Proceedings of the 2009 Winter Simulation Conference
M. D. Rossetti, R. R. Hill, B. Johansson, A. Dunkin and R. G. Ingalls, eds.

ESTIMATING PATIENT SURGE IMPACT ON BOARDING TIME IN SEVERAL REGIONAL EMERGENCY DEPARTMENTS

Martin Miller
David Ferrin

FDI Simulation
1707 East Highland, Suite 190
Phoenix, AZ 85016, U.S.A.

Niloo Shahi

LAC+USC Healthcare Network
1200 North State Street
Los Angeles, CA 90033, U.S.A.

ABSTRACT

The sudden or prolonged increase in patient arrivals to hospital Emergency Departments can cause overcrowding which adversely affects patient care. Healthcare leadership must anticipate and prepare for patient surge before it hap-pens. They need to understand how much overcrowding will occur with each incremental increase in patient volume. This paper describes how simulation was used to determine the impact of various patient surge levels on three regional Emergency Departments. This paper also de-scribes the impact of potential action items which the hospitals can take to mitigate their overcrowding.

1 INTRODUCTION

1.1 Background

Over 10 million people reside in Los Angeles County. Their public healthcare system annually serves 700,000 people and treats more than 300,000 emergency and trauma victims. The system seeks to make quality medical services accessible throughout the county using an integrated network of hospitals, health centers and clinics.

The Los Angeles Department of Health Services (DHS) is the second largest health system in the nation and is governed by the Los Angeles County Board of Supervisors. They employ about 22,000 people, have an annual budget of over $3 billion, and operate four hospitals:

- LAC+USC Healthcare Network
- Harbor-UCLA Medical Center
- Olive-View UCLA Medical Center
- Rancho Los Amigos National Rehab Center

These hospitals provide acute and rehabilitative patient care, train physicians and other health care clinicians and conduct patient care-related research. In addition, DHS operates numerous health centers throughout the county in partnership with private, community-based providers. Notably, DHS provides most of the county's uncompensated healthcare to more than two million uninsured county residents.

1.2 Process Challenge

The Los Angeles County Board of Supervisors instructed the Department of Health Services (DHS) to work with Facilities Development, Inc. (FDI) to conduct a study and present findings on patient surge for three of their regional facilities. Specifically, how would a patient surge of 5 per-cent, 10 percent, 15 percent, and 20 percent affect the Emergency Department Boarding Time (EDBT) when their hospitals operate at 80 percent, 85 percent, 90 percent, and 95 percent staffing of all available inpatient beds? Also, what is the regional impact of such surge? Com-pounding this challenge was that one hospital recently moved to a new, smaller facility with fewer inpatient beds

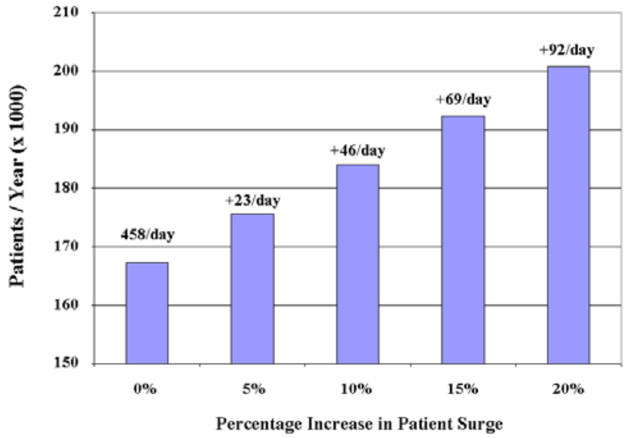

Figure 1: Patient Surge at a County Hospital.

Figure 1 shows how a 5 percent surge in patient volume at one hospital equates to 23 more patients per day, or about one more patient per hour. Similarly, a 20 percent surge in patient volume equates to about 4 additional patients per hour.

