USING SIMULATION MODELS FOR SURGICAL CARE PROCESS REENGINEERING IN HOSPITALS

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ABSTRACT

Hospitals are beginning to reengineer the ways they provide healthcare services. This paper reports the results of a study that used simulation models for surgical care process reengineering at a Singaporean hospital. The results will prove helpful to those who consider reengineering the process of surgical care in hospitals.

Keywords: Simulation, business process reengineering, hospital, surgical care

INTRODUCTION

Many organizations have reengineered their business processes to contain costs, improve efficiency, and stay competitive in the marketplace. With escalating healthcare costs, hospitals have also sought ways to contain costs and provide quality healthcare service. Hospitals have traditionally emphasized on breakthroughs in procedures and technology for surgical care. As competition among hospitals continues to intensify, however, patients perceive little difference in such procedures and technology used by different hospitals. Further, the facility for surgical care, which is a critical segment of any hospital that provides surgical care service, can consume multitudes of resources, but at the same time, it can generate significant revenue if managed properly. For this reason, hospitals are seeking ways to optimize the process of surgical care.

This paper reports the results of a study that used simulation models for surgical care process reengineering at a Singaporean hospital (referred to as 'the Hospital' hereafter, for anonymity and brevity). The simulation models intended to reduce any inefficiencies or bottlenecks inherent in the process of surgical care at the Hospital and improve the utilization of locations and resources involved in the process. Given the paucity of studies on the methods and techniques for surgical care process reengineering in hospitals, the results will prove helpful to those who consider reengineering surgical care or other similar healthcare processes in hospitals.

MANAGEMENT OF OPERATING THEATRES AT THE HOSPITAL

Management of operating theatres (OTs), the facilities for surgical operations, often involves human resources, information systems, finance, physical plant design and utilization, capital equipment, clinical quality and efficiency and regulatory [Merriam-Webster, 2002]. A surgical

group comprises of several surgeons who share allocated OT time. The term *block time* is the time allocated to each surgical group, and only the surgeons belonging to that surgical group can schedule their patients during the *block time*. Managing multiple OTs is a difficult task, because the facilities are highly complex and tense environments. Many personnel working in OTs are not under the direct control of the manager of OTs.

The OT schedule sets the stage for the daily flow of patients and staff. Once the day starts, deviations from this schedule are frequent and expected. The schedule must accommodate both elective and emergent surgical cases. An elective case is one whereby the patient can wait at least three days without sustaining morbidity or mortality [Dexter, 2001]. Surgical cases may be longer or (rarely) shorter than scheduled, patients may be late or fail to arrive at all, and personnel may call in sick or become ill during the course of the day [Gabel *et al*, 1999]. Thus, management of OTs requires an effective scheduling system that provides the following two basic but critical functions. First, the system should perform the actual scheduling of cases, which involves finding out the time available on the schedule and whether that time occurs in a surgeon's specific *block time*. It should assign a surgeon (or a surgical group) a *block time* that is exclusively for his (or the group's) cases. Second, the system should facilitate management of resources needed for surgical operations. It must provide data on how resources are used in relation to their availability [Harris *et al*, 1998].

The anesthesia service is often provided by a separate department; in some hospitals it is a division under the surgery department. In contrast with surgical sub-specialties, anesthetists specializing in specific clinical areas such as pediatric anesthesia, obstetric anesthesia and cardiac anesthesia are not typically organized into distinct departments. The anesthesia department must be organized in such a way as to ensure availability of a sufficient number of anesthetists for elective as well as emergent surgical cases, which requires 24-hour-a-day coverage [Gabel *et al*, 1999].

THE STUDY

There are a total of twenty-one OTs at the Hospital. The number of surgical operations conducted at the Hospital was 59,377 in 2000, of which about 45 percent (26,818) were outpatient (day) surgeries. Out of the twenty-one OTs, nineteen are allocated for elective surgery and operate eight hours a day from 8:30am to 5:30pm. The remaining two OTs are used for emergent surgery and operate twenty-four hours a day. Every day, each OT is reserved for a specific clinical discipline to carry out surgical operations. Some OTs are exclusively reserved for a particular discipline, whereas others may be used by different disciplines for each day of the week. Utilization of resources in OTs has reached at a saturated level, due to the increasing demand by patients on the services provided in OTs and the acute shortage of healthcare personnel. The Department of Surgery at the Hospital oversees the surgical operations that take place in OTs, and it considers employing reengineering practices to achieve more efficient and effective utilization with its existing resources.

The study used historical data that was extracted from the Hospital's scheduling database for the period from January 2001 to September 2001. The data included the percentage utilization of all OTs and the logs of all the surgical operations conducted. As a simulation tool, the study used

MedModel, a simulation software tool for evaluating, planning or re-designing hospitals and other healthcare systems [ProModel Corporation, 2002]. MedModel enables the user to model the elements of a healthcare system and experiment with different operating strategies and designs to achieve the best results.

