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REDUCING CAPITAL COST AND SEMI-PRIVATE BED EXPERIENCE BY SIMULATING HOSPITAL INPATIENT OPERATIONS

Martin Miller

Decision Analytics, LLC
10029 Brompton Drive
Tampa, FL 33626, USA

ABSTRACT

Hospital planners want to build the right capacity based on expected demand. Overbuilding means overspending and building beds that become underutilized. Underbuilding means insufficient beds, causing longer bed queues. Placing inpatients in semi-private beds reduces capital investment cost by building fewer rooms, or potentially fewer floors, but this option usually reduces patient satisfaction compared to placing inpatients in all private beds. Additionally, studies show inpatients with private bed experience have shorter lengths of stay. This paper describes how simulation modeling can help reduce capital costs by determining an appropriate number of semi-private rooms that ensure sufficient capacity yet care for most inpatients with a private room experience. Results from a recent inpatient simulation project indicates possible reduction of private rooms by 25 percent yet only requiring inpatient placement in semi-private beds 5 percent of time. Further analysis shows this result is only possible when inpatient capacity is precisely determined.

1 INTRODUCTION

Hospital planners (i.e., healthcare architects, interior designers, facility planning consultants, hospital-based managers and planners, and various other professionals) want options that allow flexibility with inpatient capacity (Burnette 2006). One common option is to build shell space, where walls and floors are built, but not finished until later years, when the space is needed. This is a good alternative if the hospital needs more beds. Another option is to care for patients in semiprivate beds, where one room holds two patients, which creates lower capital investment cost, but also lower patient satisfaction, lower revenue than all patients in private beds (Boardman, Forbes and Buller 2007). Patient satisfaction is higher with private room and research indicates improved recovery and reduced length of stay. Hospital leadership may strategically decide to operate only private beds.

Hospital planners in the United States continue to trend toward all-private inpatient rooms. The Facility Guidelines Institute's Guidelines for Design and Construction of Health Care Facilities states "The maximum number of beds per room shall be one unless the functional program demonstrates the necessity of a two-bed arrangement. Approval of a two-bed arrangement shall be obtained from the licensing authority." Research supports the benefits for private rooms, including patient preference and better infection control. However, recent literature suggests planners should not completely abandon the semi-private approach (Verderber and Todd 2012). Hospital in the Netherlands continue to successfully utilize semi-private rooms with lower infection rates than the United States.

This paper considers a delicate option to balance private and semi-private beds. But this places increases pressure to determine the right number of inpatient beds to meet future-state demand. Traditionally, planners use spreadsheets and averages to calculate bed capacity. However, planners increasingly look to more precise tools, such as simulation modeling, to improve planning accuracy.

2 MODELING ASSUMPTIONS

2.1 Inpatient Simulation

Complex systems are better suited for simulation modeling, compared to mathematical models and spreadsheets (Law and Kelton 1991). Simulation models can help identify where process bottlenecks occur when stable systems become stressed from increasing volumes. Additionally, simulation analysis can help determine which changes reduce or eliminate these bottlenecks (Ferrin, Miller and Giron 2000). Simulation models can test more process scenarios and provide more detail than conventional spreadsheet analysis (Miller, Ferrin and Szymanski 2003). Simulation results can provide more insight about facilities capacity and throughput (Nance and Sargent 2002).

Inpatient systems contain complexity with the timing of patient arrivals and discharges. For example, the same bed can be used for two patients in the same day if the discharge occurs before the admission. Also, patients may be placed in more than one unit, depending on the type of patient and the state of the system. For example, a surgical acute patient may be placed in a medical acute unit based on available beds. Other system complexities include variability with unit length of stay, internal patient transfers between units and limitations on patient placement in semi-private rooms due to gender and infection control. Note every increasing complexity to a simulation model does not always add value to the final analysis. Too much complexity becomes counterproductive when excess effort is required to validate that the model behaves like reality (Nance and Sargent 2002).

HKS has developed a reusable inpatient simulation model, written with ExtendSim9™, to test alternative design scenarios for existing and proposed bed towers. This model resulted from a need by hospital administrators to improve Key Performance Indicators (KPIs), such as wait time for a bed and bed utilization. The inpatient simulation model also helps hospital planners to predict future-state performance before finalizing architectural designs.

