

Determining the Size of the  
Gastroenterology Division Expansion  
Using Simulation: A Case Study

By

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## Background

The Division of Gastroenterology (GI) at the University of California at San Diego, Medical Center has experienced rapid growth in recent years. Over the past decade, the Division has witnessed a tripling of volume, growing from 700 to 2200 procedures annually, and a 65% increase over the past five years. There are several factors that have contributed to this growth:

- (1) Development of new therapeutic endoscopic procedures.
- (2) Advent of endoscopic procedures used for the screening of pre-malignant lesions.
- (3) Increased reliance on endoscopic procedures as preferred diagnostic modality over x-ray barium studies.

During this growth period, facility resources have remained unchanged. Only one GI Suite has been available to accommodate procedures, while recovery takes place in a number of remote locations or in an overcrowded nursing area.

To remain a force in the competition for private physician referrals, a well-functioning operation, capable of high quality service while providing easy system access is essential. Thus, the Medical Center considers it a high priority to create a GI facility acceptable to physicians, staff, and patients.

## Problem

The Endoscopy Suite at the UCSD Medical Center is unable to meet present and future requirements of the Gastroenterology Division. The following is a listing of the facility's shortcomings:

- (1) Procedure Room - Only one, ill-equipped procedure room exists. This is thought to be a serious impediment to meeting demand in a timely manner. Additionally, the room lacks the necessary space to properly perform endoscopic procedures.
- (2) Recovery Area - The GI facility does not have an adequate recovery site. Oftentimes, patients are required to recover in the Main Recovery room because of bed shortages in GI.
- (3) Equipment Space - There is insufficient space for equipment storage within the facility. As a result, equipment is stored elsewhere requiring transport to and from GI.

(4) Waiting Room - No formal waiting area exists.

(5) Office Space - A small office area exists, causing difficulty conducting patient consults, holding meetings, and maintaining a Division office.

UCSD Medical Center Administration agreed with the GI Division claim that the facility could no longer adequately serve the existing patient population, and considered the reconfiguration and renovation of its facility to be a high priority. As a result, a task force was organized consisting of physicians and nurses from the GI unit, and representatives from Medical Center Administration, Facilities Management, and Management Engineering.

## Objective

The overall objective of the task force was to create a facility that would properly support the research and patient care activities of the GI Division. Management Engineering was charged with supporting this effort by determining appropriate procedure room(s), recovery spaces, daily nursing and physician complements and operating hours that would ensure a smooth running, cost effective operation.

## Study Methodology

Because of the dynamic nature of the system, it was necessary to utilize a stochastic modeling approach. To adequately replicate system behavior, a simulation model was built in the SIMPLE 1 programming language. Utilizing a simulation model offered the following advantages:

- (1) Ability to incorporate daily demand variation.
- (2) Ability to incorporate service time variation.
- (3) Ability to incorporate variations in delivery of service, i.e. number of servers and service location by procedure type.

By imposing variability on demand and service time parameters, all types of activity levels are represented in the analysis, enabling optimal resource decisions to be made.

Another advantage of the simulation technique is that decisions can be based on numerous system outcome

variables. The following measures were developed for the GI mOdel:

**UTILIZATION:** The model calculated daily utilization of each resource under study: procedure rooms, recovery beds, recovery recliners, physicians and nurses. In determining the optimal resource level, frequency of various utilization magnitudes was considered. Procedure room utilization includes room turnaround time, while nursing utilization includes room turnaround time and time supporting procedures in areas other than the GI Suite.

**PATIENT WAITING TIME:** This is defined as the time between request for service and initiation of service. This is further stratified to measure the difference in waiting time for urgent and elective patients.

**DAILY OVERTIME:** Counted as the time beyond normal operating hours that a resource continued to supply a service.

**TIME UNABLE TO ACCOMMODATE PATIENT:** This is the time the system is unable to accommodate a recovering patient in either a recovery bed or a recovery recliner.

