FFA ORs

Idea Generation
- Find out root causes of OT under-utilisation
- Propose solutions based on insights from historical data

Model Development
- Build the simulation model with O2DES
- Estimate input parameters from past data

Results Analysis
- Test proposed ideas by using simulation model
- Identify the relatively optimal solutions based on simulation results

Recommendation
- Advice on how to implement each approach
- Evaluate and recommend the most optimal approach

Data Processing

$$Proportion\ of\ one\ discipline = \frac{Actuall\ demand\ of\ one\ type\ of\ surgery\ (duration\ in\ minutes)}{Actual\ total\ surgery\ demand\ (duration\ in\ minues)} \times 100\%$$

$$Ideal\ number\ of\ slots\ in\ a\ week = 68 \times Discipline\ proportional\ weights$$

Where 68 is the total no. of timeslots in a week

Discipline	Current allocation	Optimal Allocation	Suggestion
CTVS	16	17	+1
Orthopaedic Surgery	6	7.5	+1.5
Urology	4.5	5.2	+1
Otolaryngology & Head & Neck Surgery (ENT)	7	6.6	-0.5
Obstetrics & Gynaecology (OG)	9.5	8.9	-1

Model Development & Results

Proposed Approaches

1. Allocation plan with optimal FFA proportion

To identify the optimal utilisation rate to FFA slot ratio by exploring the relationship between no. of FFA slots and the utilisation rate.

Highest Priority to be selected as FFA OR

Rest of the ORs	OR 6	OR 14	OR 5
1) ORs 4, 10 and 11	1) OG has low demand	1) Most of the disciplines allocated have low count 2) Current allocation assigned for FFA	1) OG has low demand 2) Current allocation assigned for FFA

2. Data-based allocation plan

To adjust resources allocated to each discipline to reduce discrepancies between the allocated OR slots for disciplines and their demand based on historical data.

3. Integrated approach

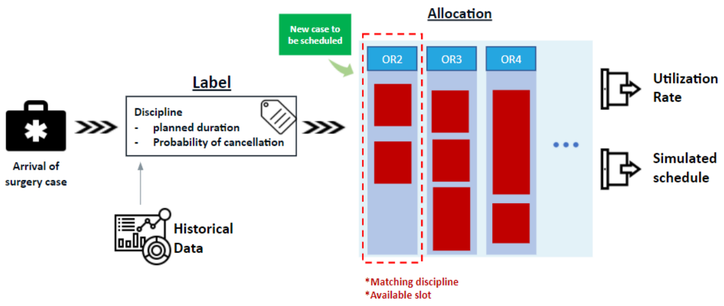
To develop a balanced solution by combining the first two approaches.

Relevant Tools

O²DES.NET SIMULATION FRAMEWORK

In order to test the proposals, a simulation model of the MBOT system is built using concepts of object-oriented programming and discrete-event simulation.

Model Illustration



The simulation starts with the **arrival of the surgery requests**, the type of surgery is determined by the **probabilities based on historical data**. Based on the discipline, case is labelled with **planned duration** and **probability of cancellation**. Surgery case is scheduled into the OR slot with the criteria of **OR-Discipline matching** check and **OR availability**. From the model, we have **utilisation rate** as the performance metrics.

Model Output

```
11-Mar-21 17:05:12      Orthopaedic      03:30:56.1775055        0.21
11-Mar-21 17:27:15      CardiacThoracicAndVascular       03:38:38.8720005        0.16
11-Mar-21 17:32:12      ObstetricsAndGynaecology         03:56:02.1952802        0.23
11-Mar-21 17:55:21      ObstetricsAndGynaecology         01:40:04.8821204        0.23
11-Mar-21 20:46:54       Suregery Request Cancelled      Paediatric       01:42:23.6896811        0.16
11-Mar-21 22:42:35       Suregery Request Cancelled      Surgery 00:15:02.4581701        0.21
12-Mar-21 00:00:00      Statistics Collected!! Utilization: 0.7334225123988137
```

The model output consists of **arrival time**, **discipline**, **estimated surgery duration**, **probability of cancellation** of surgery requests. Cancelled cases are also captured in the output. At the end of every simulation duration, the **utilisation rate** of ORs is computed.

Results Analysis

Summary table for Approach 1

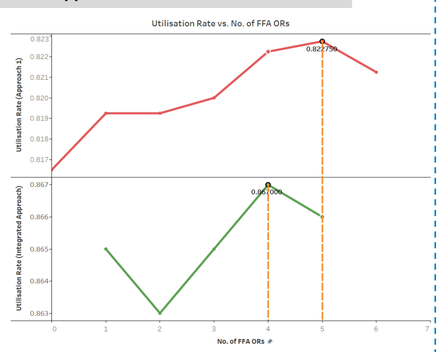
Permutation	No. of FFA OR	FFA proportion	Utilisation rate
Current allocation (based on model)	0	0%	0.817
OR 5	1	7%	0.819
OR 5, 14	2	14%	0.819
OR 5, 14, 6	3	21%	0.820
OR 5, 14, 6, 4	4	29%	0.822
OR 5, 14, 6, 4, 10	**5**	**36%**	**0.823**
OR 5, 14, 6, 4, 10, 11	6	43%	0.821

From results in Approach 1, the optimal FFA proportion is identified to be 36% (5 FFA ORs). The best utilisation rate is **0.823**.

Utilisation rate for Approach 2 = 0.865

Summary table for Integrated Approach

No. of FFA OR	FFA proportion	Utilisation rate
1	7%	0.865
2	14%	0.863
3	21%	0.865
4	29%	0.867
5	36%	0.866



Results in Integrated approach (Approach 3), shows the optimal FFA proportion after adopting the data-based allocation plan is 29% (4 FFA ORs). Best utilisation rate is **0.867**.

Recommendations

Evaluation of Approaches

< Approach 1 >
- Utilisation rate = 0.823
- Low feasibility (Constraints on equipment and manpower)
- Very difficult to manage (Frequent turnovers)
- Potentially higher cost

< Approach 2 >
- Utilisation rate = 0.865
- High feasibility (Mainly one-time reallocation of resources)
- Easy to manage
- Reasonable cost

< Approach 3 >
- Utilisation rate = 0.867
- Reasonable feasibility (One-time reallocation of resources and fewer FFA slots)
- Difficult to manage
- Reasonable cost

Multi-Criteria Decision Analysis

Rank	Attribute	Weight	Approach: Optimal FFA proportion	Approach: Data-based allocation	Approach: Integrated approach
1	Performance	52.1	1	4	5
2	Feasibility	27.1	1	4	2
3	Affordability	14.6	2	4	3
4	Ease of Management	6.3	2	4	3
	Overall		1.21	**4.004**	3.774

Based on current setting, the data-based allocation approach (Approach 2) shows the best overall performance.

Depending on current priority of NUH, attributes may be ranked differently. As a result, overall scores for each solution may change drastically, leading to different conclusions.

Future Directions

Limitations

- **Fundamental Blocks:** The model designed uses the ORs in the scheduling system as a fundamental block as compared to the actual MBOT system which uses a specific timeslot.
- **Scope of Performance Indicators:** Currently, the model only outputs the utilisation rate as a performance indicator. It does not take into consideration the number of surgery cases in the queue.

Future Direction

- Improvements can be made to the simulation model to solve above limitations.
- The programming environment of the simulation model can be designed to be more intuitive and user-friendly to enable a smoother handover to NUH.