Evaluating Operating Room Efficiency Using Data Envelopment Analysis

Tze Yan Jane Ip, Michael W. Carter
Centre for Research in Healthcare Engineering, Department of Mechanical and Industrial Engineering, University of Toronto

Wait Times and Operating Room Efficiency

Surgery is an important treatment for many patients. To improve access to surgical resources, the Surgical Efficiency Targets Program (SETP) collects and analyzes performance data on Ontario's operating rooms.

Since 2007, SETP has developed 18 key performance indicators (KPIs) to measure operating room efficiency. Each KPI represents a single aspect of operating room performance. For example:

- % First Case On-Time or Early
- % Subsequent Case On-Time or Early
- Average Patient In to Patient Out Minutes
- Average Patient In to Anaesthesia Ready Minutes
- Average Turnover Minutes
- % Scheduling Accuracy
- % Utilization 7am – 3pm

Where is the gap?

1. Although intuitive to understand, KPIs cannot be used to evaluate operating room units as a whole. Also, environmental factors are not included as part of the calculation.
2. Setting performance targets using KPIs can be ineffective. Applying the notion of "gold standards" is impractical.
3. The Surgical Process Analysis and Improvement Expert Panel recommend the formation of perioperative coaching teams. A systematic approach is needed to group comparable units.

Our Solution

We propose a data envelopment analysis (DEA) model using SETP data to identify less efficient operating room units, establish performance targets, and set up peer groups. The model has the following features:

- Peer Identification
- Unit-Specific Performance Targets
- Non-Parametric Method
- Multi-Dimensional Evaluation

Brief History of DEA

- **1978:** Charnes, Cooper, & Rhodes developed DEA, an optimization method to estimate the production frontier and calculate the technical efficiency of multiple-input/ multiple-output systems.
- **1978 – Present:** DEA has since been applied in educational institutions, banks, healthcare organizations etc.
- **This Work:** This work applies DEA to support operating room management.

Some Applications of DEA in Healthcare

- Nursing homes: Nunamaker T. Measuring routine nursing service efficiency: a comparison of cost per day and data envelopment analysis models. Health Serv Res. 1983;18(2 Pt 1):183–205.
- Hospitals: Sherman HD. Hospital efficiency measurement and evaluation. Med Care. 1984;22(10):922–8.
- Primary care: Szczepura A, Davies A, Fletcher CJ and Boussofiane A, Efficiency and effectiveness in general practice, J. Management in Medicine 1993;7(5): 36–47.

Basic Ideas of DEA

DEA calculates efficiency scores by simultaneously considering the evaluated units' inputs (enabling factors of a system) and outputs (a system's products).

It uses linear programming (LP) to optimize the input and output weights to give each unit the highest score possible, while respecting that no unit will receive a score exceeding one under the same weights:

Original Formulation

$$\max h_o(u,v) = \sum_r u_r y_{ro} / \sum_i v_i x_{io}$$

subject to:

$$\sum_r u_r y_{rj} / \sum_i v_i x_{ij} \le 1 \text{ for } j = 1, \ldots, n,$$
$$u_r, v_i \ge 0.$$