2 PROCESS SOLUTION APPROACH

2.1 Objectives

FDI Operations Modeling & Simulation built a realistic simulation model which demonstrated the capability of various operational alternatives. The simulation model and associated analysis estimated, at a regional level, the surge impact to EDBT with patient volume increases while staffing various levels of available inpatient beds. The model also showed the value propositions for Emergency Department (ED) capacity, associated inpatient capacity and various process improvement scenarios.

2.2 Modeling Regional Emergency Departments

Initial research examined dependencies and interactions between the three targeted regional hospitals. If sufficient dependencies existed, then the team would build a single model consisting of all three hospitals. For example, if one hospital goes on diversion, do corresponding EMS patients route to one of the other targeted hospitals? However, initial research found much less than one percent of diverted EMS patients route to another targeted hospital. Because the targeted hospitals are more than ten miles apart, EMS drivers transport their patients to other nearby hospitals. Therefore, the team modeled the three hospitals independently, using three distinct models.

The simulation project included typical phases for model development and analysis (Miller, Ferrin, and Messer 2004), which included:

- Develop conceptual model
- Program simulation and user interface software
- Test the software
- Experiment with specific scenarios,
- Present results to project stakeholders.

2.2.1 Modeling Detail

Simulation models need many inputs to accurately model a facility (Miller, Ferrin, and Szymanski 2003), such as:

- Number of beds in hospital
- Volume and arrival pattern of patients
- Activities that occur for each patient
- Human resources needed to perform activities

- Duration of patient activities
- Etc.

As the simulation model runs, limited resources, such as ED beds, constrain the flow of patients moving through the system. Although the accuracy of a simulation model does not necessarily increase with more model detail, the cost of building a simulation model usually does. A simulation modeler must rely upon research and experience to determine the appropriate detail included in a project's scope.

The team built the conceptual model through three primary mechanisms:

- Facilitate process modeling workshops
- Interview Subject Matter Experts (SMEs)
- Conduct process observations

The conceptual model encompassed more than just the ED because adjacent areas, such as inpatient floors, highly impact patient throughput (see Figure 2).

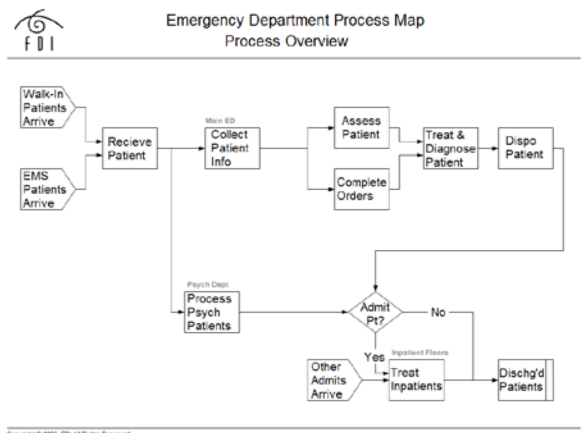

Figure 2: Conceptual Model Example

2.2.2 Model Parameters

2.2.3 Key Performance Indicators

A simulation model can answer difficult questions about how a facility will operate (Miller et al. 2007), such as:

- How long will patients wait?
- When does the department get full?
- How many more beds do we need?
- How can we handle more patients with the beds we have?
- Does that improvement save time?

Simulation models can produce large volumes of Key Performance Indicators (KPIs). The simulation modeler should determine which KPIs are important to their client (Miller, Pulgar-Vidal, and Ferrin 2002). Also, modelers must clearly define each KPI to prevent ambiguity or error with model results (see table 1).

