

Maximizing Cardiac Surgery Throughput at a Major Hospital

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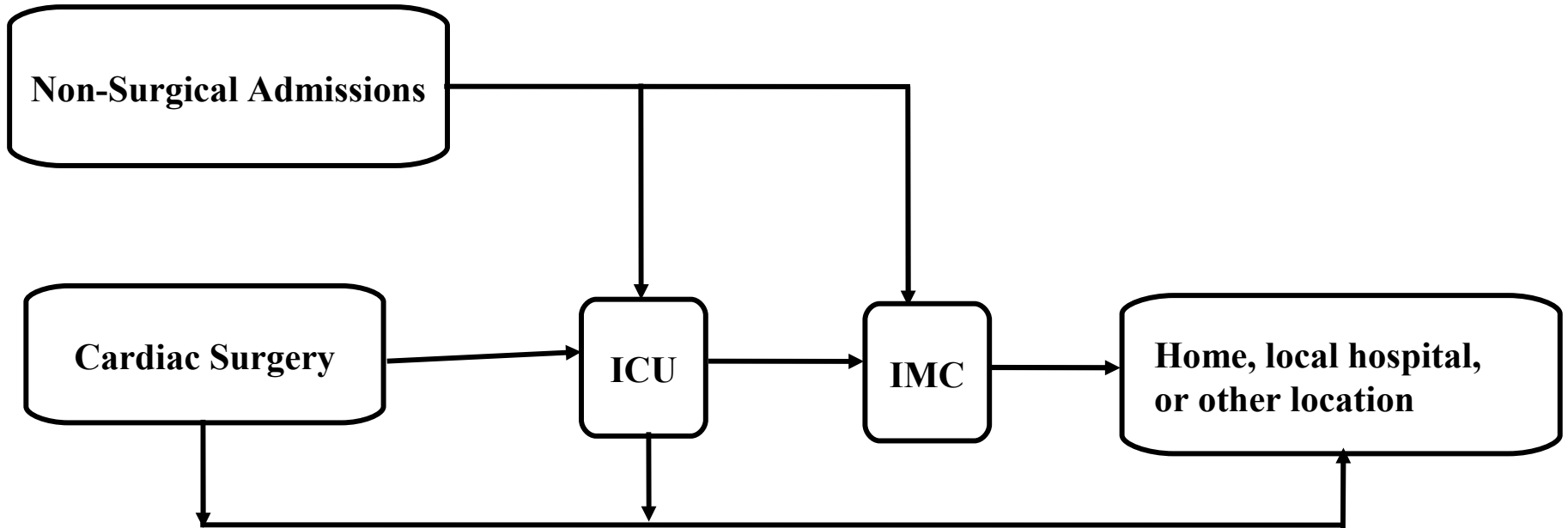
Problem Statement

- The Cardiac Surgery service line at the UMMC has 30 beds that are split between the intensive care unit (ICU) and the intermediate care unit (IMC)
- Total yearly capacity is $365 \times 30 = 10,950$ bed days
- From 7/1/05 to 6/30/06, there were 9,613 bed days used
- The service line is expected to grow at a rate of 13%
--FY07 utilization will be at 99.2% of capacity

Problem Statement--continued

- At the time of the study, there were 11 ICU beds and 18 IMC beds
- One bed was not in use because of insufficient staffing
- **Key Question:** What is the best mix of ICU and IMC beds?

