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FIXING THE EMERGENCY DEPARTMENT: A TRANSFORMATIONAL JOURNEY WITH EDSIM

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ABSTRACT

Hospitals today are investing time and money to expand and improve their Emergency Departments (ED). Using simulation to test their many improvement ideas can necessitate running numerous scenarios. Model changes such as the number of ED beds, inpatient beds and process improvements will yield an exponentially growing list of permutations in alternative ED designs. This paper uses recent project experience to describes where to begin and which steps to take to go from an As-Is ED configuration to the best To-Be configuration.

1 EMERGENCY DEPARTMENT BACKGROUND

1.1 Building Trends

Hospital construction is expected to continue to boom for years to come according to a survey of 200 senior healthcare executives (Romano 2004). Most hospitals are very likely to initiate major expansion within the next three years.

Expanding hospital facilities, like all change, will yield uncertainty for how the patient experience will occur in the future. Emergency departments face especially critical issues, such as

- Is the new ED design big enough? Will it fix current overcrowding problems? Is it too big?
- How much will the construction cost? Can this cost be reduced by right-sizing the facility?
- Will the new facility fix our process or will the same old problems continue to happen?
- What process improvements will work best in the new facility?
- What is the right number of staff? Will the new facility be overstaffed or understaffed?

Addressing these issues will take advantage of the opportunity to greatly boost both patient and employee satisfaction. What if a reliable method or tool existed which would allow the hospitals to predict what will happen in the new facility? What if potential risks could be mitigated? Opening a new facility provides a perfect opportunity to implement process change in an organization. Implementing the right changes will move the hospital toward process excellence. However, implementing the wrong changes will lead to false starts, wasted time and effort (as well as political capital), and ultimately discourage staff. What if there was a way to know which process changes the hospital should pursue?

1.2 Simulation Advantages

Simulation is a state-of-the-art tool for process analysis. It analyzes the behavior of either real or imaginary systems over time. Simulation is usually performed on a computer using either off-the-shelf or customized software. Simulation's main capability is to analyze what-if scenarios, especially those proposed in Emergency Departments (Miller, Ferrin and Szymanski 2003). Also, simulation is one of the most widely used analytical techniques used by professionals in Operations Research and Management Science (Law and Kelton 1991).

Computer simulation has existed for almost 40 years and has been used in every industry to study systems where there are resources at locations acting upon people or products (Nance and Sargent 2002). A few examples of simulated systems are manufacturing plants, banks, airports, or business organizations (Ferrin, Miller, and Giron 2000).

There are several methods to study an Emergency Department and determine the impact of changes. The most direct way is to experiment on the actual system. This might involve testing a change on a small part of the ED for a short period of time and then collecting statistics to quantify the impact. Alternatively, we could build a mathematical model of the ED, either as an analytical solution or simulation (Law and Kelton 1991). Simulation is more effective than analytical solutions for complex models, where the state of the system changes over time. In fact, an analytical solution may not be possible as system complexity increases. Emergency departments are considered one of the most complex systems to analyze.

1.3 EDsim Product

Simulation has been successfully used to model and analyze numerous emergency departments around the world (Mahapatra et al. 2003). Business Prototyping, Inc. (BPI) has developed a reusable product, EDsim, to quickly model and test alternative design scenarios for existing and proposed hospital emergency departments. This product is the result of a basic need by hospital administrators to improve Key Performance Indicators (KPIs), such as patient length of stay (LOS), bed utilization, elimination of bottlenecks, etc. EDsim is also ideal for predicting performance of proposed emergency departments before the finalizing architectural designs. Hospital administrators not only hope to avoid the same problems they currently face, but proactively eliminate new problems associated with opening a new ED.

Examples of the kind of answers which the EDsim product has yielded to hospital executives include (Miller, Ferrin and Szymanski 2003):

- Discharging inpatients about five hours earlier each day reduces ED patient LOS by a third,
- Adding 30 more inpatient beds will potentially cut the ED patient LOS in half,
- Reductions in lab test turnaround time won't significantly affect overall patient LOS until it is reduced by at least 20%,
- The new ED only needs two-thirds of the proposed beds currently being designed (which will save millions of dollars),
- The new ED will handle up to 65,000 patients annually before ED LOS becomes unacceptable,

BPI's EDsim product was developed to be user friendly and client transferable. Since every ED is different, EDsim can switch on and off activities and functionality. Although, customization and consulting usually accompanies the product. This remainder of this paper will discuss how to more efficiently complete an EDsim project by reducing the time and effort associated with experimentation.