Table 1. KPI Definitions

KPI	Definition
Boarding Time	The time from when the physician writes the order to admit until the patient is placed in an Inpatient bed.
LWBS	Leave Without Being Seen; patients who leave before placement in an ED bed, usually due to long wait times.
Arrivals	Patients that present to the ED and are placed in an ED bed. LWBS or routed to appropriate area; ED arrivals may not be exactly the same as ambulatory visits.
Patient Surge	Increase in patient arrivals to the ED.
IP Bed Occupancy	Standard used for hospital reporting; Occupancy is calculated as the number of patients in beds at midnight divided by the number of staffed beds available.
IP Bed Utilization	Used primarily in simulation modeling; Utilization is calculated as the total hours that a bed is used in a day divided by 24 hours. Utilization is generally a lower number than Occupancy, but more accurate. For example, 95% utilization approximately equals 98% occupancy.
Other IP Admits	Inpatient admits which come from other sources besides the ED, such as Transfers, Direct Admits, etc.
Fast Track	A unit designed to provide urgent access for low-acuity patients who present to the ED, thereby decreasing wait times for all ED patients.
ED LOS	Length of stay for Emergency Department patients. KPIs calculated for patients that admit to an inpatient bed, discharged from the ED and overall (for all patients combined).
ED Diversion	Rerouting of EMS patients to another hospital. Typically due to ED overcrowding conditions that exceed specified thresholds.

2.2.4 Assumptions and Constraints

The primary modeling assumptions used by FDI to conduct the analysis included, but were not limited to, the following:

- Analysis focused on the main emergency department (ED) of each facility. Patients who were routed directly to the pediatrics ED, triaged to urgent care, etc., were not included in the model.
- The type of patient surge that was used in the model is one that reflects an increase in patient visits to the main ED applied evenly over time. This analysis does not consider a surge related to a large scale incident or natural disaster.
- Patients were assumed to leave without being seen if not placed in a main ED bed or treatment area within 24 hours of arrival.

- Per DHS Emergency Medical Services (EMS) policy (County policy 709), facilities can be on diversion (not receiving additional 911 transports to the ED when the ED is full) for 45 minutes and then will go off diversion for 15 minutes before evaluating the need to go back on diversion again.

The most common protocol for diversion is when the hospital patient acuity levels involving the ED is full, critical care beds (ICU/CCU) are at capacity as well as step down units cannot accept more patients. There are also additional determining factors as designed by the individual facilities.

Some patient types remained out of scope for this model. For example, Burn, Jail, Neonatal Intensive Care (NICU) and urgent care (a.k.a. Fast Track) patients do not receive treatment in the main ED. These patients route directly to other areas of the hospital for treatment.

2.3 Data Collection

Electronic data from each hospital's Information Technology (IT) systems provided another key source of process data. Arrival data is usually the first data collected from hospitals (Miller et al. 2006). The model used the previous year's data from each hospital, including arrival data and activity duration data (i.e., time from arrival to ED bed; time from ED bed to inpatient bed, discharge, or transfer; etc.). The model generated entities based upon actual patient arrival data (see figure 3). The team also used historical data to assign patient acuity probabilities. The duration of hands-on patient activities were based on historical data or observations. When duration data was not available, the team used SME estimates.

The team conducted many days of observations, sampling data from each hospital. Since the team could not observe all patients, the team developed an effective plan to obtain sufficient data. Team members would:

- Follow patients through the process
- Follow staff through process
- Observe the materials process
- Evaluate documentation process for duplication between areas
- Observe the registration and discharge of patients
- Observe the support processes

The first objective from observations ensured the process, when applicable, actually occurred as SMEs described. The second objective gathered random samples of process data to create more accurate durations for the simulation model.

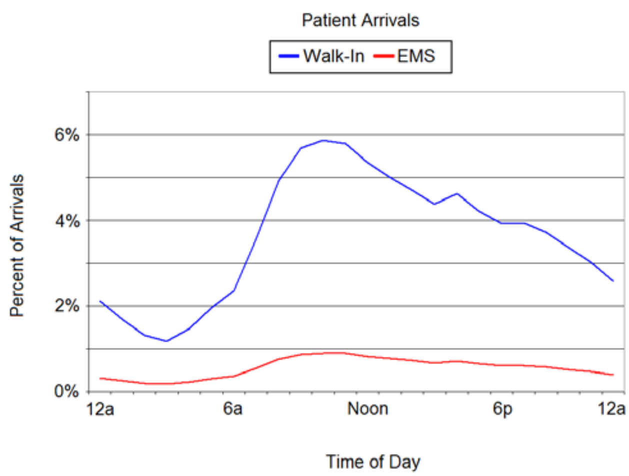

Figure 3: Patient Arrival Pattern

2.4 Software Development

FDI developers followed a phased approach to building the simulation model. The developers unit test each phase of code before beginning the next phase of coding. The first phase of the model entailed generating entities in the right quantity and arrival pattern. The second phase involved routing entities to various locations using patient attributes or probabilities. Next, resources were added and activities coded which seized and released these resources for specified durations. The next phase included coding KPIs such that model results export to a spreadsheet for analysis. The final phase of simulation software development included coding a compelling animation (see figure 4).

