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Health Systems Engineering (HSyE)

A Strategic Capability for Optimizing and Transforming Healthcare Delivery

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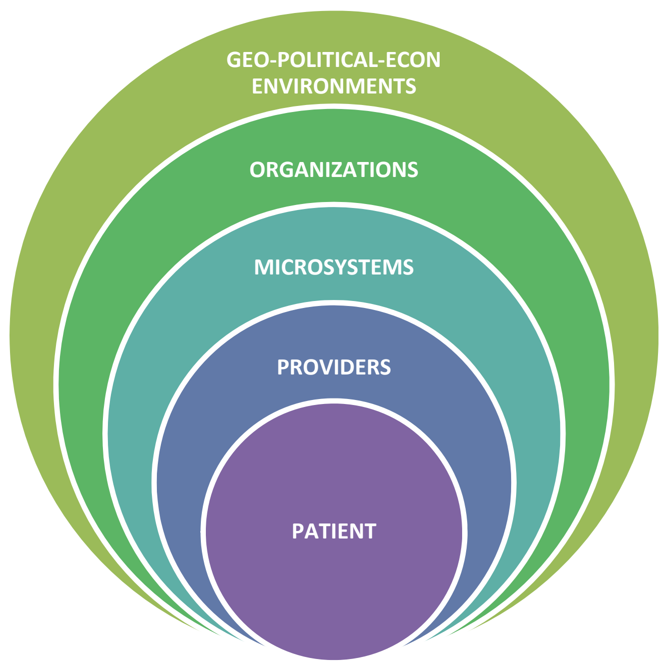
What is HSyE?

Health Systems Engineering (HSyE) is an emerging discipline that considers the healthcare industry as a complex system (or system of systems). HSyE employs a set of analytical, mathematical, computer, and graphical methods and tools to understand, model, improve, control, and optimize process and system performance for the full spectrum of the allied healthcare field. HSyE overlaps, integrates, and optimizes methodologies, processes, and best practices from traditional technical management and systems engineering areas such as Biomedical, Industrial, Operations Research, Information Technology, Human Factors and, even Aerospace Engineering. Non-healthcare industries, which have engaged in parallel improvement initiatives, have significantly advanced the efficiency, reliability, productivity, quality, safety, and value of their systems.

System engineering is used in almost every complex industry such as aviation, transportation, telecommunications, manufacturing, and pharmaceuticals, but it is underutilized in the healthcare industry.

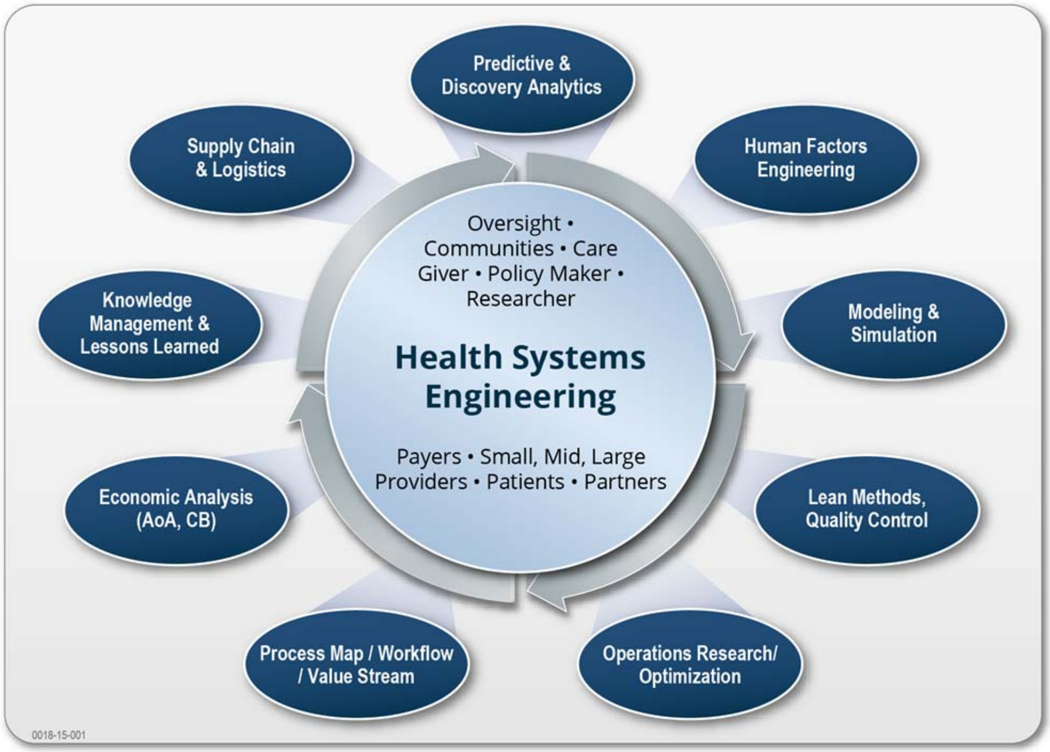
Healthcare is a complex ecosystem that takes in a variety of organizational settings and environments, from patients to healthcare providers and microsystems to organizations that provide infrastructure and resources to government, political, and economic environments. HSyE takes a systems view of healthcare, using evidence-based, measurement, and mathematical methods and tools to understand and address problems and make improvements. Modeling can be used to better understand the relationships and effects of potential solutions and can lead to better designs, processes, and policies from the knowledge gained, resulting in improved healthcare. HSyE is a critical technological capability that moves all organizations down the path to improvement through better efficiency and effectiveness, thereby maximizing capital and resource utilization and long-term success.