2.2 Inpatient Arrivals

Typically, simulation arrival volumes come from historical inpatient data. This model separated inpatient arrivals into three distinct sources because each sources contained distinctly different arrival patterns which influence the availability of inpatient beds. The arrival pattern also varies by hour of day and day of week (Figure 1).

Analysis of the hourly variation of patient arrival volumes over an entire year may also show the impact of seasonality. This variability can cause a model to overestimate or underestimate the demand when using the annual mean. Figure 2 shows the highest volume occurred in February and the lowest volumes occurred in May. However, the variation range is less than +/- 5%. The Inpatient Simulation tested scenarios that increase arrival volumes up to 15% over the expected annual mean. Identifying future-state volumes cannot be done perfectly; therefore, simulation scenario for this analysis assumed a 10% volume increase. This should encompass any impacts from seasonality.

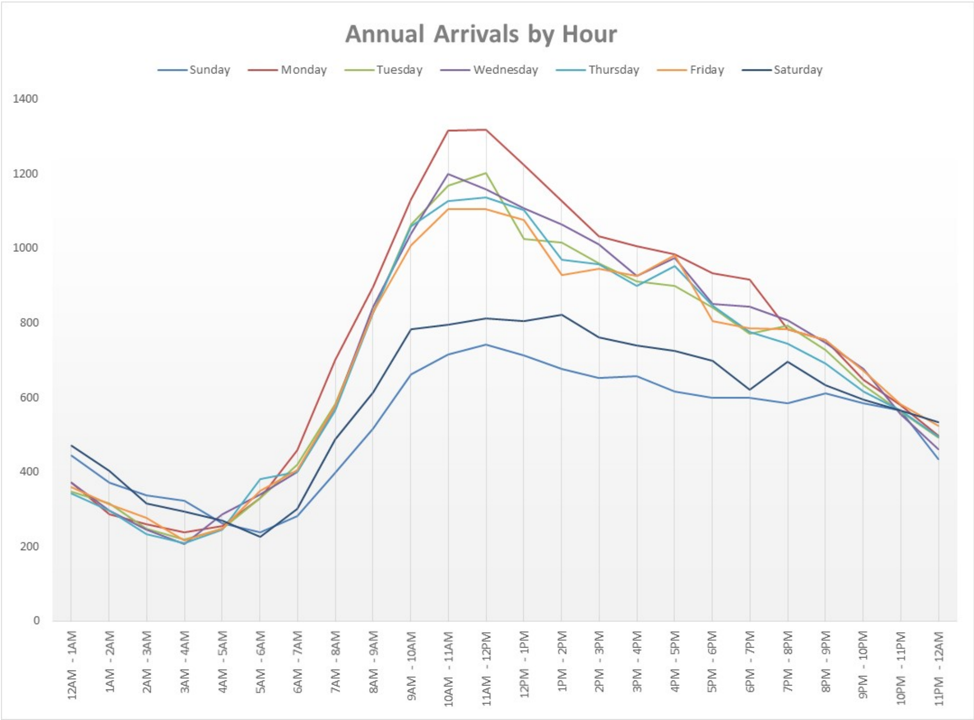

Figure 1. Inpatient arrival volume by hour of day and day of week.