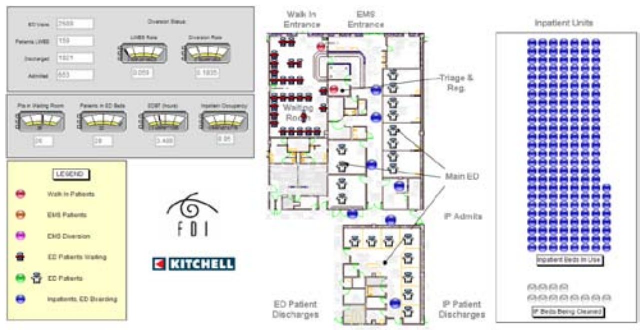

Figure 4: Image of Hospital Animation

This project required development of three similar, yet distinctly different models. The similarity between facilities allowed model reusability. However, the team customized models for each hospital. Model testing included comparison of simulation results to current process results which helped ensure model validity (see Figure 5).

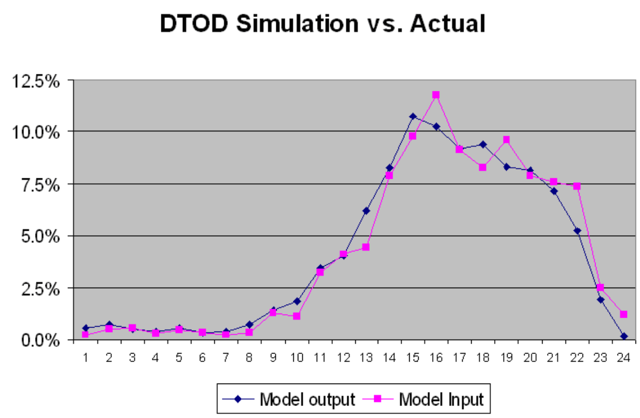

Figure 5: Example of validity results for inpatient Discharge Time of Day (DTOD).

3 EXPERIMENTAL OUTCOMES

Analysis showed patient surge impacts most KPIs, such as percentage of time a facility is on diversion, length of stay for patients in the ED, and percentage of patients who leave without being seen. Analysis also showed these KPIs worsen as patient surge increases from 5 percent to 20 percent.

However, the negative trend of the indicators become less severe as the percentage of available inpatient that are staffed increases from 80% to 95%. Physicians can only place inpatients in staffed beds since unstaffed beds are not available. As the percentage of available beds that are actually used for patients increases, the impact of a patient surge is less severe (see figure 6).

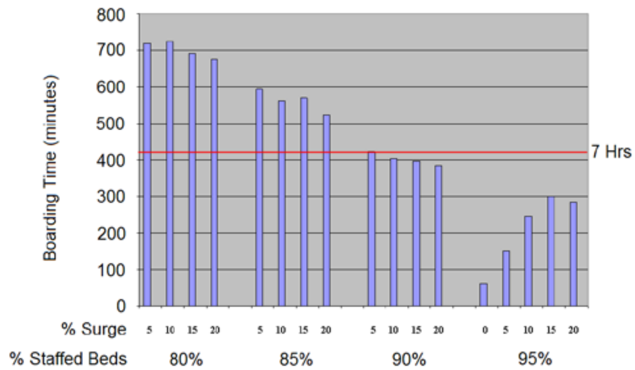

Figure 6: EDBT at one hospital for various levels of staffed inpatient beds and various surge levels.

