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THE USE OF SIMULATION TO DETERMINE MAXIMUM CAPACITY IN THE SURGICAL SUITE OPERATING ROOM

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ABSTRACT

Utilizing ambulatory care units at optimal levels has become increasingly important to hospitals from both service and business perspectives. With the inherent variation in hospitals due to unique procedures and patients, performing capacity analysis through analytical models is difficult without making simplifying assumptions. Many hospitals calculate efficiency by comparing total operating room minutes available to total operating minutes used. This metric both fails to account for the required non-value added tasks between surgeries and the delicate balance necessary between having patients ready for surgery when an operating room becomes available, which can result in increased waiting times, and maximizing patient satisfaction. We present a general methodology for determining the maximum capacity within a surgical suite through the use of a discrete-event simulation model. This research is based on an actual hospital concerned with doctor/resource acquisition decisions, patient satisfaction improvements, and increased productivity.

1 INTRODUCTION

There is growing concern regarding the rising cost of health care in the United States. The impact of increasing health care costs is making basic health coverage unaffordable for both businesses and individuals. The consumer price index shows that an important split is expanding between the two dominant sectors in the economy, services and goods. In 2003 prices for services rose 3.2 percent over the course of a year while prices for manufactured goods fell 1.5 percent (Stiles, 2003). Lagging sales and increased health care costs are creating major losses for many corporations. After a recent quarterly loss of $1.6 billion, General Motors, Inc. proposed a restructuring effort which would cut health care for union retirees by 25 percent, which would result in about one billion in cash savings a year (Carty, 2005). Many employers are beginning to pass on the costs of health care to employees. For those individuals not covered by an employer, rising health care costs are resulting in an increased number of individuals who are uninsured. “In 2003, 45 million Americans under the age of 65 lacked health insurance. National surveys consistently show that the primary reason people are uninsured is because health coverage is too expensive” (Kaiser Commission, 2004).

Another major issue facing health care providers is a changing demographic. “From 1950 to 2000 the proportion of the population age 75 years and over rose from 3 to 6 percent. By 2050 it is projected that 12 percent, or one in eight Americans, will be 75 years of age or over” (National Center for Health Statistics, 2004). It has been well documented that the elderly require not only more service, but the services tend to be more expensive, including operations such as cataract and hip replacement surgeries. This increase in the elderly population, therefore, means that hospitals must be prepared to meet a greater demand.

Hospitals today are faced with several pressures such as increasing equipment costs, a shortage of qualified health care professionals, and limited hospital facilities. With health care costs rising and an aging population, the health care industry is progressively faced with the problem of growing demand and diminishing reimbursements. Many hospital executives are faced with a lack of quantifiable data regarding surgical suite capacity and the impact of adding new surgical procedures. If the caseload is increased beyond maximum capacity, patient satisfaction decreases due to increased waiting times, surgeons and nurses become physically and mentally drained, and the hospital incurs the cost of overtime. The ultimate goal for hospital administration is to care for the largest number of patients while maintaining the highest standards of patient satisfaction.

The chasm that exists between trying to satisfy an increasing number of U.S. citizens requiring health care while a decreasing percentage of the population can afford adequate coverage is expanding. In order to provide affordable health care to a larger audience, efficient utilization of resources within the health care industry is crucial for providing a low cost service to an increasing number of patients. In order to remain profitable while providing quality patient care, many hospitals are looking for ways to improve their system. Accurately determining a facility's maximum capacity is the first step in the improvement process. The proper capacity metric will provide administration with a solid understanding of potential patient volumes under current conditions. As hospitals become more efficient, more patients can be seen, lowering the cost of care per patient, while maintaining, if not increasing, profitability and patient satisfaction.

Due to the complexity of health care systems and their inherent variability, simulation is widely used for analysis in hospitals. Consequently, we introduce a simulation model that can be used to determine the current efficiency of a surgical suite, the potential maximum capacity of the suite, and how either changing resources or adding surgical procedures affects surgical suite performance.

2 SURGICAL SUITE OVERVIEW

For many hospitals, ambulatory care units, or surgical suites, are the financial engine that drive a significant portion of the hospital's overall profitability. Depending on the size of the hospital and the area it supports, surgical suites can range from a single operating room to well over 50. In this section of the hospital, patients are usually scheduled in advance to undergo an elective surgery. The types of surgeries that can be performed often include, but are not limited to: cardiac, dental, obstetrics, ophthalmology, oncology, ENT (Ear Nose Throat), plastic, urology, orthopedic, and other general surgeries. Within these categories there are an ever increasing number of surgeries that can be performed.

2.1 Patient Flow

The patient flow, or the sequence of processes encountered by the patient from arrival to discharge, is largely determined by the type of surgery the patient is undergoing, as can be seen below in Figure 1. This patient flow is common of many ambulatory care units.