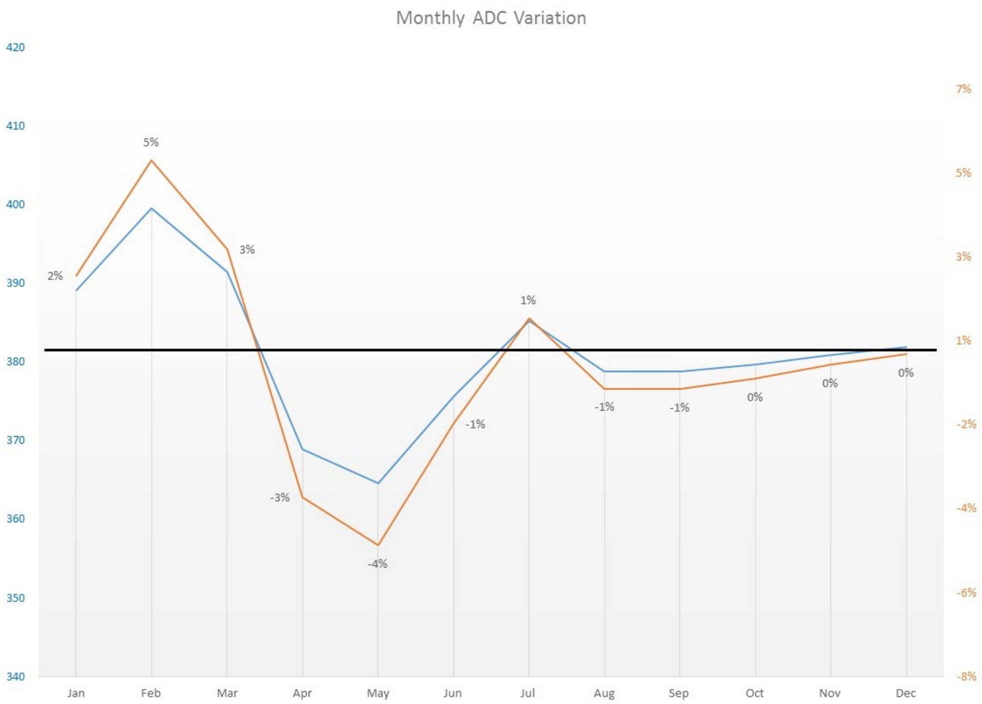

Figure 2. Seasonal variation in patient volumes.

When inpatients arrive in the simulation model, their attributes govern their routing to appropriate units of care. This model defined patient type volumes by mapping their current units to their new, future state units. Inpatients frequently transfer from higher acuity units to lower acuity units during their length of stay (LOS). The Inpatient Simulation model assumes a majority of patients transfer from Critical Care units to Acute Care units.

2.3 Inpatient Unit Placement

The next modeling step assigns patient attributes and places them in queue for the appropriate bed. Some patient types can go into another, similar unit when their primary unit is unavailable. When no optional patient units are available, then the patient continues to wait in queue until one of the unit options becomes available.

2.4 Inpatient Unit Length of Stay

Once placed on a unit, the simulation keeps the inpatient in that bed according to a statistically sampled length of stay (ALOS). This variability causes higher capacity needs compared to fixed demand, such as using the average in a spreadsheet calculation. Typically, a simulation model assumes unit LOS distributions based historical data (Figure 3). Alternatively, an approximate distribution can be synthesized around the ALOS, which is the number of patient days divided the number of patients. This model approximated distributions based on careful consideration of several hospitals.