2 PROJECT APPROACH

2.1 Objectives

Project begin with well defined objectives. Simulation project objectives for an ED will typically include

- How can the hospital capitalize on the project growth of patient arrivals in the next 3-7 years?
- What process improvements will improve patient LOS, particularly when hospital volumes increase?
- How can the ED mitigate the frequent problem of a lack of ED beds?
- How many beds should the new ED construction include? How many years of projected growth will this accommodate until more construction is needed?
- How does the lack of inpatient beds impact the ED?

Understanding, meeting and exceeding specific client objectives will ensure a successful project. The phases of a simulation project usually include

- Development of a conceptual model
- Programming the simulation and user interface software
- Testing the software
- Experimenting with specific scenarios,
- Presenting the results to project stakeholders.

Ultimately, the answers that a simulation model provides should tell a story. This is especially important when presenting results to executive management. A common mistake when presenting results is to overwhelm the audience with data. Although much effort and pride accompanies this data, it is wise to summarize results into a limited number of slides. Composing the answers graphically will help the audience view the recommendations as a journey into the future.

2.2 Modeling the ED

It is often useful to build a model when trying to understand a system. Engineers and managers usually study a system to gain better understanding of how their processes work and find ways to improve operational performance or design, if it doesn't exist yet (Miller, Pulgar-Vidal, and Ferrin 2002).

Similarly, it is always useful to design a product before construction (e.g., architectural blueprints of a building). An emergency department simulation begins with a conceptual model. A conceptual model is more than just a process map, or flowchart, however (see Figure 1). There are detailed descriptions and business rules which accompany the objects on a process map. This information is best stored externally which improves readability of the process map and doesn't visually overload it.

BPI's approach to building a conceptual model involves process modeling workshops, interviews with subject matter experts (SMEs), and data collection. Whenever possible, build off previous flowcharting efforts, which avoids 'reinventing the wheel' and reduces project time and costs.

Also, the conceptual model provides a useful interim deliverable and a way to control scope. Changes to the model are more expensive as the project progresses, so it is important to obtain stakeholder sign-off of the conceptual model before continuing with programming. The conceptual model is also useful even if no simulation model is

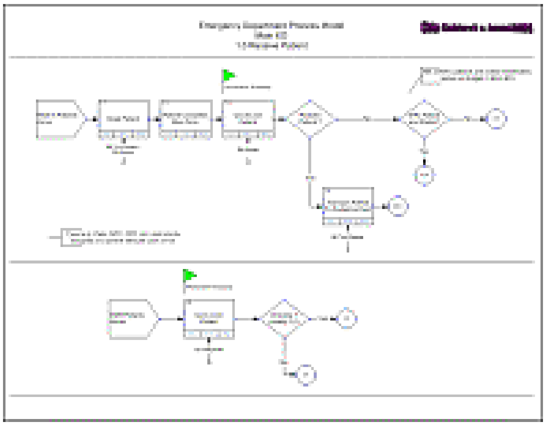

Figure 1: Conceptual Model for ED Simulation

constructed. Building a conceptual model helps increase the understanding of a process which no single individual may possess knowledge of. Staff can now see the 'big picture' of a process and better understand how their contribution impacts the end result.

2.3 Assumptions

Adding more complexity to the emergency department model doesn't always add value to the final analysis. In fact, too much complexity is counterproductive because more time and effort are involved with ensuring validity (the model behaves like the real system). Also, the data available may not apply to the level of model detail. For example, actual data to process lab orders may only exist an overall level and not for individual activities. As a result, the process model should reflect a single activity for processing lab orders. The goal is to find the right level of complexity which allows you to meet project goals (see Figure 2).