Recording patient procedure and recovery times is standard procedure at surgical suite and hospital facilities. Not only do surgeries differ in their flow, procedural minutes, anesthesia administering, and recovery, but also in the time required for paperwork processing, pre-surgery examination, and medicinal preparation. Furthermore, the patient's type of surgery determines operating room cleaning time, equipment preparation, and doctoral dictation. In order to conduct a thorough analysis, a hospital must be able to specify the process times associated with various procedures and the percentage of patients who receive these surgeries. All of these variables are captured in the simulation model developed in order to accurately determine maximum capacity.

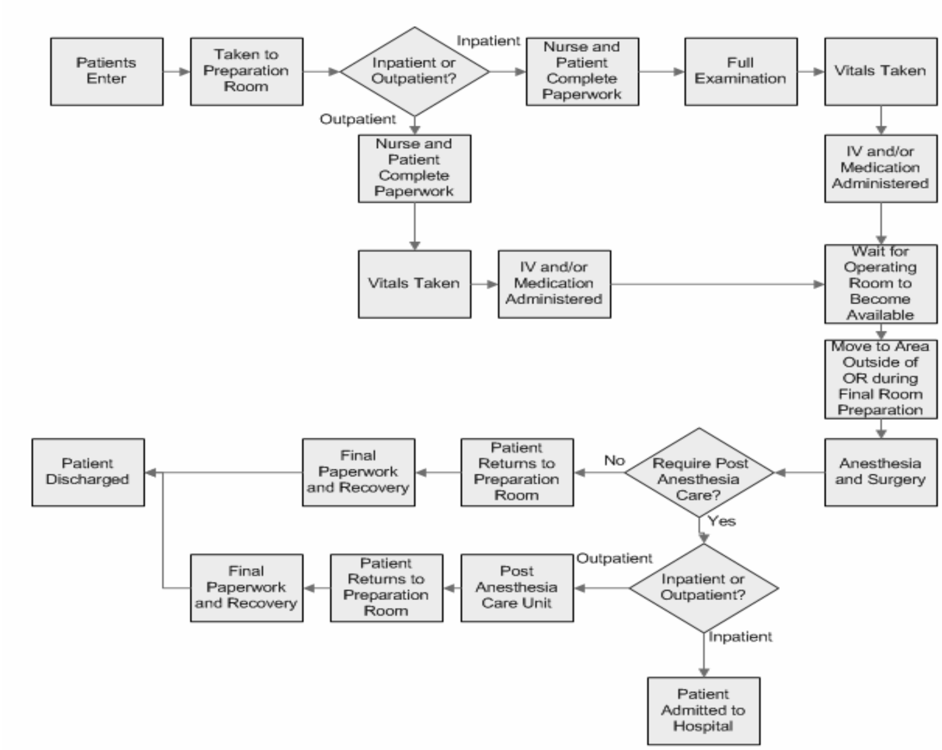

Figure 1: Typical patient flow through a surgical suite

2.2 Resources

The general surgical suite will usually consist of triage or interview rooms, preparation rooms, operating rooms, and recovery beds. Personnel usually consist of health care aids, registered nurses, surgeons, and operating room teams. Health care aids complete pre-surgery interviews, paperwork, cleaning, and some patient preparation. Registered nurses often assist in patient preparation, paperwork, physical examinations, and drug administering. An operating room team is usually assigned to a surgeon or a certain operation type. Their responsibilities include preparing the surgical equipment, in-OR patient preparation, surgical assistance, and room cleanup.

3 THE SIMULATION MODEL

The simulation model is designed to aid a hospital in evaluating the current efficiency of a surgical suite, the potential maximum capacity of the suite, and how either changing resources or changing the set of surgical procedures performed would affect surgical suite performance. The simulation model is constructed using the Rockwell Software simulation package Arena.

While the model is based on a particular hospital, the simulation model is generalized such that any facility can easily input their own data to determine capacity and efficiencies. Each user is able to input the percentage of patients receiving a certain genre of surgery (e.g. orthopedic). Next, the user can specify up to ten types of surgeries within each genre along with how long the surgery takes, what percentage of patients within that genre receive that particular surgery, whether it is an inpatient or outpatient procedure, the operating room the procedure will use, and the time to administer anesthesia. Resources such as nurses, OR teams, and preparation rooms can also be specified.

Procedural, anesthesia, and recovery times are continuously compiled by hospital staff in most hospitals. Many facilities have years of data, that can be extremely useful in capturing operating time averages and variability. Observation and/or expert opinion can be used to determine preparation, paperwork, cleaning, dictation, and equipment restocking times.

