Optimising Cardiac Catheterisation Laboratory Utilisation and Reporting

NUS National University of Singapore

Department of Industrial Systems Engineering and Management

IE3100M Systems Design Project (Group 4) AY2017/2018
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National Heart Centre Singapore
SingHealth

1. Background

❖ Company Information & Problem Description

NHCS is a public healthcare institution that specialises in heart care. At present, the centre has six rooms in the Catheterisation Laboratory (Cath Lab), with four rooms equipped to perform minimally invasive test and procedures, such as angiogram, angioplasty and implantation of pacemakers. The other two rooms could be equipped and put into operation should demand increases significantly.

Currently, the centre is experiencing low utilisation of its rooms. With an increase in healthcare demand due to an ageing population in Singapore, NHCS is required to optimise the use of its resources by tackling operational inefficiencies that contribute to its low utilisation rates in order to meet this growing demand in a sustainable manner.

This project aims to help NHCS develop a better work flow by introducing an automated data management tool and proposing solutions to improve the current work schedule, to raise its utilisation rates and operational efficiency.

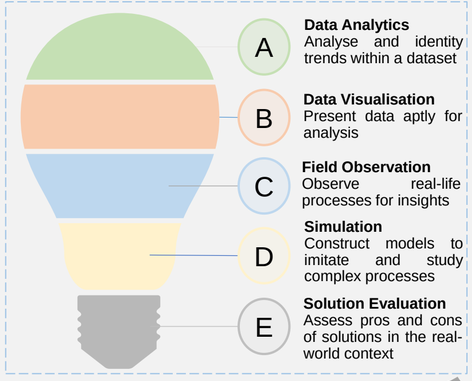
❖ Key Objectives

Automated Data Cleaning
Standardise and automate the data cleaning process to reduce data processing time

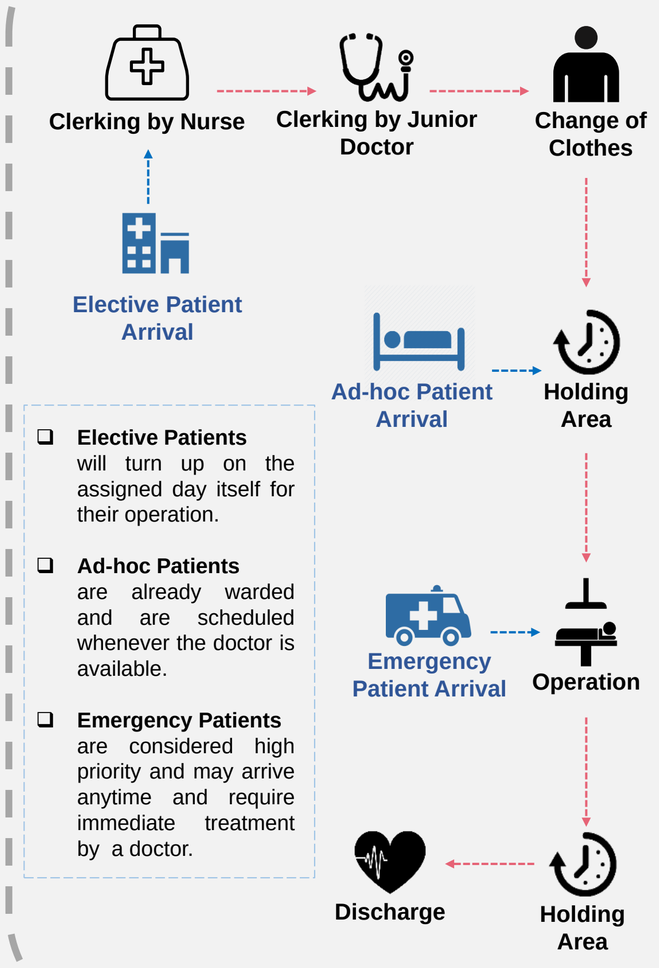
Easy Monitoring & Reporting
Automate the data visualisation tool to reduce graph generation time for reporting

Cost-Efficient Work Plan
Propose solutions to improve the utilisation rates to the industrial average level

❖ Key Skillsets



2. Process Flow



- ❑ **Elective Patients** will turn up on the assigned day itself for their operation.
- ❑ **Ad-hoc Patients** are already warded and are scheduled whenever the doctor is available.
- ❑ **Emergency Patients** are considered high priority and may arrive anytime and require immediate treatment by a doctor.