HSyE is applicable to solving a wide range of issues in virtually every segment of the healthcare industry and across organizational enterprises, including:

- Supply Chain/Logistics
  - Supply chain management
  - Streamlining transportation and logistics
  - Inventory management
- Queuing and Patient/Personnel Modeling
  - Patient demand (patient load versus staffing)
  - Patient flow optimization (access, delays, other)
  - Utilization management planning
  - Hospital occupancy planning
  - Capacity planning, scheduling (OR, outpatient, staff)
  - Diversion and evacuation planning and modeling
- Analytics
  - Risk analysis
  - Data analysis
- Systems, Processes, and Networks
  - Quality systems design
  - Integration of procedure
  - Process and work flows (value stream maps)
  - IT systems, networks, and design
- Process Improvement
  - Business process reengineering
  - Production and productivity improvement
  - Organizational, process, and business optimization (administrative, treatments/therapy, ER, ICU, chronic care)
  - Human factors engineering
  - Preventing readmissions
  - Quality control
  - Benchmarking and best practices
- Health Economics (policy and costing)
- Knowledge Management and Lessons Learned

We define a "system" from a broader and more holistic context. It includes a variety of influencing resource elements such as people (actors, institutions, stakeholders, and regulators responsible for financing and delivery of care) and organizations, processes, policies, information technology and infrastructure assets, facilities, knowledge management/information management assets, decision and training tools, budgets, etc. The HSyE ecosystem diagram below illustrates the myriad of competencies that come into play to enable healthcare transformation.



Why Do We Need HSyE Now?

The United States continues to lag other countries in the provision of cost-effective healthcare and is not comparable to other industrialized nations in terms of the quality of care provided. The U.S. spends $3 trillion annually on healthcare, one-third of which is waste. [1,2,3,4]

The following examples illustrate waste and improvement opportunities:

- 770,000 injuries and deaths occur each year due to unintended injury caused by medical management that result in death, life threatening illness, disability at the time of discharge, admission to the hospital, or a prolonged hospital stay (adverse events)

Health System engineering and adaption of engineering principles is key to achieving learning healthcare system that is delivering quality healthcare reliably, consistently, and affordably.

- $500,000,000 is spent on suboptimal healthcare annually

1 Benneyan, JC, 2013, The National Healthcare Systems Engineering CMS Demonstration Project, Healthcare Systems Engineering Institute, Presentation at World Conference on Quality and Improvement.
2 Luycx, R, Loxton, M, & K Coniglio. PE LL Utilization Management Report, Product Effectiveness, 2014,
3 Kohn, LT, Corrigan, JM, and Donaldson, MS, Eds. To err is human: building a safer health system. Committee on Quality Healthcare in America, Institute of Medicine, National Academy Press: Washington, DC, 2000.
4 Berwick, DM, Nolan, TW and J Whittington, 2008, The Triple Aim: Care, Health, and Cost, Health Affairs, 27, no 3:759-769. http://content.healthaffairs.org/content/27/3/759.full.html

- On an annual basis, there are 99,000 deaths, 1.7 million healthcare-associated infections, and $5 billion spent on treating these harmed patients each year
- Unwarranted variations in medical practice are common; with only about half of U.S. patients receiving best-practice treatments
- Over $500 billion spent on clinical care choices unsupported by evidence-based medicine, accounting for 36% of end-of-life spending and 17% of total healthcare spending in the U.S.
- 40% of Medicare patients discharged after admission for congestive heart failure are readmitted within 90 days
- The U.S. ranks 31st among nations on life expectancy and 36th on infant mortality
- The average cost of poor quality care is $1500 per patient per year
- Healthcare systems and facilities often repeat the same mistakes each time they implement Health IT applications or clinical workflow and fail to take advantage of lessons learned by themselves and others.

In addition to the human and financial costs of adverse events and poor healthcare, there are tremendous costs associated with inefficient and ineffective operational processes that lead to excessive patient wait times, coding errors, overcrowded facilities, unavailability of needed staff, software that does not meet clinician needs or contributes to errors, purchasing errors, patient scheduling issues, inaccurate inventories, unneeded capital expenses, and poor facility design. These inefficiencies place excessive burdens on clinical workflows, result in silos of care, and take away from clinicians focus on the patient.

The U.S. has among the lowest rankings on Institute of Medicine (IOM) dimensions for safety, patient-centered, access timeliness, efficiency, effectiveness, and equity when compared to other industrialized nations. Twenty-five percent of total U.S. hospital spending is attributable to administrative costs, yet physicians are found to be hampered by lack of timely information and administrative issues. The U.S. ranks last on measures of financial accessibility of care and night and weekend availability compared to other high-income countries.

