122nd ASEE Annual Conference & Exposition
June 14 - 17, 2015
Seattle, WA
Making Value for Society
Paper ID #13627

Improving Healthcare by Teaming Industrial Engineers with Clinicians

Dr. James Benneyan, Northeastern University

Dr. James Benneyan is former senior systems engineer at Harvard Community Health Plan and founding director of the Healthcare Systems Engineering Institute at Northeastern University, including three NSF and CMS funded centers and five undergraduate through post-doctoral degree, internship, and fellowship programs. Jim is faculty and senior fellow at the Institute for Healthcare Improvement, holds joint appointments in Northeastern's engineering and health sciences colleges, and past is President of the Society for Health Systems. He serves on numerous editorial and advisory boards, has received 12 research, teaching, and service awards, and has been principal investigator or co-director in seven research centers totaling over $32 million in funding.

Mr. Corey Balint, Healthcare Systems Engineering Institute at Northeastern University

Corey Balint, holds both a BS and MS in Industrial Engineering from Northeastern University and currently is a staff healthcare system engineer in the HSyE institute. Current responsibilities include: serving as day-to-day project manager of our AHRQ patient safety center, leading a portfolio of roughly 10 projects at any time, and assisting with senior team projects. Balint has expertise in quality, medical staff services, change management, Lean, Six Sigma, and other performance improvement methodologies and has extensive experience working with numerous healthcare organizations and culture.

Improving Healthcare by Teaming Industrial Engineers with Clinicians

Introduction

The Center for Medicare and Medicaid Innovation funded an academic institution to conduct a national demonstration project that illustrates the value of creating an industrial and healthcare systems engineering (ISyE) regional extension center that is scalable and spreadable[1]. The extension center model was first heavily used in agriculture to spread improvement methods and ideas between different regions and systems[2]. Our regional extension center incorporates the same functions and structure, but it involves a collaboration with local hospitals. . Similar to the agricultural model, engineers apply systems engineering improvement methods, such as quality improvement, human factors, optimization, and statistical data analysis towards significant systematic problems in healthcare. The projects under the grant are guided by the "Triple Aim" and strive for improvements that help sustain better care and better health at a lower cost. The CMMI grant allows for the institution to fund students who support healthcare improvement projects with health systems. The intention is to apply methods and tools from successful projects to similar problems in healthcare systems across the country. This paper provides an overview of progress to-date and the approach towards replicating ISyE-Triple Aim projects in other health systems. Several examples highlight our success and the typical methods that are prevalent in most projects (in which there are over 60 in the past 2 years).

As espoused in the President's Council of Advisors on Science and Technology (PCAST) report sent to the President last year, the healthcare system in its present form is in need of systems engineering improvements in order to meet the demands of the future[3]. Recommendation #4 in this report states that we should "increase technical assistance (for a defined period—3-5 years) to health-care professionals and communities in applying systems approaches,"—with the foundation of the CMMI grant, our institute has answered this call for action with multiple projects that save money, provide better care, and better health.

Background

The 'Triple Aim'

The Triple Aim is a three pronged approach created by the Institute for Healthcare Improvement that focuses on improving the patient experience of care, the health of the population, and the per capita cost of care[4]. An often-cited example of the classic three-legged stool analogy, Berwick et al. (2008) explains how the different dimensions of the Triple Aim are interrelated and why all three must be coordinated into an improvement project's approach:

> *"Changes pursuing any one goal can affect the other two, sometimes negatively and sometimes positively. For example, improving care for individuals can raise costs if the improvements are associated with new, effective, but costly technologies or drugs. Conversely, eliminating overuse or misuse of therapies or diagnostic tests can lead to both reduced costs and improved outcomes. The situation is made more complex by*

time delays among the effects of changes. Good preventive care may take years to yield returns in cost or population health."

In summary, our project teams consider the experience of the individual patient while also improving the health of specific populations, and managing system costs. If you are to focus on only one of the two, positive short term effects are likely, but not sustainable. Each provide a balance that can be replicated. All three of these aims are interchangeable as each one effects the outcome of the others and ensures long term stability in healthcare. This idea is one of the main focal points of the regional extension center model.

Structure – Internal and External

Since the center is affiliated with an academic institution, most of the workforce is rooted in educational development. The majority of the staff is comprised of students at various levels of their industrial education, including postdoctoral scholars, graduate students in both Master's and PhD programs, and undergraduate students. Students are involved in our center either full time in the form of internships and co-ops, or part time as a work study, research assistant, project support, or capstone team. In the past two years, interning students have been applying from various disciplines beyond industrial and systems engineering, including bio-medical engineering, economics, statistics, human factors, electrical and computer engineering, medical, and nursing. These students are the main driving force behind projects. Students work together with mentors to learn and apply engineering tools and methods that are applicable to the project. The rest of the staff is comprised of the following support: engineering, reporting and writing, communication and events, and a clinician.

The 'clinician-in- residence' position was developed as a resource for students and staff working on projects requiring advanced clinical knowledge. The clinician also brings knowledge of culture, operations, and finance to project development and implementation, in addition to teaching the engineers the basics of disease, diagnosis, and treatment relevant to each project. For example, in certain scenarios, it may be important to understand hospital culture when proposing or implementing a change, or when dealing with a complicated medical condition, such as sepsis, the clinician can help guide and inform the engineering team's approach. The clinician, in-turn, also learns how systems engineers approach problems and develop solutions. Clinicians embedded on the engineering team can interact with the clinicians at the healthcare site to more fully understand the specific clinical implications of engineering decisions so we make most effective solutions early on in the iterative process

Figure 1 provides an overview of the center and a visual representation of its relationship with the healthcare industry. The center takes what is learned in the academic setting and sets out to apply it in healthcare systems. While great focus is put on the hospital setting, a large amount of care takes place elsewhere. During the grant period, the center has worked with large scale multi- hospital systems, as well as with small regional hospitals and clinics.

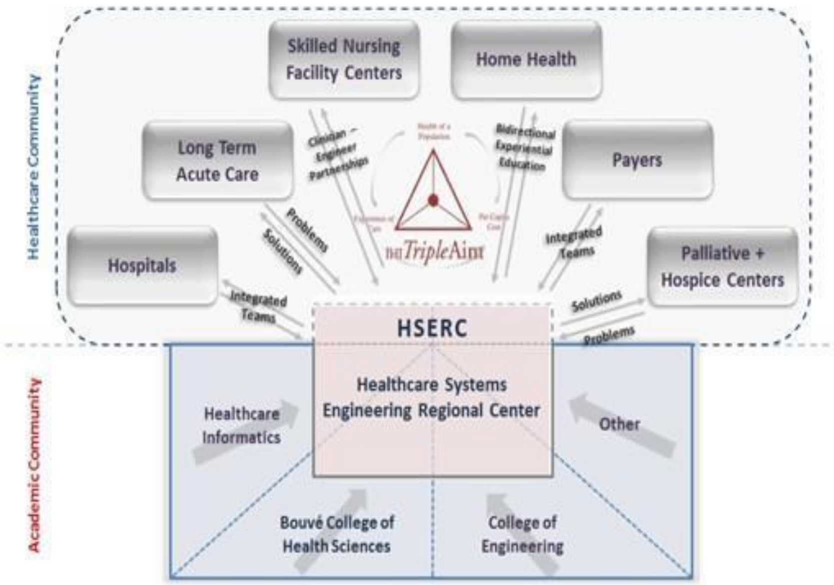


Figure 1: Structure of relationship between institute and industry partners

The center works with any level of employee in a healthcare system. Projects have been brought to our attention from CEOs, physicians, and an orderly for one unit in the hospital. We work with these employees and their teams on a day to day basis to have solutions implemented.

Project Processes

Upon receiving the grant, the institute began setting up structure and processes for project lifecycles. Project management, a core ISyE methodology, was necessary to have projects succeed and ultimately be disseminated. The tools developed are very important to future work as each solution is meant to be used in multiple systems with minimal revision. This meant developing project timelines, charters and measurement for each project, as well as a strategy for working with health systems.

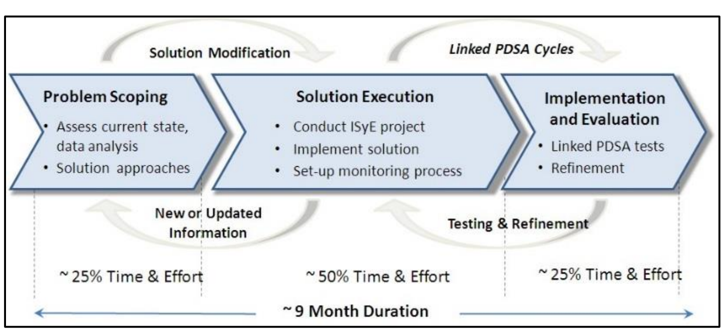
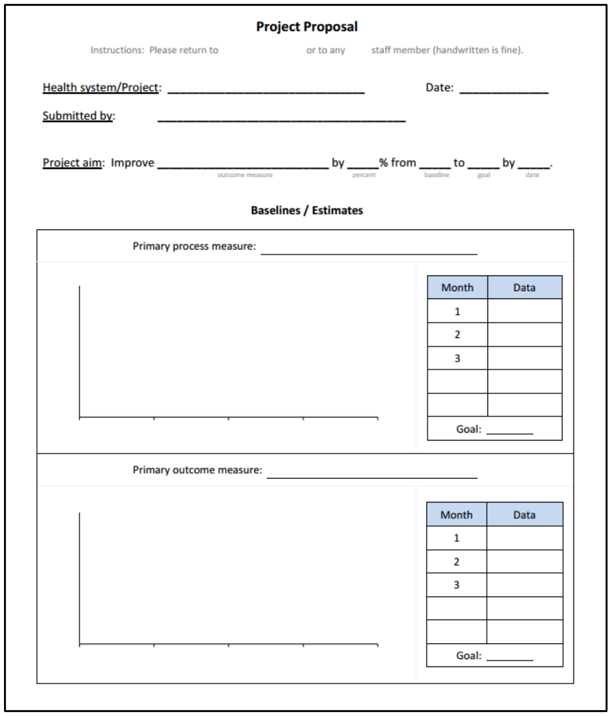


Figure 2: Standard project lifecycle

This standard project lifecycle was established as an ISyE project management tool to keep projects on similar timelines and paths. The unified approach on projects enabled clinicians and engineers to work on a common timeline.



Project Proposal

Instructions: Please return to or to any staff member (handwritten is fine).

Health system/Project: ____________ Date: ________

Submitted by: ____________

Project aim: Improve ____________ by ____% from ____ to ____ by ____.
outcome measure percent baseline goal date

Baselines / Estimates

Primary process measure: ____________

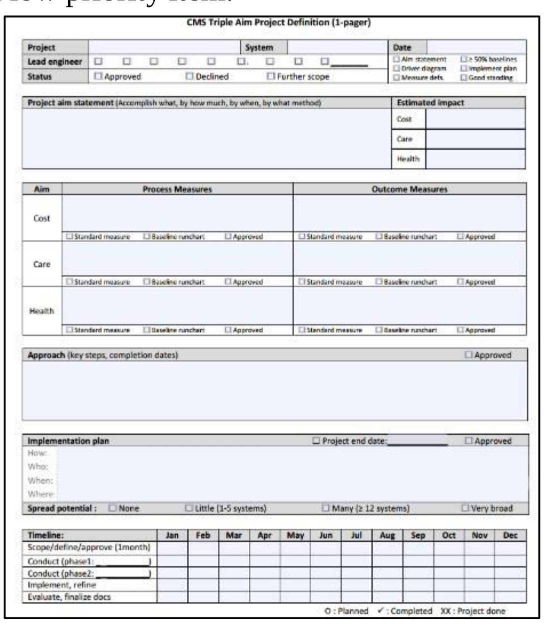
Month	Data
1	
2	
3	
Goal: ______	

Primary outcome measure: ____________

Month	Data
1	
2	
3	
Goal: ______	

Figure 3: Project proposal form

The project proposal form was developed for rapid development of a project idea and to quickly assess the potential for measurable impact to the "Triple Aim." This became a cost-benefit-analysis tool. If the project did not have any significant measureable impact, it became a low priority item.



CMS Triple Aim Project Definition (1-pager)

Project | System | Date
Lead engineer ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ______
Status ☐ Approved ☐ Declined ☐ Further scope
☐ Aim statement ☐ ≥ 50% baselines ☐ Driver diagram ☐ Implement plan ☐ Measure defs ☐ Good standing

Project aim statement (Accomplish what, by how much, by when, by what method)

Estimated impact	
Cost	
Care	
Health	

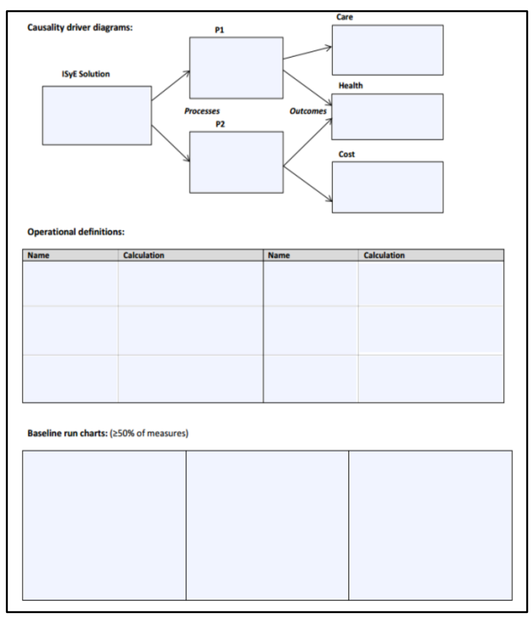
Aim	Process Measures	Outcome Measures
Cost	☐ Standard measure ☐ Baseline runchart ☐ Approved	☐ Standard measure ☐ Baseline runchart ☐ Approved
Care	☐ Standard measure ☐ Baseline runchart ☐ Approved	☐ Standard measure ☐ Baseline runchart ☐ Approved
Health	☐ Standard measure ☐ Baseline runchart ☐ Approved	☐ Standard measure ☐ Baseline runchart ☐ Approved

Approach (key steps, completion dates) ☐ Approved

Implementation plan ☐ Project end date: ________ ☐ Approved
How:
Who:
When:
Where:
Spread potential: ☐ None ☐ Little (1-5 systems) ☐ Many (≥ 12 systems) ☐ Very broad

Timeline:	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Scope/define/approve (1month)												
Conduct (phase1: ________)												
Conduct (phase2: ________)												
Implement, refine												
Evaluate, finalize docs												

O : Planned ✓ : Completed XX : Project done



Causality driver diagrams:

Operational definitions:

Name	Calculation	Name	Calculation

Baseline run charts: (≥50% of measures)

Figure 4. Project charter form.

After the initial meeting has occurred and the project proposal form is agreed to, the team develops the more advanced charter. This details specific aims and goals for the project. It also outlines the approach and a rough timeline for when major milestones should be occurring

Industry Partners

While the standardized work was being developed, staff and students started to meet with healthcare systems, both physically and virtually, to explore what major problems they seemed to be encountering. This set-up time also allowed for data sharing agreements and any other nondisclosure and HIPAA paperwork to be drafted and signed with partnering systems. Typically, systems only require a data use agreement and a business associates agreement for HIPAA compliance[5] and volunteer paperwork. Once this work was launched, it gave the center an initial group of projects to focus on and test its vision and processes. Without partnership from these initial systems, it would have been impossible to test ISyE methods for healthcare improvement.

Industry partnerships were developed primarily by networking. Most connections in this case are established by the institute's Primary Investigator. The work described above was able to launch quickly for a few reasons:

- The primary extension center is located in Boston, which is world renowned for its number of highly respected healthcare systems.
- These systems are all highly engaged with local universities on their own research projects, so a collaborative culture has already been established to a high degree.
- The work is very timely, as government funding and penalties are at a high point.

Partnering Results

As illustrated in Figure 5, the institute has far surpassed its initial goal of working with four healthcare systems. This fulfilled our initial proposal to the grant agency of working with four systems in the local area.

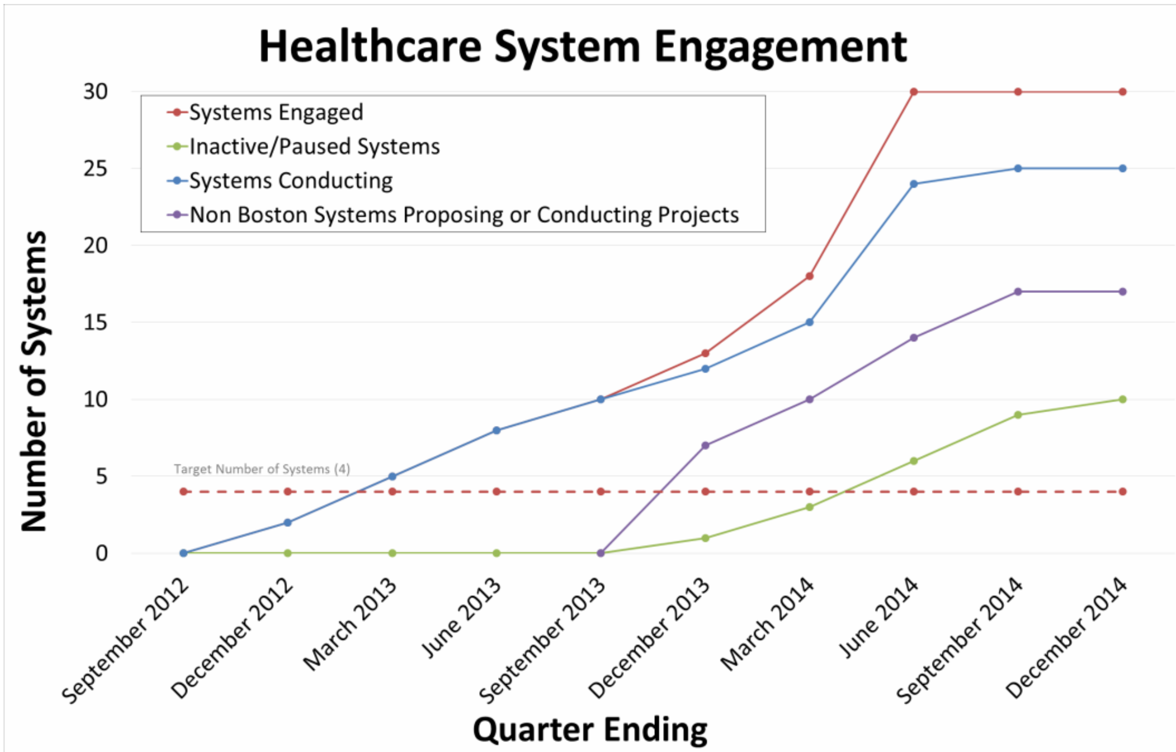


Figure 5: Healthcare System Engagement

Boston / New England (19/23)		**Seattle (4/7)**	**Charlotte (1/4)**
Baystate Medical Center	Maine Health	Evergreen	Carolinas Health System
Beth Israel Deaconess Med Cnt	Maine Medical Center	Harborview Medical Center	*Hospice & Palliative Charlotte*
Boston Children's Hospital	Mass General Hospital	*Providence Health System*	*Novant Health*
Boston Medical Center	MidCoast Maine	*Seattle Cancer Care Alliance*	*Premier*
Brigham & Women's Hospital	*Mount Auburn Community IPA*	Seattle Children's Hospital	
Cambridge Health Alliance	Southcoast Hospital (NEQCA)	*Swedish Health*	**Denver (0/2)**
Commonwealth Care Alliance	*Southern Maine Health*	Virginia Mason Medical Center	*Colorado Childrens*
Dana Farber Cancer Institute	Tufts Medical Center		*Kaiser Permanente*
Hallmark Health System	*UMass Memorial*	**Elsewhere (2/2)**	
Harvard Vanguard Med Associates		Moffit Cancer Center (Tampa)	**San Francisco (0/2)**
Lahey Health System		MDACC Cancer Ctr (Houston)	*Contra Costa*
Logix Health		Mary Washington Hospital (Balitmore)	*Kaiser Permanente*
Lynn Health Center		*Centrastate Medical Center (NJ)*	Doctor's Medical Center Modesto

Table 1: Systems engaged in CMMI grant with Institute

The work quickly expanded as the establishment of core areas of projects (figures 11-15 in the appendix) allowed for potential industry partners to see what type of work and improvements can be worked on with the help of an academic based team.

Figure 6: Map of systems participating in the grant

While the number of systems that have seen an impact from our partnership is now over 40 in three years, the number of healthcare employees who have been exposed to ISyE methods has far exceeded what was initially anticipated (no formal goal had been set, but given the goal of only working with 4 systems, that number has increased more than tenfold). Figure 7 shows that ISyE methods have been taught to nearly 1400 clinicians in partnering healthcare systems. This number speaks to how important it is for academia and industry to partner.

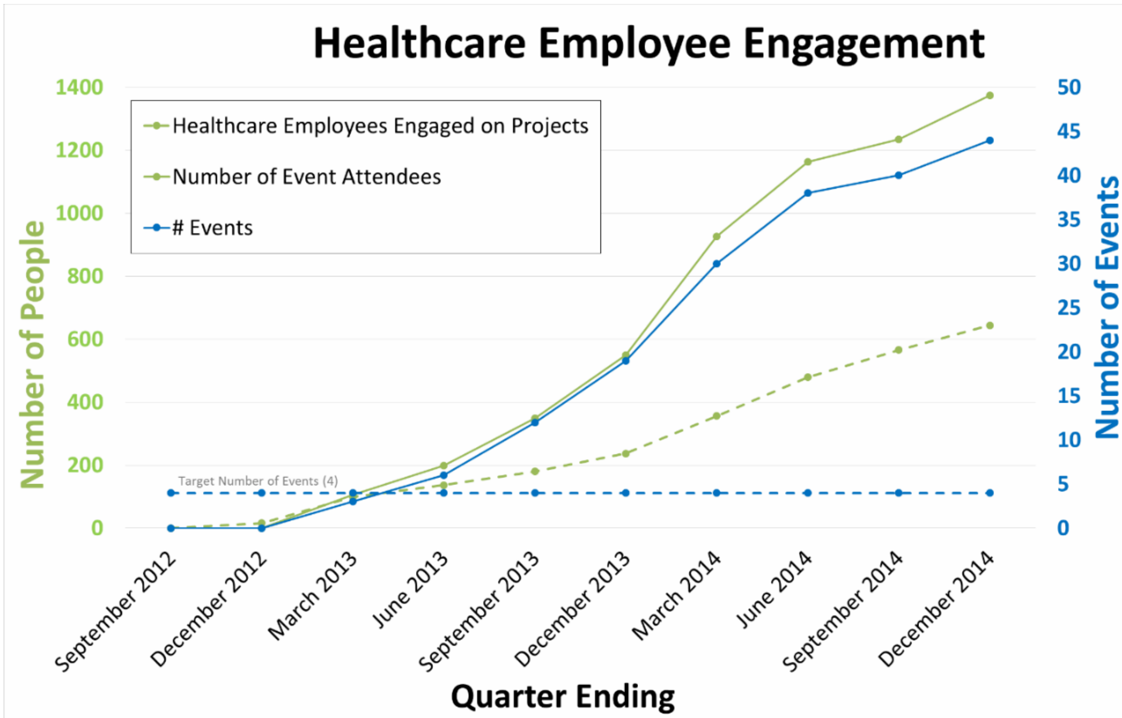


Figure 7: Healthcare employee engagement

In most cases, the first project with a system helps establish a firm relationship between academia (the Institute) and industry (the health system). It allows them to get a sense of how their partner functions and creates a bond for future projects, which are often more comprehensive than the first. Presumably, because both sides have an understanding of each other after the initial project (ISyE to healthcare and healthcare to ISyE), that is what allows for rapid development of stronger projects.

Expanded Relationships

In two separate instances, previous work through the CMMI grant has established such a productive working relationship with an industry partner that the systems have asked for the Institute's assistance in co-writing another grant.

The first grant that was written with a partnering healthcare system provided over $800,000 of funds to work on an unnecessary utilization project. The system had seen a large increase in patients seeking prescription pain medication and was in the process of testing ways to reduce these instances to an allowable level.

The second grant written with a partnered system provided over $3,000,000 to the healthcare system to work on patient safety related problems. The major area of focus for the grant is adverse events, primarily falls.

In addition to project work, the relationships have also expanded to classroom instruction. For our 2014 Summer Internship program, numerous healthcare partners came to participate and in some cases, lead the seminar.

Week / Date	Industrial Engineering	Health Care / Guest speaker
1 (5/27)	Orientation, IE in healthcare Project & meeting management	Process improvement basic methods (6 sigma, Lean, IHI improvement model)
2 (6/2)	CPLEX tutorial	Health system tours (MGH, Lahey, HVMA)
3 (6/9)	Healthcare simulation	Measuring for improvement
4 (6/16)	Reliability science (safety)	Healthcare 101: Who, what, where
5 (6/23)	Human factors in health care	The US healthcare system cont'd
6 (6/30)	Optimization in health care	Patient safety
7 (7/7)	Control charts for the common man	Staffing and workforce planning
8 (7/14)	Statistical HC improvement methods	Accountable care and population health
9 (7/21)	IEOR in population health	Care coordination
10 (7/28)	Medical decision making	Quality improvement in neonatology
11 (8/4)	Operations research in public health	Healthcare informatics
12 (8/11)	Intern presentations	Health policy and analytics

Table 2: Summer seminar series taught by academics and industry leaders and hosted by the Institute

Results so far

In its first two years, this grant has created a successful regional center in Boston and is beginning to cultivate satellite centers in Seattle, Charlotte, and San Francisco. Results to-date include 62 projects in 28 health systems, workforce development of 127 industrial engineers and 472 healthcare personnel, $24.5m in savings, and significant reductions in harm, poor access, and unnecessary utilization of imaging, diagnostics, and referrals.

A key objective and CMS criteria for broader scale is to demonstrate repeatability in terms of the ability to extend this impact beyond New England, to multiply benefits several-fold, and to repeat successful projects in other health systems. During the course of this grant, numerous seminars and workshops were developed and run from both the industry and collegiate perspective. Faculty and students spoke to industry members on industrial engineering approaches and solutions to their problems, while healthcare employees spoke about their problems and what they've been doing to combat them:~~. Highlighted qualitative notes listed below~~:

"The team was instrumental in helping us unlock opportunities to achieve better performance. As engineers, they provided a unique perspective and a different toolkit that's not common in our current system. From scoping the project, to collecting and analyzing data, to providing solutions, they were with us every step of the way."

"I thought the organizational project management skills brought to this project were outstanding. The dedication to the triple aim of the program was consistent and guided our decisions and planning at every level."

"The user interface created by Northeastern was key to this project's success. Whether talking to physicians, office staff, or HVMA administration it took only moments to evaluate the implications (beneficial or not) of any solution anyone proposed. Despite being in a large complex relatively sophisticated organization there was no internal understanding (much less skill) that there is a scientific method for "location allocation". We just do it by opinion and guesswork."

Through all of the discussions with these systems, the center was able to establish five core areas of projects that have strong ISyE solutions. The projects are in areas of overuse of imaging and diagnostics, bed demand prediction, breast milk feeding and healthy starts, macro system design and patient safety. Snapshots of each project are located in the appendix (figures 11-15) to showcase all the engineering methods used in solving these issues.

Students are heavily involved in working with and developing relationships with healthcare systems as they work on projects and seek out future opportunities for improvement. From these experiences, many students affiliated with the center have gone on to work in partnered institutions. Additionally, the center has brought 55 students in for co-ops and internships from over 14 universities. This has created a large nationwide network of student friendships that were founded on a focus on healthcare improvement. Upon entering the workforce, the bonds created here will only strengthen the college-industry relationship having both clinician and students being immersed in each other's work.

References

1. Center for Medicare & Medicaid Services, CMS Innovation Center. (2011). Healthcare innovation challenge fact sheet. Retrieved from CMS website: http://innovations.cms.gov/Files/fact-sheet/Health- Care-InnovationChallenge-Fact-Sheet.pdf
2. Jones, G.E. and Garforth, C. (1997) The history, development, and future of agricultural extension in Swanson, B. "Improving Agricultural Extension: A Reference Manual (3rd Edition)" FAO
3. President's Council of Advisors on Science and Technology (PCAST). (2014)." Report to the President: better health care and lower costs: accelerating improvement through systems engineering". Washington, DC. Holdren,et al.
4. Berwick, DM et al. (2008) The Triple Aim: Care, Health, and Cost. Health Affairs.
5. "Business Associate Contracts." <i>Business Associate Contracts</i>. Health and Human Services, 25 Jan. 2013. Web. 15 Jan. 2015. http://www.hhs.gov/ocr/privacy/hipaa/understanding/coveredentities/contractprov.html

Appendix

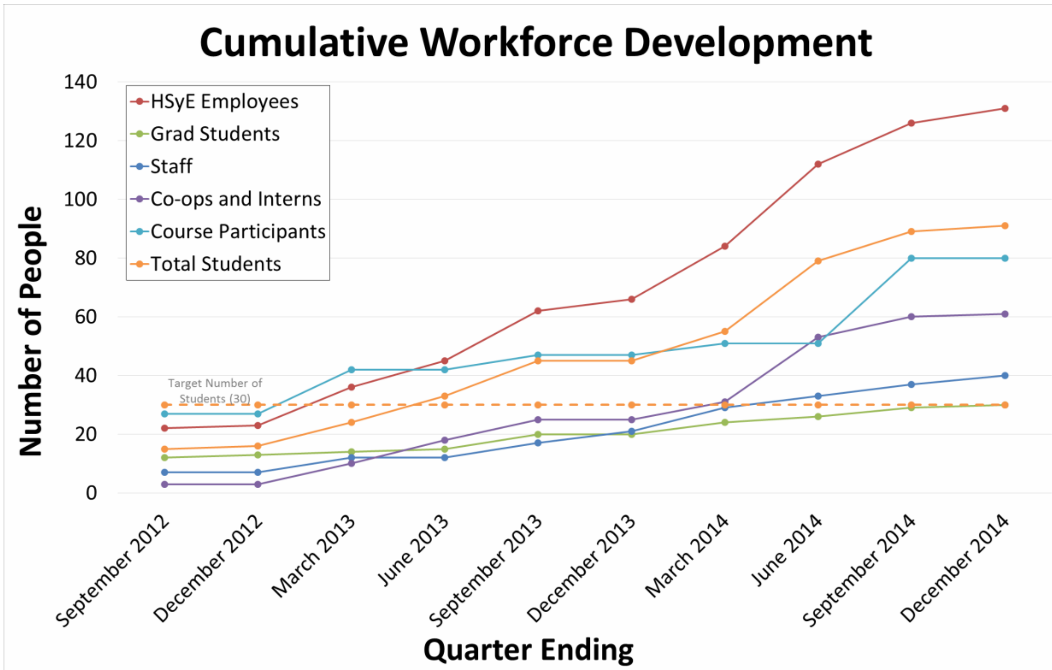


Figure 8. Number of workers employed by the institute. Note that the goal was exceeded within a year of receiving the grant. The initial target was to have 30 students involved with HSyE. After two and a half years, there have been over 90 students actively engaged on projects.

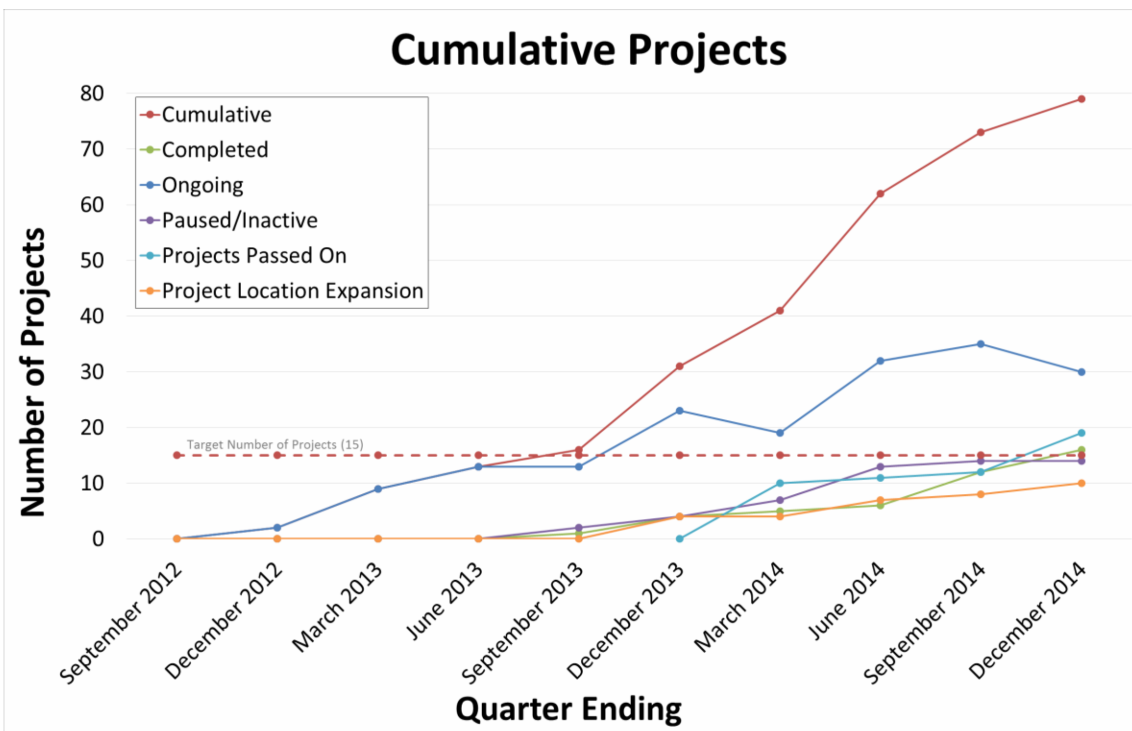


Figure 9. Number of projects worked on by the institute. Note that the goal was exceeded just over a year after receiving the grant. Again, all projects are developed around ISyE approaches and solution methods.

Since inception of the Healthcare Systems Engineering Institute		**Over the duration of the award**	
Name	**Placement**	**Name**	**Placement**
Erkhan Ceyhan (PhD)	Lahey Health	Alessandra Snigur	HSYE Staff engineer
Jordan Peck	Maine Health	Ronit Patnaik	IU School of Medicine
Natasha Taylor	UMass Memorial	Debashree Sengupta	SUNY Downstate College of Medicine
Claire Bond	UMass Memorial	Natalie Souther	Premier Inc.
Bonnie Baker	Martin's Point Health Care	Amanda Bell	U or Toronto Healthcare Systems Engineering
Sam Ruokis	University of Chicago Medicine	Kelli Crosby	Pitt VA
Kim Eng	BIDMC	Melissa Marinace	Johns Hopkins University APL Healthcare
		Tom Abreu	Beacon Health Strategies
Over the duration of the award		Sabrina Tang	U or Toronto Healthcare Systems Engineering
		Ellen Wilson	Booz Allen Hamilton
Name	**Placement**	Cory Stasko	MIT IE student, HSyE Research fellow
Luke Romeo	Long Island Jewish Medical Center	Ally McCall	Healthcare Consulting
Rachel Miller	Hill Physician's Medical Group		
Nick Andrianas	Johns Hopkins University APL Healthcare		
Onur Uzunlar	Sandoz		
Laura Hyde	Athena Health		
Hande Musdal	Northeastern Post-doc		
Dayna Martinez	Northeastern Faculty		
Corey Balint	NU HSyE Staff Engineer		
Salah Haridy	Academia		
Kendall Sanderson	HSyE grad student		

Figure 10. Employees who have moved onto healthcare positions after their time in the institute. This is referenced to note that the influence ISyE trained employees, at the academic level, are now branching out into industry and the partnerships between the two grow stronger. By the end of 2015, over thirty students and staff who have come through HSyE will have been hired into another healthcare improvement role.

