Simulation of Alternative Models of Operating Theatres Utilisation

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Abstract: The efficiency of an operating theatre is commonly expressed in terms of theatre utilisation, and is a frequently quoted performance indicator sought by managers seeking to ensure that the public are getting good value for their elective surgery health dollar. However, it has been found that there is no consistent or universally acceptable measure of theatre utilisation. Models applied in different settings and using different anaesthetic practices yield inconsistent results, making it impossible to benchmark and identify changes in theatre utilisation. Variations of the order of 50% in theatre utilisation statistic have been observed as a result of the use of different definitions. Ten commonly used models have been selected and simulated to illustrate the inconsistencies inherent in the alternative definitions based on hospital settings and different anaesthetic practices used for various specialties. A definition of theatre utilisation has been developed which yields consistent value of the descriptor and is the first reporting level in the Theatre Information, Management and Efficiency (TIME) system developed at James Cook University and the North Queensland Clinical School.

Keywords: Operating theatres; Benchmarking; Performance descriptors; Simulation; Theatre utilisation

1. INTRODUCTION

1.1 The Study Overview

The efficiency of an operating theatre is commonly expressed in terms of theatre utilisation, and is a frequently quoted performance indicator. However, the world literature concerning theatre utilisation has shown that there is no universally accepted or consistent descriptor of theatre utilisation. This makes it extremely difficult to benchmark and improve theatre utilisation and resource allocation within the health system.

Based on extensive literature search from the multidisciplinary areas of surgery and medicine, information technology and systems and industrial engineering, ten commonly used models have been selected for analysis and simulation. These models have originated in Scotland, U.S., New Zealand, and the three most populous States in Australia. These models have been simulated to demonstrate differences in the values of theatre utilisation descriptors under identical conditions. Time elements included in various definitions of theatre utilisation have been identified and relationships between alternative definitions of theatre utilisation have been derived to explain the variations in the values of the descriptor.

It has been found that these models yield widely varying values of theatre utilisation. This is inherent in the dissimilarity of definitions and the varying practices of administering anaesthesia for different surgical specialties. Variations of the order of 50% in theatre utilisation statistic have been observed using the same theatre data. This makes it impossible to benchmark and identify improvements in theatre utilisation. Based on this study, a definition of theatre utilisation has been developed which yields consistent value of the descriptor under different settings, using varying anaesthetic practices and is independent of the scale of operations. This descriptor is the first reporting level in the TIME system developed at James Cook University and the Clinical School.

1.2 Descriptors of Theatre Performance

Several descriptors have been used to represent utilisation of operating theatres. These include theatre utilisation, theatre occupancy, session utilisation, surgeon utilisation, and anaesthetist utilisation. Other descriptors can be developed.

Theatre utilisation is the most common descriptor of theatre performance and is usually defined as the ratio of theatre used time to theatre allocated time [O'Donnell, 1976].

$$\text{Theatre Utilisation} = \frac{\text{Theatre used time}}{\text{Theatre allocated time}}$$

1.2.1 Theatre allocated time

The theatre allocated time is a period for which the theatre is adequately staffed and scheduled for given service or clinician. Theatres may be scheduled by one of the following methods [Ozkarahan, 1995]:

- A theatre may be allocated to a surgeon for a full-day session or a half-day session on a regular basis. This is called blocked booking;
- Theatre time may be allocated to a surgeon on the basis of specific requests which may vary each day or week. This is non-blocked booking system and is more commonly used in private hospitals..

The block booking system provides an unambiguous definition of theatre allocated time. This is also called the "session time". In the simulations presented in this paper, blocked booking system of theatre allocation is used.