Recently, the Triple Aim[5] of the IOM has been written into the Affordable Care Act. While in recent years the increase in healthcare expenditures has slowed, the cost of healthcare to the U.S. economy is huge, comprising nearly 20% of GDP, and it is the most expensive per capita healthcare in the world. These costs remain a drag on other segments of the economy and affect the cost of living and financial security of the nation's poor and socially disadvantaged.

[5] HSyE can provide a laser focus on improved outcomes for the IHI Triple Aim objectives of better health, better care, and lower costs in healthcare organizations.

The Affordable Care Act includes provisions to monitor and ensure quality care while reducing costs. This has enormous importance to healthcare providers since it means that reimbursement rates will be impacted when metrics for improvement are not met, as well as the added pressure of containing costs. This is in addition to years of the escalating cost of healthcare where payers shifted a growing share of the costs on providers and patients. All of these pressures taken together make healthcare reform and improvement a strategic imperative for all healthcare related organizations. Additionally, the Center for Medicare and Medicaid (CMS) has established Centers for Medicare and Medicaid Innovation (CMMI) to: develop, test innovative payment and delivery methods; improve triple aim; and bend the curve in program costs.

HSyE is a methodological approach to understanding the gaps in required capabilities and performance, analyzing alternatives to close these gaps, and providing solutions to address the needs of organizations in providing better care, achieving faster and better results, maintaining improvements, and getting the needed financial results by permitting healthcare organizations to accomplish more with fewer resources and keeping ahead of rising costs.

How can HSyE Help?

There are numerous healthcare related organizations that have an interest in HSyE such as IOM, Institute for Healthcare Improvement (IHI), Agency for Healthcare Research and Quality (AHRQ), National Academy of Engineering (NAE), National Science Foundation (NSF), President's Council of Advisors on Science and Technology (PCAST)[6], and others. Their interest in HSyE lies in its ability to make a real and substantive impact on quality and safety through improved patient care and focus, value-added efficiency and effectiveness, improved availability and timeliness of care, better patient experience, and lower costs.

Leading hospital systems and nationwide projects focusing on improvement and using HSyE methodologies are taking great strides and achieving some outstanding results. Some of these results and methodologies are being shared regionally and nationally. Whitney Bradley & Brown, Inc. (WBB) has both participated in the development and employment of these methodologies. These hospitals set industry benchmarks for excellence and provide guiding lights for what can be accomplished. Their readmission and mortality rates are lower and their profit margins are higher than typically found.

Hospitals and other healthcare organizations which innovate by using HSyE principles are often the highest performing health systems based on measures of quality and efficiency. HSyE tools and methodologies have been shown to successfully address healthcare performance gaps.

[6]http://www.whitehouse.gov/sites/default/files/microsites/ostp/PCAST/pcast_systems_engineering_in_healthcare_-_may_2014.pdf

HSyE provides strategic opportunity and evidence-based approaches to optimize system performance to meet quality and safety goals, significantly improve predictability and measurement of performance goals (cost, access, risk, and productivity), dramatically reduce process variability, and facilitate the implementation of a reliable and learning healthcare system. Some exemplars include increasing utilization and capacity management of surgical processing, optimizing task performance in surgery, and streamlining patient access to outpatient care.

Denver Health and Kaiser Permanente are two examples of leading healthcare institutions that have implemented HSyE. Denver Health's lean journey won them the Shingo Bronze Medallion for Operational Excellence and ranked them in the top 10 in the University Health System Consortium Aggregate Accountability and Quality Score. This institution clearly felt of the benefits of taking a lean approach, and its impact on cost, quality, and employee engagement realized $159 million in financial benefit. Kaiser Permanente uses systems engineering as a driver for continual improvement, resulting in faster sepsis identification and mortality reduced by half.

The U.S. Department of Veterans Affairs Office of Academic Affiliations has implemented VA Advanced Fellowship Program in HSyE. The VA has also established VA Engineering Research Centers[7] to apply systems engineering and improvement methods to solve healthcare operational and delivery problems. Using these approaches, VA has overhauled inventory space for operating rooms, standardized decision-making processes and workflow, and increased efficiency and effectiveness. Mayo Clinic has an established an HSyE program as well.

The examples above highlight opportunities exploited by renowned healthcare institutions. The following section outlines tangible benefits.

Who Will Benefit?

Pivotal stakeholders (patients, small and medium clinical practices, large health providers, communities, payers, health researchers/economists, policy makers, and quality and safety professionals), stand to benefit from improved, high quality, safe, effective, and efficient healthcare. Money saved on healthcare can move into other segments in the economy fueling growth and prosperity. Patients will gain the most from safe, patient-centered, on time, and high quality healthcare. Lives will be saved and lengthened at decreased costs. Payers will reap higher profits or lower costs when reimbursing for healthcare. Providers and clinicians will gain real-time, accurate information and be able to translate the practices stemming from managed knowledge into better care for their patients in a lower stress work environment. Hospitals, hospitals systems, long-term acute care, skilled nursing, ambulatory care, palliative, and hospice facilities will be able to continually improve their processes, provide for development of their workforce, and reduce costs and administrative burdens. This will