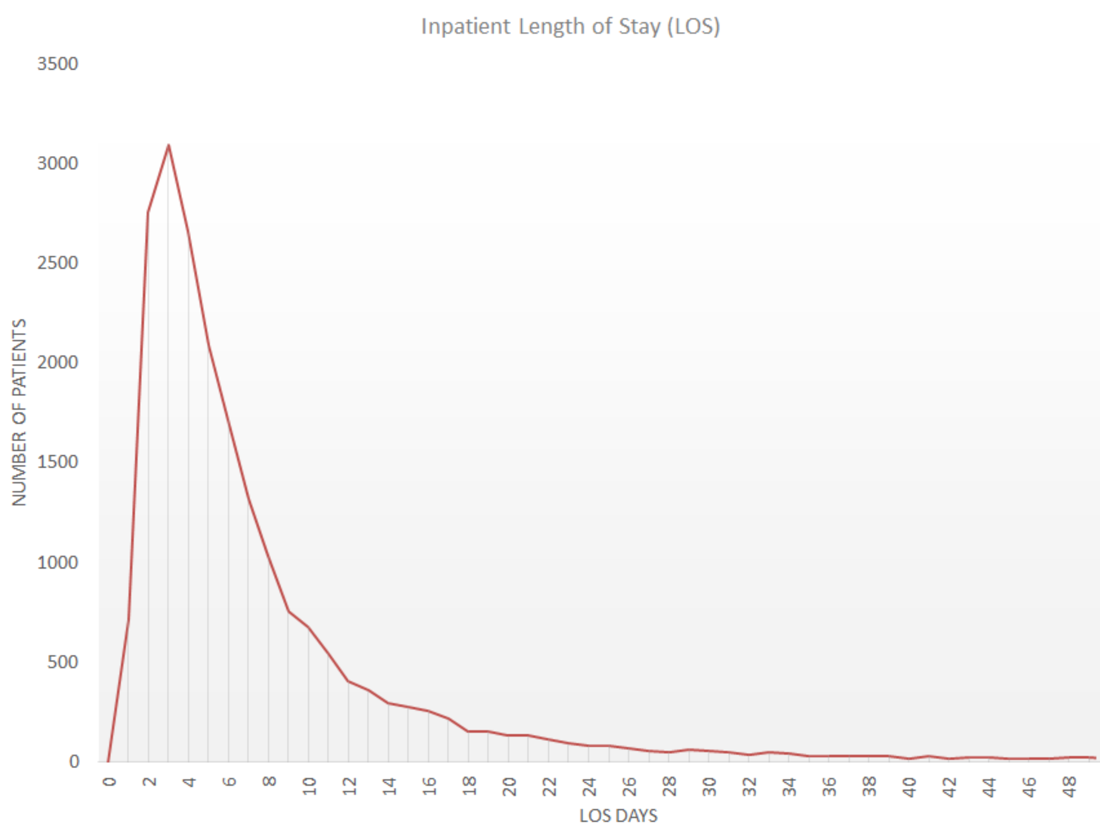

Figure 3. Distribution of historical inpatient LOS.

2.5 Inpatient Transfers and Discharges

The previous modeling step seizes an inpatient bed for a length of stay sampled from the appropriate statistical distribution. After this LOS, the model moves the patients out of the unit, such as transferring from critical care units to acute care units, when appropriate. This stay may range from 1 day to over 30 days, in some instances. Note the unit LOS may differ from the patient LOS, which is the sum of the LOS for all units, plus queue times, transport times, etc. The unit LOS is only equal to the patient LOS when the patient stays in one unit.

Inpatients eventually discharge from the hospital upon completion of their total length of stay. The time of discharge for many hospitals follow a similar pattern, shaped around an average discharge time of day. Most hospitals average between 3:00 PM and 6:00 PM discharge time of day (DTOD). The inpatient simulation model assumed an industry benchmark curve with an average equal to 4 pm. Future state scenarios test earlier discharge times that move the entire distribution in 1 hour increments (Figure 4).

Therefore, the final step in the simulation model process releases the inpatient bed and exits the patient from the hospital. The model assume discharge time encompasses room turnaround, making the bed immediately available to the next inpatient admission.