1.2.2 Theatre utilised time

Different definition of theatre utilised time are used by surgical facilities, and there is no consensus on its definition. This results in discrepancy in theatre utilisation statistic even with the same theatre data

During the theatre allocated time, a theatre may be in one of the following states:

- a patient undergoing an operating procedure
- a patient may be administered anaesthesia
- the theatre being cleaned or set up
- the theatre may be unused

The theatre could be unused due to one of the following reasons:

- delay in starting the first case
- delay between cases
- end of scheduled list

The various definitions of theatre utilised time are based on which of the above theatre state durations are included in the definition and what is excluded. Another important factor affecting the definition of theatre utilised time is the location of anaesthesia administration – operating or anaesthetic room.

2. SETTING AND DATA

2.1 The Setting

This study is set in a 400-bed large regional hospital with eight operating theatres. The practices and management of theatre facilities at this teaching hospital result in emulations of situations in large metropolitan as well as country hospitals providing an ideal setting in which the definitions of theatre utilisation can be simulated and critically reviewed. This hospital currently performs operations in 12 different surgical specialties which matches with many metropolitan hospitals. On the other hand, there are several theatres in which specialities can be switched which emulates situation in many country hospitals. In fact, this hospital was selected as a case study site for the Pilot Study of Theatre Utilisation under the National Hospital Access Program. [Donnelly & Wadhwa, 1997]. Table 1 shows the theatre-specialities relation during the period for which the data has been used in this study. Switching between specialities among theatres is not uncommon.

Table 1. Theatre-speciality relationships at the study hospital.

Theatre	Speciality
OT1	General Surgery, Otorhinolaryngology, Paediatric Surgery and Plastic Surgery
OT2	Ophthalmology and Plastic Surgery
OT3	General Surgery, Urology Surgery, and Vascular Surgery
OT4	Cardio Thoracic Surgery, General Surgery, and Vascular Surgery
OT5	Anaesthetics, Faciomaxillary & Oral, General Surgery, Neurosurgery, and Urology Surgery
OT6	Dental, General Surgery, Orthopaedics, Paediatric Surgery, and Urology Surgery
OT7	Faciomaxillary & Oral, General Surgery, Otorhinolaryngology, and Urology
OT8	Orthopaedics

2.2 Theatre Data

Real data for three months representing about 500 sessions and 2000 cases have been used in this study. The data relates to the period Sept. – Nov. 1999. It has been observed from theatre data that disruptions to theatre activity are caused during major holiday periods (Christmas, Easter etc.), and periods when majority of new clinical staff appointments take effect (January and July). These periods are avoided in selecting the data.

3. MODELS

The models used in this study have come from Australia, the United States, Scotland, and New Zealand. These are:

- Operating Room Management Information System (ORMIS), Queensland Australia
- AUSTIN System, Victoria Australia
- Princess Alexandra Hospital (PAH) System, Queensland Australia
- Patient Tracking System (PTS) Pittsburgh, USA
- Operating Theatre Information System (OTIS), Aberdeen, Scotland
- National Demonstration Hospitals Project System (NDHP), Queensland Australia
- Operating Theatre Management System (OTMS), New South Wales Australia
- Operating Room Scheduling and Information System (ORSIS), USA
- Scottish Accounts Commission Model (SCAM), Scotland
- ORSOS model, Wellington, New Zealand

A brief description of various systems is provided in the following sections:

3.1 The ORMIS System

Operating Room Management Information System (ORMIS) developed by Health Administration Software Solution [HAS Solutions, 1996] was installed at the study hospital and several other hospitals in Queensland to collect data from operating theatres and provide theatres and hospital management with information about theatre performance.

$$\frac{\sum(\text{Patient out OR - Anaes. Start}) \text{ inside scheduled time}}{\text{Scheduled time}} * 100\%$$

This definition of theatre utilisation excludes cases conducted outside the scheduled hours while several other models include these cases.