[7] http://www.newengland.va.gov/verc/

result in higher profit margins while boasting improved patient care and health outcomes along with a satisfied and engaged staff. Best practices will be easily spread, and scaled and repeatability and sustainability will be increased. Some examples of how stakeholders can benefit include:

- Prevented hospitalizations and reduced length of stay
- Enhanced patient flow and throughput and reduced wait times, delays, and bottlenecks
- Reduced medical errors, adverse events, and hospital acquired infections
- Improved logistics and capacity
- Readmission reduction
- Optimized demand management
- Enhanced safety and reliability
- Better treatment (reduced overuse and underuse)
- Improved medical decision making and reduced variation
- Better diagnosis of patient conditions
- Enhanced policy support and analysis
- Healthier, better satisfied patients and family centered care
- Improved scheduling, information flow, and care coordination
- Streamlined administrative processes
- Reduced supply waste
- Alternative, less expensive treatment and equipment usage
- Improved access to medical knowledge-bases that learn and improve with care experience
- Improved redundancies, feedback loops, and safeguards to perfect system performance
- Better handoffs and patient experience
- Enhanced culture, teamwork, and sustainment

WBB HSyE Solution Set

The number and types of tools in the HSyE toolset is enormous. Which tools to use depends on the nature, scope, and complexity of the problem at hand. Seventy percent of the solutions can be generated using methods-based HSyE tools. The remainder use computer simulation modeling, mathematical models based on probability, and stochastic analysis or optimization modeling.

HSyE tools are applicable to every facet of the healthcare landscape from large-scale systems to subsystems to departmental process issues. The problems being addressed shape the nature of the data. In complex systems, individual differences create significant variability, so the tools needed have to account for this variability. For simple problems, easy-to-use tools make quick and easy work of coming up with successful results. WBB has the experts, including six sigma black belts, master black belts, and lean experts needed to choose the right tool for the problem at hand. They have the ability to identify and collect or design methods to generate good data through accurate measurements, observations, and attention to model or test design, thus facilitating and achieving cost effective and permanent solutions.

HSyE analytical tools facilitate an understanding of root causes for simple problems and provide a window to how complex systems operate. They can detect how well the system or process meets its goals, whether it is safety, efficiency, reliability, or customer satisfaction, and the tools can demonstrate how performance can be improved and problems resolved. System design tools can be used to design systems

Complex Scheduling Optimization

Overall Problem: Doctors, nurses, clinical, other staff co-availability for patient encounters, procedures, consultations, and team meetings; resource/meeting rooms availability, patient consultation, emergency, patient beds, or surgical rooms

Applies to scheduling for admissions, appointments, personnel, clinics, emergency, and surgical departments, operating rooms, chronic care, mental health, cancer care, hospital beds, and group/specialty doctor offices

Problem: Optimize oncology surgical team scheduling

Solution: Use detailed mathematical models similar to airline scheduling that describe how to: Maximize total number of common time slots of teams/ Provider assignment/Satisfy task requirements/Previously set activities/Preferences of providers as hard constraints/Coverage requirements/Team assignment/ Team assignment balancing

Results:
94% increase in desired team co-availability assignments/Up to 152% increase in weekly team assignments/No disruption related to OR utilization and patient waiting time

For more healthcare related examples, please see Appendix A

that meet the needs of stakeholders, including providers, patients, and organizations-all operating in concert to improve care and reduce costs.

While healthcare systems are inherently complex, tools such as *human-factors research/engineering* can help anticipate situations and provide environments or interfaces that help organize the conditions to improve clarity, determine if cross-checks are effective, reduce mistakes through computer assisted decision making, or manage a process which is negatively impacting human performance. A human factors knowledge-base can help guide ways to improve human performance in a myriad of ways. Best practices can be found in other healthcare settings or industries. In some cases, the needed information can be captured in and presented from a *knowledge management system* to optimize the retrieval of crucial information when and where it is needed.

Failure analysis tools can be used to identify ways that process or equipment is not providing the expected results. They help analyze the potential problems, errors, and failures for products, systems, processes, and services, as well as help design systems by identifying and controlling potential design flaws before they are implemented. These tools help identify the consequences or potential root causes of failure events or form the basis for a proactive hazard analysis.

Mathematical models can be used to apply *queuing theory* to patient flow to improve patient experience and reduce wait times or to address scheduling issues. *Supply chain management tools* can help reduce inventory, delays, and costs, or match resources with demands. *Economic models* can evaluate financial risks to the organization or patients if certain actions are taken. *Discovery analytics* permit the examination of large databases to identify and address a myriad of issues and develop solutions often for system-wide issues. Information from different databases can be grouped and analyzed providing new previously unavailable insights.

Modeling and simulations permit analysis of the expected performance of a system under defined conditions. It can be used to determine the impacts to changes in scheduling and staffing and provide an understanding of what happens to wait time or resources under particular circumstances. Systems can be described where probability and statistics are used to describe human actors in relation to their environment and activities. Validated models are used to test the consequences of changing variables in the model.

Risk management tools pave the way for developing strategies to reduce risk for patients, providers, and organizations, and protect against losses by quantifying, analyzing, predicting, and forecasting risks. Among other uses, stochastic analysis is one tool used to predict and quantify risk.

