IMPROVING MRI MACHINE UTILISATION AND PROCESS EFFICIENCY

IE3100R Systems Design Project| Department of Industrial and System Engineering

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ABSTRACT: Magnetic Resonance Imaging (MRI) is one of the diagnostic imaging services provided in National University Hospital (NUH) . Over the last 3 years, the number of MRI scanners increased from 3 to 6 scanners to meet the growing requests for MRI service. With the increasing demand for healthcare and quality diagnostic imaging services, it is crucial for NUH to improve the current level of machine utilisation and process efficiency. By adopting the DMAIC framework, this project is centered on improving asset utilisation, productivity and throughput.

1. DEFINE

Machine Distribution

Functional Imaging Centre (FIC)

Kent Ridge Wing (KRW)   **NUH Medical Centre (NMC)**

Project Goals
- Define utilisation and evaluate current status
- Identify wastages and workflow deficiencies
- Assess capability to cope with future demand

Key Constraints

- 3 Locations: FIC, KRW, NMC
- Only FIC serves Inpatients
- 14 Radiographers go through rotation at each location
- Demand should meet target appointment turnaround time (ATT) by priority and patient type

Priority	Target Appointment Turnaround Time (ATT)		
	Inpatient	Private	Subsidised
STAT	< 24 hours	1-2 days	
Early	1-3 days		<7 days
Routine	< 7 days		<21 days

2. MEASURE

Current Utilisation

Current Utilisation Rate
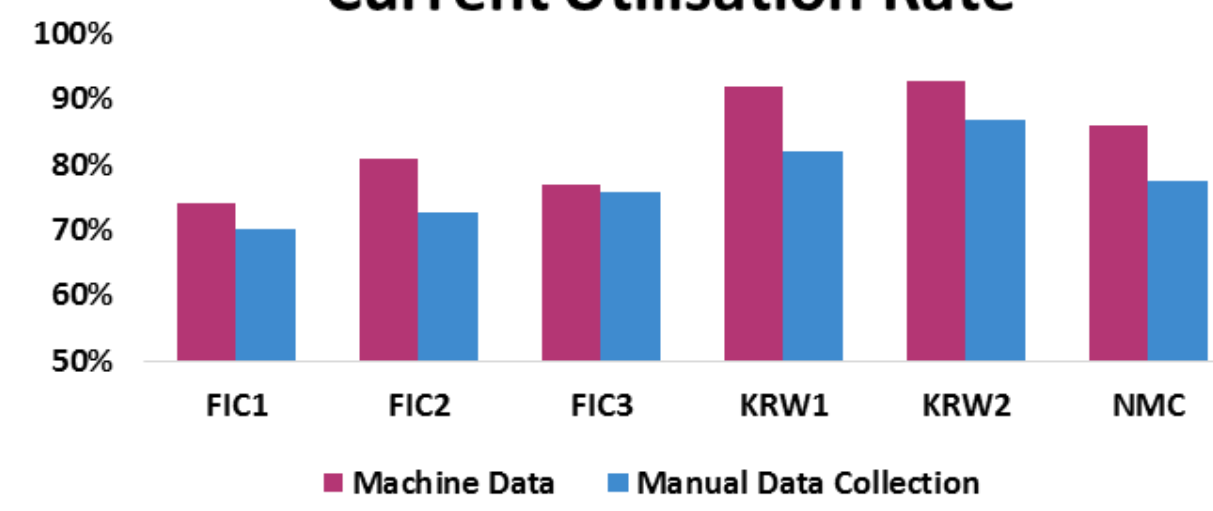
Data Source: Apr '15 - Dec '15 Machine Use Report (Machine and Manual Collection)

Data Collection
- Patient profiles (Patient type, Priority, Scan type, etc.)
- List of MRI procedures (over 100) and expected procedure time
- Standardised machine use data (time in/out)