First Simulation Model

In order to keep the simulation as simple as possible, the simulation models deal with only eight OTs, each reserved for a different category of surgery. As such, the number of entities and resources used in the simulation models are scaled down from the real numbers extracted from the historical data obtained. In accordance with the eight categories of surgical cases, the patient is also classified into eight different types. Table 1 shows the distribution of patients by patient types. It should be noted that the number convention assigned to each surgery category and patient type (such as "1" for CLR, "2" for CTS) is the same throughout the simulation.

Patient type	Clinical code	Percent	Surgery required	
1	CLR	12	Colorectal surgery	
2	CTS	6	Cardiothoracic surgery	
3	ENT	9	Ear, nose and throat surgery	
4	GES	26	General surgery	
5	GYN	11	Obstetrics and gynecology	
6	OTHERS	9	Other surgery	
7	ОТО	22	Orthopedic surgery	
8	PLS	5	Plastic surgery	

Table 1. Distribution of patients by patient type

The surgical care process involves various entities, resources, and locations. There are two entities in the process, namely *patient* and *setup*. Before the entity *patient* is routed into an OT, the entity *setup* is first routed into the OT, together with the resource *anesthetist*. This is to model the pre-operation procedures required to get the OT ready for surgery on the incoming patient. These pre-operation procedures take 30 minutes. As such, there is no need to classify the entity *patient* into one of the eight different patient types. The entity *setup* stays in the OT for 30 minutes with the resource *anesthetist* before the entity *patient* is summoned into the OT to join them.

Locations represent fixed places in the process where entities are routed for processing or some other activity or decision. The simulation models have five locations including *entrance*, *pre-op*, *OT*, *recovery*, and *exit*. The location *entrance* is the point of entry for the entity *patient*. The number of entries (or the number of arrivals of the entity *patient*) at this location is determined by an arrival cycle. The entity *patient* is next routed to the location *pre-op*, the pre-operation area where the entity *patient* waits for 30 minutes before it is called to the next location in the process, which can be any of the eight OTs. Should the next location be full, the entity *patient* remains at this location until the next location becomes available. The location *pre-op* is a multi-capacity location; it is capable of accommodating twenty patients. There are a total of eight OT locations, *OR_table1* to *OR_table8*. The entity *patient* is routed into one of these eight locations, depending on the surgical category. The location *recovery* has a capacity of sixteen patients. The simulation models assume that each patient spends 15 minutes in the recovery area. After waiting for 15

minutes in the location *recovery*, the entity *patient* is then routed to the location *exit*. The entity then leaves the process.

A resource is a person, piece of equipment or some other device used for one or more of the following functions: treating or moving patients, assisting in performing tasks for entities at locations, performing maintenance of locations or other resources. In the process, there are ten groups of resources. Eight groups represent the eight groups of surgeons from the eight different surgical specialties, *Surgeon1* to *Surgeon8*. The other two groups represent the resources *anesthetist* and *gurney*. Table 2 shows the list of the ten groups of resources and the number of units for each resource.

Resource type	Resource name	Number of units
Surgeon (CLR)	Surgeon1	6
Surgeon (CTS)	Surgeon2	7
Surgeon (ENT)	Surgeon3	6
Surgeon (GES)	Surgeon4	16
Surgeon (GYN)	Surgeon5	8
Surgeon (OTHERS)	Surgeon6	14
Surgeon (OTO)	Surgeon7	8
Surgeon (PLS)	Surgeon8	9
Anesthetist	Anesthetist	17
Gurney	Gurney	4

Table 2. Number of units of each resource

Second and Third Simulation Models

It has been noted that the level of utilization of OTs is saturated. The next step is to improve the efficiency of the surgical care process, such that the process can generate greater output with utilization of the same amount of resources. Currently, OTs for elective surgery at the Hospital operate for eight hours a day from 8:30am to 5:30pm. But surgical operations often end after 5:30pm, due to delays occurring in individual OTs throughout the course of the day. Sometimes the delays are simply due to the complexity of the surgery. In an effort to improve the utilization of OTs, OT personnel have suggested the possibility of implementing two shifts in operating hours in place of the current eight operating hours.

The following two changes of arrival cycle and number of resources unit were made to the original simulation model described above, in order to incorporate two shifts in operating hours. First, instead of patients arriving between 8:00am and 6:00pm over a 24-hour period, patients now arrive between 8:00am and 4:00am over the same period and with the same distribution. This represents two shifts with ten hours to each shift. Second, since two shifts utilize the same amount of resources as before, the pool of resources has to be shared between two shifts. This results in a less number of surgeons and anesthetists on duty at any one time. Thus, the number of resource units available was halved in the second simulation model. But resources may not be sufficient to cope with the increased workload caused by the two shifts. In an extreme scenario, twice the amount of resources is needed to maintain the level of effectiveness of the process. This was incorporated in the third simulation model that maintains the same number of resource units while implementing two shifts. The objective of the third simulation model is to show that

in order to maintain the current level of utilization, it might be necessary to increase the number of resources available when two shifts are implemented.

