

The background of the page features a large, abstract graphic of flowing, translucent blue lines that curve and swirl from the top right towards the bottom left, creating a sense of dynamic movement and depth.

White Paper:

**SIMULATION FOR LEAN  
SIX SIGMA (LSS) IN  
HEALTHCARE**

**ProModel®**  
Better Decisions—Faster

# Simulation for Lean Six Sigma (LSS) in Healthcare

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## INTRODUCTION

As anyone engaged in business process improvement activities knows, Lean Six Sigma (LSS) has become the de facto methodology for improving process performance. Though initially used in manufacturing, LSS has been increasingly gaining acceptance in the healthcare industry, which faces many of the same issues and challenges—how to reduce waiting time, how to increase capacity, how to best deploy resources, etc. Many LSS practitioners have discovered, however, that deciding what changes to make is not always easy, nor is it easy to accurately predict the impact of proposed changes. Dealing with complex systems having numerous interacting components poses the risk of making sub-optimal or even detrimental decisions. This paper explains how simulation, with its powerful predictive and visualization capabilities, eliminates the risk of failing in your attempts at process improvement work and helps ensure that the best possible solutions are found and implemented within the context of the LSS methodology.

## THE HEALTHCARE CHALLENGE

It is estimated that errors due to faulty healthcare procedures lead to the death of roughly 100,000 Americans each year and cause harm to another 2,000,000. More than half of these errors are preventable through more controlled procedures. On top of pressures to reduce procedural errors, hospitals, medical centers, and other healthcare institutions are being challenged to improve their operational efficiency. According to Mark Graban, author of *Lean Hospitals*,

“Hospitals worldwide face a wide range of problems and pressures that have inspired them to look outside of healthcare for inspiration. Payers, ranging from government agencies to private insurers, are forcing price reductions on hospitals, which require hospitals to reduce costs in order to maintain their margins. Even not-for-profit hospitals need to have a surplus to remain financially viable and to drive future growth. Hospitals are becoming less able to demand ‘cost plus’ pricing that pays them for their efforts as opposed to being paid flat rates based on patient diagnoses.”

Compounding these economic pressures, government agencies (e.g., JCHAO, DVA), as well as industry watchdog groups (e.g., IHI, AMA) have emerged for the sole purpose of promoting healthcare improvements. The burning question is: who is providing the solutions?

In searching for effective and efficient healthcare solutions, there is more than just the needs of the patient to consider. Healthcare systems must also respond to the demands of physicians, nurses, support staff, healthcare administrators, the board of directors, and others. To complicate the situation, these different constituents often have competing agendas regarding the optimal operation of the healthcare system.

Finally, there is the complex and variable nature of healthcare systems which makes it difficult to predict how a change here or there may affect overall performance. Thus, everyone has his or her own opinion of how a system should be improved. Making intelligent and informed process improvement decisions requires analytical skills that often exceed the capabilities of even the best LSS analysts.

Given the complexity of many healthcare systems and the increasing demand for better, more affordable healthcare services, it is no wonder that determining the optimal healthcare system has become a major challenge facing healthcare organizations today.

## **TRADITIONAL LEAN SIX SIGMA PRACTICES**

To help curb the rising costs of healthcare and provide the quality of care demanded by its many constituents, healthcare organizations are increasingly turning to LSS practices. Lean Six Sigma, of course, is a composite of two process improvement methodologies: (1) Lean and (2) Six Sigma. Following is an overview of how these two methodologies work together.

### **THE LEAN APPROACH**

Lean is both a strategy and a set of techniques. The strategy of Lean is simple yet compelling: minimize waste and maximize customer satisfaction. Translated to healthcare, Lean continuously seeks to drive out waste in healthcare processes so that patient needs are more effectively and efficiently met.

Lean focuses on waste elimination where waste (Japanese = muda) is defined by Shoichiro Toyoda, founder of Toyota, as “anything other than the minimum amount of equipment, materials, parts, space, and worker’s time which are absolutely essential to add value to the product.” Adapted to healthcare, waste is anything other than the minimum amount of supplies, equipment, personnel, space and time that is absolutely essential to delivering a quality level of clinically accepted patient treatment.

