
CONTEST PROBLEM 12

IIE/RA Contest Problems

Twelfth Annual Contest: Rocksoft City Hospital¹

Rocksoft City Hospital is a non-profit urban hospital established in 1956 to supply the best in quality health care to the community. For its first 40 years, the hospital was a thriving institution, but over the last 10 years, increases in patient demand and costs have put significant pressures on all parts of the hospital — especially the Emergency Department (ED). Patients in ED compete with those from outpatient imaging and the scheduled elective surgery center for medical personnel, examination and operating rooms, imaging and laboratory services. Increasingly, ED arrivals are not being seen in a timely manner, impacting both quality of care and revenues.

The board of directors has heard many of their colleagues bragging about how a simulation analysis improved their operations, reduced costs, or both. Therefore, the board has hired you to analyze the hospital system and recommend improvements.

Facility Details

The ED is one of four adjacent departments that are part of this full-service hospital. The other three departments are Imaging, Lab, and Surgery, all of which provide service to the ED as well as to the rest of the hospital. Expansion capability is limited to two rooms adjacent to the existing ED.

The ED consists of:

- One check-in counter
- One 2-desk registration area adjacent to check-in
- Six standard treatment rooms, generally used for non-critical patients
- Two trauma rooms, generally used for critical patients

Diagnostic Imaging consists of:

- One imaging area (in which only a single person can be seen at a time)
- (The process to analyze the images is outside the scope of this model)

The Diagnostic Lab consists of:

- Two draw stations where blood and urine samples are collected
- (The process to analyze the lab work is outside the scope of this model)

Surgery consists of:

- Three operating rooms (ORs)
- (Detailed OR operation is outside the scope of this model)

¹We express our gratitude to the Society for Health Systems for their assistance in the development of this contest problem.

All four of these departments are driven by external demand (e.g., patients arriving directly to each department from outside the hospital). In addition, there is internal demand for services provided by the three other departments (not including ED); for example, ED generates patients who require surgery, Surgery generates the need for diagnostics (Imaging and Lab work), and so on. Further, hospital inpatients also generate internal demand for each of these three departments.

Operational Details – Overview

Rocksoft City Hospital never sleeps. Not only do patients come to the hospital 24 hours a day, seven days a week (mostly to the ED), but all areas of the hospital experience scheduled and unscheduled activities around the clock. ED patients are classified into one of three general types (based on condition severity):

- Moderate (non-urgent patients with conditions; e.g., flu, cuts, or sprains)
- Serious (urgent patients with conditions ; e.g., broken leg)
- Critical (emergency patients with life-threatening conditions; e.g., a heart attack)

There are four other types of patients who do not come to the ED but who need to use the same facilities that the ED patients often need. These four are:

- Inpatient Diagnostic (current patients who need diagnostic work; e.g., gastro-intestinal x-ray series or blood work)
- Outpatient Diagnostic (people who come for scheduled doctor-ordered diagnostic work; e.g., mammogram or blood work)
- Emergency Surgery (current inpatients who need unscheduled surgery; e.g., to treat a complication)
- Scheduled Surgery (in- or outpatients who need a scheduled surgery; e.g., knee surgery or a gall bladder operation)

You should model the latter types of patients only in enough detail to determine impact on the ED.

Preference in allocating rooms, nurses, doctors, registration, and other resources is always given to the patient with the most severe condition or highest Treatment Priority as specified in Table 1. Since the hospital is fairly small, for the purpose of this analysis, you can ignore movement times between areas.

Unfortunately, there are times when the facilities get so busy that some patients must wait a long time before a room is allocated. Some patients who think they have waited too long decide to “Leave Without Being Seen” (LWBS). Rocksoft City Hospital measures waiting time starting from patient arrival and ending when the patient leaves the waiting room. Typical waiting tolerances differ by severity of condition. If a patient has not yet been allocated a room by the time specified in Table 1, then the patient will leave (LWBS). LWBS not only gives the patient a very bad impression of the hospital, but also results in lower quality care to the population and lost revenue for the hospital.