**CASE THROUGHPUT:** The model counted the total number of cases completed on a daily basis.

**TIME LAST CASE ENDS:** This is the time of day that the last case is completed. This is generated to indicate whether a physician is utilized appropriately, i.e. large amounts of idle time combined with a late end of day time is considered suboptimal utilization of physicians.

The optimal scenario is attained through an iterative process of running scenarios at varying resource levels and selecting the scenario displaying the most favorable results. From the GI model, optimal numbers are produced for procedure rooms, recovery beds, recovery recliners, physicians/shift and nurses/shift. Optimal system operating hours (eight hour days vs. ten hours days) are also chosen.

#### Data/Parameters For The Model

Three data components were needed to develop the model:

- (1) Demand.
- (2) Service time.

#### (3) Activity sequence / Resource consumption.

The data were obtained from department log books, hospital productivity standards, hospital databases, and physician/nurse interviews. The first step in the parameter development process was the creation of nine procedure groups (as listed in Table 1). These groups were established based on resource consumption pattern similarities. Patients within each group were required to have like procedures performed and/or follow the same sequence of activities.

Once procedure groups were created, daily demand and service time probability distributions were developed for each group. This information is also shown for each procedure group in Table 1. Additionally, room turnaround time, and patient and equipment transport times are time parameters incorporated in the model.

#### Demand Variation

The GI department logs show a considerable amount of variation in the monthly number of procedures performed. Table 2 is a listing of the average daily procedure number for the most voluminous procedures over a 12-month period. The variability of activity at a monthly level is exacerbated at the daily level. It is important to note that request dates are not tracked by the Medical Center; therefore procedure dates are used as a proxy for demand.

#### Service Time Variation

Service time information is not tracked by the GI group, thus this information was gathered through a series of interviews with physicians and nurses. In most instances a great deal of variation occurs, with the majority of the cases completed in less than the average time and a few cases taking significantly longer than the average time. Additionally, minimum and maximum times were built into the distributions, as procedure times seldom approached zero and did not reach the extreme end of the right tail. This modified negative exponential distribution having a sizable frequency of times at the floor seemed to match estimates provided by clinicians, and therefore was utilized in the model.

Finally, activity sequence paths were developed for each procedure group. The typical sequence for most patients is prep - procedure - recovery. For the first case of the day, the prep activity takes place in

Table 1. Patient Groups and Service Parameters

Patient Group	Daily Demand	Elective/ Urgent Split	Procedure Location	Required Staff	Procedure Time	Recovery Bed Time	Recovery Recliner Time
Patient Group 1	<i>Poisson Dist'n</i> Mean - 3.5	80/20	G1 Suite	1 Phys 1 RN	<i>Neg. Exp. Dist'n</i> Mean = 40 in	<i>Discrete Dist'n</i> 45 m 80% 60 in 20%	15M
Patient Group 2	<i>Poisson Dist'n</i> Mean = 1.2	80/20	G1 Suite	1 Phys 1 RN	<i>Neg. Exp. Dist'n</i> Mean = 50 in	<i>Discrete Dist'n</i> 60 m 50% 75 m 33% 90 in 17%	15 in
Patient Group 3	<i>Poisson Dist'n</i> Mean = 1.6	90/10	G1 Suite	1 Phys 1 RN	<i>Neg. Exp. Dist'n</i> Mean - 45 m	<i>Discrete Dist'n</i> 75 in 67% 90 in 33%	15 in
Patient Group 4-A	<i>Poisson Dist'n</i> Mean = 0.7	90/10	G1 Suite	1 Phys 1 RN	<i>Neg. Exp. Dist'n</i> Mean = 60 in	<i>Discrete Dist'n</i> 75 in 67% 90 in 33%	15 in
Patient Group 4-B	<i>Poisson Dist'n</i> Mean - 0.2	90/10	G1 Suite	1 Phys 1 RN	<i>Neg. Exp. Dist'n</i> Mean - 50 in	<i>Discrete Dist'n</i> 90 in 67% 120 in 33%	15 in
Patient Group 5	<i>Poisson Dist'n</i> Mean = 3.0	90/10	G1 Suite	1 Phys 1 RN	<i>Neg. Exp. Dist'n</i> Mean = 30 in	0 in	1om
Patient Group 6	<i>Poisson Dist'n</i> Mean = 0.2	67/33	Radiology	1 Phys 2 RNs	<i>Discrete Dist'n</i> 45 in 25% 60 m 25% 90 in 25% 120 in 25%	<i>Discrete Dist'n</i> 60 m 25% 90 in 75%	<i>Discrete Dist'n</i> 0 in 25% 15 in 75%
Patient Group 7	<i>Poisson Dist'n</i> Mean = 0.1	67/33	Radiology	1 Phys 2 RNs	<i>Discrete Dist'n</i> 60 in 25% 90 in 50% 120 in 25%	60 m	0 in
Patient Group 8	<i>Poisson Dist'n</i> Mean - 0.4	100/10	Recovery Room	1 Phys 1 RN	<i>Neg. Exp. Dist'n</i> Mean - 40 m	<i>Discrete Dist'n</i> 6 hrs 50% 7 hrs 50%	30 m
Patient Group 9	<i>Poisson Dist'n</i> Mean - 0.4	-	ICU	1 Phys 1 RN	<i>Neg. Exp. Dist'n</i> Mean = 50 in	0 in	0 m