Statistical process control permits users to monitor, control, and improve process performance over time and determine if the variation in the process is within acceptable limits. The control charts provides a way of detecting whether a process is under control.

Scheduling of staff in healthcare is a pervasive issue and applies to everything from operating rooms to clinics to pharmacy in all types of facilities providing healthcare delivery. Tools can be used to match supply and demand in order to make the best use of personnel, facilities, and inventories.

Many of the methods and methods-based tools are used in *lean and six sigma improvement* methodologies and as stand-alone tools. Lean engineering uses various techniques and tools to reduce waste by eliminating or minimizing unnecessary movement or people and product, wait time, excess inventory, overproduction, over processing, and defects. An example of a tool used in lean is value stream mapping.

Six sigma is a set of tools and techniques to improve processes by reducing defects in products or outputs of work. Process variation is reduced through measurement, analysis, control, and improvement using verifiable data and statistics. The six sigma methodology is comprised of five phases: Define, Measure, Analyze, Improve and Control (DMAIC). The list of quality tools that can be used in each of these phases is extensive.

Some example methods-based tools include business process mapping, histograms, design of experiments, quality function deployment, (Supplier, Inputs, Process, Outputs, Customers (SIPOC)) analysis, pareto analysis, statistical analysis of various kinds, root cause analysis, fishbone diagrams, interrelationship digraphs, etc. These tools and methodologies can be used to solve a wide array of problems and issues in most healthcare settings.

WBB has the experts needed to identify which methods and tools are most appropriate to solve even the most difficult and tenacious of problems in healthcare. We have deep experience in applying and facilitating systems engineering solutions to a wide range of clients and problems.

HSyE Tools

Examples of Methods and Methods-Based Tools

- PDSA
- Process capability analysis
- Six sigma (DMAIC)
- Lean
- Statistical and reliability analysis
- Risk and failure analysis, RCA[8], Checklists
- Design of experiments
- Decision support analysis
- Quality metrics
- Project management support
- Patient feedback analysis
- Knowledge management
- Benchmarking
- Best practice analysis
- Quality function deployment
- Supply chain management
- Formal lessons learned analysis
- Failure analysis methodologies
- Economic analysis
- Human factors engineering
- Decision analysis
- Concurrent engineering principles
- Discovery analytics
- Predictive analytics (Big Data)
- X-bar charts
- Exponential moving average
- Histograms
- Fishbone diagrams
- Control charts
- Flowcharts
- Process maps/Flow analyses
- Pareto charts
- Statistical process control
- Operations management, Queuing

Tool Type	Description	HSyE Application
Computer Simulation	Uses computer program models to mimic process logic and randomness; used to test ideas, "what if analysis," process optimization, robust designs	▪ Discrete event – patient flow ▪ Monte Carlo – treatment decisions ▪ Agent-based – epidemic spread ▪ System dynamics – feedback loops
Probability and Stochastic	Uses mathematical models based on probability theory to describe randomness and how thing vary; used to describe demand, duration, health status, capacity versus service, and optimal timing of care	▪ Queuing, networks – patient flow ▪ Markov models – disease progression, patient location ▪ Probability and expected cost models – treatment decisions
Optimization	Uses mathematical models, programs, methods, and analytics based on objective functions such as cost quality and safety, constraints such as resources, capacity, time, and sequences, and decision variables such as staff level, start time, locations, and capacity as elements in optimization decision making	▪ Linear, nonlinear, and integer math programs ▪ Genetic algorithms and random searches for optimal search methods ▪ Calculus-based methods

[8] Root Cause Analysis

WBB Case Study in HSyE

WBB has been in business for over 30 years providing government and industry its systems engineering expertise. We have a wide range of experts providing the following services.

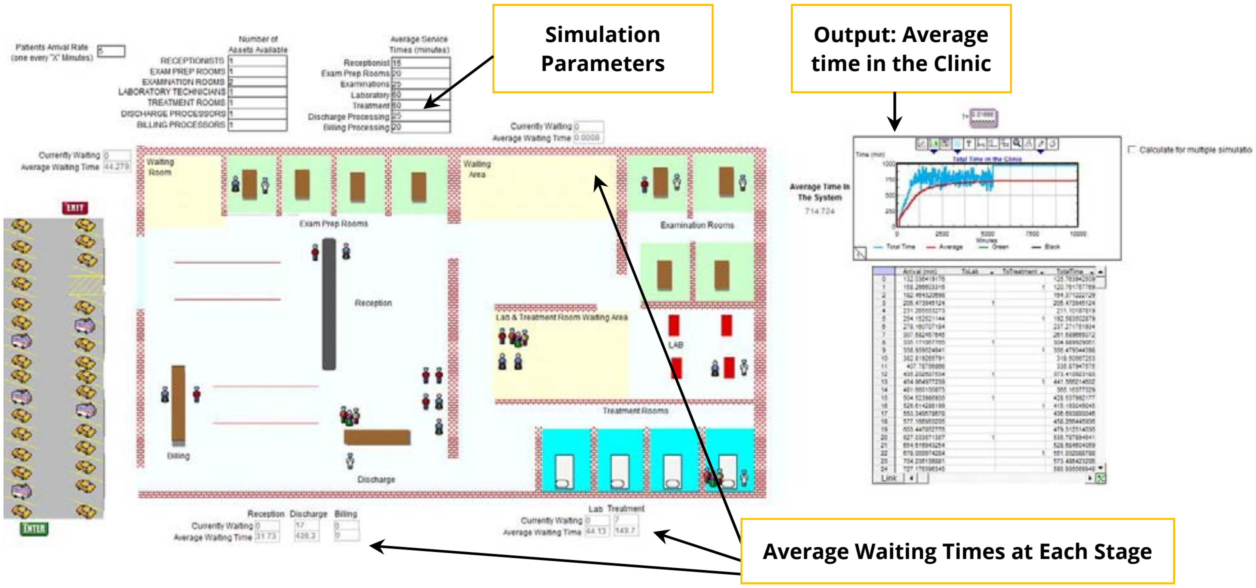
- Requirements establishment
- Design and design criteria
- Systems integration
- Systems interoperability
- Performance verification/validation
- Fielding of systems
- Regulatory requirements
- Systems engineering planning
- Technical management
- Project measurement
- Project management support
- Six sigma
- Lean
- Knowledge management
- Lessons learned
- Quality management system design and development
- Records management
- Document management
- Risk and failure analysis
- Process design
- Best practice analysis
- Statistics
- Process capability
- Decision analysis
- Wide range of quality tools
- Statistical process control
- Operations management
- Acquisition management
- Discovery analytics
- Business process reengineering
- Computer simulations
- Cost modeling
- Staffing analysis
- Monte Carlo techniques