Fourth Simulation Model

When two specialties are allocated to use the same OT on the same day, one uses the OT in the morning and the other in the afternoon. This allows more flexibility in planning and scheduling surgical operations. In an extreme scenario, declassifying all OTs means that no surgical specialty has the exclusive right to any OT. This facilitates the allocation of surgical operations on a first-come-first-served basis. It also accommodates varying patient load for each specialty – the utilization level is averaged out evenly for each OT. Classification of OTs by patient types was removed in the third simulation model. Removing it would allow the entity *patient* to go to any OT regardless of the patient type.

RESULTS AND DISCUSSION

The first simulation model was run for 168 hours (7 days), with a warm-up period of 48 hours, with 20 replications. Table 3 summarizes the utilization of locations. The highest level of utilization is observed in OT (OTO), which is reserved for orthopedic surgery. The pre-operation area is also highly utilized due to the number of patients waiting for orthopedic surgery. This creates a bottleneck at the pre-operating area, and leads to patient arrival failures. This observation suggests possible reengineering in the pre-operating area.

Location	Capacity	Total entries	Average minutes per entry	Utilization (%)
Entrance	1	45.65	80.69	33.26
Pre Op	20	63.65	3012.29	92.43
Recovery	16	50.85	31.49	0.99
Exit	1	50.85	0.00	0.00
OT (CLR)	1	5.20	199.75	10.24
OT (CTS)	1	2.75	286.62	8.18
OT (ENT)	1	4.90	286.56	14.26
OT (GES)	1	18.45	379.87	69.09
OT (GYN)	1	6.10	194.34	11.58
OT (Others)	1	6.60	1478.34	88.87
OT (OTO)	1	6.10	1790.40	100.00
OT (PLS)	1	2.25	350.80	8.56

Table 3. Location utilization

All four simulation models were similarly run for 168 hours with 20 replications. Table 4 compares the location utilization in the four models. We refer to the simulation model with two shifts as Model 2, the simulation model with two shifts and increased staff as Model 3, and the simulation model that declassifies OTs as Model 4. OTs are renamed as OT1 to OT8 in Model 4. Finally, Table 5 summarizes the states of entities and the overall efficiency of the four simulation models. Based upon the results of simulation, the most efficient model is Model 4, which declassifies OTs and allows any surgical specialty to conduct surgical operations in any OT. This reengineered process reduces the utilization of pre-operating area to about 69 percent from over 90 percent, which indicates alleviation of the bottleneck seen previously at this location. The

efficiency of this proposed process is found to be about 65 percent, an improvement from about 45 percent of the current process. The main reason for the improvement is that utilization of OTs is evened out with declassification of OTs. Thus, when one specialty has more surgical cases than the others do, it is able to utilize more than OT. This proposed process is a departure from the usual block booking system, and allows more flexibility in scheduling surgical operations.

Location	Utilization (%)				
	Original model	Model 2	Model 3	Model 4	
Entrance	33.26	59.16	55.76	23.00	
Pre Op	92.43	96.40	96.06	69.36	
Recovery	0.99	1.05	0.97	1.90	
Exit	0.00	0.00	0.00	0.00	
OT(CLR)/OT1	10.24	9.23	10.29	92.44	
OT(CTS)/OT2	8.18	10.34	9.18	91.13	
OT(ENT)/OT3	14.26	13.05	15.85	92.49	
OT(GES)/OT4	69.09	78.37	69.21	93.94	
OT(GYN)/OT5	11.58	10.46	9.42	92.77	
OT(Others)/OT6	88.87	91.04	83.37	94.27	
OT(OTO)/OT7	100.00	100.00	100.00	94.15	
OT(PLS)/OT8	8.56	7.34	7.45	94.12	

 Table 4. Location utilization: comparison of four models

Table 5. Entity states and efficiency: comparison of four models

Entity	Original model	Model 2	Model 3	Model 4
Average time in system (mins)	1237.80	1207.46	1291.56	1314.72
Average time in blocked state (mins)	874.34	852.37	920.46	864.70
Total number of exits	99.40	100.00	96.55	186.95
Total remaining in system	16.90	17.50	17.30	1.90
Total number of failed arrivals	138.95	141.85	141.90	102.50
Efficiency (%)	45.60	45.30	44.50	64.80

CONCLUSION

This study used simulation models for surgical care process reengineering at the Hospital to reduce any inefficiencies or bottlenecks inherent in the process and improve the utilization of locations and resources involved in the process. Several possibilities for reengineering surgical process were proposed to reduce the utilization of the OT complex. OTs that service certain surgical specialties are highly utilized, and surgeons belonging to those specialties are also in high demand. Anesthetists are also highly utilized, possibly due to their anesthetic responsibilities outside OTs and the pre-operative and post-operative works that they conduct for surgical cases. In order to maximize the productivity of the OT complex without increasing the workload of surgeons and anesthetists, the management needs to look for a way to redesign the OT process. It is also recommended that data collection with regards to OT utilization be reviewed periodically for accuracy and transparency in the data collection process. This is crucial in order to obtain a true representation of the states of utilization of OTs, from which an accurate productivity index can be derived.

References available upon request from the authors.