

A Systems Approach to Implementing Systems Engineering within the UT Health Institutions

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Abstract

The University of Texas has six health institutions and Industrial and Systems Engineering faculty throughout university locations across the state. These academic medical centers and schools of Engineering, Business, Nursing, and Medicine are partnering to implement Systems Engineering in healthcare throughout the UT System. The "systems approach to implementing Systems Engineering" is an opportunity to serve as a world-class model for collaboration across academic institutions for Engineering, Business, Medicine, Nursing, and healthcare organizations to implement Systems Engineering and systems thinking in healthcare. The UT initiative includes the application of front-line tools such as Lean, Six Sigma, PDSA as well as more traditional Industrial Engineering disciplines such as Operations Research including scheduling, simulation, and heuristics; Human Factors; Applied Statistics; Supply Chain; and Facility Design Layout. The objective of the collaboration is not just to produce successful projects, but to achieve transformational change. This presentation will explain what has been done so far in terms of funding, leadership, training, and communication; describe the grant application process for transformational efforts; and review specific efforts already underway to use Systems Engineering to deliver healthcare that is safe timely, effective, efficient, equitable, and patient-centered.

Keywords

Systems Engineering, Healthcare, Industrial Engineering

1. Introduction

Why does anyone receive suboptimal care? After all, society could not have given us people with more talent, more dedication, and more training than the people in medical science have—than you have. I think the answer is that we have not grappled with the fact that the complexity of science has changed medicine fundamentally. This can no longer be a profession of craftsmen individually brewing plans for whatever patient comes through the door. We have to be more like engineers building a mechanism whose parts actually fit together, whose workings are ever more finely tuned and tweaked for ever better performance in providing aid and comfort to human being (Gawande 2010)

Dr. Gawande's often-quoted comments highlight the central premise that the US healthcare system has failed in its central goal of promoting and restoring a state of good health for the country's citizens. Numerous studies have confirmed glaring inconsistencies in the delivery of health services; patients routinely receive too much care (over-utilization) and others receive too little care (the under- and un-insured populations)—and unfortunately, too many times, patients receive poor quality care that provides no benefit or that is even harmful. Furthermore, healthcare is consuming ever greater amounts of the nation's resources in trends that are simply unsustainable.

The mission of an academic medical center (AMC) includes patient care, education and research/innovation. As a result, the nation's AMCs are in a unique position to provide creative solutions for the healthcare crisis. AMCs maintain large clinical enterprises, and an inability to adapt those enterprises to an environment focused on providing more services of higher quality to more patients at lower costs will compromise the AMCs capacity for education and research. In short, a failure to act will inevitably lead to a degradation of AMCs to fulfill the tripartite mission of patient care, education, and research/innovation at huge cost for all stakeholders, including the AMCs and the society that supports them.

Like other academic medical centers, the University of Texas (UT) health institutions are driven today by the need for greater effectiveness and efficiency in all mission areas - patient care, education, and research. Affordable, high-quality health professionals, clinical care, and research are critical to success. UT has responded to this challenge with a number of system-wide innovative efforts to improve quality outcomes (effectiveness) and streamline processes (efficiency):

- Transformation in Medical Education (TIME);
- Clinical Safety & Effectiveness (CS&E) program;
- System-wide Revenue Cycle Committee;
- Clinical Quality Reporting Initiative through Meaningful Use of EHR (CQRI);
- Medical billing compliance programs;
- Clinical research billing system improvements;
- HIT/clinical care research grants;
- Effort Certification software (ECRT);
- Supply Chain Alliance; and
- Cyber-research Infrastructure.

To ensure that these projects (and subsequent projects that are derived from these efforts) become more than the sum of their parts, UT is implementing a systems approach, including the use of Systems Engineering tools and methodology to sustain a system-wide transformation effort with a culture of continuous improvement embedded at all units. Sponsored by the Vice Chancellor for Health Affairs, the initiative is led by a Chancellor's Health Fellow for Systems Engineering in Healthcare, with the involvement of a system-wide governance committee and the associated steering committee, comprised of representatives from the six health institutions as well as UT Austin's McCombs School of Business and the Engineering schools at UT Arlington, UT Austin, and UT San Antonio. A significant part of this systems approach is the use of Systems Engineering tools and methods.

1.1 Literature Review and Examples of Success at Other Institutions

Litvak (2011) made the point that, as more people are insured, demand for healthcare services will increase. However, the payment for each individual unit of care is likely to decrease. In order to meet the new demands for service and remain solvent, providers must become more efficient. The alternative, adding additional capacity, is a recipe for bankruptcy. Litvak's work with the operating rooms at Cincinnati Children's Hospital has decreased emergency department waiting time and increased the efficiency of the operating rooms and of the inpatient units allowing the hospital to accommodate more patients without adding additional capacity.

Virginia Mason in Seattle has implemented the "Toyota Production System" since 2001. The management system includes Lean methodology, policy management, daily management, an employee idea system, and a focus on patients reducing waste in the systems. Some of the benefits realized at Virginia Mason from this effort are documented in the book, *Transforming Healthcare* (Kenney 2010):

- Reduced time for med administration of chemotherapy by 88%
- Reduced trips by patients to locations across the hospital by 3 hours, 40 minutes (about a 30% reduction) and 564 feet.
- Patient satisfaction in the cancer center went from 70% to 90%
- Increased efficiency in the cancer center to increase visits by 1,100 (to 14,927) with no increase in number of employees and an increase in staff satisfaction to 95th percentile.
- Liability insurance expenses declined 26% from 2007 to 2008 and another 12% the next year.
- Increased patient satisfaction re answering the phone from 40% to 85% resulting in 50,000 fewer calls each year (since calls are addressed the first time.)

- Increased contribution margin for Primary Care in Kirkland Clinic from negative \$4.6 million in 2003 to \$4.3 million in 2009
- Setup reductions in the OR resulted in a 40% increase in the number of cases per room, 40% increase in the number of cases for four rooms, 50% reduction in case turnaround time, and 20% reduction in surgery prep time, 82% reduction in patient travel distance, and 40% reduction in patient time in process (check-in to discharge on DOS)
- Reduced in-patient LOS from 4.5 days to 4 days

There have recently been reports and recommendations encouraging the use of systems engineering in healthcare (Valdez et al., 2010). However, much of the documentation regarding systems engineering in health care is focused on specific examples of applying a tool such as lean (Joseph 2006; Womack et al 2005; Jimmerson et al 2004; Weber 2006), six sigma (Feng 2007), or simulation (Sanchez et al 2000; Benneyan 1997) to single projects in healthcare. Many focus solely on operations research (Flagle 2002; Cayirli 2003). Other publications (Kopach-Konrad et al.2007) list a variety of systems engineering methods but also include information systems.

In this paper, an overview of many areas of systems engineering will be presented along with examples of application in healthcare. In addition to specific project examples, an overall strategy for implementing “systems thinking” and a system-wide approach to integrating systems engineering will be presented.

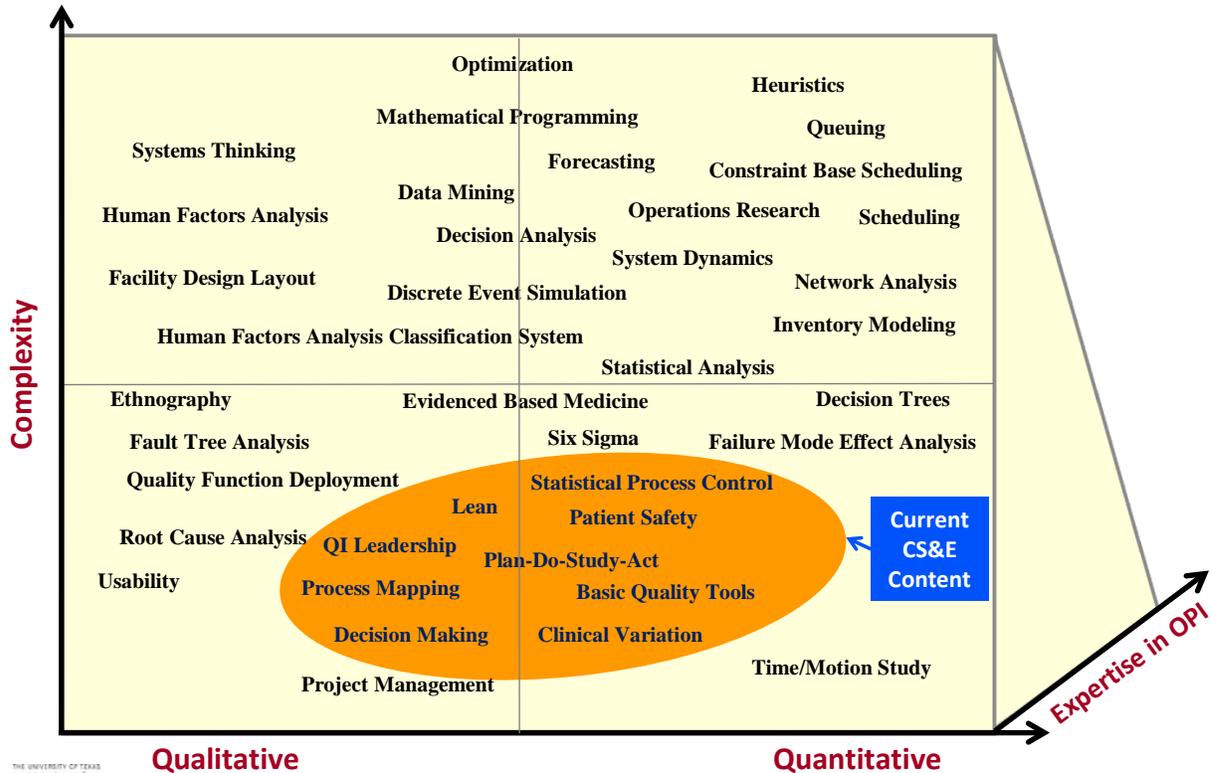
1.2 Success within the UT System

Recent “Lean” efforts at UT MD Anderson Cancer Center have resulted in the following improvements:

- Diagnostic Center – pull process reduced wait times from over an hour to 10 minutes
- Internal Medicine Center – reduced wait time by 50% and increased the percent of follow up appointments scheduled before patient left by 47%
- New triage process in Emergency Center reduced time from arrival to medication for fever by 33%
- Reduced time to deliver care package to patients in Thoracic Center by 64%
- New process, layout, and hours in Leukemia Center reduced patient walking distance by 89%, reduced walking distance in “fast track” by 50%, and reduced patient wait time by 36%

The Clinical Safety and Effectiveness (CS&E) program which introduces the Plan-Do-Study-Act (PDSA) improvement process has now spread throughout UT System. Hundreds of projects have been completed; many resulting in permanent process change and significant positive patient care outcomes (including decreases in Ventilator-Associated-Pneumonia.) The CS&E program teaches and deploys several tools in the realm of Systems Engineering, including PDSA, an introduction to statistical process control, and process mapping. While the CS&E Program introduces some Systems Engineering tools, a robust Industrial and Systems Engineering program across the UT System would expand the scope of issues that could be addressed in clinical quality improvement efforts and operational improvement as illustrated in Figure 1. (Examples include optimizing scheduling for patient appointments, surgeries, treatment plans; facility design layout; reducing patient and material flow; “error-proofing” to reduce the likelihood of mistakes; standardization; optimization.)

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Figure 1: Systems Engineering tools available compared with those taught in current CS&E course

To establish a UT Systems Engineering Initiative, the following actions are being implemented:

- Industrial and Systems Engineering tools added to the quality improvement toolboxes of the UT system and each component institution
- An over-arching management system developed that will support an organizational culture that seeks to continuously improve value.
- An organizational structure established across the UT System to support these efforts
- Operational support implemented for implementing the Systems Engineering efforts

These initiatives are outlined in greater detail in the following sections.

2. Systems Engineering Initiative

2.1. Systems Engineering Tools and Methods

A part of the systems-thinking culture is a focus on wide-spread deployment of existing Lean course materials. “Lean” is based on concepts of the Toyota Production System (TPS) that focus on improving quality and reducing cost by eliminating waste; TPS has been successfully adapted for healthcare by Virginia Mason Medical Center and ThedaCare, among others. “Six Sigma” is based on the Motorola and GE methodology for reducing process variability. These “front-line” tools are used by a wide audience, thus giving front-line staff a working knowledge of how to look at processes and increase their efficiencies. Courses are standardized and offered via a Quality College throughout the UT System as outlined in the next section.

Additional, more complex Industrial and Systems Engineering tools such as those used by the Mayo Clinic and Geisinger will require more specialized expertise than can be taught on the job. So, in addition to the “front-line recommendations”, a core group of Systems Engineering professionals facilitates the use of tools such as operations research, human factors and facility design layout. These individuals partner with experts in the UT Schools of Engineering and Business for research opportunities in developing and applying Systems Engineering methods in healthcare and work to share improvements across the six health institutions.

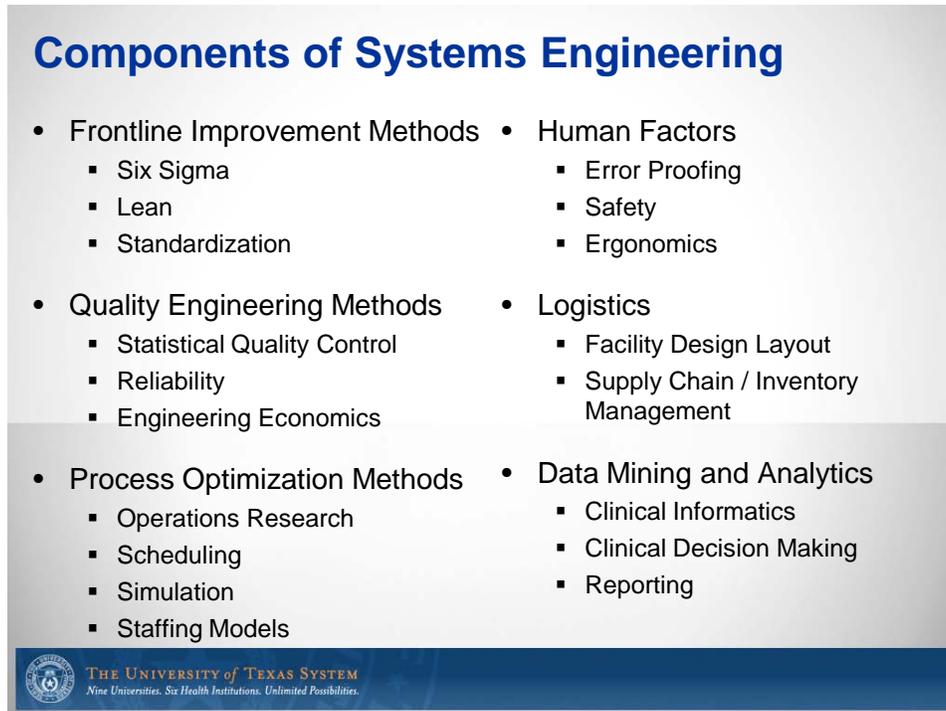


Figure 2: Components of Systems Engineering

2.2. Training, Education, and Facilitation

Training courses are available to assist in the transformation effort. A Quality College includes all quality-related training material (internally developed and externally available) made available to employees. This includes web-based, taped, and in-person courses as well as facilitation support. Executive level courses are available to introduce Systems Engineering and build an understanding and enthusiasm for what these tools provide in terms of improvements in patient safety, patient satisfaction, patient flow, employee involvement and satisfaction. Some of the training options are summarized in Figure 3, including courses for Lean tools and concepts and courses for achieving Six Sigma Green Belt and Black Belt certification. Additional programs are available to provide sponsor/champion education in Lean and Six Sigma. The capability to train the staff to be trainers of some of the courses is also available. Specific to the Systems Engineering effort, courses include an overview of Systems Engineering tools and concepts to provide to the leadership (and Board members) at each organization, an introduction to Lean to be added to the current CS&E curriculum, and courses in lean and Six Sigma.

Systems Engineering Training Opportunities		
Subject	Course	Length of Course
Systems Engineering in Health Care	Overview (Executive Presentation)	30 minutes
	Systems Engineering Module (may be added to the CS&E Course) - Introduction to Systems Engineering Tools / Methodology	½ day
Lean	Managers interested in Lean & Team Sponsors	2 hours
	Using Lean Tools to Increase Efficiency and Reduce Waste	2 days
	Train the Trainer	5 days
Six Sigma	Management Overview (Yellow Belt)	4 hours
	Six Sigma for Reducing Variability (Green Belt)	10 days over several weeks including a project
	Train the Trainer (Black Belt)	10 days

Figure 3: Initial offering of systems engineering related courses

Successful projects are shared via an annual conference, so that the knowledge gained can be used to add value in other areas. Those projects that are less successful are also shared, as those lessons learned may help future teams avoid similar problems.

All Lean and Six Sigma projects include a calculation for a return on investment (ROI) where possible or identify impact of improvement (on safety, patient satisfaction, etc.) The calculation methodology developed in collaboration with the University of Texas, McCombs School of Business is the preferred methodology to allow for consistency across institutions.

2.3 Research

The UT System seeks to learn from other industries and within healthcare to identify specific activities that could benefit one or all of the organizations. For example,

- From Human Factors: identify opportunities to error-proof care; adopt HFACS classification system of errors; develop system for identifying and investigating and preventing mistakes; implement use of “the matrix” for M&Ms
- From Operations Research, identify methods for scheduling using simulation and heuristics to replace manual methods (including “overbooking” to address no-shows); use optimization models for staffing and resource planning; use optimization models for medical decision making (e.g. location of radiation beams); use optimization models for inventory management and material handling
- From Facility Layout Design and Logistics, use tools for designing patient flow and staff work patterns when designing new buildings, additions, or changing existing layouts to increase efficiency and optimize space utilization

Collaboration with other academic institutions within the UT System is critical. To increase collaborative research efforts, UT has identified opportunities for student projects (e.g. capstone projects for Undergraduate and Master’s Students; more substantive technical projects for Ph.D. students), identified target journals for papers on Systems Engineering in Healthcare, and implemented a grant application process with funds available for efforts that seek transformational improvement using systems Engineering tools.

The Systems Engineering Grant Program funds clinical transformation projects in which systems approaches play a significant role. Projects may target individual institution issues or issues that affect multiple health institutions. Partnership with UT System general academic institutions is encouraged, but the primary focus of the project must be a clinical quality or outcome challenge at a UT Health Institution. An external panel of experts serves as grant evaluators in the award process. Members of the evaluation team will represent experience in quality practice, education, administration, and systems engineering.

The grading criteria includes:

- Transformative Impact
- Scope of the Problem Addressed - Two possibilities will be considered: wide applicability – problems affecting large populations: severity – problems with serious consequences.
- Creativity of Approach - Higher scores will be given to original approaches or new applications of systems engineering tools.
- Productive Use of Systems Engineering - The application of systems engineering in the broad sense must be a major component of every submittal.
- Academic Value - Application should contribute significantly to expanding knowledge.
- Practical Value and Applicability of Results
- Adaptability by Other UT Health Institutions
- Collaboration across departments and across disciplines
- Accountability: proposal must include timeline, milestones, and meaningful metrics

Although organized by the UT System Chancellor’s Health Fellow for Systems Engineering, the grant program does not seek to promote systems engineering for its own sake. We seek to fund those projects in which systems engineering in the broad sense significantly contributes to transformative improvements in clinical outcomes and quality.

2.4 Internships and Sabbaticals

In an effort to promote healthcare applications in education for Industrial and Systems Engineering and to promote an understanding of Systems Engineering in Medical School, internships and sabbaticals are being established with preference to applicants from within the UT System.

Internships include having Industrial Engineering students work part-time on projects, summer internships for upper-class Engineering and Business students, an potentially longer “fellowships” for Industrial Engineering graduates. They also include internships for medical and nursing students to work in quality improvement and systems engineering areas. The first sabbatical for an Industrial Engineering professor at a health institution within UT will be offered in the Fall 2012 at MD Anderson Cancer Center.

3. Ensuring Transformational Change

3.1 Overarching Management System to Support an Organizational Culture of Systems-Thinking and Continuous Improvement

Bringing state-of-the-art care to all Americans in every community will require a fundamental, sweeping redesign of the entire health system, according to a report by the Institute of Medicine (IOM), an arm of the National Academy of Sciences. *Crossing the Quality Chasm: A New Health System for the 21st Century*, prepared by the IOM’s Committee on the Quality of Healthcare in America (2001) concludes that merely making incremental improvements in current systems of care will not suffice. In order to truly cross the quality chasm and build a new health system, we must evolve an organizational culture with a singleness of vision focused on continuously improving the value produced by the processes that permeate our complex systems. This culture must guide everyone from top leadership to front-line staff.

Achieving high value for patients must become the overarching goal of health care delivery, with value defined as the health outcomes achieved per dollar spent. This goal is what matters for patients and unites the interests of all actors in the system. If value improves, patients, payers, providers, and suppliers can all benefit while the economic sustainability of the health care system increases.

Value — neither an abstract ideal nor a code word for cost reduction — should define the framework for performance improvement in health care. Rigorous, disciplined measurement and improvement of value is the best way to drive system progress (Porter 2010).

Experience at Mayo Clinic and Virginia Mason Medical Center has shown that a singleness of purpose can create an integrated, collaborative system. Leadership is a key ingredient in accomplishing this. Leadership cannot be imposed from the outside. However, it may be fostered. To that end, we propose that the UT System sponsor a symposium that will feature leaders of successful complex organizations within and external to healthcare – Mayo,

Virginia Mason, Southwest Airlines, and Disney – which have effectively deployed systems engineering tools to create a systems-thinking culture. UT participants will include health institution presidents, Chief Business Officers, Chief Quality Officers, Deans, Chairs, and Medical Directors – the leaders in education, clinical practice and research.

One method for implementing systems-thinking is outlined in the “Framework for Improving Value in the Enterprise” or “FIVE” developed at UT MD Anderson Cancer Center, outlined in Figure 4. The framework is based on five essential strategies: (1) enhance patient involvement; (2) reduce clinical variation and overuse; (3) reduce preventable complications, mistakes, and errors; (4) reduce in-process waste; and (5) establish metrics and supporting IT structures (Swenson, et al., 2011). The information-based decision making component includes many tools and strategies from Systems Engineering.

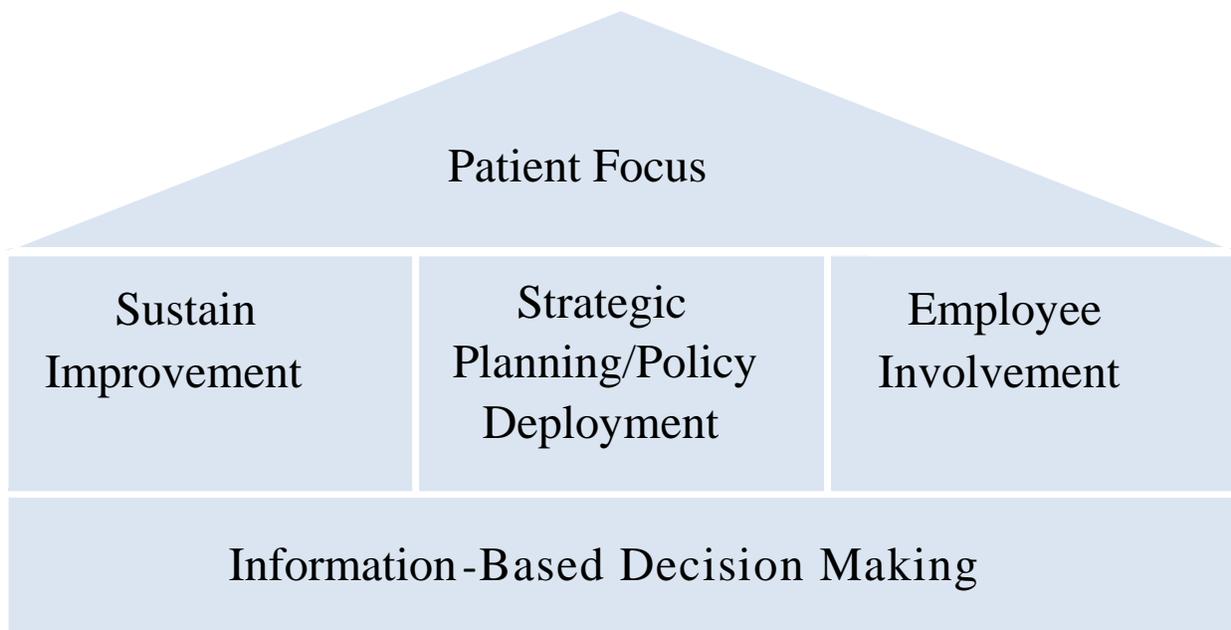


Figure 4: Framework for Improving Value in the Enterprise from the Office of Performance Improvement, UT MD Anderson Cancer Center

Strategic Planning/Policy Deployment includes developing an institutional / departmental vision, obtaining goal alignment & agreement from leadership, developing short and long term goals with AIM statements and measures of success, defining scope and boundaries, using a deployment process to align goals throughout the organization, aligning team goals with incentives, assessing the current state and gaps for information and technology, instituting accountability reviews and quarterly reviews with responsibility and accountability assigned; identifying lessons learned and how to spread to other areas as appropriate, and linking improvement efforts to value.

Sustain Improvement is based on standardizing processes, implementing systems for kaizen (incremental continuous improvement), and monitoring and maintaining improvement efforts.

Employee Involvement (Faculty & Staff) includes establishing a “Culture of Safety” and/or “Just Culture” to encourage employee involvement via suggestions, team participation, and continuous improvement efforts.

Patient Focus means that processes are viewed from the patients’ perspective, decisions are made with the patient as the priority, and patients are included in care decisions, in committees, reviews, etc., and as part of improvement teams. It includes a priority focus on Patient Safety and the Patient Experience.

Information-Based Decision Making means establishing a practice of making decisions based on facts and data; establishing a reporting / feedback system to measure and track improvement (for example, with dashboards tracking patient satisfaction results, OPPE (On-going Provider Practice Evaluation), benchmarking data, and process and outcomes metrics.) Information-based improvement strategies are used for improvement efforts, such as PDSA, Six Sigma, Lean, or Systems Engineering methods. Evidence-Based Practice is used for standardizing processes where possible.

3.2. Establish an Organizational Structure Across the UT System to Support these Efforts.

To operationalize these objectives, an infrastructure has been established to provide administrative support and grant funding for research initiatives. Systems Engineering support is made available to health institutions from current staff (share across the system), through “train the trainer” sessions, and from professors through grants and research opportunities. An annual conference allows results of projects and grants to be shared across the UT System, to show leadership how Systems Engineering can help solve clinical problems, and to invite external experts to share ideas.

3.2.1. Systems Engineering Support

Systems Engineering support for this effort comes from Industrial and Quality Engineers at some of the health institutions, Business and Industrial engineering faculty, and front-line expertise is being generated via a “train the trainer” approach.

3.2.2. Administrative Support

In order to support these efforts from an administrative standpoint, a program coordinator position was created to support the Chancellor’s Health Fellow for Systems Engineering (and the Steering Committee) to set up a website, organize meetings, coordinate the grant application process and internship process, etc.

3.2.3. Operational Support for Implementing the Systems Efforts

One challenge to successful implementation of these efforts is that information systems in healthcare have generally been less advanced than in other industries. All of the organizations identified as being leaders in applying systems engineering approaches to improve their businesses have relied heavily on state-of-the-art information technologies, whether they be enterprise resource management systems, interactive websites to promote customer self-service, or highly integrated workflow management systems that help the organizations control their inventories, billing, and human resource management issues, for example. Designing, developing, implementing, and evaluating the myriad improvements required to improve the quality and safety of the healthcare we deliver, while simultaneously reducing its cost requires close collaboration with all the groups responsible for the implementation and operation of the clinical and administrative systems that are currently being rolled out at each of the UT campuses. These system engineering efforts need access to clinical (e.g., percentage of patients with condition X who were treated with medication Y), administrative (e.g., mean time to complete specific types of operations, along with room occupancy data for the OR suite), and usage data (e.g., percentage of medication orders entered by physicians that were subsequently modified by pharmacists before dispensing) from the existing clinical information systems to help develop and evaluate their models and interventions.

Likewise, clinical information systems professionals need to work with the systems engineering experts to help them optimize and leverage the existing clinical, administrative, and financial systems, as well as develop new system features and functions, required to implement the systems engineering improvements. While many see the implementation of health information technology as a single, albeit large, project, in truth, these technologies represent a new way of doing business and therefore require on-going design, development, and implementation. All of which provide excellent opportunities for systems engineering to make a significant and lasting positive impact on both these systems as well as the healthcare delivery system that they interact with.

4. Conclusion / Next Steps

While this is a long-term effort that is in its initial phases, this is an exciting opportunity for the UT System to serve as a world-class model for collaboration across academic and healthcare institutions to implement Systems Engineering in healthcare. By synthesizing the efforts of the UT components, UT can ensure reduced costs, reduced wait times, safer processes, and more efficient and effective care.

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