A hospital that is on diversion for 45 minutes must reopen for 15 minutes before evaluating whether to go back on diversion status. Since these hospitals cannot stay on diversion status more than 75% of the time. When operating at 80% staffed inpatient beds, all three facilities will stay on diversion status a majority of the time. At 90% and 95% staffed inpatient beds, the facilities begin to realize capacity and handle lower surge levels. Finally, at 95% staffed available inpatient beds, all facilities anticipate going on diversion less than 75% of the time, even with 20% surge volume.

Most patients that leave without being seen (LWBS) do so because the main ED is full and they would wait over 24 hours for a main ED/treatment area bed. The LWBS rate is high at all inpatient occupancy levels and all surge levels until staffing 95% of available inpatient beds. At 95% and 20% surge levels, the hospitals' LWBS rate increases were:

- Hospital 1: from 2% to 9%
- Hospital 2: from 7% to 17%
- Hospital 3: from 9% to 22%

The simulation model predicted median EDBT remains over 12 hours at all facilities at all surge levels when staffing 80% of available inpatient beds. When staffing 95% of available inpatient beds, EDBT falls below 7 hours at all surge levels. Figure 7 shows the rate of increase in boarding time varies between hospitals as surge levels increase. This implies that each hospital has differing capabilities for handling patient surge. Hospital 2 shows the lowest boarding time of the three hospitals at 5% surge. However, hospital 2 shows the highest boarding time when surge reaches 20%.

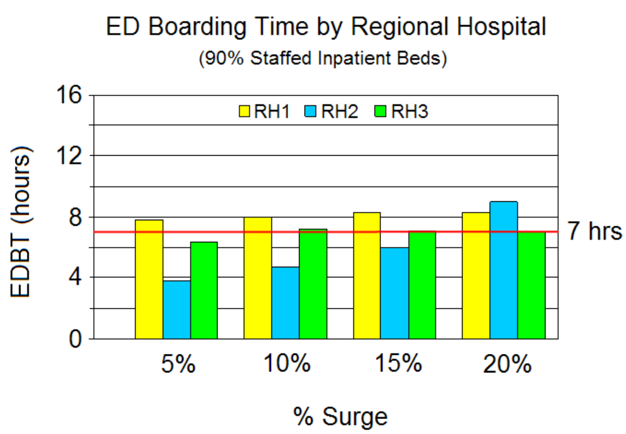

Figure 7: Hospital EDBT Comparison

The simulation model predicts overall ED LOS remains over 12 hours in all three facilities at all surge levels when only staffing 80% of available inpatient beds. However, when increasing staffing levels to 95%, the model predicted the overall Main ED LOS:

- Hospital 1: from 5 hours with a 5% patient surge to 8 hours with a 20% patient surge
- Hospital 2: from 8 hours to nearly 11 hours
- Hospital 3: from 11.5 hours to 12.5 hours

The simulation model predicted each Main ED remains completely full with close to 100% utilization of ED treatment areas at all surge levels when staffing only 80% of available inpatient beds. The situation improves at 95% staffed inpatient bed levels with the ED utilization ranging from 73% to 98% depending on surge levels. Figure 8 shows how much of the overall Main ED LOS contains boarding time.

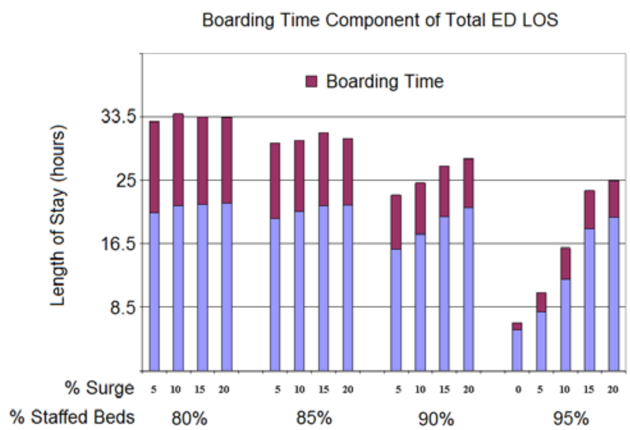

Figure 8: Amount of EDBT Within ED LOS

FDI Operations Modeling & Simulation tested process improvement scenarios on high surge levels to help the hospitals understand how to cope with ED overcrowding. Process improvements must be tested individually so that simulation results are attributed only to that particular modeling change (Miller, Ferrin, and Messer 2004). Once the best individual improvements were identified, the team began to combine scenarios to determine the best case scenario. Selected scenarios included:

- Bedside triage
- Bedside registration
- Reduce lab or radiology turnaround times
- Move the inpatient discharge time earlier in the day
- Streamline admitting activities
- Reduce inpatient length of stay by a half day
- Increase the number of staffed inpatient beds

The team determined how much impact these scenarios would have in each hospital by comparing the results against a formulated confidence interval. Figure 9 shows that several scenarios fell below the lower bound for EDBT. The hospital should implement these scenarios first.

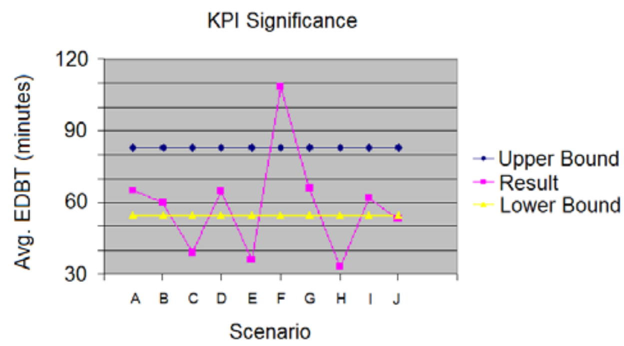

Figure 9: Magnitude of Scenario Impact on EDBT

4 CONCLUSION

Patient surge impacted all KPIs at all three hospitals and worsened as the surge increased from 5% to 20%. This included the amount of time that the facilities are on diversion, percentage of patients who leave without being seen, number of hours that patients remain in the ED after a physician writes an order to admit to an inpatient bed, and total number of hours that patients spend in the ED from time of arrival to discharge, admission or transfer.

The regional impact of patient surge on the county hospitals depended on how effectively each hospital could handle their patient surge volumes. The simulation model predicted all hospitals in this study could handle small surges of 5% and 10%. However, not all hospitals were capable of handling larger patient surges. Once a hospital reaches their patient capacity limit, then surge impact falls mostly to the surrounding medical centers where EMS diverts patients.

The simulation model indicated that handling surge depends largely on the percentage of available inpatient beds that a hospital staffs. Also, the simulation model identified occupancy thresholds that trigger when a hospital should staff more inpatient beds.

Predicting the process performance of complex systems, such as Emergency Departments, is a challenging problem that can be best solved with simulation. Bottlenecks in the ED occur because patients arrive at a rate faster than they can be treated and discharged. Determining how to eliminate the bottleneck is complex and usually involves testing many scenarios. Simulation can show hospitals how to improve their patient throughput. Hospital executives need to know where the major issues will occur so they can begin implementing a mitigation strategy.

REFERENCES

Ashby, M., D. Ferrin, M. Miller, and N. Shahi. 2008. Discrete Event Simulation: Optimizing Patient Flow And Redesign In A Replacement Facility. In *Proceedings of the 2008 Winter Simulation Conference*, ed S. J. Mason, R. Hill, L. Moench, and O. Rose, pp. 1632-1636. Piscataway, New Jersey: Institute of Electrical and Electronics Engineers, Inc.

Crosslin, R. 1995. Simulation, *The Key to Designing and Justifying Business Reengineering Projects*, The Electronic College of Process Innovation.

Law, A.M., and W.D. Kelton. 1991, *Simulation Modeling and Analysis*, McGraw-Hill, New York, NY.

Miller, M., D. Ferrin, N. Shahi, and R. LaVecchia. 2008. Allocating Outpatient Clinic Services Using Simulation And Linear Programming. In *Proceedings of the 2008 Winter Simulation Conference*, ed S. J. Mason, R. Hill, L. Moench, and O. Rose, pp. 1637-1644. Piscataway, New Jersey: Institute of Electrical and Electronics Engineers, Inc.