3.2 The AUSTIN Model

This model was developed at the Austin and Repatriation Medical Centre, Victoria [Doolan, 1997]. The operating room utilisation is calculated for all operating time (not limited to session time) and is expressed as:

$$\frac{\sum(\text{Patient out OR - Anaesthetic start})}{\text{Scheduled Time}} * 100\%$$

3.3 The PAH Model

The Theatre Utilisation Project was carried out at the Princess Alexandra Hospital (PAH) Brisbane in 1995-1996 to identify preferred measures of theatre performance [Kasap, 1997]. PAH adopted the theatre utilisation approach using the occupancy definition of utilised time.

$$\frac{\sum(\text{Patient out OR - Patient in OR})}{\text{Scheduled time}} * 100\ \%$$

This definition is different to ORMIS in that utilised time includes all operating time and not just in the session allocated time.

3.4 The PTS Model

Concepts of the real-time Patient Tracking System (PTS) were developed and implemented at the University of Pittsburgh Medical Center (UPMC), PA, USA, for patients undergoing ambulatory surgery [Rotondi et al 1997]. PTS calculates scheduled and actual utilisation using scheduled and actual start and finish times for each operation and is identical to the PAH system.

3.5 The OTIS Model

The Operating Theatre Information System (OTIS) was developed as a result of a study at Aberdeen Royal Infirmary and at Raigmore Hospital in Inverness in the United Kingdom [Low and Nimmo, 1990]. In this system, the theatre utilised time is defined as the time between anaesthetic.start time for the first patient on the list to the time of resuscitation of the last patient on the list. According to this definition, the theatre utilisation is calculated as:

$$\frac{\sum(\text{Resuscitation finish for the last case - Anaesthetic start for the first case})}{\text{Scheduled time}}$$

Delays between cases are included in this model.

3.6 OTMS Model

The NSW Department of Health formed the Theatre Information System Working Party to establish data definitions and utilisation indicators for Operating Theatre Management Systems (OTMS) [Pereira, 1998]. This measure of theatre utilisation is based on start of anaesthesia to out of O.R. in session time only.

3.7 NDHP Model

The National Demonstration Hospital Program [NDHP, 1997] is an Australian Government initiative which was established to reduce waiting time for elective surgery. In this system, the theatre utilisation is based on the anaesthetic definition of utilised time and is identical to the PAH model.

3.8 The ORSIS Model

The Association of Anaesthesia Clinical Directors (AACD) has developed the Operating Room Scheduling and Information System in which both the raw utilisation and adjusted percent service utilisation are computed [Donham, 1998]. The raw utilisation refers to the percent of the block time or session during which the O.R. is occupied by patients, while the adjusted service utilisation refers to the percent of block time during which O.R. is used for cases. The latter includes start-up and clean-up time. Cases outside the block time are also included.

$$\frac{\text{In - own block hours + Outside block hours}}{\text{Block Time}} * 100\%$$

3.9 The Scottish Accounts Commission Model

Utilised time has been defined as the time from the induction of anaesthesia for the first patient on the list, or the procedure commencement time, whichever is the earliest (called 'start'), until the last patient on the list leaves the operating theatre (called 'finish'). Theatre utilisation is given by:

$$\frac{\sum(\text{Finish - Start})}{\text{Held session time}} * 100\%$$

'Held session time' includes only sessions in which at least one operation took place.

3.10 Wellington's ORSAS Model

This system is identical to the ORSIS system developed by AACD.

3.11 Data Collected in Various Systems

The data collected in different systems is shown in Table 2. The respective data points allow the calculation of theatre utilisation statistics as defined in these systems. However, the data used in this study has been obtained with the ORMIS system which does not cover the start-up and clean-up times. These times are required by some of the models included in this study. Therefore, a survey was undertaken over a period of one month at the study hospital to observe and record the change-over times between cases. An average value of 9.2 minutes has been obtained and used in this study.

4. SIMULATIONS

The ten models of theatre utilisation have been simulated using the theatre data from the study hospital. The simulations were carried out to determine theatre utilisations for each theatre and each major speciality using alternative models. The results from these simulations have been summarised and presented in Tables 3 and 4. Some systems use common definitions.