Lean emphasizes the continuous movement towards a best process, not the typical American concept of an innovative step change in performance. This attitude of striving for continuous improvement must be embraced by the entire organization and become part of the cultural DNA if it is to be truly successful.

### **TACTICAL TOOLS OF LEAN**

At the tactical level, Lean is implemented through the use of a set of practical tools and techniques. Below is a brief description of the principal Lean techniques that have particular application to healthcare processes.

Value-stream mapping (VSM): used to diagram and document the patient flow, information flow or flow of supplies in order to see where value is being added and waste is occurring. A VSM enables analysts to look at entire processes, such as the complete door-to-door journey of patients, instead of focusing on individual functions or departments, which is how many hospitals are organized and operated.

An example Phlebotomy Process Value Stream Map is shown below:

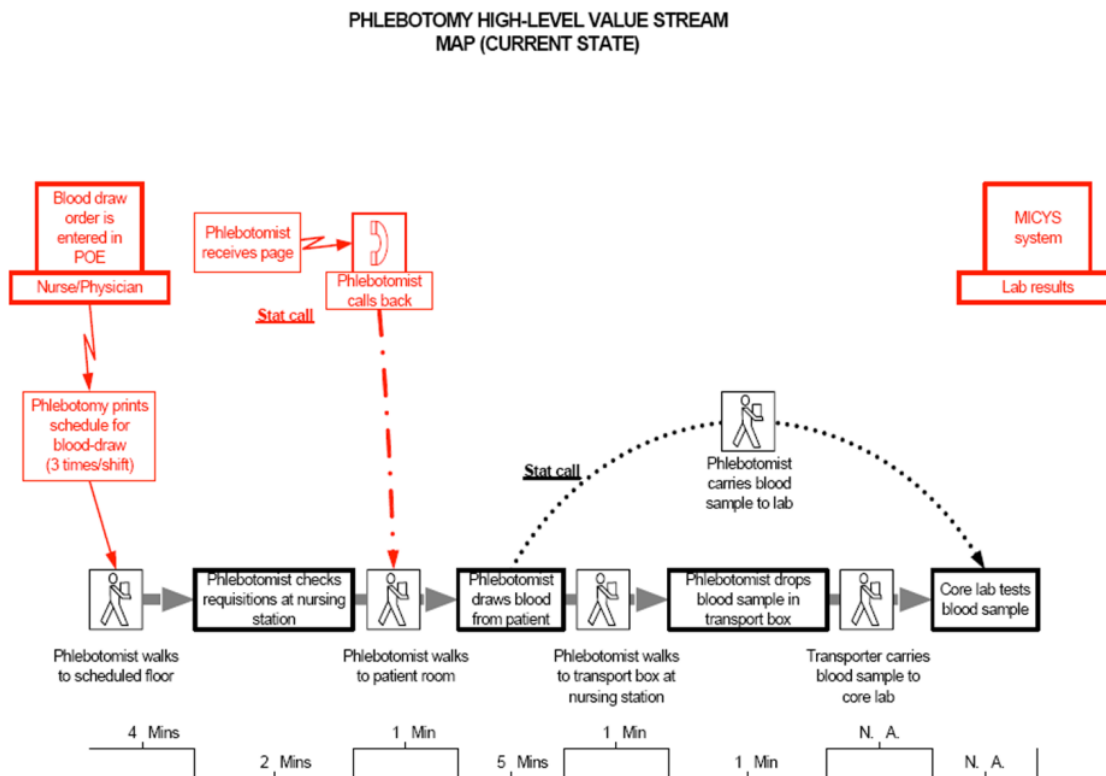


Figure 1. Phlebotomy Process Value Stream Map

**A3 Reporting:** used as a documentation tool to define the problem, specify the solution and outline an action plan for implementing the solution. The A3 report helps ensure that Lean follows a structured problem solving process.

**Kanban (pull) production:** used primarily to regulate the reordering of supplies and their delivery to their point of use. It can also be used for scheduling and moving patients through a process. The intent is to eliminate having more items or people in the system than what the system can handle.

**Takt time:** the pace at which activities need to be performed to keep up with patient demand. Takt time is calculated by dividing available work time per period by the expected number of patients for the same period. For example, during an 8-hour shift a doctor or technician might have only 400 minutes of available time (any allowances for personal time or time to perform ancillary tasks should be considered). If the expected number of patients per shift is 50, the takt time is 20 minutes. Adjusting resources and activities to meet takt time is a simple yet effective way to ensure that bottlenecks are avoided and patient demand is satisfied.