3. Methodology

1. Automation of Data Visualisation → **2. Data Analysis** → **3. System Simulation** → **4. Sensitivity Analysis** → **5. Evaluation of Proposed Solutions**

The original manual data processing tool using Excel is replaced with an automated tool using a combination of VBA and Tableau to reap the following benefits:

- √ Fully automated to save time and costs
- √ Operationally efficient
- √ Easy to pick up and maintain for new users
- √ Possible to integrate with other SingHealth institutions

Various charts generated from the automated data visualisation method are analysed to identify factors that contribute to low utilisation rates. These factors are verified through interviews with hospital staff and then modelled using system simulation to identify critical factors that significantly impact utilisation rates, in order for solutions to be proposed to tackle them.

A base model is built to simulate the current work conditions and workflow of the Cath Lab. There are four key steps in building the model, namely making assumptions, input modelling, code-crunching and output validation. The model must be able to achieve a high degree of flexibility to accommodate service customisation in the healthcare industry to reflect the system performance accurately.

By varying the key parameters in the base model, performance of the lab could be assessed through sensitivity analysis of the factors. Scenario analysis is subsequently conducted by varying several key factors simultaneously to derive the system performance under the best and worst scenarios. The model is also useful for analysing new scenarios such as testing lab capacity in the face of rising demand for heart care.

Solutions are proposed to specifically address the sensitive factors identified and improve lab utilisation rates. These solutions are evaluated with five criteria:

- ➢ Financial cost
- ➢ Doctor's willingness
- ➢ Disruption to the current workflow
- ➢ Effectiveness
- ➢ Sustainability

to compare their strengths and weaknesses.

4. Visualisation Findings

❖ Utilisation Heatmap

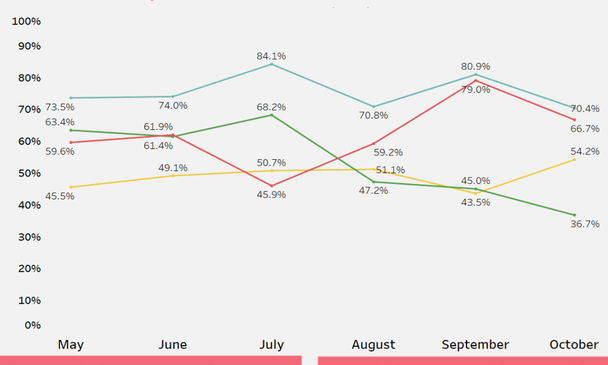
Average room utilisation during the day

	Room 1	Room 2	Room 5	Room 6
8:00	0.0%	0.0%	0.0%	0.0%
8:15	4.5%	4.5%	0.0%	0.0%
8:30	18.2%	13.6%	9.1%	0.0%
8:45	31.8%	22.7%	9.1%	13.6%
9:00	50.0%	40.9%	18.2%	22.7%
9:15	54.5%	59.1%	22.7%	27.3%
9:30	63.6%	68.2%	22.7%	36.4%
9:45	68.2%	63.6%	22.7%	40.9%
10:00	59.1%	86.4%	22.7%	40.9%
10:15	54.5%	90.9%	22.7%	36.4%
10:30	63.6%	90.9%	27.3%	31.8%
10:45	68.2%	86.4%	27.3%	36.4%
11:00	68.2%	95.5%	36.4%	40.9%
11:15	77.3%	86.4%	36.4%	45.5%
11:30	68.2%	81.8%	36.4%	45.5%
11:45	68.2%	81.8%	45.5%	45.5%
12:00	68.2%	72.7%	54.5%	45.5%
12:15	72.7%	68.2%	50.0%	36.4%
12:30	77.3%	68.2%	40.9%	36.4%
12:45	54.5%	68.2%	36.4%	31.8%
13:00	59.1%	54.5%	31.8%	36.4%
13:15	59.1%	54.5%	22.7%	36.4%
13:30	54.5%	54.5%	22.7%	36.4%
13:45	63.6%	50.0%	36.4%	54.5%
14:00	63.6%	59.1%	31.8%	59.1%
14:15	68.2%	68.2%	40.9%	59.1%
14:30	72.7%	63.6%	45.5%	54.5%
14:45	81.8%	68.2%	45.5%	54.5%
15:00	77.3%	63.6%	45.5%	59.1%
15:15	72.7%	59.1%	45.5%	45.5%
15:30	68.2%	68.2%	50.0%	45.5%
15:45	63.6%	59.1%	50.0%	40.9%
16:00	63.6%	59.1%	31.8%	45.5%
16:15	59.1%	54.5%	36.4%	45.5%
16:30	54.5%	63.6%	36.4%	31.8%
16:45	54.5%	59.1%	27.3%	27.3%
17:00	63.6%	54.5%	13.6%	31.8%

Legend: 0.0000 – 1.0000

❖ Utilisation Rates (2016)

Monthly utilisation rates for the four rooms in Lab 1



Key Observations

- ❖ **Rooms start late**
  Rooms should start at 8am, but low utilisation rates are observed in the first 30 to 60 minutes.
- ❖ **Rooms end early**
  Rooms should end at 5pm, but utilisation rates decline in the last 1 to 2 hours before 5pm.
- ❖ **Idleness during the day**
  Low utilisation rates are sometimes observed during the day due to rooms being left idle.