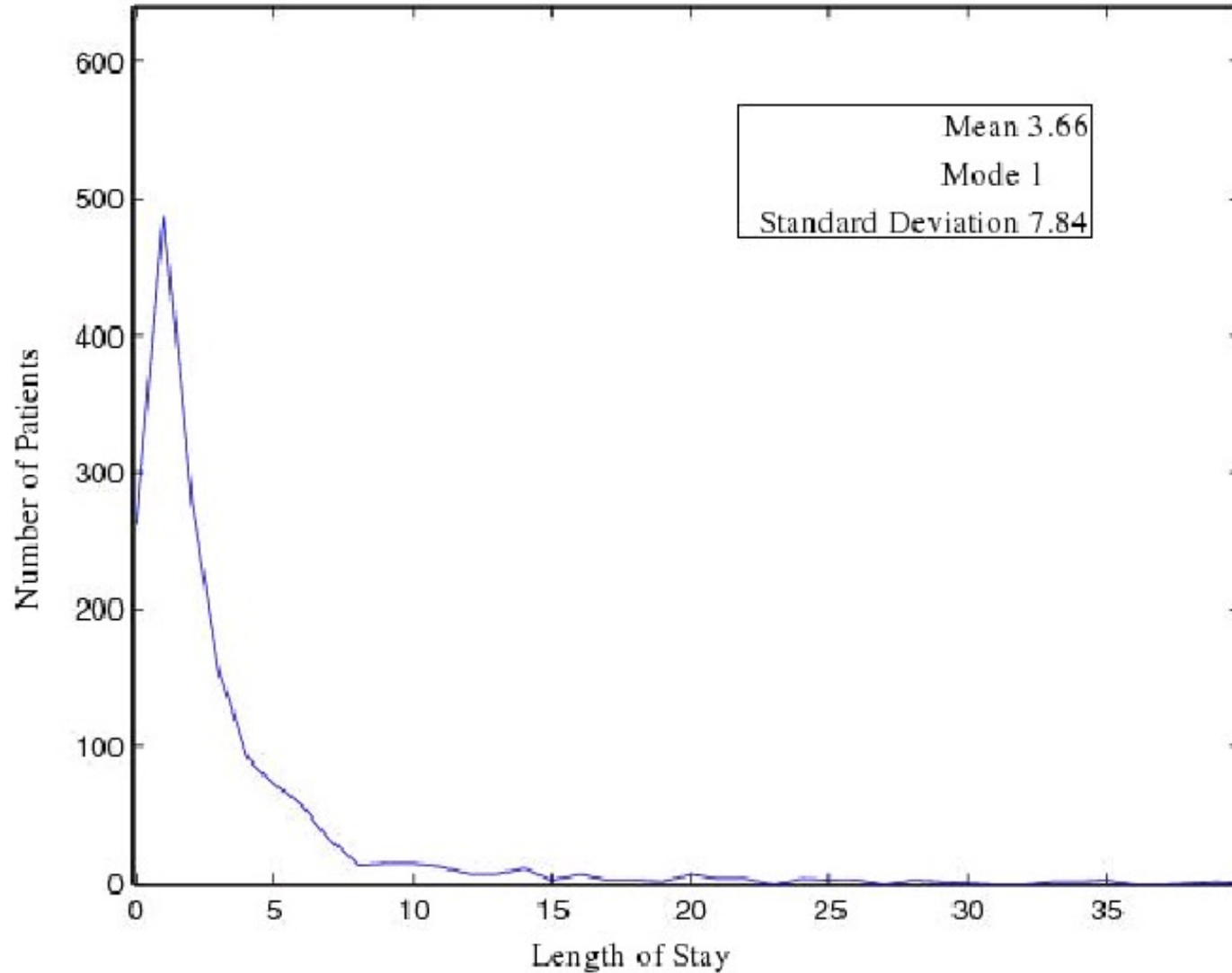
Flow of Patients



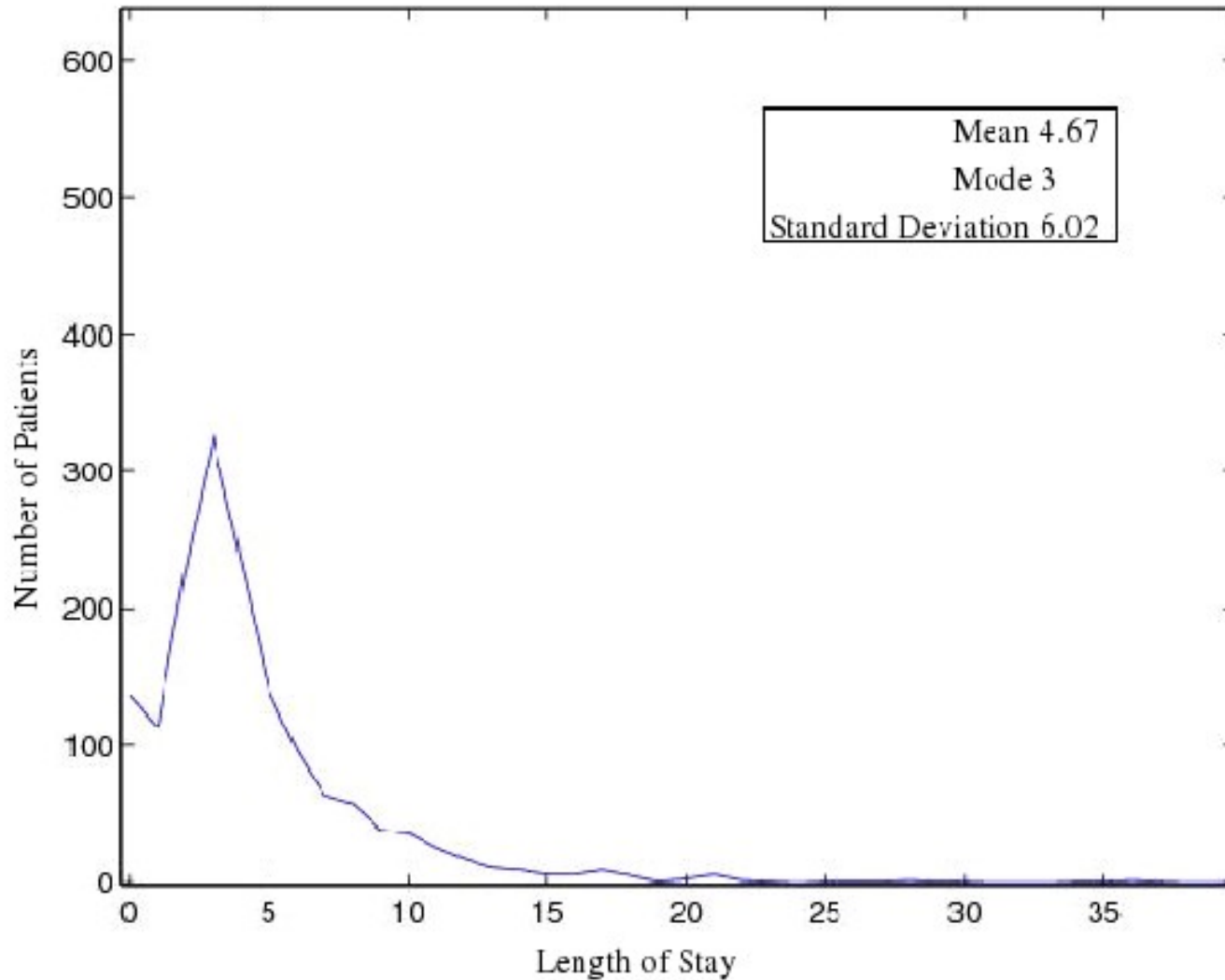
Data Set

- The data set contained detailed information about the length of stay for every cardiac surgery patient from FY05 and FY06
- 1,675 patients had 1,725 operations and spent more than 17,000 days in the hospital
- 83 patients did not spend time in cardiac surgery post-operative units
- On average, each patient in post-operative care had 1.085 operations

ICU Length of Stay



IMC Length of Stay



Methodology

- We used the data to perform a simulation of different mixes of ICU and IMC beds
- Blocking occurred when the IMC was full
- Initially, we assumed that the amount of time spent blocked in the ICU does not effect time in IMC
- We wanted to determine the maximum throughput, so a patient was admitted to the ICU whenever there was an open bed

Methodology--continued

- There were two different scenarios
 - Scenario 1: looked at maximizing throughput using all 30 available beds
 - Scenario 2: maintained the current staffing level of 80 nurses
- Each case in each scenario was simulated 999 times
- To approximate steady-state conditions, we simulated a 13 week period with a warm-up period of 13 weeks

ICU Throughput--Scenario 1

Bed Mix	11 ICU 18 IMC	12 ICU 18 IMC	13 ICU 17 IMC	14 ICU 16 IMC	15 ICU 15 IMC
Mean	230.04	248.31	262.88	270.20	268.39
Standard Deviation	15.44	14.66	13.17	12.03	11.40
Minimum	175	202	213	227	227
Bottom 5%	204	224	240	250	249
Median	230	248	264	271	268
Top 5%	255	272	283	290	288
Maximum	278	291	299	305	300