**Note:** Takt time should be based on anticipated demand, which may not necessarily correspond to historical census information. It should also take into account fluctuations that may occur during the shift, day or week.

**Workflow diagram:** a.k.a. a spaghetti diagram, this is a layout of the facility with arrowed lines depicting the physical flow of supplies, information, patients, etc. within the facility. This helps identify unnecessary or inefficient movement and use of space.

**Work cells:** a streamlined, modular approach for carrying out a process. Doctors, nurses and technicians operate as a team to get patients to flow through a sequence of activities.

**5S:** a systematic way of organizing and standardizing practices in the workplace (sort, straighten, shine, standardize, sustain). 5S eliminates much of the time staff might spend searching for supplies, medication or information.

**Quick Setup:** a systematic method of reducing setup or changeover time for operating rooms, MRI machines, and other equipment as well as reducing personnel prep and cleanup times. Quick setup techniques help reduce patient waiting time and maximize resource utilization.

**Total productive maintenance (TPM):** conscientious and systematic maintenance of equipment to keep it operational, thus minimizing equipment failures and avoiding long delays.

**Visual Controls:** utilization of visual signals and images to alert attention and ensure correct action and meaningful feedback occurs. Such controls reduce errors and wasted time. They also improve communication and prevent errors caused by handoffs across caregivers and departments.

**Poka Yoke (mistake proofing):** designing procedures so they can *only* be performed the right way. Poka Yoke focuses on error prevention rather than detection and correction. It often utilizes visual controls to eliminate error and provide verifying feedback. Poka Yoke directly attacks the roots of many of the causes contributing to the unprecedented patient mistreatment that occurs each year.

**Standardized Work Methods:** ensures that procedures are documented and performed consistently. This is often achieved through printed instructions and staff training.

**Level Loading:** distributes and balances work load so that doctors, nurses and equipment are kept productive, and patient waiting time is minimized. Level loading reduces patient delays and helps solve capacity shortages.

**Cross-training:** trains staff to function in multiple aspects of the process to provide greater interchangeability of workers. This reduces patient waiting time and improves worker utilization.

## THE SIX SIGMA METHODOLOGY

Where the strength of Lean lies in providing a set of proven techniques for eliminating waste, Six Sigma provides a structured methodology based on quantitative analysis for carrying out and sustaining Lean initiatives (or any other initiative for that matter). Lean and Six Sigma thus complement each other in driving process improvement.

The standard Six Sigma methodology for process improvement is called the **DMAIC** process, an acronym which stands for the following steps:

**Define** the most important problem to resolve as determined by the “voice of the customer” (i.e., what the patient values most).

**Measure** the current performance of the process that is failing to meet objectives as determined by the voice of the customer.

**Analyze** the process to find cause-and-effect relationships (i.e., how independent or decision variables affect dependent or performance variables). Find the transfer function  $y = f(x_1, x_2, \dots, x_n)$  that quantitatively defines these relationships.

**Improve** the process by finding the solutions that best achieve the desired performance and then implement these solutions (this is where Lean solutions come into play).

**Control** the implemented process improvements through monitoring and feedback mechanisms.

The DMAIC process is intended to be repeated as a cycle of continuous improvement (see Figure 2).