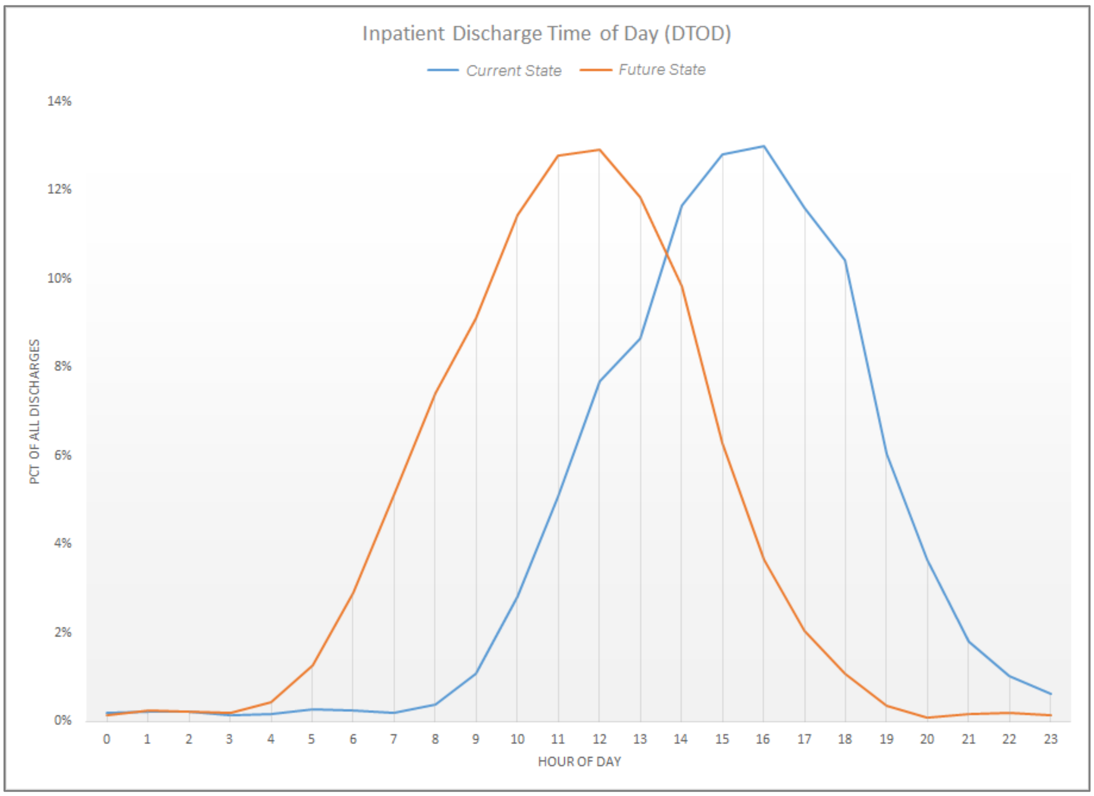

Figure 4. Baseline and alternative distribution of patient discharges by hour of day.

3 SIMULATION RESULTS

3.1 Stable Systems

Numerous scenarios were run through the inpatient simulation model, beginning with projected patient volumes, then scenarios to right-size inpatient beds for each unit. Model runs to quickly determine capacity started with:

- Un-constrain inpatient units, so that all patients go to the appropriate bed for their patient type; capture the average and 95th percentile occupancy for each unit
- Constrain the inpatient units, using the 95th percentile occupancy as the number of beds for each unit
- Constrain the unit capacities further until bed wait times reach acceptable thresholds

Additional model scenarios were run to evaluate volume changes, process improvements, alternative bed placements, and other "what-if" questions within project scope. This paper evaluates the fine-tuned unit capacity and how a portion of the beds within appropriate units could be planned as semi-private rooms. Appropriate units may include medical and surgical acute beds. Higher acuity units, such as critical care (intensive care) and burn units are usually designed as all private rooms. Hospital planners ultimately decide which units to make private, semi-private or a combination of both.

Figure 5 shows the dynamic plot of midnight daily census, with available capacity in the blank space near the top of the graph. This particular figure shows a maximum capacity of 78 beds. If we assume all private beds, then the periods of available capacity represent empty rooms. However, if we assume 8 semi-private beds, then rooms become empty only when the census drops below 70. When the census is between 70 and 74, then all patients still have a private bed experience. For each patient over a census of 74 patients, two patients get a semi-private bed experience.