% Days Blocked--Scenario 1

Bed Mix	11 ICU 18 IMC	12 ICU 18 IMC	13 ICU 17 IMC	14 ICU 16 IMC	15 ICU 15 IMC
Mean	0.33	0.69	2.04	4.44	8.43
Standard Deviation	0.37	0.60	1.20	1.88	2.63
Minimum	0.00	0.00	0.00	0.38	1.51
Bottom 5%	0.00	0.03	0.45	1.65	4.16
Median	0.19	0.55	1.79	4.21	8.30
Top 5%	1.06	1.86	4.25	7.80	12.86
Maximum	2.55	3.75	8.76	11.23	16.10

Blocking

- Throughput is significantly effected when the system is in the blocked state more than 4% of the time, on average.
- It is counter-intuitive that changing an IMC bed to and ICU bed would reduce the throughput (a patient can spend his IMC time recovering in an ICU bed)
- We changed the model so that every day a patient spends blocked in an ICU bed, one fewer day was spent in the IMC.

ICU Throughput--Scenario 1

Bed Mix	11 ICU 18 IMC	12 ICU 18 IMC	13 ICU 17 IMC	14 ICU 16 IMC	15 ICU 15 IMC
Mean	285.62	317.85	337.72	367.97	375.77
Standard Deviation	35.14	30.26	32.83	35.12	40.42
Minimum	222	229	254	272	262
Bottom 25%	265	299	312	346	351
Median	282	318	343	372	382
Top 25%	305	334	360	390	406
Maximum	360	390	425	446	447

% Days Blocked--Scenario 1

Bed Mix	11 ICU 18 IMC	12 ICU 18 IMC	13 ICU 17 IMC	14 ICU 16 IMC	15 ICU 15 IMC
Mean	8.40	11.73	17.60	25.16	29.96
Standard Deviation	5.24	5.20	5.89	6.04	6.90
Minimum	1.35	1.43	3.85	11.29	14.12
Bottom 25%	4.61	7.72	13.58	20.76	26.38
Median	7.91	11.39	17.68	25.29	30.46
Top 25%	11.76	15.46	22.13	29.34	35.19
Maximum	20.28	22.56	32.39	39.01	51.69

