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Enhancing Process Improvement Decision-Making Framework with Discrete-Event Simulation in a Diagnostic Radiology Department

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Background

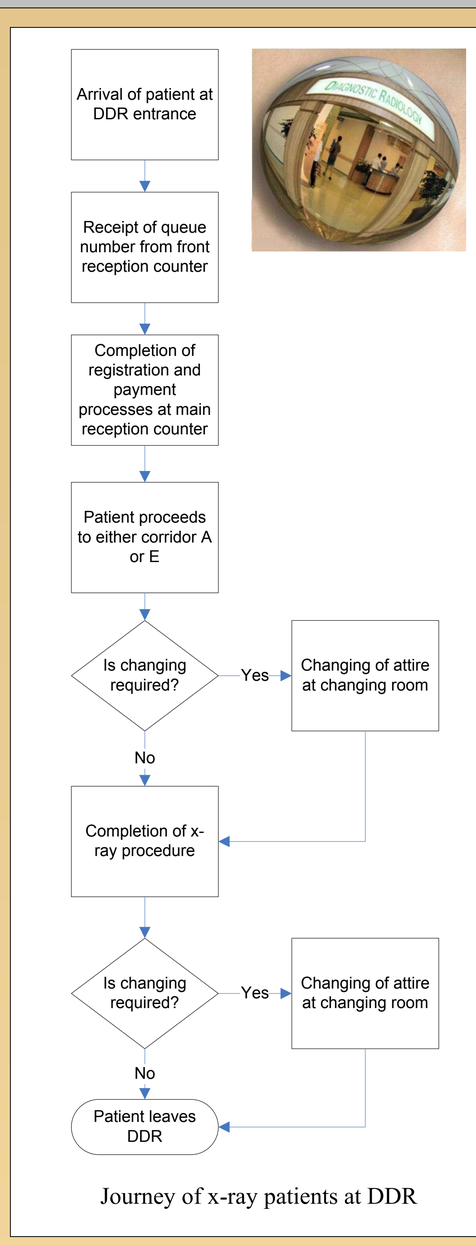
- In response to long waiting time complaints of patients who had undergone plain film x-ray imaging procedures, the Department of Diagnostic Radiology (DDR) at Singapore General Hospital (SGH) performed a cross-sectional survey over one week in August 2006
- Cycle time data of its randomly picked x-ray patients were collected where cycle time is defined as the time interval between the point when patient is attended to at the registration counter to the time when the x-ray imaging is done and patient is ready to leave DDR
- This survey showed that more than a quarter of its x-ray patients spent more than one hour at DDR before their x-ray imaging was completed and this was a cause for concern to DDR from both clinical and patient perspectives

Objective

- This project aimed to reduce the cycle time of x-ray patients to DDR to a performance target which required at least 95% of these patients to spend one hour or less at DDR

Methods

- Based on quantitative analysis of DDR operational data (e.g. patient arrival pattern, patient load distribution among the x-ray procedure rooms, cycle times of patients in these rooms, etc) and using the classical process improvement framework of Plan-Do-Study-Act (PDSA), the project team identified several cycle time reduction strategies which include:
  - installation of new x-ray machines (digital)
  - hiring of new reception staff
  - redesign of queue system
- However, there was uncertainty over the relative effectiveness of these strategies in addressing the long cycle time issue
- Experimentation of these strategies through full or pilot scale implementation is impractical since it may incur substantial expenditure and/or operationally disruptive
- With these limitations in mind, the project team decided to employ discrete-event simulation (DES) in evaluation of these cycle time reduction strategies to complement the PDSA framework



Journey of x-ray patients at DDR

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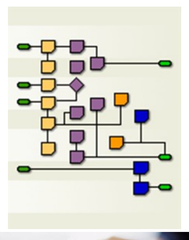
Patient characteristics

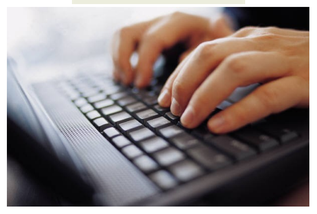
- Arrival patterns
- Proportion of patients who require gown changing
- Rate distribution of gown changing
- Proportions different x-ray types
- Motion time intervals between stations

Manpower availability schedule

Service rate distributions of

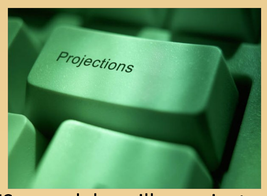
- Reception counter staff
- Radiographers