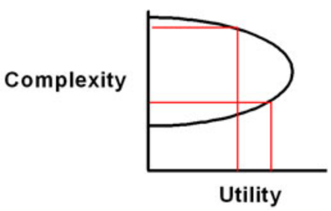

Figure 2: Utility Curve For Model Complexity

Making valid assumptions simplifies the model and allows the project team to control scope and proceed efficiently. Typical emergency department assumptions may include

- ED is open 24/7
- Equipment (e.g., IT system) does not breakdown
- No catastrophic events occur (e.g., terrorist attack)
- Sufficient parking space available for all EMS arrivals
- Sufficient waiting space available for patient's family

2.4 Scenarios

Scenarios are defined and documented before beginning experimentation runs. Usually, scenarios are discussed with the client early in the project lifecycle, while discussing goals and expectations. Supplementing this list with other industry best practices helps to exceed client expectations. Grouping scenarios in the following hierarchy will be instrumental when executing scenarios and finding the best alternatives:

1. Arrival volumes
2. Inpatient beds
3. Ratio of main ED and FastTrack beds
4. Process improvements

For example, arrivals volume scenarios may include current volumes as well as projected volume, incremented in 5,000's. Inpatient bed scenarios may include current numbers as well as future available beds, incremented in 24's. Also, the ED may only have so many beds, so there are different scenarios to test the ratio of main ED beds and FastTrack beds (see Section 3.3). Process Improvements may be tested individually or in combinations.

BPI's EDsim product includes a graphical user interface, a.k.a. Control Panel, which allows the simulationist to quickly create scenarios and capture results (see Figure 3). Despite this tools usability, an algorithm is necessary to efficiently harvest the valuable results from the simulation model. This algorithm should eliminate unnecessary or redundant scenarios which don't add value.

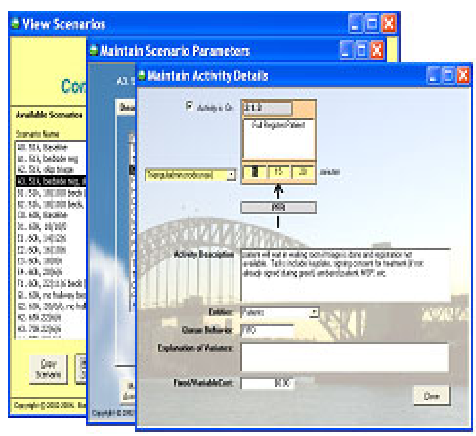

Figure 3: EDsim Control Panel

Each alternative should be tested individually so that simulation results are attributed to that particular modeling change. Hundreds of scenarios can exist, considering the various scenario alternatives possible. Executing and recording every permutation may be difficult or impossible.

3 BEGINNING THE JOURNEY: EXPERIMENTATION APPROACH

3.1 Start at the Back and Work Forward

BPI's experimentation algorithm for executing EDsim scenarios follows the scenario categories mentioned in section 2.4. The algorithm begins by removing space-related bottlenecks from the end of the process and moves forward to the process beginning. The algorithm then introduces process improvements to ultimately find the best scenario combinations.

For a given arrival volume, the capacity constraints are solved first. Keep in mind, this assumes that the new hospital facility can change its bed availability. For example, the new facility design is not finalized or the hospital can add more beds by increasing staff. If capacity constraints are fixed, then proceed to the next category in the algorithm by testing the ratio of Main ED beds to FastTrack beds. These beds are upstream in the ED process relative to the inpatient beds. Finally, individually test various process improvements. These improvements may occur anywhere in the process.

Bottlenecks in the process occur when the number of entities surpasses the system's ability to store and process them. For hospitals, this means there are not enough beds or staff to move the patients through from arrival to discharge. Removing bottlenecks means either adding more beds, adding more staff, or improving the process to move patients more quickly through the process. Reducing the number of patients will also remove bottlenecks, but to hospitals, that means lost revenue.

3.2 Fix the Inpatient Constraints

Inpatient beds are used by patients who stay overnight or longer. Emergency Department patients whose condition is severe enough to require admission to the hospital are eventually taken from an ED bed to an inpatient bed. Many hospitals keep a Transitional Stay Unit, or buffer area, which is used to hold patients waiting for an inpatient bed without tying up an ED bed.