Table 2. Demand Variation Example

Daily Average Demand/Month

Month	Procedure 1	Procedure 3	Procedure 5
11/90	3.8	0.8	1.8
12/90	2.8	1.0	1.8
11/91	3.4	1.4	1.7
2/91	3.1	1.1	2.3
3/91	3.9	1.4	2.6
4/91	4.4	1.4	2.2
5/91	4.6	2.1	1.8
6/91	3.2	0.8	1.8
7/91	3.2	1.0	1.7
10/91	2.0	1.0	0.6
11/91	3.1	2.2	1.7
12/91	4.7	1.3	0.7
Average	3.5	1.3	1.7
Range	2	1.4	2.0

Please note that Procedure 3 and Procedure 5 do not include new business demand reflected in Table 1 Averages.

the procedure room, and for all subsequent cases, the prep activity is performed in the shared prep/recovery area. The procedure itself can take place in the procedure room, the prep/recovery room, the Radiology procedure room, or in the ICU. The number of nursing staff necessary for a procedure or recovery also varies depending upon the procedure group, from one to two nurses. The modality of patient recovery can be either bed, recliner, or both (stepdown bed to recliner).

### Model Logic

To accurately represent the operation, several logic elements are incorporated into the model. To reflect the fact that most procedures are scheduled, patient demand is "front-loaded" to the start of each day. This means that as each day begins, the total number of patients requesting service on that day is known.

Additionally, a "demand smoothing" component is incorporated into the model. This is done to dampen unnecessarily large peaks in demand due to unrealistic scheduling practices. To impose a reasonable scheduling routine into the model, patient waiting time thresholds are developed based on patient acuity level. Waiting time thresholds are defined as the time within which each case must be performed. Urgent patients are given a one day threshold and Elective patients a five day threshold. Thresholds are used to ensure that the time from the initial patient demand point until service completion does not exceed a reasonable time

duration (overtime would be used if necessary to enforce threshold requirement). For example, if an Elective patient is next in queue, his/her case will be completed if enough time is available that day. However, if the case would cause the system to go into overtime, the threshold is checked to determine whether service can be withheld until the next day. If not, overtime is initiated. Overtime is forced on Fridays if the patient will reach threshold by the beginning of Monday morning.

Priority logic is also built into the model to determine which patient would receive a resource if more than one were competing for it. For example, if a patient needing prep activity and a patient needing recovery activity were in queue for a shared prep/recovery bed, the recovery patient has priority and will receive the bed first. Urgent patients always get the next available procedure room.