Table 1. Treatment Priority and Waiting Tolerance by Patient Type

Patient Type	Treatment Priority (1=most important)	Waiting Tolerance (minutes)	Action After Waiting Tolerance
Moderate-ED	5	120-180	LWBS
Serious-ED	2	90-240	LWBS
Critical-ED	1	60-120	Expires
Inpatient Diagnostic	4	180-360	LWBS
Outpatient Diagnostic	4	45-120	LWBS
Emergency Surgery	1	60-120	Expires
Scheduled Surgery	4	180-360	Surgery cancelled

For Critical ED and Surgery patients, waiting tolerance has a slightly different meaning. For Critical ED and Emergency Surgery patients, if their waiting tolerances expire, so do the patients (they die). For Scheduled Surgery, if the waiting tolerance expires, then the surgery is cancelled. It is very important to track both of these statistics because of the obvious impact on quality of care and hospital revenue.

Operational Details – ED

A few years ago, Rocksoft City Hospital started recording data on patient arrivals, so the hospital now has a fairly good idea of the arrival rates for the various types of patients. These arrival rates differ by day of week and time of day as illustrated for the ED patients in Tables 2 through 4.

Table 2. Moderate ED Patient Arrival Rates

Day of Week	Arrival Rate (Patients per Hour) During Time Period					
	0000-0600	0600-0900	0900-1200	1200-1500	1500-1800	1800-2400
Monday-Thursday	0.1	1	2	1	2	0.1
Friday	0.1	1	2	1	2	1
Saturday	0.5	1	2	1	2	1
Sunday	0.5	1	2	1	1	0.1

Table 3. Serious ED Patient Arrival Rates

Day of Week	Arrival Rate (Patients per Hour) During Time Period					
	0000-0600	0600-0900	0900-1200	1200-1500	1500-1800	1800-2400
Monday-Thursday	0.5	0.5	1	1	2	0.5
Friday	0.5	0.5	1	1	2	1.5
Saturday	1.2	0.5	1	1	2	1.5
Sunday	1.1	0.5	1	1	1	0.5

Table 4. Critical ED Patient Arrival Rates

Day of Week	Arrival Rate (Patients per Hour) During Time Period					
	0000-0600	0600-0900	0900-1200	1200-1500	1500-1800	1800-2400
Monday-Thursday	0.3	0.5	0.5	0.3	0.3	0.3
Friday	0.3	0.5	0.5	0.3	0.3	2.0
Saturday	1.5	0.5	0.5	1.5	1.5	2.0
Sunday	1.5	0.5	0.5	0.5	0.5	0.3

Critical Patients

Critical patient arrivals are sent directly to any available trauma or standard room, with preference for a trauma room, if one is available. If no room is available, then the critical patient is sent to the waiting area to wait for the first available room.

Non-critical Patients

Arriving non-critical patients first check in at the front desk. This 1- to 5-minute process (using the first-available registration person) identifies the patient's severity and treatment priority. The patient then goes to the waiting area until he or she is called for registration. Registration takes 3 to 8 minutes. The patient then returns to the waiting area to wait until any standard room is available. Non-critical patients are not assigned to trauma rooms.

Table 5. ED Processing Data

Patient Type	Nurse Prep Time (minutes)	Doctor Exam Time (minutes)	Cleanup Time (minutes)
Moderate-ED	5-10	5-10	2-8
Serious-ED	5-7	5-15	3-9
Critical-ED	3-7	5-25	5-20

All Patients

Upon arriving at a room, every patient is seen by a nurse who checks the patient's vital signs. After the nurse prep time specified in Table 5, the nurse departs and the patient is seen by a doctor. After the doctor exam time specified in Table 5, the doctor departs. Upon completion of the doctor's exam, some of the patients move to diagnostics (images or lab work) and some are sent elsewhere as detailed in "Initial Service" in Table 6. If necessary, a patient waits in his or her room until the destination is available.

If a patient does **not** require diagnostics, the patient proceeds as indicated in "Notes" in Table 6.

If a patient **does** require diagnostics, the room is held for the patient during the diagnostics procedure. After returning to the room, the patient waits for the test results to be completed and to see the doctor to discuss the diagnostic results (requires 2-5 minutes of the doctor's time). The patient then proceeds according to "Final Service" in Table 6.

After any non-diagnostic dispositions, the patient departs based on "Notes" in Table 6, the room is cleaned according to the time specified in Table 5, and the room becomes available for reuse.

Table 6. Patient Treatment Plan/Disposition after Doctor Consultation

Disposition After Doctor Consult	ED Moderate		ED Serious		ED Critical		Notes
	Initial Service	Final Service	Initial Service	Final Service	Initial Service	Final Service	
Diagnostic Images	20%	n/a	25%	NA	40%	NA	Returns to same room after completion.
Diagnostic Lab Work	15%	n/a	20%	NA	40%	NA	Returns to same room after completion.
Surgery	0%	1%	3%	3%	10%	15%	Patient enters first available OR and follows normal surgical procedure.
Admitted to Hospital	2%	7%	8%	14%	6%	75%	Patient leaves room (and model) after an average wait of 45 minutes (exponential distribution).
Treated and Discharged	63%	92%	44%	83%	4%	10%	Patient leaves room after treatment time by nurse of 10-30 minutes.

Operational Details – Surgery

Three types of patients need surgery. Two patient types may require emergency surgery: certain ED patients or, occasionally, patients from elsewhere in the hospital. The arrival rates for these patients are listed in Table 7. Modeling other hospital operations is beyond the scope of this project. You will assume that all patients for emergency surgery remain in their present locations until an OR is available.

Table 7. Emergency Surgery Arrival Rates

Day of Week	Arrival Rate (Patients per Hour) During Time Period					
	0000-0600	0600-0900	0900-1200	1200-1500	1500-1800	1800-2400
All	0.02	0.05	0.05	0.05	0.05	0.02

Scheduled surgery (such as a scheduled knee replacement) defines the third type of surgery patient. For modeling simplicity, the timing of these surgeries can be represented by the arrival rates listed in Table 8. Under current policy, scheduled surgeries take place only on Tuesday, Wednesday, and Thursday, which leaves the four-day weekend available for other activities (such as office hours, academic responsibilities, and research). These surgeries are only scheduled to start early in the day so they may be completed by mid-afternoon. The registration process for surgery is independent and outside the scope of this model, but the overall waiting time is important to calculate service metrics. Patients must wait in the surgery waiting area until an OR is available.

Table 8. Scheduled Surgery Arrival Rates

Day of Week	Arrival Rate (Patients per Hour) During Time Period					
	0000-0600	0600-0900	0900-1200	1200-1500	1500-1800	1800-2400
Tuesday	0	0.8	0.8	0	0	0
Wednesday	0	0.8	0.8	0	0	0
Thursday	0	0.8	0.8	0	0	0
Other Days	0	0	0	0	0	0

Once the patient actually arrives at the OR, the process (including any prep work and cleanup) starts immediately. The entire process requires 0.75 to 6.0 hours with a mode of 2.0 hours. After the process ends, the room is immediately available, and the patient is moved elsewhere in the hospital (and out of the model).

Operational Details – Diagnostic Facilities (General)

There are four types of patients who need diagnostic work. In addition to lab or imaging needs related to the ED and surgery, inpatients from elsewhere in the hospital also occasionally need diagnostic work. The arrival rates for these are listed in Table 9. Modeling other hospital operations is beyond the scope of this project, so you will assume that all internal patients for diagnostic work remain in their present location until the appropriate diagnostic facility is available.

Table 9. Inpatient Diagnostics Arrival Rates

Day of Week	Arrival Rate (Patients per Hour) During Time Period					
	0000-0600	0600-0900	0900-1200	1200-1500	1500-1800	1800-2400
Monday-Friday	0	5	3	2	0	0
Saturday	0	1	1	1	0	0
Sunday	0	1	1	1	0	0

The fourth type of diagnostic patient is outpatient diagnostic service (such as a mammogram ordered by an outside physician). These are currently only scheduled on weekdays from 0900 to 1500 and Saturday mornings from 0900 to 1200. The arrival rates for these patients are listed in Table 10.

Table 10. Outpatient Diagnostics Arrival Rates

Day of Week	Arrival Rate (Patients per Hour) During Time Period					
	0000-0600	0600-0900	0900-1200	1200-1500	1500-1800	1800-2400
Monday-Friday	0	0	10	10	0	0
Saturday	0	0	10	0	0	0
Sunday	0	0	0	0	0	0

Arriving patients for diagnostic work may go directly in and immediately start the processing if they have already reserved the appropriate diagnostic technician time. The registration process for diagnostics is independent and outside the scope of this model, but the overall waiting time is important to calculate service metrics. Outpatients must wait in the diagnostics waiting area until the diagnostic technician is available.

Since inpatients generally get their specimens taken at the bedside, all inpatients who come to this area are here for imaging. For outpatients, generally about 44% of them need only images and the rest need only lab work.

Operational Details – Diagnostic Lab

Lab operations are similar for all patients. The procedure starts as soon as the patient arrives and the technician is available. It takes from 3 to 9 minutes, with a mode of 6 minutes. The patient is free to leave at this point. If results are needed immediately, it requires 8 to 17 minutes for Priority 1 patients and 10 to 34 minutes for all others.

Operational Details – Diagnostic Imaging

Imaging operations are similar for all patients. The procedure starts as soon as the patient arrives and the technician is available. It takes from 4 to 18 minutes, with a mode of 7 minutes. The patient is free to leave at this point. If results are needed immediately, it requires 4 to 12 minutes for Priority 1 patients and 10 to 25 minutes for all others.

Staffing

Because of its size, Rocksoft City Hospital currently schedules only two nurses and one of each of the other hospital staff positions around the clock. Changes to the staffing schedule are permissible as long as the minimum shift for scheduling staff is 6 hours. That is, the hospital cannot add a person from 0900 to 1200. The person must work a minimum of 6 hours; e.g., 0600 to 1200. There is no requirement to have the same staffing level every day.

The current staffing levels are shown in Table 11.

Table 11. Monday through Sunday Staffing

Position	Personnel on Duty During Time Period					
	0000-0600	0600-0900	0900-1200	1200-1500	1500-1800	1800-2400
ED Doctors	1	1	1	1	1	1
ED Nurses	2	2	2	2	2	2
Lab Tech	1	1	1	1	1	1
Imaging Tech	1	1	1	1	1	1
Registration	1	1	1	1	1	1

Cost Data

Table 12 describes the operating costs of the hospital facilities. These hourly costs are in addition to the costs for staff. There is limited money and space available for new facilities. The capital cost of adding new facilities is also reflected in this table. Table 13 defines the hourly cost of the scheduled staff.

Table 12. Facility Operating and Capital Costs

Room Type	Operating Costs/Hr	Capital Costs (new)
Registration	\$25	\$20,000
Standard Room	\$450	\$175,000
Trauma Room	\$1400	\$600,000
Operating Room	\$3400	\$1,000,000
Imaging	\$360	\$750,000
Lab	\$285	\$125,000

Table 13. Staff Hourly Cost Including Overhead

Staff Type	Burdened Costs/Hr
Doctor	\$175
Nurse	\$85
Image Technician	\$75
Lab Technician	\$62
Registration	\$43

Measures of Effectiveness

The primary measures of service, quality of care, and operating efficiency are:

- Time until treatment (“door-to-doctor” time, the time from arrival until primary caregiver is seen) by patient type
- Total operating cost per week

Secondary measures include:

- Time until first seen (“door-to-seen” time, the time from arrival until the start of registration)

- Total time in system (length of stay (LOS)) before being discharged or admitted to a hospital bed)
- The percent VAT (value-added time) by patient type; that is, the total time being given care divided by the total time in the system
- Percentages of LWBS by patient type, emergency surgery patients who expire while waiting for surgery, and scheduled surgery patients who had their surgery cancelled
- Resource utilization (rooms and personnel by type)

Project Objectives

The board would like your recommendations on the following questions:

1. What staffing schedule should be used in the ED and Diagnostics to optimize overall service with current levels of other resources?
2. Can the hospital better plan the scheduled surgeries and diagnostics in order to minimize their impact on the ED?
3. The Joint Commission of Healthcare Accreditation has issued new requirements for maximum allowable service times for critical patients. The door-to-treatment standard for critical patients is to have at least 95% of patients begin to receive a doctor's care in less than 12 minutes.
 - What level of resources would be necessary to achieve this level while still treating the same number of patients?
 - How could the hospital meet this standard with no additional resources, and what effect would that have on other patients?
4. The hospital anticipates volume increasing by 4% next year for all of the patient categories. How can this increased volume be accommodated?