Table 2. Data collected in different systems

Data field	ORMIS	AUSTIN	PAH	PTS	OTIS	NDHP	OTMS	ORSIS	SCAM	ORSOS
Anaesthetic start										
Patient in O.R.										
Procedure start										
Procedure finish										
Patient out O.R.										
Session start										
Session finish										

Table 3. Theatre Utilisation by Operating Theatre.

Theatre #	Session Time	ORMIS		AUSTIN		PAH, PTS NDHP		OTIS		OTMS		ORSIS, ORSAS		SACM	
	(hhh: mm)	Used Time	%	Used Time	%	Used Time	%	Used Time	%	Used Time	%	Used Time	%	Used Time	%
MOP1	215:00	100:19	46.66	94:27	43.93	109:21	50.86	119:56	55.78	85:46	39.89	113:27	52.77	126:42	58.93
OT1	354:00	254:31	71.90	299:32	84.61	287:16	81.15	390:33	110.32	266:17	75.22	340:10	96.09	334:33	94.51
OT2	177:45	115:28	64.96	157:25	88.56	123:08	69.27	160:04	90.05	148:19	83.44	184:24	103.74	155:56	87.73
OT3	64:30	49:09	76.20	56:22	87.39	51:21	79.61	63:48	98.91	53:04	82.27	58:58	91.43	57:14	88.73
OT4	429:00	337:49	78.75	417:16	97.26	368:04	85.80	440:05	102.58	375:01	87.42	433:12	100.98	427:41	99.69
OT5	426:00	267:08	62.71	289:26	67.94	280:54	65.94	368:34	86.52	275:40	64.71	318:43	74.82	336:45	79.05
OT6	362:30	227:06	62.65	272:19	75.12	241:38	66.66	355:54	98.18	256:17	70.70	311:34	85.95	303:29	83.72
OT7	427:00	306:29	71.78	359:56	84.29	341:26	79.96	462:04	108.21	323:54	75.85	402:06	94.17	405:56	95.07
OT8	416:00	277:52	66.79	307:26	73.90	291:36	70.10	407:23	97.93	293:41	70.60	341:37	82.12	341:53	82.18
Total	2871.4	1935.5	67.41	2254.0	78.49	2094.4	72.94	2768.2	96.40	2077.5	72.36	2504.1	87.20	2490.9	86.71

Table 4. Theatre Utilisation by Clinical Speciality.

Spec	Session Time	ORMIS		AUSTIN		PAH, PTS, NDHP		OTIS		OTMS		ORSIS, ORSAS		SACM	
	(hhh: mm)	Used time	%	Used time	%	Used time	%	Used time	%	Used time	%	Used time	%	Used time	%
CTS	414:30	317:55	76.70	391:12	94.38	344:03	83.00	354:01	85.41	419:28	101.2	406:50	98.15	405:50	97.91
DEN	66:30	39:45	59.77	47:48	71.88	40:48	61.35	46:19	69.65	61:50	92.98	55:28	83.41	53:54	81.05
ENT	169:45	114:12	67.28	146:07	86.08	137:15	80.85	122:51	72.37	202:10	119.10	169:53	100.08	170:19	100.33
FMX	75:00	57:37	76.82	65:01	86.69	64:25	85.89	58:13	77.62	82:50	110.44	71:55	95.89	75:29	100.64
GEN	700:30	469:39	67.04	533:37	76.18	525:49	75.06	475:57	67.94	663:24	94.70	593:06	84.67	605:31	86.44
NEU	327:45	202:09	61.68	216:31	66.06	208:33	63.63	210:07	64.11	268:30	81.92	237:13	72.38	244:36	74.63
OPH	173:45	111:48	64.35	153:31	88.35	119:00	68.49	144:52	83.38	154:24	88.86	180:11	103.71	151:28	87.18
ORT	419:30	280:59	66.98	310:43	74.07	295:02	70.33	296:39	70.72	411:21	98.06	345:31	82.37	345:27	82.35
PDS	143:30	88:57	61.99	109:10	76.07	94:07	65.59	103:38	72.22	138:28	96.49	127:43	89.00	123:34	86.11
PLA	91:30	70:53	77.47	74:20	81.24	75:34	82.59	69:38	76.10	101:23	110.80	82:46:	90.46	83:47	91.57
URO	206:00	116:21	56.48	131:53	64.02	120:31	58.50	126:50	61.57	178:00	86.41	155:02	75.26	153:20	74.43
VAS	69:30	55:25	79.74	62:30	89.93	58:25	84.05	58:09	83.67	69:56	100.62	64:57	93.46	63:22	91.18
Total	2871.4	1935.5	67.41	2254.0	78.49	2094.4	72.94	2768.2	96.40	2077.5	72.36	2504.1	87.20	2490.9	86.71