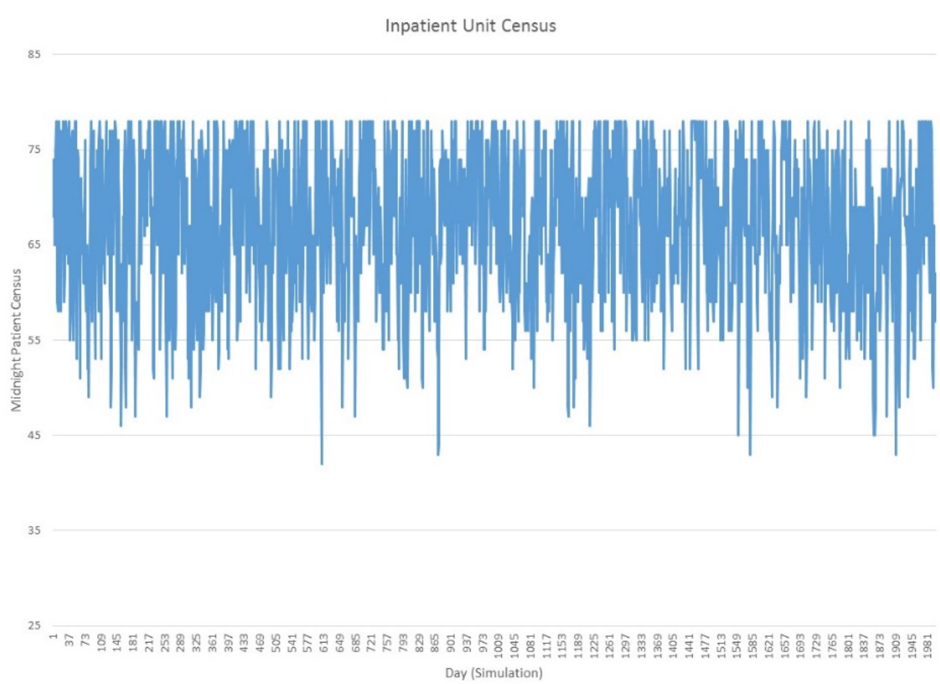

Figure 5. Plot of midnight census during portion of simulation run.

This inpatient simulation model exported to a spreadsheet a table of midnight daily census over a four year simulation run. Compiling the census data using "count if" formulae allows the operational planner to quickly summarize how often the census exceeds a threshold. For example, the Figure 6 tabulates analyzes census data from a simulation run with 70 Medical Acute beds. The planner may enter 54 as the total number of private beds/rooms, which means 8 additional rooms contain another 16 semi-private beds: 54 + (16 ÷ 2) = 62 single occupancy rooms. The spreadsheet looks up the frequency when the Medical Acute unit census exceeds 62, which is 85% in this example.

Table1. This table shows the percent of time that occupancy was private vs. semi-private.

		Beds [1]		Private	Semi	Rooms	% Private [2]
Adult Acute Care							
	Medical Acute	70		54	16	62	85%

In another example, Table 1 summarizes the percent frequency of private patient experience for a 96 bed Acute Care Unit. When the operational planner enters 12 private rooms, the remaining 84 rooms are semi-private and the census is at or below 54 patients for 34% of the simulation run. Continuing this rubric in 12 bed increments yields the graph below. The private room experience curve for this stable system shows a linear relationship until the number of private rooms reaches an inflection point and tangentially approaches the total capacity. This inflection point seems to coincide with the point of available capacity previously seen in Figure 7. There is a diminishing return with more private beds because the highest census happens less frequently. This helps planners to decide acceptable tradeoff between the percent of private bed experience and size of patient units/floors.

Table 2: This table shows the percentage of patient days with a private bed experience under various unit capacities.

Medical Acute Care Unit	
12	34%
24	49%
36	64%
48	77%
60	87%
72	94%
84	98%
96	100%

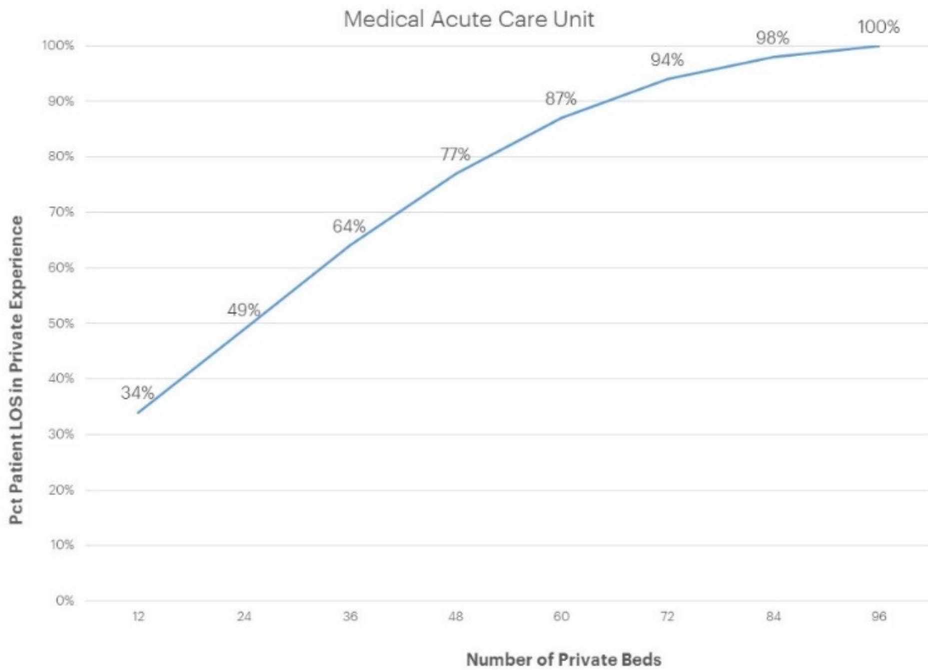

Figure 7. Plot of the number of private beds vs. the % of private experience.