Patients do not exit the queue for commencement of prep activities until both the prep room is available and the procedure resources (procedure room, physician, and nurse(s)) are within the patient's prep time of becoming available. Patients are brought into the recovery room for prep activity at a point in time equal to the time that all procedure resources are available minus his/her prep time. This is done so that the patient is ready for the procedure at precisely the time all resources are available, thus maximizing the operation's efficiency. This is further illustrated below in Figure 1.

Figure 1. Timing Mechanism for Model

*Resources Necessary to be Available Before Activity Can Occur*

<i>Activity</i>	<b>Recovery Bed</b>	<b>Procedure Related Resources'</b>	<b>Recovery Bed</b>
<b>PREPARATION</b>	$\text{Max}(x,y,z)\text{-Prep time}$	$\text{Max}(x,y,z)$	
<b>PROCEDURE</b>		$R+\text{Max}(x,y,z)$	
<b>RECOVERY</b>			$R-\text{Max}(x,y,z)$ * Procedure Time

\* Procedure Related Resources are Procedure Room, Physician, and Nurse

### Legend

- x: Time when next physician available
- y: Time when next nurse available
- z: Time when next procedure room available
- R: Time spend waiting for prep activity due only to recovery bed shortage

The matrix in Figure 1 shows the time that each activity will commence. For example, assume that the Physician will be available at 9:30 (x), the Procedure Room will be available at 9:45 (y), and the Nurse will be available at 10:00 (z). The latest of these three points in time,  $\text{Max}(x,y,z)$ , is 10:00. Further assume that the patient has a prep service time of 30 minutes. The model will then start the patient's prep activities at 9:30, ( $\text{Max}(x,y,z) - 30$  minutes), should the prep bed be available. The procedure will then start at 10:00, which is the point in time equal to the time the patient has spent waiting (if any) for the prep bed +  $\text{Max}(x,y,z)$ . Suppose that a five minute wait occurred for the prep bed, procedure starting time would then be 10:05 instead of 10:00. The same logic is used for the start of the patient's recovery time which is equal to the time spent in queue at prep +  $\text{Max}(x,y,z)$  + patient's procedure time

A detailed flow chart of the model is found in Attachment 1.

### Operating Hour/Staffing Scenarios

Eight hour workday and 10 hour workday scenarios are developed to offer alternative hour and staffing plans. Included in the procedure room part of these scenarios are time to start up the rooms, time for first patient preps of the day, procedure time, and time to close down the rooms. Recovery rooms lag by one hour for both opening and closing of rooms. These are explained in Figure 2.

Since 10 hour shifts were considered in this analysis, it was necessary to determine procedure related nursing requirements for this alternative. Figure 3 demonstrates nursing assignments for 5 - 10 hour shifts for both 2 and 3 procedure rooms. Note that nursing levels for this type of schedule is one more than the number of procedure rooms.

Figure 2. Operating Hours Scenarios

8 Hour Day		10 Hour Day	
SHIFT COVERAGE:	7:00 AM - 3:00 PM	SHIFT COVERAGE:	7:00 AM - 5:00 PM
Procedure Room Prep:	7:00 AM - 7:40 AM	Procedure Room Prep.	7:00 AM - 7:40 AM
Procedure Room Hours.	8:00 AM - 3:00 PM	Procedure Room Hours	8:00 AM - 5:00 PM
Procedure Room Cleanup:	2.30 PM - 3:00 PM	Procedure Room Cleanup:	4.30 PM - 5:00 PM
Recovery Room Hours	8:00 AM - 4:00 PM	Recovery Room Hours.	8.00 AM - 6 00 PM
- Staffing Note: 4 Nurses needed to cover three procedure rooms and one recovery room.		- Staffing Note: 5 Nurses needed 10 cover three procedure rooms and one recovery room.	