Miller, M., D. Ferrin, M. Ashby, T. Flynn, and N. Shahi. 2007. Merging Six Emergency Departments Into One: A Simulation Approach. In *Proceedings of the 2007 Winter Simulation Conference*, ed S. G. Henderson, B. Biller, M.-H. Hsieh, J. Shortle, J. D. Tew, and R. R. Barton, pp. 1574-1578. Piscataway, New Jersey: Institute of Electrical and Electronics Engineers, Inc.

Miller, M., D. Ferrin, T. Flynn, M. Ashby, K. White, and M. Mauer. 2006. Using RFID Technologies To Capture Simulation Data In A Hospital Emergency Department. In *Proceedings of the 2006 Winter Simulation Conference*, ed L. F. Perrone, F. P. Wieland, J. Liu, B. G. Lawson, D. M. Nicol, and R. M. Fujimoto, pp. 1365-1371. Piscataway, New Jersey: Institute of Electrical and Electronics Engineers, Inc.

Miller, M., D. Ferrin, and M. Messer. 2004. Fixing The Emergency Department: A Transformational journey with EDsim. In *Proceedings of the 2004 Winter Simulation Conference*, ed R. G. Ingalls, M. D. Rossetti, J. S. Smith, and B. A. Peters, pp. 1988-1993. Piscataway, New Jersey: Institute of Electrical and Electronics Engineers, Inc.

Miller, M., D. Ferrin, and J. Szymanski. 2003. Simulating Six Sigma Improvement Ideas For A Hospital Emergency Department. In *Proceedings of the 2003 Winter Simulation Conference*, ed S. Chick, P. Sanchez, D. Ferrin, and D. Morrice, pp. 1926-1929. Piscataway, New Jersey: Institute of Electrical and Electronics Engineers, Inc.

Miller, M., F. Pulgar-Vidal, and D. Ferrin. 2002. Achieving Higher Levels Of CMMI Maturity Using Simulation. In *Proceedings of the 2002 Winter Simulation Conference*, ed E. Yücesan, C.-H. Chen, J. L. Snowdon, and J. M. Charnes, pp. 1473-1478. Piscataway, New Jersey: Institute of Electrical and Electronics Engineers, Inc.

AUTHOR BIOGRAPHIES

MARTIN J. MILLER is a Senior Manager for FDI Healthcare Process Modeling. He previously worked over four years as a Senior Manger for Business Prototyping, Inc. developing simulation models and analysis primarily for the healthcare industry. He also worked over eight years for Accenture and was a Manager for their Capability Modeling and Simulation practice. He obtained his CMM for Software certification from the Software Engineering Institute in 1998. 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 <mjmiller@fdiplan.com>

DAVID M. FERRIN is Principal for FDI Healthcare Process Modeling and has over 20 years of experience in Health Care consulting having worked with some of the largest and most prestigious health care systems in the nation serving on senior management teams, as department head and consulting. He was previously President of Business Prototyping, Inc. and an Associate Partner with Accenture's Capability Modeling and Simulation practice where he served on numerous Global Leadership Groups and as the Lead of the America's practice helping establish the world's largest international practice devoted to simulation. David has served as an Assistant Professor in the Health Systems Management department at Rush University, Chicago, Illinois and Adjunct Professor at York College of Pennsylvania. Mr. Ferrin is one of the most presented and published individuals in the nation in regards to simulation in health care. His email address is <dferrin@fdiplan.com>

NILOO SHAHI is Assistant Hospital Administrator IV at LAC+USC Healthcare Network. She is in charge of process redesign and organizational development projects related to the Move Transition activities for the Replacement Facility. She has over 18 years of experience in facility operations with various healthcare institutions mainly in the Los Angles County- Public Hospitals. She has extensive experience in operational transformations, quality and process improvement in many departments within County operated facilities. She has a Doctorate Degree in Public Health Administration from UCLA. Her email address is <nshahi@lacusc.org>