Development of DES model that represents processes in DDR

Incorporate a process improvement strategy in the DES model by changing the appropriate model parameters



DES model will project the impact of the strategy on the cycle time performance of DDR

Figure 1: Overview of DES Model Development & Application at DDR

DES Model Development

- After mapping out the journey of the patients in DDR as illustrated in Figure 1, a DES model that represented the work flow processes in DDR was developed using a commercial simulation software
- This model uses system characteristics of DDR to simulate the journey of patients in DDR and the interaction of these patients with various DDR staff like receptionists and radiographers

Key Results

- After the DES model was validated by comparing the model's projection with DDR historical performance, the project team went on to evaluate the relative effectiveness of abovementioned cycle time reduction strategies
- These strategies were emulated in the DES model by changing the appropriate system characteristics in the model accordingly. For example, the throughput of a new x-ray machine is higher than that of existing machines (analogue). Thus, the deployment of new x-ray machine is emulated in the model by increasing the rates at which the x-ray procedures can be completed
- Based on the performance projections of the DES model with regards to the impact of each cycle time reduction strategy, the queue merging strategy was only one among the three strategies that resulted both in a reduction (12.6%) in the average cycle patient time and an increase (2.2%) in the proportion of patients with cycle time less than or equal to one hour
- The queue merging strategy basically entails combination of two existing queues into one so that patients at one section of DDR will wait for their turns for x-ray procedures at one queue instead of two
- After queue merging strategy was implemented in late May 2009, the proportion of patients with cycle time less than or equal one hour in the subsequent weeks was consistently above performance target achieved as shown in Figure 2

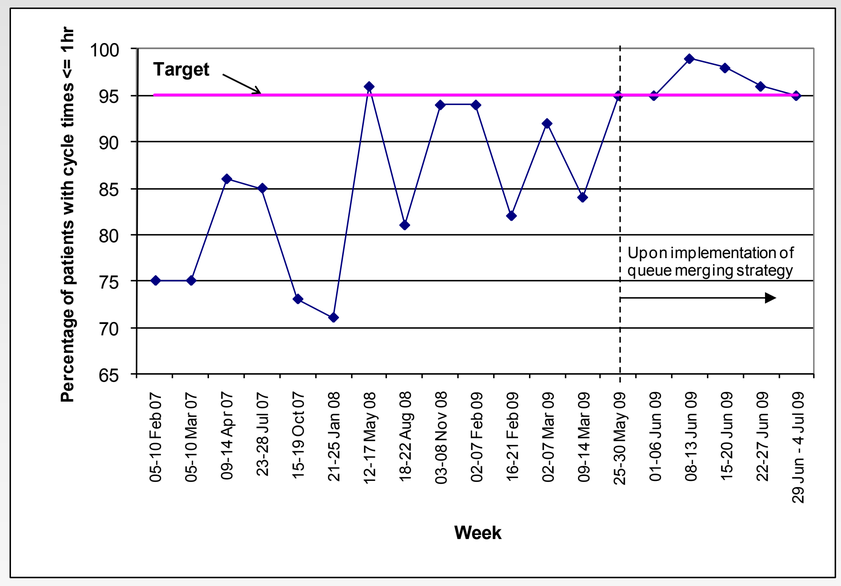


Figure 2: Post-implementation performance trend of DDR

QUICK FACTS OF DISCRETE EVENT SIMULATION (DES)

- DES entails mathematical representation of a real world system where changes in the system state occur at discrete points over time
- Based on historical characteristics of a system and given a predetermined system design, DES projects the performance of the system involved
- With this projection, inferences can then be made with regards to the operating characteristics of the real system and/or the effectiveness of one or more process improvement measures
- Since the introduction of DES in the late 1950s, it has evolved to become one of the most commonly used modeling techniques in industries which involve manufacturing/assembling processes (e.g Toyota & Volvo), transportation and provision of services
- Types of decisions that DES can support in health care industry include facility layout & capacity planning, manpower planning, evaluation of outpatient appointment scheduling strategies & organ allocation processes

Conclusions

- In this project, we have demonstrated the effectiveness of DES in supporting healthcare process improvement projects
- DES allowed decision-makers to evaluate the effectiveness of process improvement strategies without committing excessive resources and/or disrupting the workflow within of a system of interest
- Such benefits are of great value to healthcare professionals as they work continually to improve health-care operational efficiency in response to rising health-care costs and patient expectation.
- These benefits also make DES a complementary scientific framework that can help to maximize the value of HTA, particularly in contexts where impact of new health technologies on quality of health service delivery also has to be evaluated.

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