① **System recording errors**
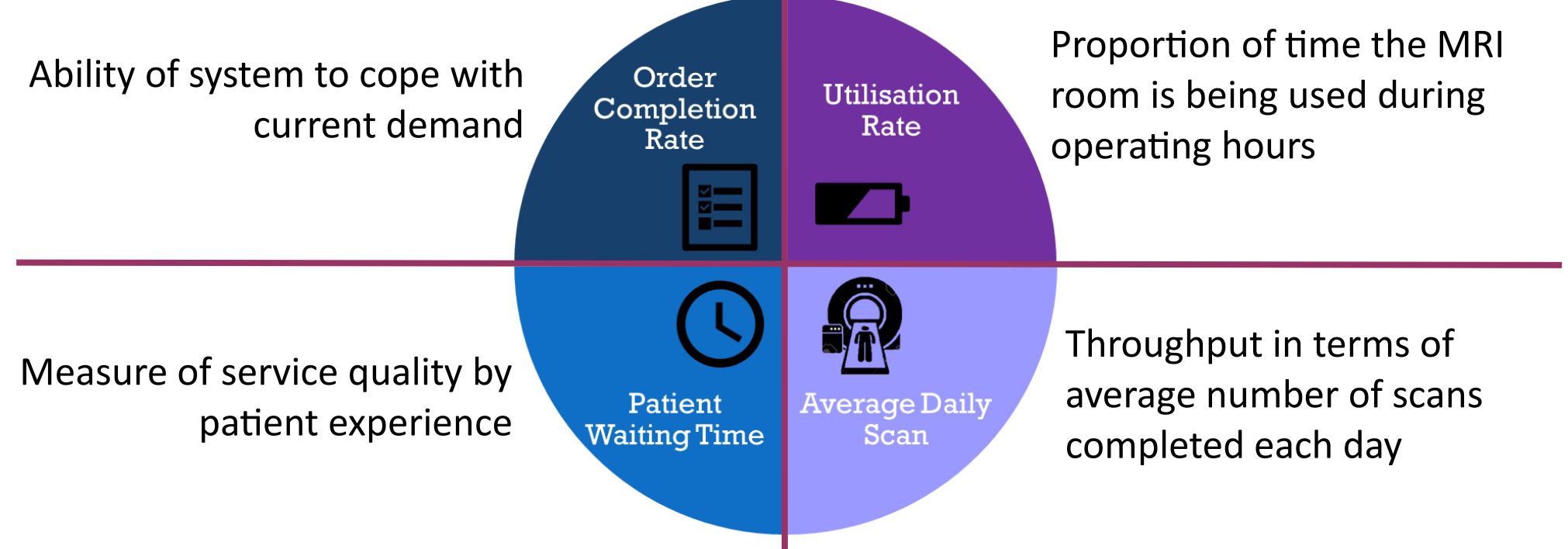- Inconsistency and human error in the practice of recording start and end times

② **Uneven utilisation rates**
- Complexity in dealing with inpatient cases but not accounted for (e.g sedation)
- Outpatient no-show is a common occurrence

Ground Observation
- High variability in patient arrival rate
- Outpatient no-shows result in idle rooms at KRW and NMC
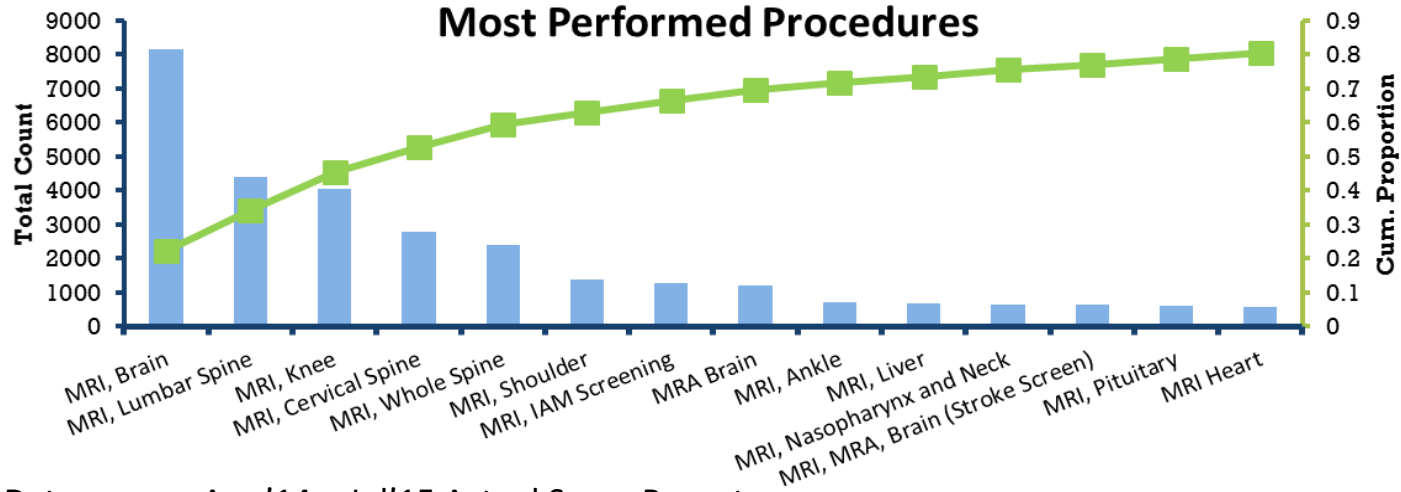- 3-way information gap between doctors, radiographers, and schedulers