Figure 3. Nurse Scheduling Scenarios

Nursing Coverage:  
3 Procedure Rooms and 1 Recovery Room for 5 - 10 hour shifts (5.0 Nursing FTE's)

	Monday	Tuesday	Wednesday	Thursday	Friday
Procedure Room #1	N1	N1	N1	N2	N1
Procedure Room #2	N2	N2	N3	N3	N2
Procedure Room #3	N3	N4	N4	N4	N3
Recovery Room	N5	N5	N5	N5	N4

Nursing Coverage  
2 Procedure Rooms and 1 Recovery Room for 5 - 10 hours shifts (3.75 Nursing FTE's)

	Monday	Tuesday	Wednesday	Thursday	Friday
Procedure Room 01	N1	N1	N2	N1	N1
Procedure Room 02	N2	N3	N3	N2	N3
Recovery Room	N3	N4	N4	N4	N2

(Note. Nurse 4 only needed for 3 - 10 hour shifts)

N1 = Nurse #1  
N2 = Nurse #2  
etc.

## Results

Because of the wide scope of the model and the dependencies between the various resources under study, numerous scenarios would have to be created to determine the optimal solution. To reduce the number of iterations, a three step process was introduced. The first step was to find appropriate procedure related levels. This constituted rooms, nurses, physicians, and operating hours. Since the flow through the prep component of the recovery area had a direct impact on procedure resources, these levels were inflated in step one to insure no bottlenecks existed. Therefore, the first iteration produced - optimal procedure related resources without prep constraints. The second step was to determine the optimal recovery resource levels given procedure levels from step one. Finally, a third step was used to determine whether the resource levels generated from steps one and two fit together. If not, variations had to be tested. See Table 3 for a complete set of results.

Additionally, a sensitivity analysis was run to test competing alternatives under a 10% growth scenario.

The following is a listing of the alternatives studied:

### (1) Procedure Related:

- (A) Procedure rooms (2-4)
- (B) Procedure dedicated nurses (2-4)
- (C) Physicians (1 -3)
- (D) Operating hours (8 or 10)

### (2) Recovery Related:

- (A) Prep/recovery beds (3-4)
- (B) Recovery chairs (1-2)

#### *Procedure Resource Results*

Of the numerous procedure related scenarios that were tested, two emerged as leading candidates:

- (A) 3 Rooms/3 Nurses/2 Physicians/8 hour shift
- (B) 2 Rooms/2 Nurses/2 Physicians/10 hour shift

Option (A) was chosen for the following reasons:

- (1) The physician's utilization was 12 points higher (54% vs 42%), with their workday ending 2.5 hours earlier. This is because the additional procedure room and nurse, allow both to be available whenever a physician is ready, therefore reducing physician idle time throughout the day. With two Nurses and rooms, factors such as room turnaround, multiple nurses per patient and nurse transporting functions have a negative impact on patient flow. The team felt that it was of paramount importance to keep the physician active.
- (2) Bed recovery patients can utilize the additional procedure bed when a recovery bed is unavailable. Therefore one less recovery bed is necessary. Please note this does not have a serious impact on flow through the prep function. (See Options (A) and IF): Marginal additional overtime and increases in Elective patient waiting time are well within thresholds).
- (3) A 10% volume growth scenario creates an average additional 10 minutes/day overtime and higher patient waiting times for Option (B) (one less recovery bed is accounted for in this comparison). Therefore, Option (A) becomes quite appealing in that it provides more cushion should volume continue to grow. (See Table 3, Option (F+10%) and (B+10%) for sensitivity results).

It must be noted that under Option (A), procedure room and nursing utilizations are quite low (51 % and 60%, respectively).

#### *Recovery Resource Results*

Several scenarios were evaluated concerning recovery room requirements. Once again two alternatives surfaced as best:

- (E) 4 Recovery beds/1 Recovery recliner.
- (F) 3 Recovery beds/1 Recovery recliner.