The inpatient beds and the inpatient length of stay are an inextricable part of the overall ED process. EDsim models the inpatient arrivals from the ED and from other sources, such as direct admits. These patients hold an inpatient bed for a length of stay specified by an empirical distribution (see Figure 4). These patients then release a bed and exit from the model, allowing another patient to use that inpatient bed. Bottlenecks in the inpatient beds occur when the arrival volume exceeds the capacity. This can impact the ED by making admitted ED patients stay in an ED bed while waiting for an inpatient bed.

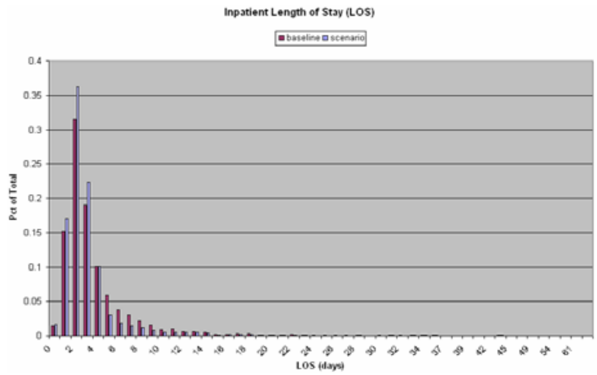

Figure 4: Empirical Distribution of Inpatient Length of Stay

The first alternatives to test are the addition of inpatient beds to see if a bottleneck exists here. Experience shows that removing inpatient bottlenecks have the largest effect on improving the ED. Continue to add more inpatient beds until there is no improvement in results. Revisit this optimal bed level later to see if it can be reduced further, particularly if process improvements are introduced. For example, improving the inpatient discharge time of day (see Figure 5).

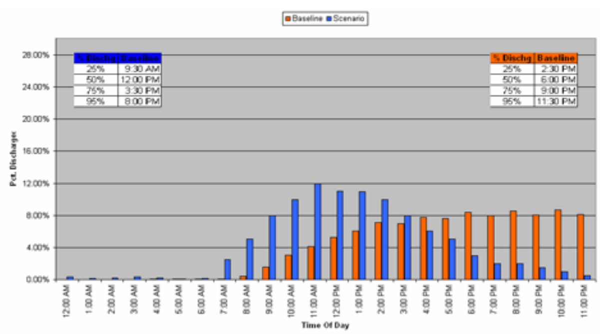

Figure 5: Inpatient Discharge Time of Day Alternatives.

EDsim tracks numerous Key Performance Indicators for each simulation experiment, including the mean and 95th percentile for ED patient length of stay. The 95th percentile is important because it can indicate how much variability there is in the process. Reducing variability will improve process efficiency and generally lead to improvements in patient satisfaction.

3.3 Fix the ED Constraints

Patients arrive to the emergency department either by walking in or by EMS (ambulance). Generally, the process involves:

1. Triage
2. Registration

3. Placement in an ED bed
4. Assessment
5. Completion of orders
6. Diagnosis, and
7. Disposition

The patient disposition is either discharge to home or admission as an inpatient. Constrained ED resources include beds and staff. Bottlenecks in the ED occur because the patients arrive at a rate faster than they can be dispositioned. Determining how to eliminate the bottleneck is complex and usually involves testing many scenarios.

The first step is to test scenarios where the beds and staff are increased. Test by incrementally increasing these resources until no improved results are achieved. Note that implementation of process improvements may allow further reduction in resources, making this algorithm an iterative process. Many hospitals include a small number of FastTrack beds for patients who only require minor treatment. FastTrack beds have a higher turnover rate, thus resulting in a shorter length of stay for a large number of patients. Determining the right mix of Main ED and FastTrack beds is important so that the limited number of beds is best utilized.

Testing the ED Constraints before fixing the inpatient constraints can waste time if the inpatient beds are overutilized. Consider the scenario where a large number of patients waiting to be admitted are tying up ED beds. Optimizing the ED would mean including a large pool of beds primarily used to hold these admitting patients. Subsequently adding more inpatient beds to remove the inpatient bottleneck would eliminate the need for that pool of ED beds to hold admitting patients. Therefore, the ED is now oversized and another iteration of optimizing the ED beds is necessary.