In order to determine maximum capacity, patients, represented by entities, are continuously added to the system. The patient flow diagram shown in Figure 1 is used as the basis for the flow of the model logic. As patients enter the system they are assigned all necessary attributes associated with their procedure based on the percentages selected by the user.

As soon as the patient enters the preparation room, the nurse will complete any remaining paperwork with the patient and provide them with a surgical gown. The nurse then leaves to give the patient time to change. If the patient is to remain in the hospital overnight, a thorough examination is conducted. Vitals are then taken for each patient and medication or an IV is administered if necessary. At this point the patient is now ready for surgery and must wait for their assigned OR to become available. As soon as the OR is available, the patient moves on their bed or chair to a holding area next to the OR. The patient waits for the OR team before entering the room. As soon as all parties are present, the patient will enter the room as previously assigned. The patient is first prepped and given the appropriate anesthesia. When the anesthesia has set in, the procedure begins. At the end of the surgery the patient is cleaned and taken to either the post anesthesia care unit (PACU) or a preparation room for recovery, depending on the type of surgery performed. The room is cleaned by the OR team and becomes available for the next patient.

If the patient was sent to PACU, they remain there for a certain amount of time depending on their procedure. Inpatients receive their post anesthesia care in the overnight ward of the hospital. Some patient types may not require post anesthesia care and can be taken directly to the preparation room. All other outpatients are taken back to a preparation room after PACU for final recovery and examination before being discharged.

3.1 Non-Value Added Activities

Besides the processes necessary for the patient to directly progress through the surgical suite, there are several non-value added activities which greatly affect the availability of the suite's resources, and thus the maximum capacity. The non-value added activities which are modeled separately include: cleaning the preparation room, pre-operative interviews, case charges, future surgery paperwork, OR preparation, OR cleaning, and the restocking of surgical equipment.

3.2 Performance Measures

As previously mentioned, it is critical for hospitals to understand their capacity to support resource acquisition decisions in response to a growing demand. Although increasing patient throughput could both meet new demand and increase revenue, it should not be achieved at the cost of patient satisfaction. Statistics of interest include: the number of each patient type seen, their time in system, utilization for operating rooms, OR teams, Nurses, or any other potentially constraining resource.

3.3 Verification and Validation

The simulation model was verified by hospital administration. Since most hospitals keep detailed patient records including the type of surgery, doctor, admittance time, time taken into the OR, time taken into PACU, time returned to preparation room, and time of patient discharge for each patient, a complete database is available for validation.

Many hospitals operate under a block schedule which allocates one operating room for a certain type of surgery for either a four or eight hour block. For example, on Tuesday, three available operating rooms may service general, obstetric, and ophthalmology surgeries all day long. While on Thursday, OR1 may service orthopedic surgeries all day, while OR2 services obstetrics in the morning and general surgeries in the afternoon, and OR3 services ophthalmology surgeries all day. Since each day is a different combination of surgeries, one replication of the simulation model represents one day of the schedule.

Two months of actual patient data from the hospital was compiled by day. This gave enough data to create a representative system with appropriate surgery percentages by day. One replication of the model represents one, nine-hour day in the surgical suite. Five days (each representing a different scenario) were simulated for 100 replications each. The average of the patient's time in OR and time in system was calculated for the actual system and the simulation. By using a two-sample t-test with $\alpha = 0.05$, it was found that there was not a significant difference between the actual system and the simulation with respect to time in OR or time in system. This test was performed for each day, and supports the simulation model as an accurate representation of the surgical suite.

4 MODEL DEVELOPMENT

Several iterations of models were created in the pursuit of defining an accurate measure of capacity. The first model of the OR was equipped with an excel spreadsheet in which the user defines the surgery type and arrival times of all incoming patients. This model, while useful for scheduling policy analysis, is not a proper method for evaluating capacity since the arrivals are not random.

The second set of models were divided by surgery type since each OR works independently of one another. Surgical operations were determined by percentages defined by hospital staff and historical data as entities were continuously entering the system. These models, though, did not account for the interaction of different types of patients in preparation and recovery.

The next set of models were broken down by day, since the block schedule employed by the hospital will allocate four or eight hour blocks to particular surgery types. Block schedules are common in surgical suites and are employed such that surgeons can schedule private practices around surgeries. While block schedules are far from optimal and frequently change with the addition of surgeons, they present unique constraints and must be considered when modeling. The final model assumes that overtime is not available in the OR such that if the expected procedure time for each patient is greater than the available time left in the day the patient will leave the system. This assumption may not be true for every facility and can easily be changed.

5 APPLICATION

The simulation model has been applied to investigate the capacity of a rural hospital. First, the hospital was interested in comparing traditionally reported OR utilization statistics, calculated by the ratio of procedural time used to total OR time available, to total OR utilization taking into account all value-added and non-value added activities. Second, the hospital was interested in comparing the current utilization with its maximum capacity. Finally, since the OR was not utilized to its full capacity, what resources could be added to achieve the maximum utilization.