Option (F) was selected for the following reasons:

- (1) Recovery bed utilization was 14 points higher (59% vs 45%).
- (2) Although an additional 20 minutes/day of bed recovery time is not accommodated by the recovery site, the additional procedure room will be available as an acceptable alternative.

Table 3. Results

	Phase I Scenarios				Phase 11 & III Scenarios		Sensitivity Runs with 10% volume growth (F+10%) (B+10%)	
	(A)	(B)	(C)	(D)	(E)	(F)		
	3 Rooms 3 Nurses 2 Phys. 8 hr shift 4 Rec Beds 2 Rec Recl	2 Rooms 2 Nurses 2 Phys. 10 hr shift 4 Rec Beds 2 Rec Recl	2 Rooms 2 Nurses 1 Phys 10 hr shift 4 Rec Beds 2 Rec Recl	4 Rooms 4 Nurses 3 Phys. 8 hr shift 4 Rec Beds 2 Rec Recl	3 Rooms 3 Nurses 2 Phys. 8 hr shift 4 Rec Beds 1 Rec Recl	3 Rooms 3 Nurses 2 Phys. 8 hr shift 3 Rec Beds 1 Rec Recl	3 Rooms 3 Nurses 2 Phys. 8 hr shift 3 Rec Beds 1 Rec Red	2 Rooms 2 Nurses 2 Phys. 10 hr shift 4 Rec Beds 2 Rec Recl
<u>Average Daily Overtime</u>								
Recovery Room	4 mins	4 mins	1.5 hrs	0 hrs	4 mins	6 mins	15 mins	27 mins
Procedure Rooms	4 mins	4 mins	1.6 hrs	0 hrs	4 mins	5 mins	17 mins	28 mins
<u>Average Daily Utilization</u>								
Physician	54%	42%	70%	36%	54%	54%	580/0	49%
Procedure Room Nurses	60%	74%	66%	48%	60%	60%	67%	77%
Procedure Rooms	51%	63%	57%	41%	51%	510/0	58%	67%
Recovery Beds	45%	36%	34%	45%	45%	59%	63%	39%
Recovery Recliners	17%	14%	12%	17%	30%	30%	31%	14%
<u>Average Waiting Time</u>								
Urgent Patients								
Elective Patients	0.5 hrs 7.6 hrs	1.2 hrs 30.3 hrs	7.7 hrs 64.3 hrs	0.2 hrs 2.6 hrs	0.5 hrs 7.6 hrs	0.6 hrs 15.9 hrs	0.9 hrs 35.6 his	1.3 hrs 48.6 hrs
<u>Average Daily time Unable to Accommodate Recovery Patients</u>								
Recovery Beds								
Recovery Recliners	6 mins 1 min	2 mins 1 min	2 mins 1 min	11 mins 2 mins	6 mins 22 mins	25 mins 20 mins	29 mins 22 mins	2 mins 4 mins
<u>Average Daily Patient Throughput</u>								
Procedure Room	11.4	11.4	11.3	11.3	11.4	11.3	12.3	12.3
Recovery Beds	7.9	7.9	7.8	7.8	7.9	7.8	8.6	8.6
Recovery Recliners	10.9	10.9	10.9	10.9	10.9	10.9	11.8	11.8
<u>End of Phys Case Day average time</u>	1:45 pm	4:15 pm	NA	NA	NA	NA	NA	NA

NOTE: Shading indicates key outcome measures for each run.