Additionally, this model assumes all beds are staffed and the hospital realizes the same private rooms benefit with a single occupancy semi-private room. Also, this model assumes the units move patients to private room when circumstances require doing so, such as gender, infection control, etc.

3.2 Overcrowded Systems

The previous section assumed an appropriate number of available, staffed beds to keep inpatient wait times within tolerable levels. For example, the average wait time for an adult, medical acute bed is between 15 and 30 minutes. This system includes variability with unit occupancy, where the unit may be full for days at a time, or have available beds for days at a time. This section discusses the impact when the system is overcrowded, either because inpatient volumes are consistently higher than planned or too few beds are available.

The dynamic plot of midnight daily census for an overcrowded system shows very limited available capacity near the top of the graph (Figure 8). This particular figure shows a maximum capacity of 70 beds. This illustrates the limited opportunity to reduce space. Instead, this indicates the need to increase the number of available beds. Other KPIs, such as wait times for an inpatient bed, would also confirm this conclusion. Operational planners should not yet consider the mix of private and semi-private beds, but focus on what is the appropriate number of available, staffed beds.

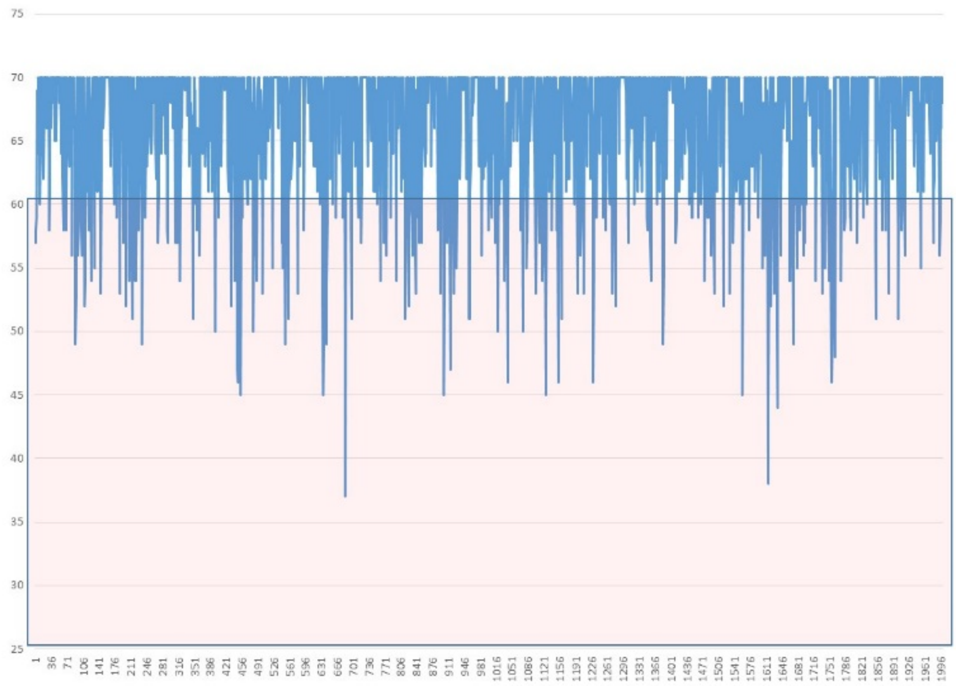

Figure 8. Plot of midnight daily census in an overcrowded inpatient unit.

Tabulating and graphing the percent frequency of private patient experience, as before, shows the influence of patient volume on the private room experience curve (Table 2). As the system become more overcrowded, the inflection point disappears and the curve is mostly linear (Figure 9).

Table 3: This table shows the percentage of patient days with a private bed experience under various unit capacities. These scenarios were run with 15% more volume than the baseline number of patients.