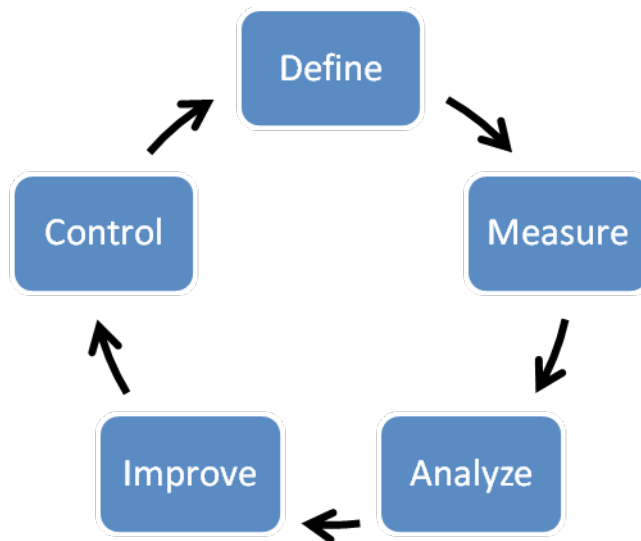


Figure 2. The DMAIC Process

## APPLYING LEAN SIX SIGMA IN HEALTHCARE SYSTEMS

A healthcare organization that is relentless in its pursuit to eliminate waste has no problem finding self-evident opportunities for process improvement. Even then, however, determining the most cost-effective way of addressing these opportunities is not always straight forward, nor does the solution implementation always go smoothly. While the traditional approaches to LSS are rooted in and guided by clear organizational goals and objectives, healthcare practitioners of LSS often face certain limitations: complexity of the system, time limitations, staff skepticism, interdisciplinary competition for budget and resources. As a result, finding the ‘best’ solution can be challenging. At times, the identified solution turns out to have adverse

unintended consequences in other parts of the system. Implementing suboptimal solutions carries the risk of disrupting workflow, impacting quality and even alienating clinicians from the LSS process.

As an example, consider a problem as simple as identifying and removing a bottleneck in a patient flow process. Bottlenecks occur when the number of patients surpasses the system's ability to process them. For hospitals, this means there is either a shortage of resources (beds, staff, etc.) or a hold-up in the way patients are processed from arrival to discharge. Removing bottlenecks may require adding more beds, adding more staff, or improving procedures for moving patients through the process. Reducing the number of patients is another way to remove bottlenecks, but for hospitals, that means lost revenue. Even though the options in this case are fairly straightforward and few in number, it isn't at all clear just how much the bottleneck can be reduced by making a particular change or combination of changes. The interdependencies and variation in the process make such a determination difficult to calculate and equally difficult to make a convincing argument to others.

Given the challenges of LSS, three gnawing questions inevitably face every LSS practitioner:

1. How do I know if the best possible solutions are being considered?
2. How can I objectively and quantitatively compare solutions?
3. How can I effectively communicate the solution to get "buy-in"?

Methods and tools for reliably predicting the impact of proposed solutions have been largely lacking in traditional LSS approaches. In many cases organizations implement changes that are overly conservative because they have no effective way of containing risk. The result is that more innovative and promising solutions may get overlooked.

The real goal of any process improvement exercise isn't to improve just individual activities, but to improve overall system performance, which requires a thorough knowledge of the peculiarities of the system being studied. Too often, hospitals assume that if they simply implement published best practices, they will get improved performance. Unfortunately, what works at one hospital may not work at another. Arbitrarily implementing process changes simply because they imitate "best practices" can result in disappointment with costly wastes in time and resources and, in a healthcare system, can put the patient's well-being at risk.

## LEVERAGING LSS WITH SIMULATION

A technology that has been shown to unleash the full potential of LSS in healthcare is computer simulation. Simulation has been used in healthcare applications for over forty years, but only recently has it become recognized as a key enabler for realizing the potential of LSS in complex systems.

Historically, LSS has been applied in a rather traditional way to healthcare processes: eliminate non-value added steps in the process, standardize the process to reduce variation, and look for glaring forms of waste. These are all improvements that can be made readily without much investigation or analysis.

"The most damaging kind of waste," notes Shigeo Shingo, "is the waste we don't recognize." What simulation provides is a way to discover and get rid of the hidden waste in healthcare



systems, especially waste that is more systemic in nature. These are more difficult to detect and correct, but can often have the greatest impact on overall system performance. Examples include tasks having the wrong priorities, suboptimal scheduling of expensive equipment, over-specialization of workers and inefficient hand-offs between processes.

Additionally, it is difficult in many healthcare processes to clearly define the driving forces or pacing process. Consequently, healthcare personnel often assume the process is resource limited by, say, the number of beds or RNs. Simulation allows for sensitivity analysis that clearly illuminates the key factors to which the process is most sensitive.

One way to think about the use of simulation in LSS is to compare it to a ladder used to pick fruit off a tree. Any LSS practitioner can go after the low-hanging fruit without the aid of simulation technology. If, however, one wants to reach the prized fruit (greatest value from the LSS initiative) located higher in the tree, simulation becomes essential.