The numbers presented in this example illustrate the scenario under consideration for this application, but are not the exact, actual results for the hospital under study.

5.1 The System

The surgical suite to be modeled currently consists of eleven preparation rooms, four operating rooms (ORs), and a sufficiently large number of beds in the post anesthesia care unit. The preparation rooms and PACU beds can be used by any patient type. The ORs on the other hand, are each equipped with surgical devices focused towards particular surgery types. General and obstetric surgeries can often be performed in the same room along with a few other exceptions. Note, that this lack of flexibility can have a significant impact on the level of efficiency achieved.

There are currently two health care aids (HCAs) and six registered nurses (RNs) assigned to the preparation area for pre-surgery preparation, paperwork, and discharge. While the surgical suite is scheduled to be open nine hours per day, two of the six RNs are scheduled after hours such that any patients exiting the OR near the end of the day can stay for recovery and proper discharge. There are a total of twelve surgeons who operate with the help of an OR team. The OR team is responsible for restocking equipment before each surgery, assisting the surgeon during surgery, and immediately cleaning the room in preparation for the next patient. There are currently a total of three OR teams, such that three ORs can be utilized simultaneously.

Within the surgery types offered by the hospital, orthopedics, general, obstetrics, ophthalmology, and ENT. There are currently a total of 24 different surgeries performed.

5.2 Experimentation and Results

Since the current system uses block scheduling where surgeries types are dedicated to a particular day of the week, a replication consisted of only one type of surgery (although the simulation does allow for multiple surgery types on a single day.) A total of 100 replications were run for each type of surgery. First, the simulation model was run under current surgery loads. The results for the current system are shown in Table 1. Next the simulation model was run under a condition to determine the maximum capacity of the system without overtime. The results for the system under maximum capacity is shown in Table 2. To obtain the results for the second case, patients were allowed to enter the system, as long as their expected time in system did not exceed the end of the day.

In order to determine their current surgical suite efficiency (which takes into account all preparation, operating room, and recovery) the total number of patients capable of being treated within a month was compared against the surgical suite's actual average monthly patient throughput. The current hospital efficiency calculated by the simulation model (Table 1) showed that with all activities considered together the surgical suite's utilization was actually 15% greater than what the hospital administration had calculated using their traditional utilization measure that only involved procedure time.

The amount of additional patients that can be cared for without any additional resources is useful information for hospital administration. However, Table 2 shows that even in the maximum capacity state at the surgical suite, on average, no one operating room will exceed 90% utilization once the system as a whole is considered.

Underestimating surgical suite utilization can result in poor administrative decisions. If administration assumes they are utilizing the OR at 65% of its capacity when they are actually utilizing at 80%, they may believe there is room for additional surgeons or additional scheduled surgeries when this may not be the case. Knowing exactly how many additional patients are capable of being seen, by surgery type, will assist administration in making good hiring decisions. This knowledge is also a powerful recruiting tool for surgeons who focus more on their surgical procedures than a private practice.

6 CONCLUSIONS AND FUTURE WORK

The current model has been useful in determining current and maximum capacity for a specific hospital and provides a general model which can be readily used by other surgical suites. Current capacity and efficiency analyses performed by many hospitals do not accurately represent the actual system and can lead administration to overestimate the potential number of patients that can be treated. This overestimation can result in poor resource acquisition decisions, setting the hospital further from their goal of increased efficiency. The approach presented in this paper can help to solve this problem.

The next phase of this project will focus on the interaction between the different types of surgical procedures performed, along with quantifying the efficiency gains of having operating rooms which are flexible enough to service multiple surgical procedures. Finally, alternatives to the block scheduling system will be investigated.

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Table 1: OR utilization statistics under current system

Daily Surgical Suite Statistics	Orthopedic	General	Obstetrics	Eyes	ENT
Number of Patients Treated Daily	3	2	4	5	3
OR Utilization	67.05%	42.06%	47.85%	41.73%	53.98%
Time in OR (min.)	83.6	104.2	49.6	34.7	68.9
Time in System (min.)	206.5	216.7	206.3	152.9	199.6

Table 2: OR Utilization Statistics under the System at Maximum Capacity

Daily Surgical Suite Statistics	Orthopedic	General	Obstetrics	Eyes	ENT
Number of Patients Treated Daily	4.72	3.93	6.49	9.97	4.31
OR Utilization	88.56%	87.55%	87.26%	89.15%	76.43%
Time in OR (min.)	76.5	91.3	53.7	33.7	74.6
Time in System (min.)	212.5	204.7	194.5	134.2	215.6

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