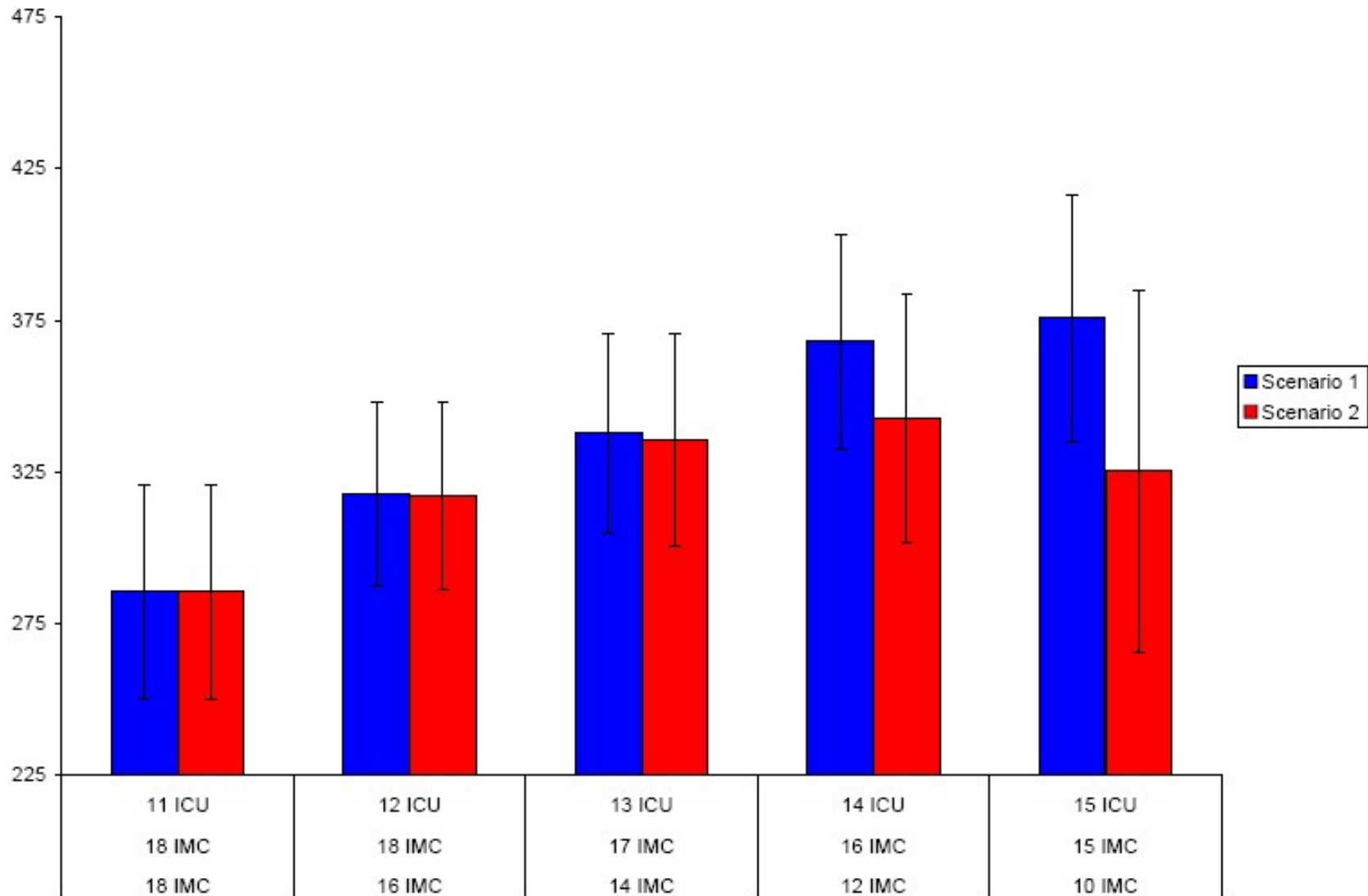
ICU Throughput--Scenario 2

Bed Mix	11 ICU 18 IMC	12 ICU 16 IMC	13 ICU 14 IMC	14 ICU 12 IMC	15 ICU 10 IMC
Mean	285.62	317.38	335.77	342.83	325.35
Standard Deviation	35.14	30.68	34.85	40.93	59.53
Minimum	222	232	244	246	237
Bottom 25%	265	295	310	318	275
Median	282	318	338	348	315
Top 25%	305	334	360	370	368
Maximum	360	387	409	429	439