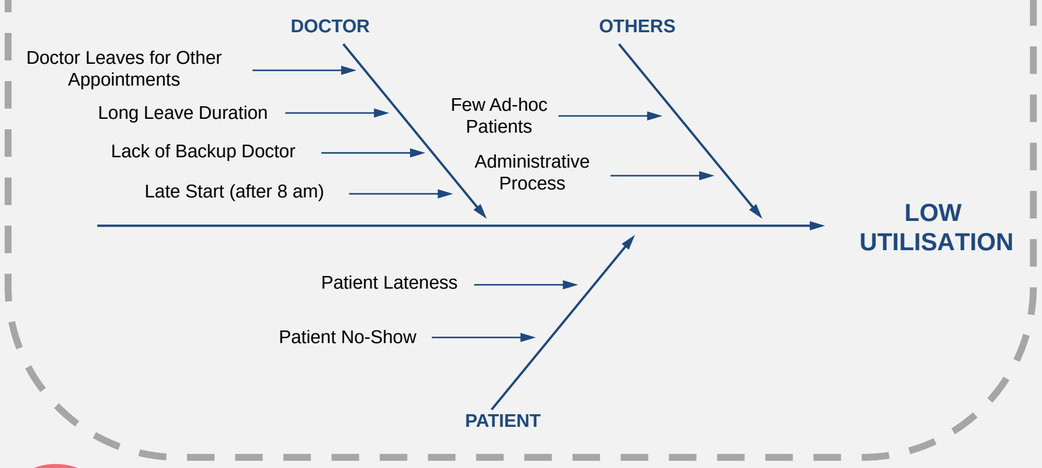
The factors that lead to these observations presented in the fishbone diagram below.

Charts Plotted

The following types of graphs are plotted in the dashboard. *Overall Utilisation by Room* is shown above to show the large fluctuations in utilisation rates over time while *Intraday Utilisation (Heat Map)* is included on the left to demonstrate the key observations from analyzing the various charts.

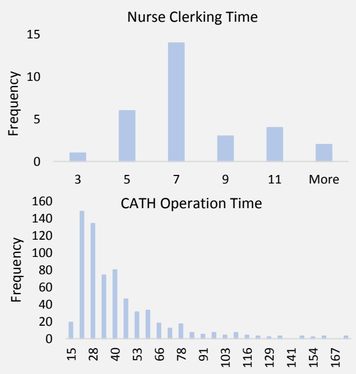
- ❑ Overall Utilisation by Room
- ❑ Lab Utilisation by Doctor
- ❑ Lab Utilisation by Case Type
- ❑ Intraday Utilisation (Heat Map)
- ❑ Lab Start and End Time
- ❑ Lab Workload

❖ Fishbone Diagram – Cause Analysis



5. Simulation Findings

❖ Input Modelling



➢ Key parameters for clerking time

	Nurse	Junior Doctor	Change Clothes
Distribution	Weibull	Lognormal	Weibull
Parameters	$\alpha = 3.7009$ $\beta = 7.774$	$\mu = 2.6052$ $\sigma = 0.35827$	$\alpha = 3.152$ $\beta = 4.411$

➢ Key parameters for operating time

	PTCA	CATH	Emergency
Distribution	Lognormal	Lognormal	Lognormal
Parameters	$\mu = 3.8952$ $\sigma = 0.62122$	$\mu = 3.4964$ $\sigma = 0.55352$	$\mu = 3.8434$ $\sigma = 0.52426$

❖ Output Validation

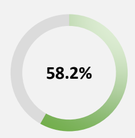
Simulation Utilisation	Historical Utilisation
58.2%	58.8%

Hypothesis Testing

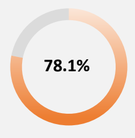
- ❑ **Null hypothesis:** historical data could be described by this model.
- ❑ **Alternative hypothesis:** historical data could not be described by this model.
- ❑ Test at 5% significant level, null hypothesis is not rejected.
- ❑ The model is reliable.

❖ Scenario Analysis

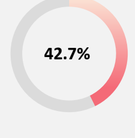
Overall Utilisation



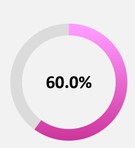
Base Case: Modelled under current parameters and process flow.



Best Case: All delaying factors are improved by 50% simultaneously. The resulting utilisation is close to the target utilisation (80%) of NHCS, which shows that this is indeed feasible if all the delaying factors are within control.