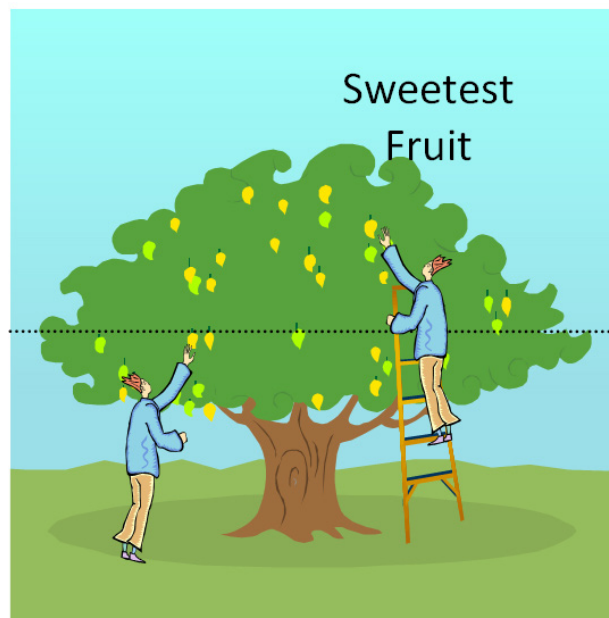


Figure 3. Simulation Puts the Best Fruit within Grasp

The use of simulation in healthcare is now a major topic in many healthcare conferences including the IHI (Institute for Healthcare Improvement) and SHS (Society for Health Systems) conferences. For several decades it has been a regular track in the annual Winter Simulation Conference (WSC). In 2004, the Society of Simulation in Healthcare (SSH) was established, which also holds an annual conference and publishes a journal entitled *Simulation in Healthcare*.

Let's look at how simulation addresses the three major concerns of LSS practitioners in healthcare.

## OVERLOOKING THE BEST SOLUTIONS

For simple processes or individual procedures, the number of different viable options for improvement is relatively small. As processes become more complex, however, the number of options (including combinations of options) to consider for improving the process grows exponentially. Given the finite capacity of the human mind to consider what could potentially be hundreds of options, the analyst often resorts to safe and familiar solutions. This is an area where simulation can make a significant difference.

Simulation captures the process complexity in a computer model and facilitates complex “what-if” analysis. It opens up the mind to possibilities that would not otherwise be obvious. As mentioned above, sometimes it is mistakenly assumed that by imitating what others have done or implementing “best practices,” the system will improve. Through the use of simulation, one can quickly determine which solution works best for the particular situation at hand. Furthermore, a sensitivity analysis can be conducted with the model to see how small incremental changes to input parameters (e.g., number of nurses, beds, etc.), can affect outcomes. This ability to experiment with a broad range of factors promotes innovation and allows many more options to be considered.

## OBJECTIVELY AND QUANTITATIVELY EVALUATE SOLUTIONS

Just as more complex systems restrict the number of different options the human mind is capable of considering, it also restricts the ability to quantitatively evaluate the impact of proposed solutions. This makes the selection difficult and forces one to resort to best-guess estimates of performance or allows strong wills to sway decisions.

Instead of relying on subjective opinions, simulation gives objective and accurate estimates of performance improvements. For example, when seeking to determine the number of patients of different types that can be handled in a radiology lab, there is no way to simply add up service times and divide into the number of hours in the day. Resources may be shared, activity times may vary, arrival rates may fluctuate, and so on. Only simulation can predict the overall performance with any degree of accuracy.

To illustrate how simulation helps take the uncertainty and personal biases out of process change decisions, consider the following situation. A hospital in the southeast United States had decided to allow pre-op procedures on patients to be performed in a planned outpatient clinic, on the day prior to their surgery. Questions arose regarding the level and disciplines of staffing, the physical capacity, and the hours of operation of the planned facility. While all involved parties suggested their own personal solutions were best, no consensus could be reached. Finally, a simulation model was created that gave this diverse group a tool to evaluate each “pet” solution as well as variant combinations of each solution.