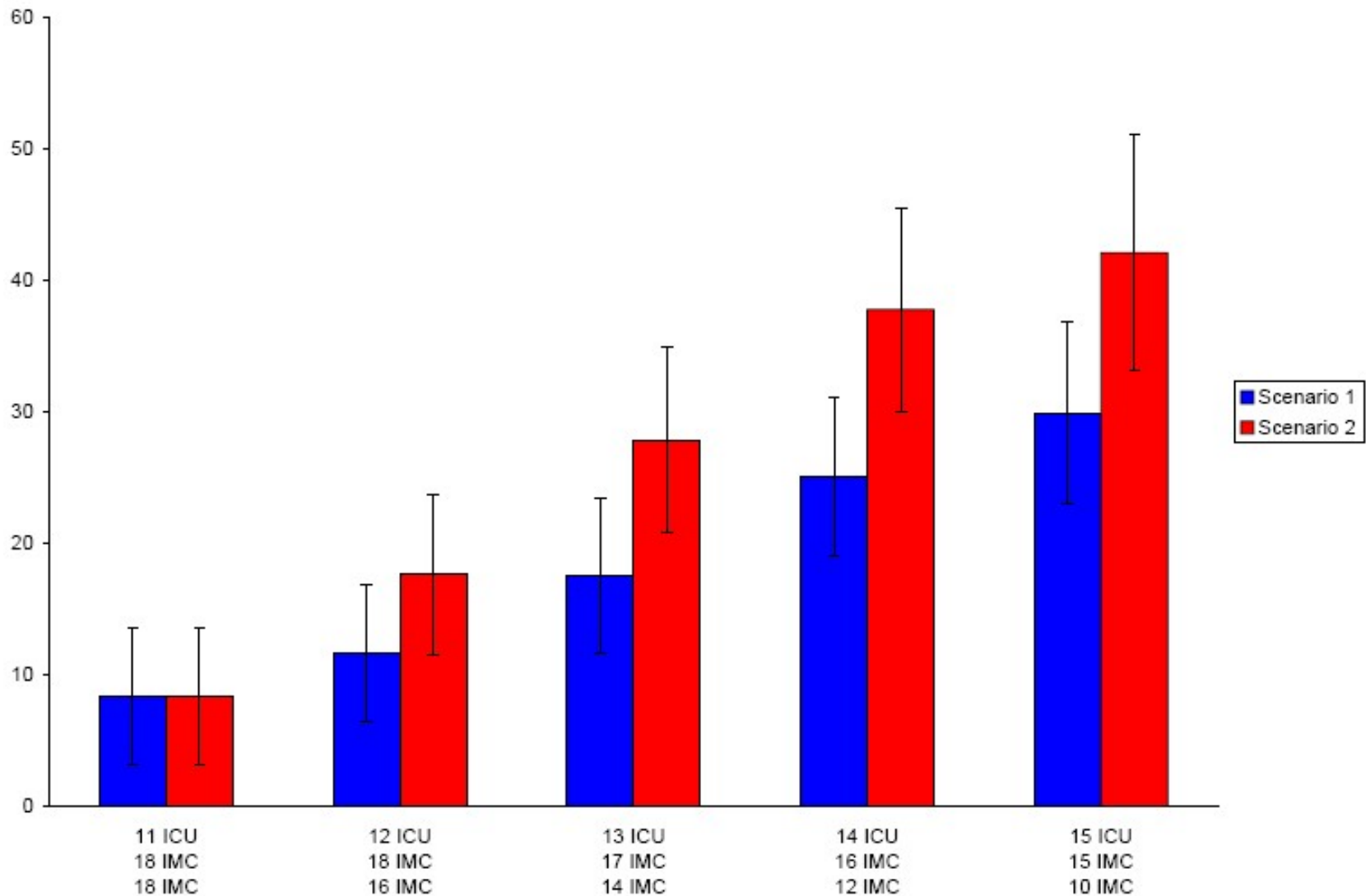
% Days Blocked—Scenario 2

Bed Mix	11 ICU 18 IMC	12 ICU 16 IMC	13 ICU 14 IMC	14 ICU 12 IMC	15 ICU 10 IMC
Mean	8.40	17.69	27.89	37.38	42.12
Standard Deviation	5.24	6.08	7.01	7.73	9.00
Minimum	1.35	3.88	9.47	15.04	24.89
Bottom 25%	4.61	13.40	22.89	30.99	32.60
Median	7.91	17.28	27.95	38.78	40.19
Top 25%	11.76	22.12	32.12	43.17	49.09
Maximum	20.28	31.66	44.94	55.44	62.71

ICU Throughput



% Days Blocked



Results--Scenario 1

- The 15/15 bed mix enabled a total volume increase of 31.57%
- Each cardiac surgery provides a net income of roughly \$20,000
- Each nurse costs roughly \$100,000
- The 15/15 bed mix yields an annual increase in profit of as much as $90 \times 4 \times \$20,000 - 8 \times \$100,000 = \$6.21$ million

Results--Scenario 2

- The 14/12 bed mix enabled a total volume increase of 20.03%
- Each cardiac surgery provides a net income of roughly \$20,000
- Staffing levels are constant, so there is no additional cost for nurses
- The 14/12 bed mix yields an annual increase in profit of as much as $57 \times 4 \times \$20,000 = \4.58 million

Financial Results

Scenario 1

Bed Mix	12 ICU/ 18 IMC	13 ICU/ 17 IMC	14 ICU/ 16 IMC	15 ICU/ 15 IMC
Change in Mean	32.24	52.11	82.35	90.16
% Change	11.29	18.24	28.83	31.57
Change in Profit	\$2,178,888.04	\$3,568,591.01	\$5,788,392.99	\$6,212,551.41

Scenario 2

Bed Mix	12 ICU/ 16 IMC	13 ICU/ 14 IMC	14 ICU/ 12 IMC	15 ICU/ 10 IMC
Change in Mean	31.72	50.16	57.22	39.73
% Change	11.11	17.56	20.03	13.91
Change in Profit	\$2,537,699.92	\$4,012,551.41	\$4,577,303.88	\$3,178,492.00

Conclusions

- Currently, the hospital uses 13 to 14 ICU beds and 16 to 17 IMC beds depending on the immediate staff availability
- Simulation can help administrators optimize resource levels under a variety of constraints
- This work can be reproduced in other service lines and at other hospitals with similar results