Medical Acute +15% Volume	
0	7%
10	22%
20	37%
30	52%
40	67%
50	80%
60	92%
70	100%

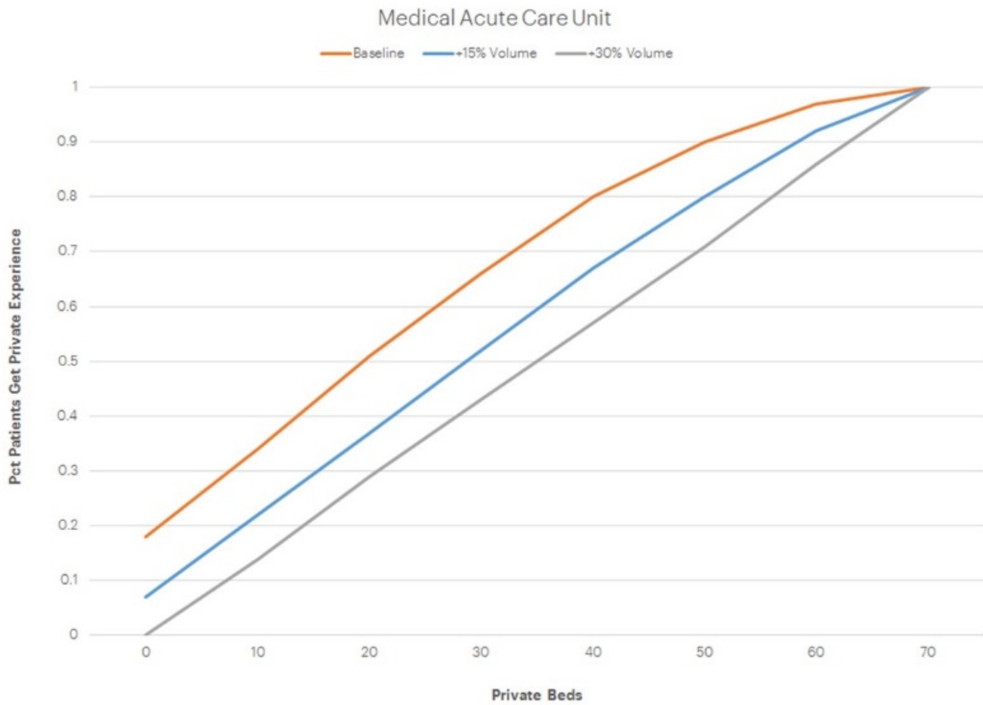

Figure 9. Plot of private patient experience with increasing volumes.

25% reduction in private beds in this situation yields 15% reduction in private experience, which is worse when the system is stressed or undersized

4 CONCLUSION

Operational Planners want to balance capacity with performance. The optimal solution includes the right number of total beds with the right percentage designates as semi-private. Not meeting this balance would have these characteristics:

- Too few beds causing long wait times for a bed
- Right number of beds, but too many patients in semi-private beds which reduces patient satisfaction
- Too many private beds causing underutilization and a missed opportunity to reduce costs

What does this mean for future hospital designs? The concepts in this paper represent an opportunity to reduce capital costs by millions of dollars. But this opportunity to reduce cost by reducing rooms will come in stepped increments. For example, the opportunity to reduce costs happen when it translates to eliminating or shelling space for a half unit, whole unit or whole floor. Eliminating only a couple rooms does not reduce the planned footprint.

What does this mean for hospitals already designed or operating with all private rooms? For hospital units with dual headwalls, or rooms that can hold two patients, implementing the concepts in this paper could reduce operational costs. Also, future inpatient volume growth may be better served with the delay of further hospital capital costs.

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AUTHOR BIOGRAPY

MARTIN MILLER is Managing Partner for Decision Analytics, LLC. He has over 18 years of simulation consulting experience in healthcare and other industry groups. Marty leads the design and development for all modeling services at Decision Analytics. He was previously a Vice President at HKS Architects, leading the delivery for all healthcare simulation modeling. He helped start several simulation consulting groups, including FDI Healthcare Simulation, Capability Modeling, Northern Lights, and Business Prototyping. He also worked over eight years for Accenture and was a manager in their simulation practice. He obtained his Capability Maturity Model Certification from the Software Engineering Institute. He received his Masters of Science in Industrial & System Engineering and Bachelors of Science in Aerospace Engineering from the University of Florida. His email address is marty@thedecisionanalytics.com.