Performance Metrics

Ability of system to cope with current demand — **Order Completion Rate**

Utilisation Rate — Proportion of time the MRI room is being used during operating hours

Measure of service quality by patient experience — **Patient Waiting Time**

Average Daily Scan — Throughput in terms of average number of scans completed each day

3. ANALYSE
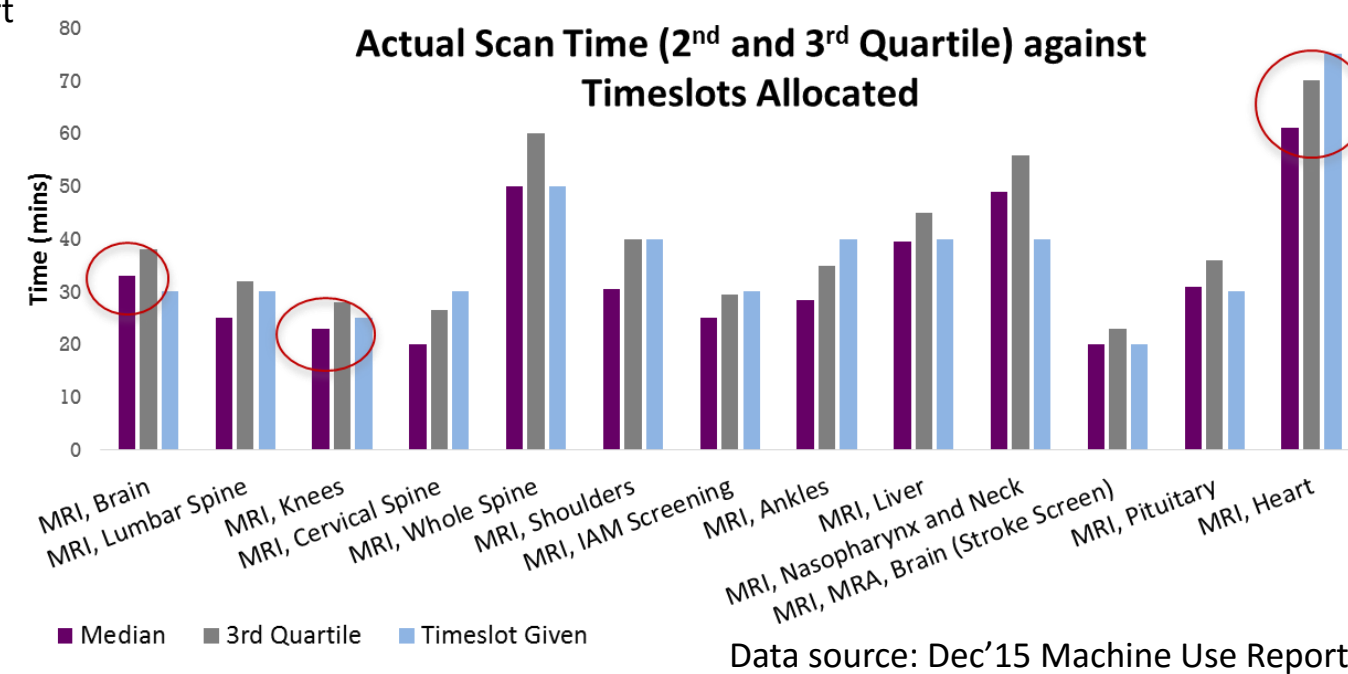
Statistical Analysis

Most Performed Procedures

Data source: Apr '14 - Jul'15 Actual Scans Report

① **Areas of Focus**
- Applying the Pareto Principle, 14 types of scans account for 80% of all scan demanded

② **System Variability**
- Inaccurate timeslots used in scheduling of appointments result in high variability and wastage in the system
- Recommendation: Reevaluate expected scan time