CTS – Cardiothoracic; DEN – Dental; ENT – Ear, Nose & Throat; FMX – Faciomaxillary; GEN – General Surgery; NEU – Neuro-surgery; OPH – Ophthalmology; ORT – Orthopedics; PDS – Paediatric; PLA – Plastics; URO Urology; VAS – Vascular Surgery

5. DISCUSSION AND CONCLUSIONS

It is obvious from the simulations that there are significant variations in the values of the theatre utilisation statistic with alternative models, using the same theatre data. Of the five Australian systems, the AUSTIN model consistently gives higher values of theatre utilisation, while ORMIS consistently shows lower values of utilisation. OTIS system gives the highest value of utilisation under most situations. Note that the utilisation can exceed 100% in models which include cases performed outside scheduled hours or include the use of anaesthetic rooms in calculating theatre utilisation. The most significant variations in the values of theatre utilisation statistic observed from these simulation include:

- The ORMIS system produced the lowest values of theatre utilisation while the OTIS system resulted in the highest values in all cases except Ophthalmology in which the highest value is obtained with the ORSIS model.
- The variations are significant and vary from a minimum of 26% to a maximum of 77% with an average value of 43%.
- Variations in excess of 50% in the values of the utilisation statistic have been obtained for five of the twelve specialities. In descending order of the variation, these specialities are ENT (Ear, Nose and Throat), Ophthalmology, Dental, Paediatrics, and Urology. Vascular surgery showed the minimum variation of 26%.

A full listing of variations is shown in Table 5. These variations can be partially explained by the differences in anaesthetic practices, session duration, and the number of cases performed per session. However, the primary determinant of the variations in theatre utilisation statistic is the difference in its definition which may or may not include cases performed outside session block time, anaesthetic time outside the operating theatre, clean-up times, and time between cases.

Table 5. Variations in theatre utilisation statistic.

Speciality	Minimum	Maximum	Variation %
CTS	76.70	101.2	32
DEN	59.77	92.98	56
ENT	67.28	119.10	77
FMX	76.82	110.44	44
GEN	67.04	94.70	41
NEU	61.68	81.92	33
OPH	64.35	103.71	61
ORT	66.98	98.06	46
PDS	61.99	96.49	56
PLA	77.47	110.80	43
URO	56.48	86.41	53
VAS	79.74	100.62	26
Total	67.41	96.40	43

Systems which include over-run (time used outside session hours) in utilised time but not in available time will give higher value of the theatre utilisation descriptor. Models which include anaesthetic time outside the operating theatre also inflate the descriptor. Inclusion of set-up start and clean-up finish times, however, does not necessarily increase the utilisation statistic. It will increase the value if the statistic is based on procedure times only and between-cases times are excluded. However, the value will be decreased if there are delays between cases and utilisation is based on end of last case minus start of first case (between-cases delays are included)

The findings clearly demonstrate the need for a measure that gives consistent and realistic values of theatre utilisation irrespective of the anaesthetic practices, clinical speciality mix, and the size of the operating facility. This is achieved in the TIME system developed at James Cook University.

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