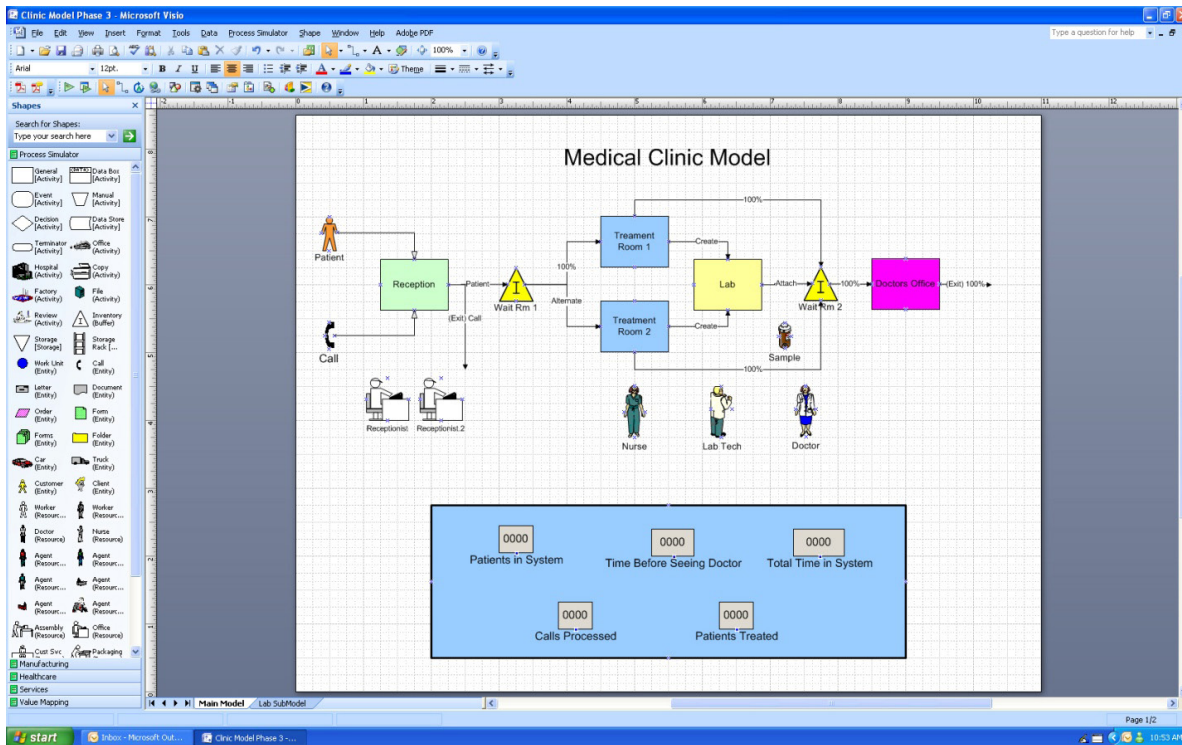


Figure 4. Example Process Simulator Medical Clinic Model

## EFFECTIVELY COMMUNICATING SOLUTIONS

Often when a decision is made to change a process, there is a certain FUD (fear, uncertainty and doubt) factor that causes resistance to the change and creates anxiety in affected personnel. Simulation effectively communicates how a process works so there is no misunderstanding and no need to harbor fear and doubt about its ability to meet demonstrated performance levels.

## PUTTING IT ALL TOGETHER

The way to get the most out of simulation is to make it part of the LSS process. Simulation can be used as early as the **Analysis** stage to gain a better understanding of key decision variables and begin to generate ideas for improvement. At the **Improve** stage, simulation can quantitatively predict results that can be expected for different design ideas and then help sell the best solutions to others (see Figure 5).