Evaluation of Patient Flow through a Clinic to Assess Service Time (A WBB Proof of Concept)

Problem: Need to evaluate if the time patients spend in a clinic are optimal or are there efficiencies that can be identified. Identify bottlenecks and patient throughput issues.

Solution: Use modeling and simulation as framework to conduct descriptive, predictive, and prescriptive analysis of the time patients spend in a clinic, from arrival to departure. *Descriptive* analysis provides a means to evaluate current state and what has happened in the past. *Predictive* analysis uses logistic regression, sensitivity analysis, or other forecasting methods to project the probability of occurrence of a potential future state. *Prescriptive* analysis uses linear programing and optimization methods to prescribe the optimum mix or resources to achieve an intended objective or goal. With a well-structured simulation model, one can apply the required rigorous analysis that would facilitate making better informed decisions. Simulating the environment saves time and provides insights into the probability of occurrence of potential futures as input parameters are changed.

Results: Flow metrics were evaluated and bottlenecks were identified in the system using a large number of potential cases in a typical clinic. Through the simulation process, other variables such as staffing requirements surfaced as critical influences to the time patients stay in the clinic. This resulted in an optimized, cost-constrained staffing model that provided the optimal staff numbers in the right stations of the clinic and at the right times of the day/week/year. This provided the required clinical services while minimized the patient total time in the clinic. Below is a screen shot of a notional representative clinic in this kind of simulation – Using ExtendSim discrete event simulation software.



Patients arrive at a specific rate and go through the clinic depending on their illness. Some steps are standard (check in at the reception area, vital signs at triage, discharge, and billing). Others steps depend on the condition of the patient and have a time delay commensurate to the complexity of the condition (doctor examination, possibility of x-rays, need to stay in the clinic for onsite treatment, or others).

Appendix A: Case Studies in Healthcare Systems Engineering

Reduced Healthcare Related Blood Stream Infections

Problem: One in 20 hospitalized patients acquires healthcare-related infection with a mortality rate of 12% to 25%.

Solution: Identify CDC best practices and implement recommendations across the state of Michigan.

Results:
- Reduced rate of central line bloodstream infractions by two-thirds within three months
- Saved 1,500 lives over 18 months and nearly $200 million
- Approach has now spread throughout the U.S.

Optimization of Care Coverage through Telehealth Services

Problem: VA Telehealth program leverages specialty care through integration of telehealth services with traditional care; eliminate second visit for specialist consult and prevent scheduling system disruptions

Solution: Maximize specialty coverage for immediate Clinical Video Telehealth Service for Primary Care Provider to Specialty Care Provider consult by using integer programming model to allocate available provider hours to maximize anticipated CVT demand; detailed mathematical model describes:

- Maximum coverage potential CVT consults
- Assignment constraint
- Task requirement
- Fixed tasks
- Room availability
- Clinical coverage requirement
- CVT dispersal requirement
- Lunch break
- Operational continuity

Results:
- 20 patients were immediately served per week without any inconvenience
- 57% of all consults were performed remotely
- Decreased probability of no-show and cancellation

Optimization of Patient Flow through a Pediatric Department

Problem: Patient Flow through a Pediatric Department – complex logistics problem – locations, equipment, personnel, supplies, regulations, unplanned events, timeliness

Solution:

- Optimize "architecture" of problem rather than day-to-day details; optimize for imperfect day, not perfect day
- Run data through process logic of department with many repetitions
- Analyze the results and accuracy for location of patients in the Pediatrics department
- Compare simulated results to collected data for the following:
  - Total wait time until patient sees Provider
  - Wait for reception
  - Wait for medical assistance
  - Wait for Provider