Actual Scan Time (2nd and 3rd Quartile) against Timeslots Allocated

Data source: Dec'15 Machine Use Report

Demand Analysis

Priority	% met within target ATT (in 2015)	
	Inpatient	Outpatient
STAT	100%	78%
	Inpatient & Private	Subsidised
Early	91%	37%
	Inpatient & Private	Subsidised
Routine	57%	30%

Data source: 2015 Actual Scans Report

① **Demand Profile**
- % met within target ATT may provide an indication of the level of backlog
- 3 in 10 cases are inpatient
- 20% of outpatients fail to turn up for their appointments on average
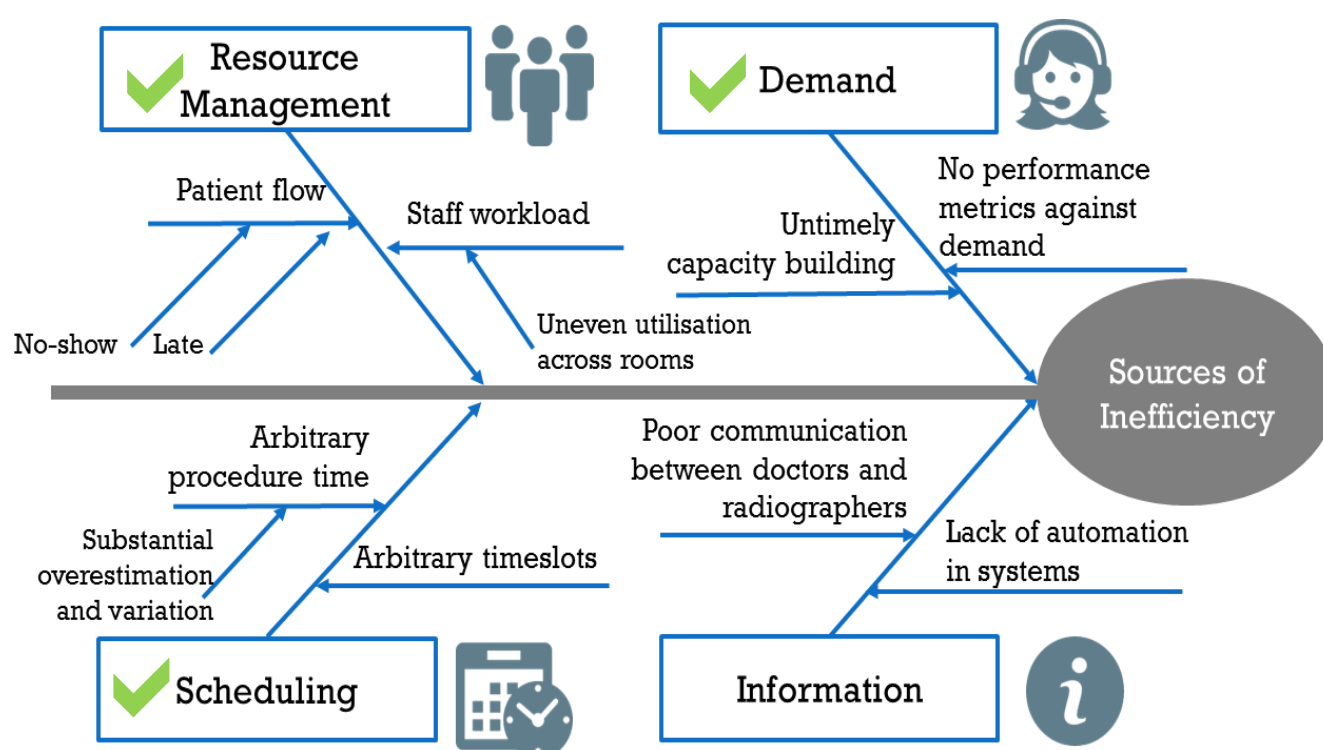
Root Cause Analysis