Conversely, testing the inpatient constraints before fixing the ED constraints may require another iteration if the ED is undersized. Experience shows, however, that most emergency departments actually do have enough beds and perceived shortages are a result of insufficient inpatient beds or process inefficiency.

3.4 Introduce Process Improvements

The final category of our experimentation algorithm focuses on process improvements, now that an iteration of capacity optimization has occurred. Examples of process improvements include:

- Bedside triage
- Bedside registration
- Reducing lab or radiology turnaround times
- Moving the inpatient discharge time earlier in the day
- Streamlining admitting activities
- Eliminating handoffs in the process
- Eliminating non-value added activities

The purpose of these improvements is to reduce the time patients spend in the emergency department waiting for care.

Simulation is a powerful tool for hospitals to understand how much impact each process improvement will have on their facility. Too often, hospitals assume they should automatically implement industry best practices. What works at one hospital may not work at another, which can waste time and effort.

Implementing process improvements in the model may cause bed over-capacity or under-capacity. Sensitivity analysis of the inpatient and ED beds will show if that it true. Sensitivity analysis includes making small incremental changes to input parameters (e.g., inpatient beds, ED beds) and seeing if makes a significant impact on the outcomes.

This algorithm of fixing the inpatient beds, ED beds and testing process improvements can then be repeated for each arrival volumes scenario. Thus, the simulation model identifies the best alternatives from a limited number of experimentation runs.

4 THE DESTINATION: EXPERIMENTATION RESULTS

The final presentation is ready for development now that experimentation results are captured and analyzed. Again, the objective of the final presentation is find what is interesting about the simulation results and tell the story about what it means. Sometimes it is as interesting to talk about why an alternative does not improve the ED as much as why an alternative does.

Previous EDsim projects have yielded valuable results, such as:

- How many inpatient beds will be needed in five years
- The hospital is building an ED that is oversized. The new facility only needs to be two-thirds as big as planned
- Process improvement A, B, and C should be implemented to dramatically reduce patient length of stay
- Do not implement process improvements X, Y, and Z because they won't yield much benefit

5 CONCLUSION

Hospitals are building and expanding their facilities with the intent that they will improve their patient throughput. Hospital executives need to know that they are designing new facilities with sufficient capacity. They would also like to know how long will the new facility last until more expansion is needed.

Predicting process performance with complex systems, such as emergency departments, is a challenging problem that can best be solved with simulation. Experimenting with simulation can mean testing a large number of scenarios. Finding the best alternatives can be done more efficiently using an algorithm that first determines the appropriate inpatient bed capacity, ED bed capacity, and then the best process improvements.

EDsim has proven to be a useful simulation model for finding answers to difficult questions. Recently, a hospital executive was so pleased to obtain detailed insight that the answers BPI provided were considered "an answer to prayer".

REFERENCES

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

Ferrin, D., M. Miller, and G. Giron. 2000. Electronic Workflow For Transaction-Based Work Cells In A Financial Services Firm. In *Proceedings of the 2000 Winter Simulation Conference*, ed J.A. Joines, R.R. Barton, K. Kang, P.A. Fishwick, pp. 2055-2058, OMNIPRESS, Madison, WI.

Mahapatra, S., C.P. Koelling, L. Patvivatsiri, B. Fraticelli, D. Eitel, and L. Grove. 2003. Pairing Emergency Severity Index5-Level Triage Data with Computer Aided System Design to Improve Emergency Department Access and Throughput. In *Proceedings of the 2003 Winter Simulation Conference*, ed S. Chick, P. Sanchez, D. Ferrin, and D. Morrice, pp. 1917-1925, OMNIPRESS, Madison, WI.

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, OMNIPRESS, Madison, WI.

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, OMNIPRESS, Madison, WI.

Nance, R.E and R.G. Sargent. 2002. Perspectives on the Evolution of Simulation. *Operations Research*, Vol. 50, No. 1, pp. 161-172.

Romano, M., P. Reilly, and L Benko. 2004. Hospital building boom expected to be long-lived. *Modern Healthcare's Daily Dose*.

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