Results: Improved patient flow and reduced patient wait time

Optimization of Lobby Space Design

Problem: New facility master space planning; number of people in lobby by time of day

Solution: Queuing flow simulation

- Inputs: 4 patients arrive/hour, 12 minutes average visit (5/hour) = 80% staff utilization

Results: New lobby space design optimized for expected number of people over course of day; as variability in exam duration increased, average waiting time performance decreased

Optimization of Number of PCs Needed per Floor

Problem: Space limitations for EMR computer terminals

Solution: "What if" queuing models using Stochastic/Variability modeling

- Inputs are number of PCs per floor, hourly need, mean on-time

Results: Outputs were percentage of time PCs were unavailable by floor and average wait time in line

Maximizing EMS Survival Rates

Problem: Maximize survival rates probabilities of EMS ambulance calls

Solution: Enhance response times using ambulance location and routing simulations; perform location analysis and simulation to analyze ambulance travel time phases, including response time, time spent on scene, transport time, and turnaround time

Results: Patient survival rates improved by faster ambulance response time

Generating Policy Recommendations for Controlling Epidemics

Problem: Need to support policy decisions for the spread or containment of epidemics

Solution: Use agent-based computer simulation models of cellular automata Monte Carlo data analytics to model the spread of Bird Flu

Results: Policy recommendations were made on how to minimize the spread of the Bird Flu epidemic

Improving Primary Care Clinic Access

Problem: Availability of primary care access in a clinic

Solution: "What if" queuing models using stochastic/variability modeling

- Patient inputs include scheduled patient access, unscheduled patient, access, and same-day wait time
- System inputs are utilization and overtime
- Queuing models are access, utilization, and delays

Results: Percentage of overtime was attributable to patient scheduling, assuming improved access and minimized wait time

Generating Screening Policy Recommendations

Problem: Screening policies for PTSD, melanoma, and others on total expected cost, accuracy, and workload using stochastic modeling

Solution: Compare alternate policies relative to the expected total cost and expected number of false negatives on a test for cancer

Results: Optimal policy recommendation was based on input data

Minimizing Total Cost for Basket of Purchases from Different Vendors

Problem: How to minimize the total cost of all items from all vendors for a supply chain contract

Solution: Using mathematical optimization techniques, analyze the following factors:

- Number of types of items
- Number of each item needed to buy
- Number of vendors
- Complex purchasing contracts based on total volume purchased from each vendor
- Take into consideration constraint of number of an item bought from a particular vendor and the total number of the item available from that vendor

Results: Best configuration of purchases were made to minimize total cost, taking into consideration all of the items from all vendors

Identify Best New Facility Locations to Improve Care and Reduce Cost

Problem: Determine best network design configuration of patient assignments, travel costs, locations of facilities, and capacities to minimize total costs

Solution: Devise mathematical models that accounts for all the variables and solves for minimizing total costs

Results: Recommendations were made for two new facilities and their optimal locations; graphical representation of locating facilities further from optimal locations; and the reduction in improvement of total costs based on change in absolute travel distance

- 5% - 15% decrease in total cost
- 10% - 35% increase in access
- 15% increase in in-house care

Maximizing Clinic Team Coverage

Problem: Maximize the average weighted team clinic coverage

Solution: Devise a mathematical model that improves the continuity of care, session coverage, attending availability, and provides for resident hours requirements

Results: Better continuity was accomplished by increasing session coverage by 20%, leading to better prevention, outcomes, and re-visits through dynamic input into a model that led to improved optimization by utilizing monthly and weekly schedules and a decision support tool

Optimize Treatment Plan

Problem: Determine the optimal timing of joint replacement based on quality of life, expected life span, and expected life of prosthesis

Solution: Devise a calculus mathematical model to maximize the area under the curve using the QALY model to determine the optimal surgery time

Results: Clinician has the needed information to determine at what age surgery for joint replacement is optimal

Impact and Optimization of Out-Patient No-Shows

Problem: How to optimize the overbooking amount to address outpatient patient no-shows

Solution: Use multiple methods: Continuous quality improvement to reduce no shows; predictive modeling to predict when no-shows will occur; probability minimum cost modeling to determine the optimal over-book amount; simulation to decide when to overbook; and Plan, Do, Study, Act to repeatedly design, test, and refine in practice.

Results: When optimized for over booking there was:

- Higher provider utilization
- Low patient wait time
- Acceptable levels of overtime
- Projected savings of $236,000 for a single clinic

Other Examples of HSyE in Use in CMS, NSF, and Other Studies

Applied

Supply chain, inventory, purchasing, patient flow analysis, discharge streamlining, PA staffing models, specialty care access, lean/QI projects (lab, pharmacy and transport), task analysis, and work design

Model Based

ED flow, observation units, urgent care, appointment access, timely care, network design, capacity, location, models, scheduling, readmissions, adverse events (clabsi, c. difficile, pressure ulcers, nicu's), cancer, mental health

Research

Predictive analytics, complex scheduling, adaptive capacity, cooperative competition (incentive design, games), spread of innovation models, home health models, screening models, risk-adjusted (start up and rare event SPC)

References and Endnotes

Baruch, K, and JS Pliskin, 2011, Optimal Timing of Joint Replacement using Mathematical Programming and Stochastic Programming Models, Healthcare Management Science, 14:361-369.