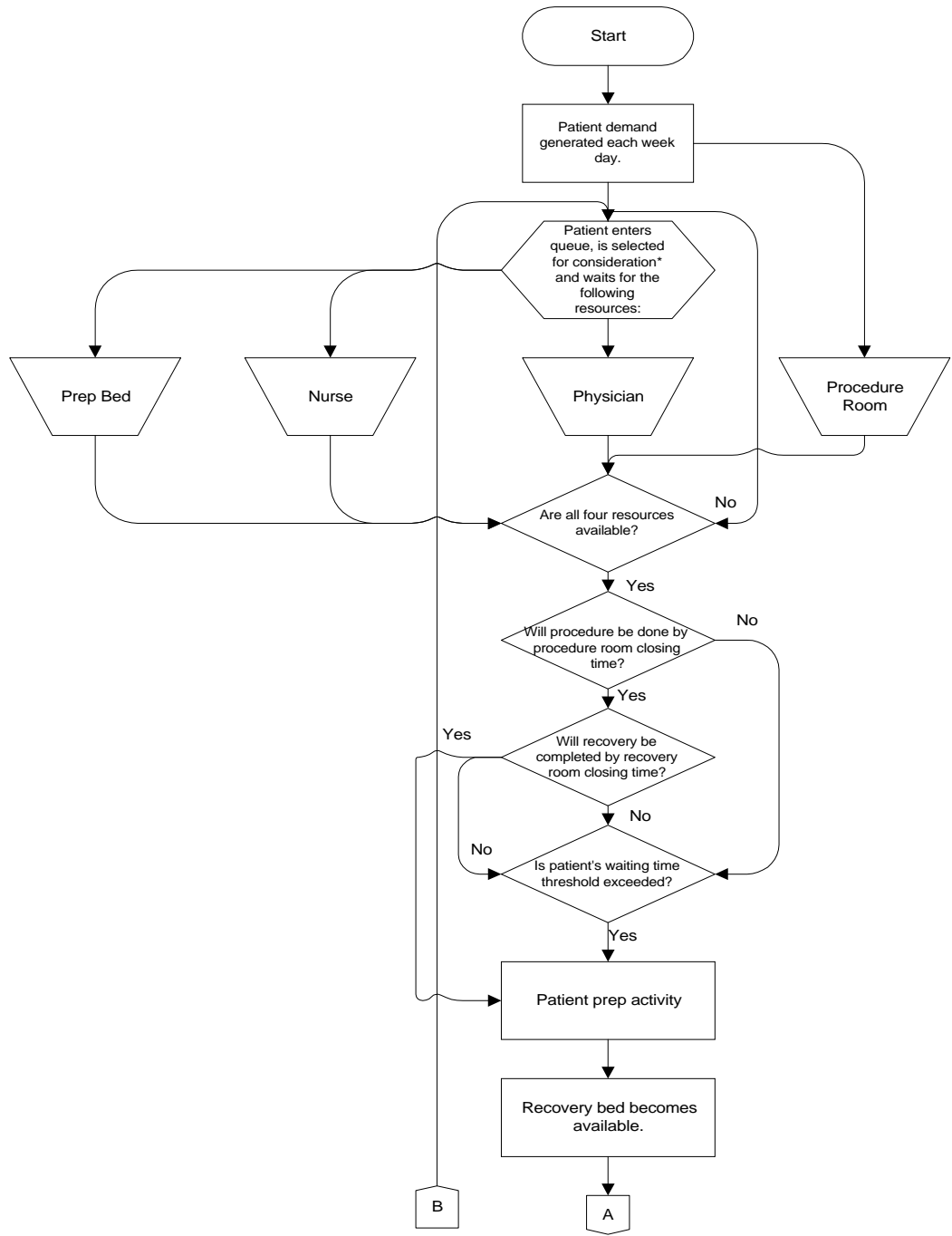
### Conclusion

The GI model built by Management Engineering provided the necessary information for Medical Center administration to understand projected system behavior and select the appropriate configuration to be built in the new GI area.

The model provided both pro's and con's of each alternative, enabling decision makers to understand the

potential consequences of each selection. As a result, tradeoffs between resource utilization and operating characteristics such as waiting times and overtime were considered in the decision making process.

By affording the opportunity to examine the system at such a detailed level, the simulation technique proved to be valuable in helping formulate a facility configuration.



\*Patients are considered for service based on the following priority levels:

1. Urgent Patients (FIFO)
2. Patients generated on previous days who haven't been selected yet (FIFO)
3. Elective Patients (FIFO)