Linear Programming Formulation

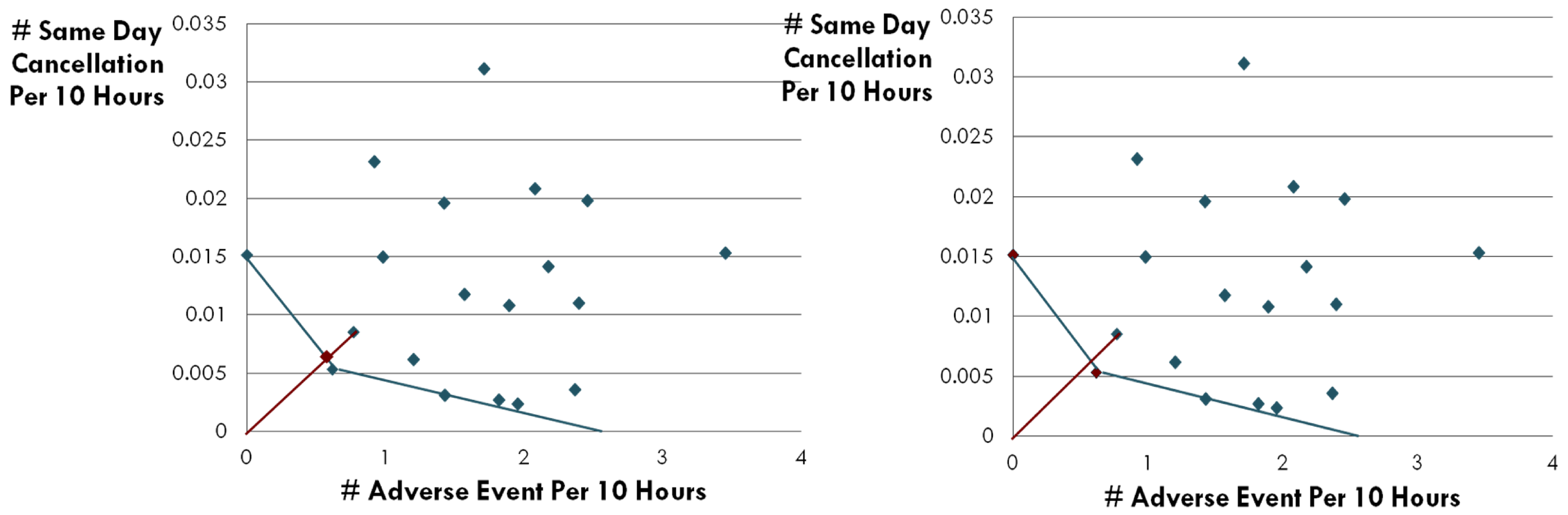
$$\max z = \sum_{r=1}^{s} \mu_r y_{ro}$$

subject to

$$\sum_{r=1}^{s} \mu_r y_{rj} - \sum_{i=1}^{m} v_i x_{ij} \le 0$$
$$\sum_{i=1}^{m} v_i x_{io} = 1$$
$$\mu_r, v_i \ge 0$$

where h_o (or z in LP) denotes the efficiency of the unit under evaluation. y_r and x_i are output and input variables; u_r and v_i (or μ_r and v_i in LP) are their respective weights.

Consider the following one-input, two-output example:



Units with a score of one defines the DEA frontier. For all other units, DEA identifies a corresponding point on the frontier as its performance targets. In addition, all non-frontier units can be matched with comparable, efficient units, called peers.

Our Model

- It focuses on resource utilization and scheduling performance to appeal to operating room management.
- It is output-oriented, to focus improvement on output variables.
- It uses variable return-to-scale calculation method (see "Discussion").

Input

Category	Metric Name
Environment	Priority 1 Cases
Resource	Adjusted Available Minutes 7am – 3pm