Benneyan, JC, 1997, An introduction to using computer simulation in healthcare, Jnl Society Health Systems, 5(3):1-15.

Benneyan, JC, Northeastern University, Healthcare Systems Engineering Institute, http://hsye.org/presentations/index.html.

Benneyan, JC, 2013, The National Healthcare Systems Engineering CMS Demonstration Project, Healthcare Systems Engineering Institute, Presentation at World Conference on Quality and Improvement.

Benneyan, JC, and Karrinsky, 1996, Statistical and economic models for analysis and optimal design of screening policies for cervical cancer, Ann Ops Re 67(1), 235-285.

Berwick, DM, Nolan, TW and J Whittington, 2008, The Triple Aim: Care, Health, and Cost, Health Affairs, 27, no 3:759-769. http://content.healthaffairs.org/content/27/3/759.full.html

Berwick, D, Godfrey, A and J Roessner, Curing Healthcare: New Strategies for Quality Improvement, John Wiley & Sons: San Francisco, 1990.

Bisognano, M, and C Kenney, Pursuing the Triple Aim: Seven Innovators Show the Way to Better Care, Better Health, and Lower Costs, John Wiley & Sons: San Francisco, 2012.

Crawford, B., et al. Kaiser Permanente Northern California sepsis mortality reduction initiative," Critical Care, 16(Suppl 3):P12, 2012.

Davis, K et al, The Commonwealth Fund Commission on a High Performance Health System, Why Not the Best? Results from the National Scorecard on US Health System Performance, 2008, The Commonwealth Fund, July 2008.

Davis, K and J Ballreich, 2014, Equitable Access to Care – How the United States Ranks Internationally. NEJM, 371(17): 1567-70.

Donaldson, MS, and JJ Mohr, Exploring Innovation and Quality Improvement in Healthcare Micro-Systems: A Cross-Case Analysis, A Technical Report for the Institute of Medicine Committee on the Quality of Healthcare in America, Institute of Medicine, The National Academies, November 3, 2000.

Gabow, PA Commentary: The Promise of Lean Processes, Institute of Medicine, July 2012.

Gabow, PA and PS Mehler, 2011, A Broad and Structured Approach to Improving Patient Safety and Quality: Lessons from Denver Health, Health Affairs, 30, 4: 612-618.

Grossmann, C, Goolsby, WA, Olsen, LA, and JM McGinnis, Engineering a Learning Healthcare System: A Look at the Future, Institute of Medicine and National Academy of Engineering, National Academy Press: Washington, DC, 2011.

Holdren, JP and ES Lander, et al., Report to the President Better Healthcare and Lower Costs: Accelerating Improvement through Systems Engineering, President's Council of Advisors on Science and Technology, May 2014.

Hummelstein, DU, Jun, M, Busse, JR, et al., 2014, A Comparison of Hospital Administrative Costs in Eight Nations: US Costs Exceed all others by Far, Health Affairs, 33(9):1586-94.

James, B and B Bayley, Cost of Poor Quality or Waste in Integrated Delivery System Settings, Agency for Healthcare Research and Quality, September 2006.

Kaplan, G, Mason, V, et al., Bring a Systems Approach to Health, National Academy of Engineering/ Institute of Medicine, July 10, 2013.

Kelley, B and R Farbius, White Paper: A Path to Eliminating $3.6 Trillion in Wasteful Healthcare Spending, Truven Health Analytics, January 2012.

Kohn, LT, Corrigan, JM, and Donaldson, MS, Eds. To err is human: building a safer health system. Committee on Quality Healthcare in America, Institute of Medicine, National Academy Press: Washington, DC, 2000.

Luycx, R, Loxton, M, & K Coniglio. PE LL Utilization Management Report, Product Effectiveness, 2014.

National Health Expenditures Projections, 2010-2020. CMS, https://www.cms.gov/Research-Statistics-Data-and-Systems/Statistics-Trends-and-Reports/NationalHealthExpendData/Downloads/proj2010.pdf, 2010.

Reid, P, Compton, W, Grossman, J and G Fanjiang, Eds., Building a Better Delivery System: A New Engineering/Healthcare Partnership, Committee on Engineering and the Healthcare System, Institute of Medicine and National Academy of Engineering: Washington, DC, 2005.

Richardson, WC, Berwick, DM, et al., Crossing the Quality Chasm: A New Health System for the 21st Century, Committee on Quality of Healthcare in America, Institute of Medicine, The National Academies, 2001.

Schoen, C, Guterman, S, Zezza, M and M Abrams, Confronting Costs: Stabilizing U.S. Health Spending While Moving toward a High Performance Healthcare System, January 10, 2013, http://www.commonwealthfund.org/publications/fund-reports/2013/jan/confronting-costs.

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WBB is a leading government and public sector solutions provider, dedicated to the enduring success of our clients. We focus on value creation through customer collaboration, domain expertise, tailored methodologies, and innovative solutions. Our goal is simple: establish clients for life through passion, integrity, innovation and quality. We are honored to serve Defense, Intelligence, Homeland Security, Health, Commercial, and Civilian agencies.