① **4 Root Causes**
- This project focuses on 3 out of the 4 root causes identified
- Factors addressing *Information* as a root cause is beyond the scope of this project
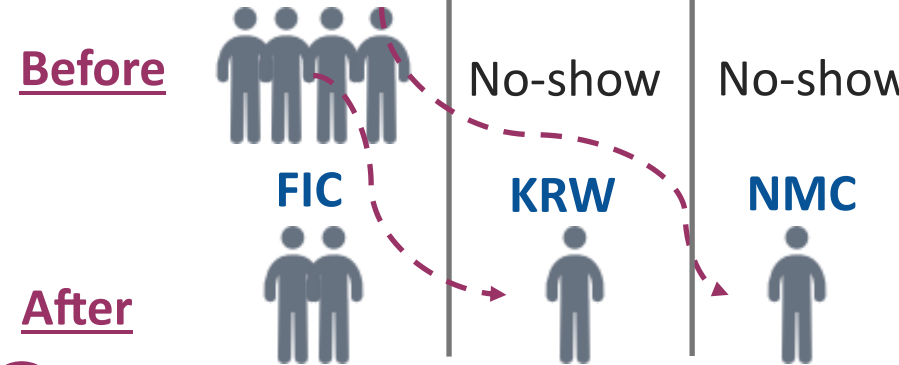

4. IMPROVE

Resource Management

① **Encouraging "Pulling" System**
Levelling workload across all rooms by taking in patients when a room is idle due to no-show and there are no patients in queue (example below)

Before   No-show   No-show
FIC   KRW   NMC
After

② **Overbooking 1 to 2 scans per room**
Offsets the effect of idle time due to no-shows without significantly increasing waiting time or overtime
- Recommendation: Spread out the additional slots as evenly as possible throughout the day (e.g. morning/afternoon slots)

③ **Creating Reserve List**
Introduces a responsive system to deal with high patient arrival variability and must be implemented with "pulling" system
- Step 1: Have a list of inpatients that do not have scans scheduled for the next day
- Step 2: Sort them by expected scan time
- Step 3: Activate list when patient do not arrive within 15 mins of scheduled time

Demand Management

① **Conducting quarterly review on all 4 key performance metrics against benchmark level (to be set by NUH)**
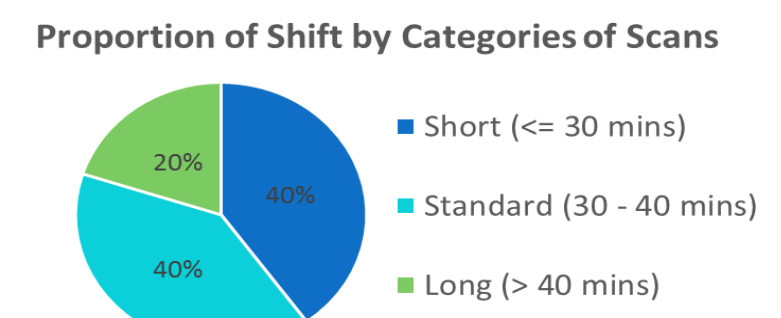
Provides a multifaceted perspective to the assessment of NUH's capacity and capability to meet current demand (No metric should be considered a standalone)
- Recommendation: 3 consecutive quarterly drop below benchmark level for order completion rate should raise a red flag

Scheduling

① **Grouping scheduling by scan duration**
Scans are categorised into 3 groups according to their expected scan duration:

Proportion of Shift by Categories of Scans
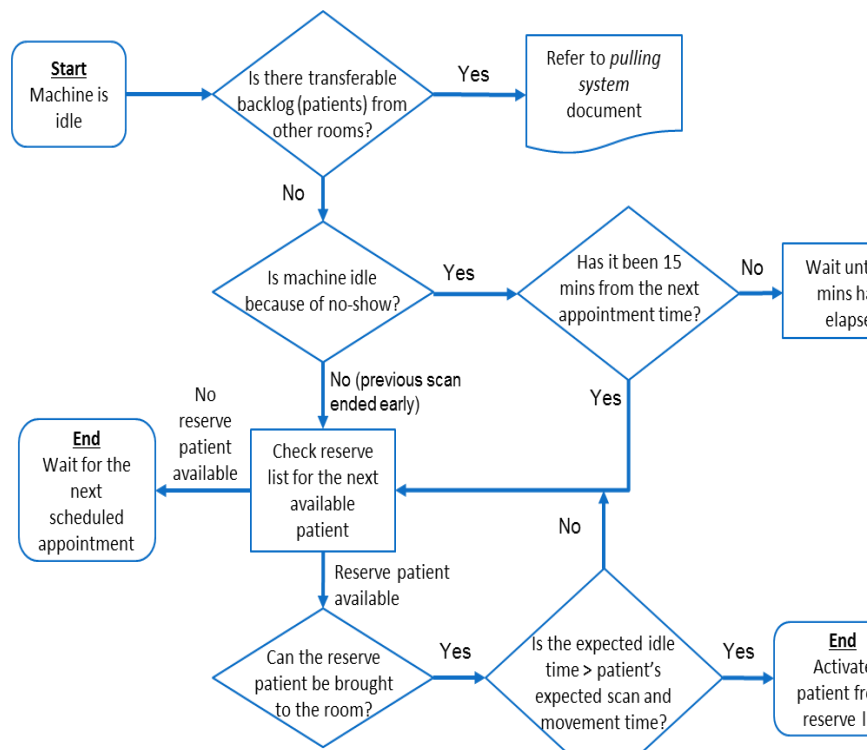- Short (<= 30 mins)
- Standard (30 - 40 mins)
- Long (> 40 mins)

② **Scheduling shortest scans first**
Shortest scans first minimises the effect of accumulated delay due to variability
- Simulation results show slight improvement in patient waiting time with all other metrics remaining relatively equal

Summary of Recommendations
Validation by simulation using Automod software

Assumptions: No-show only apply to outpatients; Radiographer assumed to be working in 2-men shift

Recommendation	Higher Utilisation	Lower Wait Time	Minimised Idle Time	Decreased Backlog
Overbooking	✔		✔	✔
Pull System	↔	✔	✔	✔
Reserve List			✔	✔
Grouping by Scan Duration	✔			

Limitations: Complexity and abandoned scans are not accounted for; Insufficient data on infrequent scans

Implementation Trade-off

- Base Case
- No Overbooking
- Overbook 1 patient
- Overbook 2 patients
- P Pull System
- P+R Pull System + Reserve List

5. CONTROL
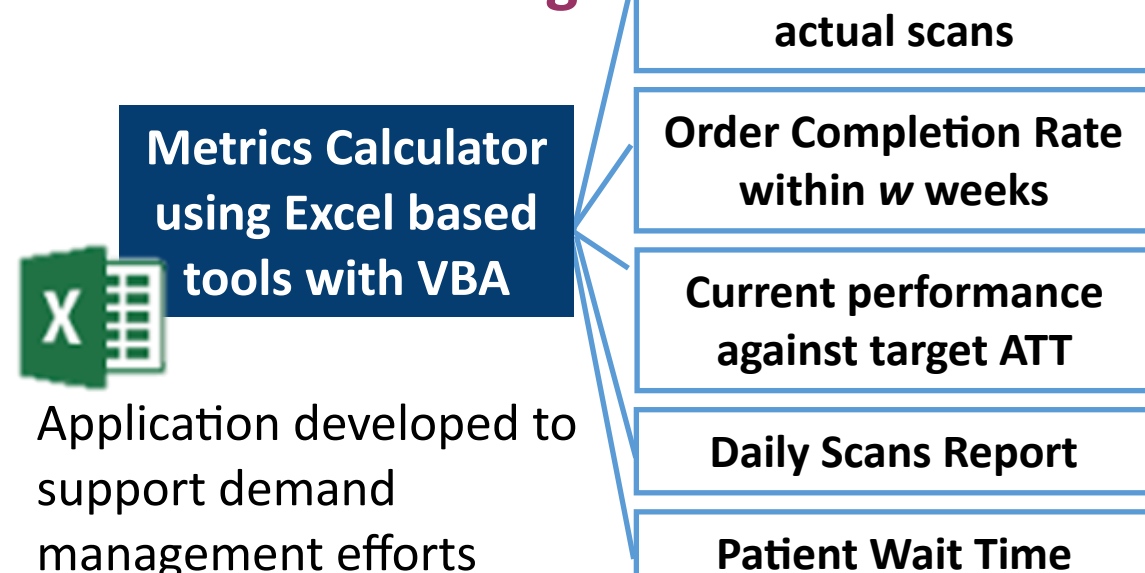
Standardisation
Standard Operating Procedures (SOPs) created for resource management and scheduling policy recommendations

SOP Example: Flowchart for Implementing Reserve List

Process Monitoring

Metrics Calculator using Excel based tools with VBA

| Summary statistics of actual scans |
| Order Completion Rate within w weeks |
| Current performance against target ATT |
| Daily Scans Report |
| Patient Wait Time |

Application developed to support demand management efforts

Future Projects
- Account for no-show and identify possible trends
- Systematic recording of abandoned scans, combination scans and frequency of one-man shifts
- Differentiate cases with varying level of complexity, especially for inpatients