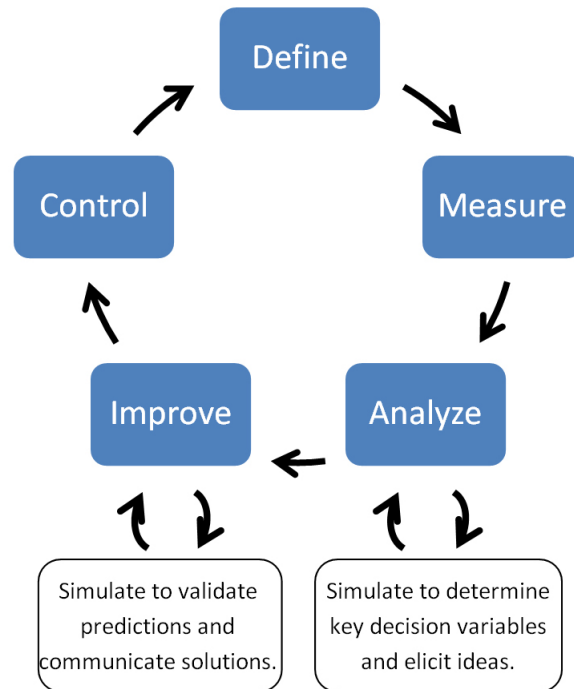


Figure 5. Integration of LSS and Simulation

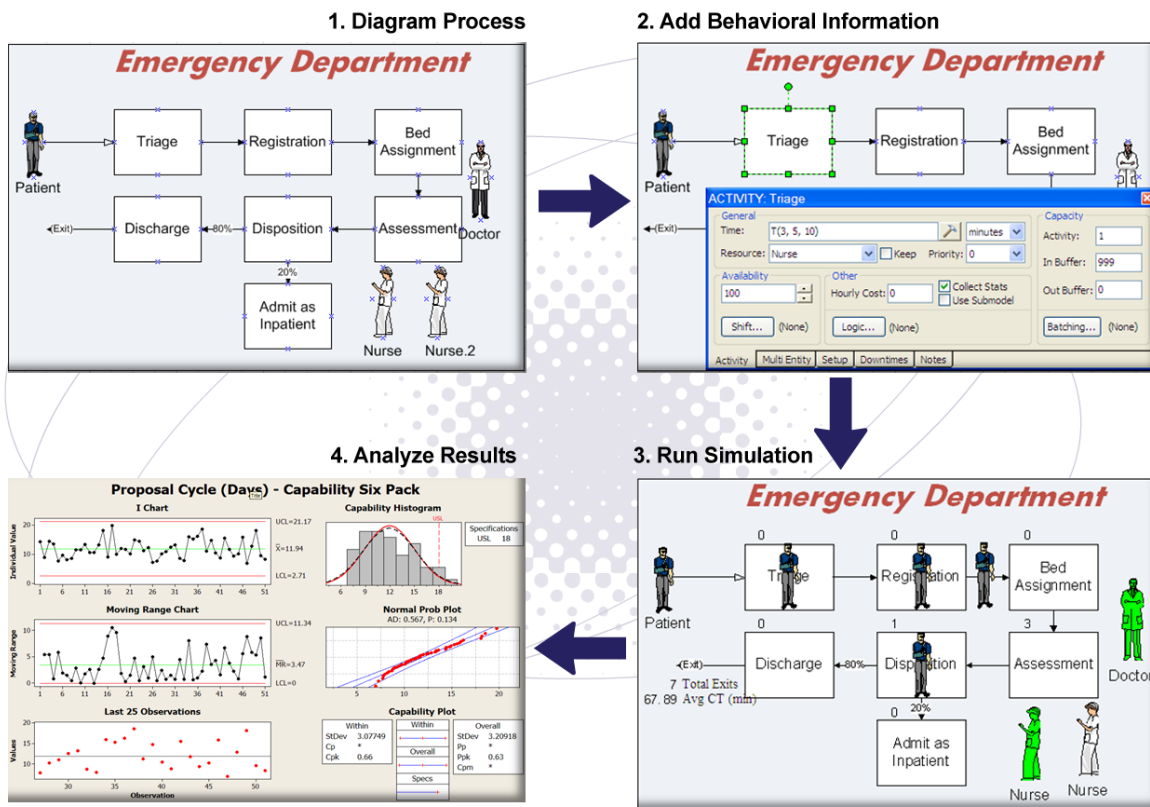
## PROCESS SIMULATOR FOR LSS

Process Simulator is a simulation tool developed by ProModel Corporation that is specifically designed for modeling processes common to the healthcare industry. What makes Process Simulator the tool of choice for LSS practitioners?