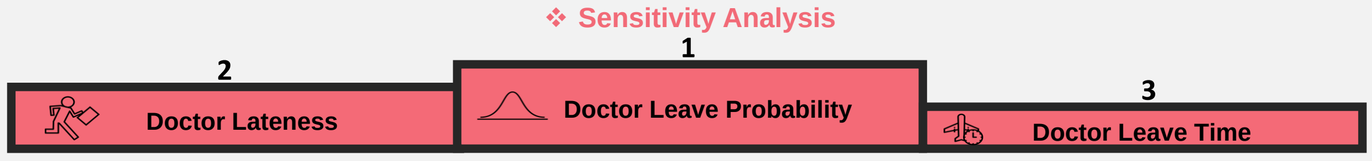


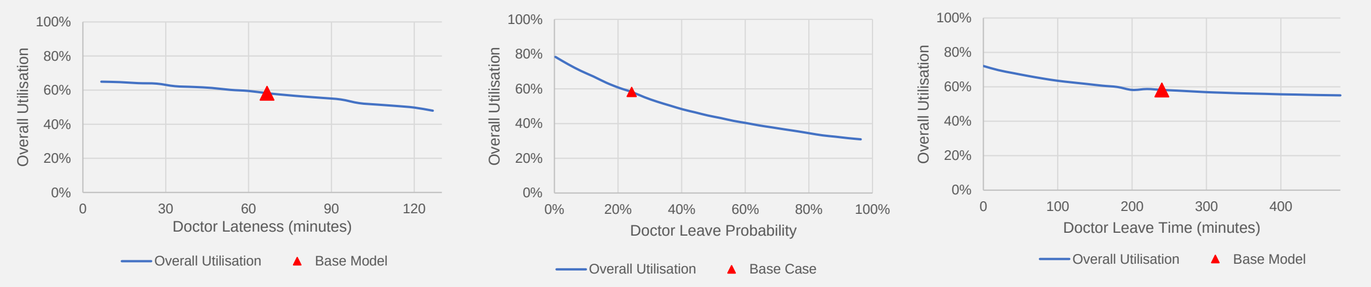
Worst Case: All delaying factors are deteriorate by 50% simultaneously. The resulting utilisation sets a lower bound for the analysis.



Reduce One Room: The number of rooms is reduced from 4 to 3 while the total number of elective patients scheduled per day remains unchanged. Overall utilisation only increases marginally from the base case, which aligns with NHCS's feedback that reducing rooms to boost utilisation is not as satisfactory as expected.

❖ Sensitivity Analysis





Currently, doctors on average start the day 67 minutes later than the official starting time of 8am. If doctors can cut this lateness to 20 minutes, the overall utilisation can be improved by 10.1%.

The probability of doctors taking leave is found to be 24.3% on average, based on historical records. If this probability could be reduced to 10%, the overall utilisation rate can be improved by about 12% and reach 70%.

The mean duration of doctors taking leave is about 4 hours. If the mean leave time could be reduced to 2 hours, the overall utilisation could be improved by 7.4%.

6. Recommendations

❖ Biometric Attendance System

- Doctors need to clock in and out when they report to office and leave office

✓ Discourage lateness and unplanned leaves during the day

❖ Standby Doctor

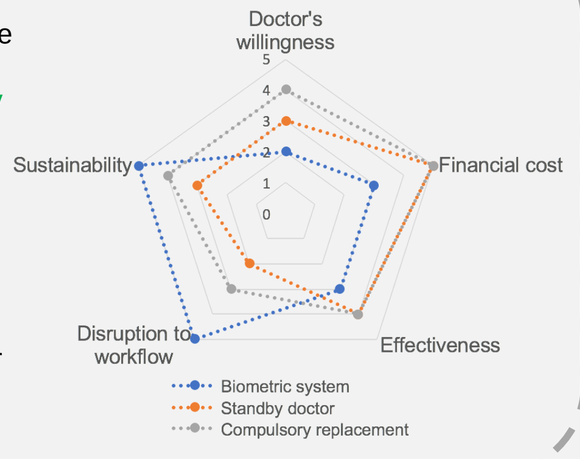
- Plan a standby doctor on each day to cover for doctors who are on leave or away for conferences

✓ Reduce idleness of rooms due to doctors taking leaves

❖ Compulsory Replacement

- Doctors are required to find their own replacement doctor if they intend to take leaves on certain days

✓ Reduce idleness of rooms due to doctors taking leaves



7. Future Directions

❖ With Four Rooms in Operation

8 elective patients a day
Last operation ends at **around 9pm**

9 elective patients a day
Last operation ends at **around 11pm**

10 elective patients a day
Last operation ends **after midnight (12am)**

❖ Key Insights

- Impractical to purely increase doctors' workload to meet rising demand
- The decision whether to increase the rooms in operation should be made by considering desired productivity, reasonable workload for doctors and their tolerance for overtime