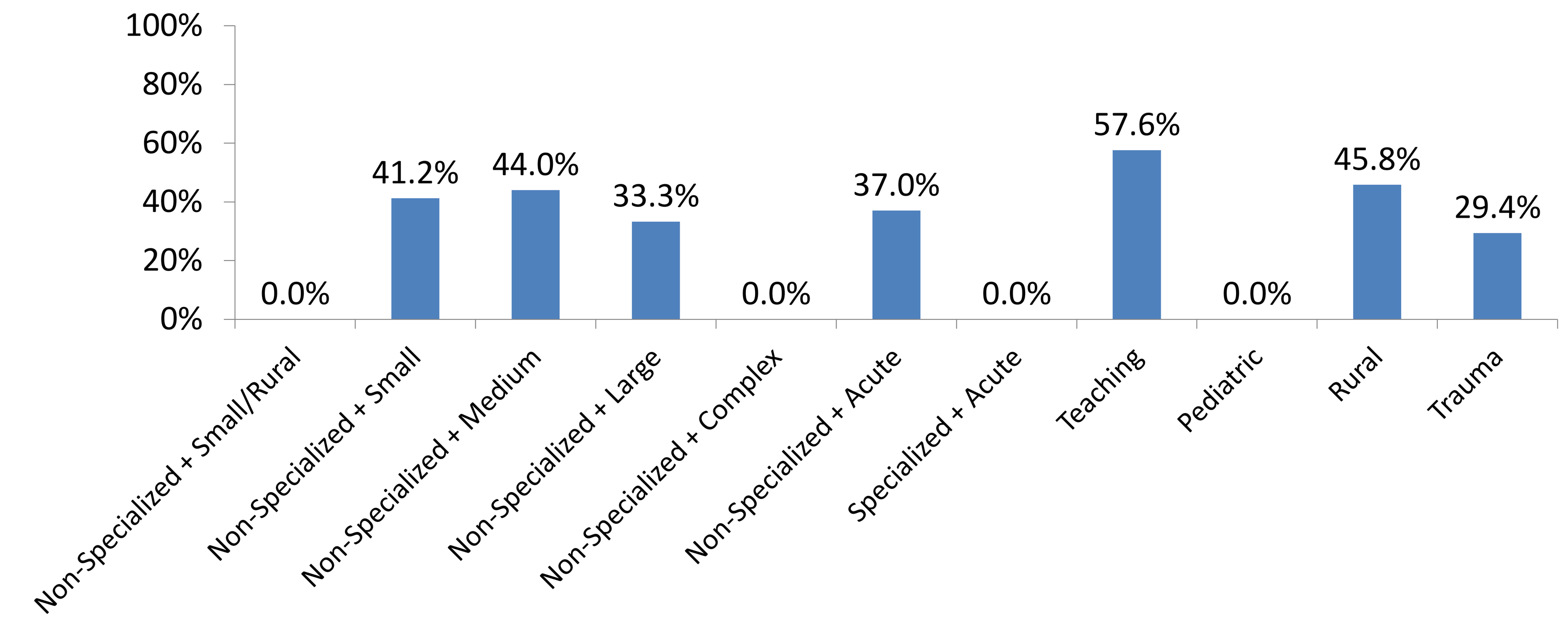
Output

Category	Metric Name
Scheduling	Utilization 7am – 3pm
	First Case On-Time or Early
	Subsequent Case On-Time or Early
	Same Day Cancelled or Postponed

To ensure comparability, the analysis population is assigned to evaluation groups before evaluation: Specialization and Regional Classification, Teaching, Pediatric, Rural, and Trauma.

Results

Percent of Inefficient Units in Each Evaluation Group



Performance Targets and Peer Group for One Unit, As an Illustration

Variables	Actual	Target	% Improvement
% Non-Priority 1	86.11	86.11	0.00%
Number of Adjusted Available Minutes 7am – 3pm	480,900.00	358,329.60	-25.49%
% First Case On-Time or Early	61.21	74.03	20.95%
% Non-Same Day Cancelled or Postponed	96.78	99.55	2.86%
% Subsequent Case On-Time or Early	39.87	61.61	54.52%
% Utilization 7am – 3pm	93.08	95.74	2.86%

Peer Units	Influence	Score
Unit A	68.02%	100.00
Unit B	23.80%	100.00

Discussion

For most of the evaluation groups, at least a third of the units can be identified as inefficient. **This model as-is**, would help set performance targets and identify peers for these units. It would also help the Ministry identify units that require most help.

Since this model is output-oriented, the targets identified for the input variables are provided for reference. P**resence of "slacks"** between the actual and target values for input variables does not impact efficiency scores.

More units are identified as inefficient when the analysis population is large. **Merging evaluation groups** that are similar (or where organizational differences are not linked to significant performance variations) can improve the model's ability to discern potential for improvement. Other strategies are available in the literature to set targets for efficient units.

The **choice of variables** for this model is influenced by user acceptance. To simulate what operating room management is accustomed to, we used a combination of ratio variables. Changing the variables to performance counts may improve the model's ability to group operationally similar units. This is because two organizations with similar performance ratios (e.g. % first case on-time or early), may in fact be different in their organization scale.

On a related note, although this model is currently specified to consider **variable return to scale**, the inclusion of ratio variables leads to loss of information about the size of the unit. Therefore, the model implicitly assumes constant return to scale.

This research is funded by: