9.8 Training Cases

9.8.1 Case 1: Improving the X-Ray Process at County Hospital*

County Hospital wishes to improve the service level of its regular x-ray operation, which runs from 8:00 AM to 8:00 PM. Patients have identified the total required time as their main concern with this process. Management, on the other hand, is concerned with utilization of available resources. Management has created a process-improvement team to study this problem. The process might be redesigned as a result of the team's recommendations.

The team has defined the entry point to the x-ray process to be the instant a patient leaves the physician's office en route to the x-ray lab. The exit point has been defined as the instant at which the patient and the completed x-ray enter the physician's office.

Broadly speaking, two types of patients arrive to the x-ray process: emergency and nonemergency patients (priority levels 1 and 2, respectively). The emergency patients arrive according to a Poisson process with a mean of four patients per hour. The nonemergency patients are registered as they enter, and a sample of the arrival time data is provided in Table 9.14. Until now, no attempt has been made to further analyze these data, so there is no insight into what the arrival process looks like.

The team has identified 12 activities in the current x-ray process (see Table 9.15), which is the same irrespective of the patient type. The only differences between patient categories are the activity times and their distributions, specified in Table 9.16.

TABLE 9.14

Sample Arrival Times of Nonemergency Patients

Patient #	Time of Arrival (in Minutes from Time Zero)	Patient #	Time of Arrival (in Minutes from Time Zero)
1	6.30	31	197.89
2	10.13	32	205.50
3	17.07	33	215.42
4	17.09	34	219.95
5	23.94	35	223.50
6	26.06	36	233.33
7	27.65	37	234.89
8	29.21	38	239.20
9	41.65	39	244.29
10	44.69	40	247.29
11	49.79	41	249.90
12	60.07	42	250.25
13	70.34	43	256.34
14	70.73	44	257.90
15	74.32	45	268.97
16	84.59	46	276.82
17	91.77	47	280.43
18	95.78	48	281.94
19	98.20	49	293.23
20	117.24	50	293.57
21	122.85	51	299.79
22	130.58	52	303.75
23	137.46	53	306.58
24	139.76	54	308.13
25	142.52	55	314.06
26	150.70	56	322.84
27	151.95	57	326.51
28	154.74	58	338.21
29	157.48	59	339.91
30	193.25	60	365.79

TABLE 9.15

Activities in the Current X-Ray Process

Activity	Description	Type
1	Patient leaves physician's office with instructions.	Start of the x-ray process
2	Patient is taken to the lab by an orderly, on foot in wheelchair or lying in bed.	Transportation
3	The patient is left in the waiting area outside the x-ray lab in anticipation of an x-ray technician.	Waiting
4	An x-ray technician fills out a standard form based on information supplied by the physician and the patient (done outside the x-ray lab). The technician then leaves the patient, who queues up in front of the x-ray labs.	Business value added
5	The patient enters the x-ray lab and undresses, and an x-ray technician takes the required x-rays (all done in the x-ray lab).	Value added
6	A dark room technician develops the x-rays. (Assume that the patient and the x-ray technician accompany the x-rays.)	Value added
7	The dark room technician and the x-ray technician check the x-rays for clarity. (Assume that the patient accompanies his or her x-rays.)	Inspection
8	If x-rays are not clear, then the patient needs to go back to the waiting room in anticipation of repeating steps 5, 6, and 7. Historically, the probability of rejecting x-rays has been 25%. If the x-rays are acceptable, the patient proceeds to activity 9, while the x-rays are put in the outbox, where eventually the messenger service will pick them up.	Decision
9	Patient waits for an orderly to take him or her back to the physician's office.	Waiting
10	Patient is taken back to the physician's office by an orderly.	Transportation
11	A messenger service transfers the x-rays to the physicians in batches of five jobs.	Transportation
12	Patient and x-rays enter physician's office together.	End

The patient priority levels determine the service order of all the x-ray activities. Emergency patients (priority 1) come first at the expense of nonemergency patients (priority 2). However, after service is started, it will never be interrupted to benefit a high priority patient.

The resource data for the x-ray process are specified in Table 9.17. The orderlies will always take one patient back from the x-ray lab when they have dropped one off. Assume that the transportation time back from the x-ray lab is exactly the same as the transportation time to the x-ray lab. If no patient is ready to go back, the orderly will wait for 5 min; if no patient becomes available during this time, the orderly will return to the ward without a patient. The time for an orderly to walk back without a patient is always 5 min. The orderlies will never go and pick up a patient at the x-ray area without bringing another patient with them from the ward.

TABLE 9.16

Activity Times for X-Ray Process

Activity	Patient Type	Activity Time Distribution	Parameter Values (Min)
1	All types	Not applicable	Not applicable
2	Emergency patients	Uniform	Max = 9, min = 5
	Nonemergency patients	Uniform	Max = 12, min = 5
3	All types	Not applicable	Not applicable
4	All types	Uniform	Max = 6, min = 4
5	Emergency patients	Normal	$\mu = 9, \sigma = 4$
	Nonemergency patients	Normal	$\mu = 11, \sigma = 4$
6	All types	Normal	$\mu = 12, \sigma = 5$
7	All types	Constant	Value = 2
8	All types	Constant	Value = 0
9	All types	Not applicable	Not applicable
10	Emergency patients	Uniform	Max = 9, min = 5
	Nonemergency patients	Uniform	Max = 12, min = 5
11	All types	Uniform	Max = 7, min = 3
12	All types	Not applicable	Not applicable

TABLE 9.17

Resource Data for X-Ray Process

Resource	Activities	No. of Units Available
Orderlies	2 and 10	3
X-ray technician	4, 5, 6, and 7	3
X-ray lab	5	2
Dark room technician	6 and 7	2
Dark room	6	1

Part I: Analyzing the Current Process Design

1. Draw a flowchart of the current x-ray process.
2. Develop a simulation model of this process.
   - The model requires analysis of input data regarding the arrival process of nonemergency patients.
   - *Modeling hint:* Build the model incrementally based on your flowchart. Do not try to put everything together at once and then test whether it works.
   - As a first check that everything works as it is supposed to, it is often useful to run a shorter simulation with animation. Use different symbols for different types of items, such as different types of labor and different types of jobs.
3. For a first-cut analysis, run a 1-day simulation with the random seed set at 100, using the correct activity time distributions. Look at the average cycle time, the throughput rate, the resource, the queue, and the activity statistics. What are the problems in this process?
4. Simulate 30 days of operation and compute the cycle time and daily throughput (average, standard deviation, and 95% confidence intervals). Also compute the activity and resource utilization statistics and queue statistics with 95% confidence intervals. (Use the Statistics block in the Value library of ExtendSim.) Assume that any patients remaining in the system at the end of the day will be taken care of by the night shift. Every morning, the system is assumed to be empty. Are there any surprises when you compare these results with the ones in question 3?
5. Assess the performance of the process using the values calculated in question 4. Where is the bottleneck? Which are the problems for reducing the cycle time and increasing the throughput rate?