1. Process Simulator is based on Visio, a tool most LSS practitioners already use to create value-stream maps, process flow charts and facility layouts. Simulation properties can be easily added to existing process diagrams or layouts.
2. With its visual animation capability, Process Simulator enables analysts to visualize how solutions work and sparks ideas for finding improved solutions.
3. Process Simulator's scenario analyzer allows alternative solutions to be simulated and compared quantitatively to determine the optimal solution.
4. Process Simulator integrates with Minitab and automates the statistical measurements needed for doing a Six Sigma analysis.
5. If more complex modeling or 3-D graphical animation is desired, models can be imported to MedModel, a comprehensive healthcare modeling tool which has extended modeling and visualization (including 3D) capabilities.

In Process Simulator, models are built and solutions are evaluated in just hours or even minutes depending on size and complexity. As shown below, Process Simulator follows a simple 4-step process:

1. Diagram the process
2. Add behavioral information
3. Run the simulation
4. Analyze the results



Changes are made by either reconfiguring the process or changing the behavioral information. Experimental changes can even be explored systematically using a built-in scenario analyzer.

Process Simulator also provides hierarchical modeling capability, which allows processes to be defined at a high level, such as the overall operation of a hospital, and then permits the user to drill-down to various sub-processes (OR, radiology, etc.) for more detailed analysis.

## CASE STUDY

The Memorial Hermann hospital system was interested in achieving a more balanced loading on resources in their emergency department (ED) between 8 a.m. and 6 p.m. Current ED wait times of 6 to 10 hours were causing an LWBS (leave without being seen) rate of 9.7%, costing approximately \$20M in contribution margin. Their goal was to bring the average wait time down to 3 hours.

After mapping the process in Visio, it was brought into Process Simulator to add behavioral information and run simulations to better understand what was happening. Performance metrics of prime interest included average D2D (door to doc) time, triage to end-bed time, end-bed to care-complete time, and care-complete to discharge time.

Once the model was verified and validated, several simulations were run experimenting with new technologies (wireless communication, RFID, EMR), reducing the number of interdependencies, changing the way care components are orchestrated, using adjustable staffing techniques, varying handling policies based on patient acuity, and doing a better job of work balancing.

As a result of systematically evaluating alternative solutions, the best improvements were chosen for implementation with predicted benefits as follows:

- Decreased LOS and wait times by as much as 40%
- Decreased LWOT's by 5% to 30%
- Decreased Radiology turn-around time by nearly 40%
- Decreased lab turn-around time
- Increased throughput capacity
- Improved design and process flow
- More efficient use of staff and facilities
- Greater flexibility to adapt to future growth
- Better quality of care through improved communication and standardized work
- Improved customer satisfaction
- Increased profitability

The ability to accurately quantify anticipated performance levels and to have such a high degree of confidence in achieving these performance levels would have been unthinkable without the use of simulation.

## CONCLUSION

Simulation using Process Simulator doesn't replace LSS, it makes it tactical so that better decisions can be made, risk free. LSS practitioners who leverage LSS methodology with simulation technology find they get the most out of process improvement initiatives. What simulation provides over traditional approaches to LSS is the following:

- An ideation tool for stimulating innovation, thus eliciting more ideas for consideration.
- An analysis tool for doing scenario comparisons and identifying key process factors affecting performance and quality.
- A predictive tool that can accurately quantify anticipated performance levels.
- A visualization tool that animates how the process will actually work.

In his book *Serious Play*, author Michael Schrage argues that “innovation is not about rigorously following the ‘rules of the game,’ but about vigorously challenging and revising them.”<sup>1</sup> The ability of dynamic models to yield counter intuitive insights and to test alternative courses of action has made process simulation a standard practice for many LSS professionals. Process Simulator gives every process analyst the means for finding the best solution for improving a process, quantifying the level of improvement that can be anticipated, and then convincingly selling the solution to others. This is ultimately the goal of every LSS analyst.

## FOR MORE INFORMATION

For further information on ProModel's healthcare solutions please contact our healthcare team at 877-333-4499, [healthcaresolutions@ProModel.com](mailto:healthcaresolutions@ProModel.com) or [www.promodel.com/solutions/healthcare](http://www.promodel.com/solutions/healthcare). An effective way to quickly and easily get a feel for the power of simulation is to download a complimentary copy of Process Simulator Lite at [www.promodel.com/products/processsimulator/](http://www.promodel.com/products/processsimulator/). Process Simulator Lite is a feature-limited, fully functional version of Process Simulator that allows people to rapidly assess its capability with a minimal learning curve.

### (Endnotes)

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