Figures 11-15 (all below). Drafted one page summary sheets for core project areas. Each core area summary sheet includes the following: aim statement, potential applications, how to approach the problem, methods, implementation, and potential measures.

Core Project Area Summary (1 of 6)
Bed Demand and Patient Flow

Focus

- Predicting downstream bed demand and patient flow so that managers can adapt resources, staffing, and/or schedules in some rational manner
- *Applications*:
  1. ED-to-inpatient admissions (same day)
  2. System wide and department-specific bed demand (long-term 1-21 days ahead)
  3. Surgery-to-PACU capacity and blockages

Approach

- Roll-forward current census (system state), scheduled work, and random arrivals, durations, and flow paths
- *Methods*:
  1. Monte Carlo simulation, probabilistic, and Markov chain models
  2. Logistic regression and machine learning classifiers
- *Implementation*:
  1. Visual basic macros embedded in Excel with user-friendly front-end for usability
  2. Test implementation via Google forms and docs prior to hardwiring into internal HIT

Measures

-
-
-
-

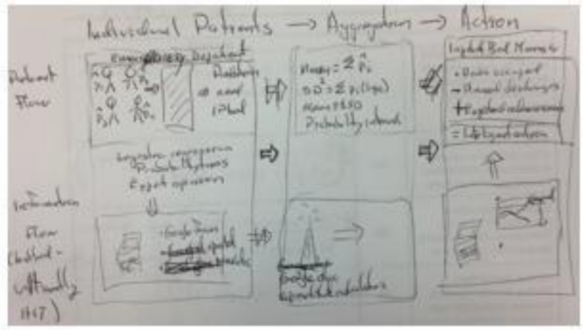


Fig 1: ED-to-inpatient admission (same day)

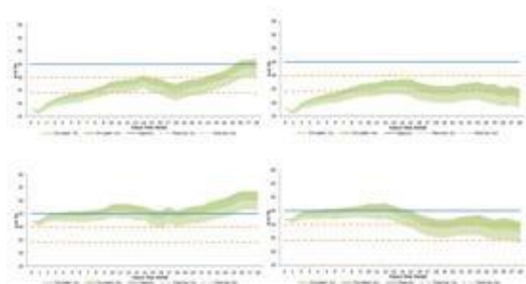


Fig 2: System-wide bed demand forecast (4 week ahead)

Fig 3: Surgery-to-PACU blockages (schedule tester)

Core Project Area Summary (2 of 6)
Unnecessary Referrals

Focus

- Reduce unnecessary utilization of specialty referrals and diagnostic studies by designing a prediction-based screening process (Figure 1).
- *Applications*:
  1. Specialty referrals (neurology, cardiology, pulmonology, others).
  2. Imaging and diagnostics (MRI, CT scans, catheterizations, others).

Approach (4 months)

- *Month 1:* Predict patients likely needing only lower cost option via historical data (methods: logistic regression, machine learning, decision trees, ensemble methods).
- Identify decision points via threshold optimization methods.
- *Month 2:* Test and demonstrate potential value via ≤ 1 month rapid cycle off-line study using retrospective data. Identify "good enough" resources and workflows for a pilot live test.
- *Month 3:* Test live via small ≤ 1 month pilot with 1-3 most willing providers. Develop compelling data and results case.
- *Month 4:* Implement, rollout, and monitor.

Measures

- Percent reduction in unnecessary utilization.
- Improved access (days until appointment) for diverted and F2F patients.
- Avoided associated costs (Figure 3).
- Provider and patient satisfaction.

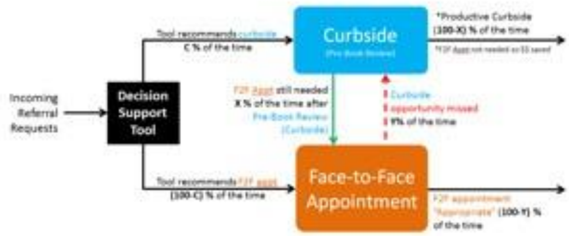


Fig 1: Referral management model

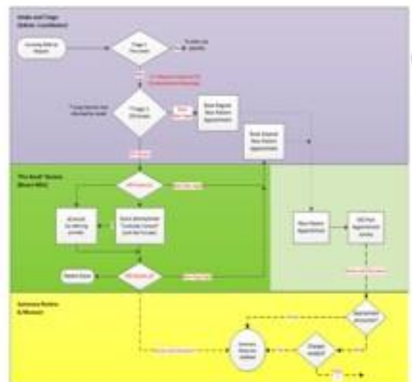


Fig 2: Referral workflow logic

Patient Request	Tool #1 Prediction: CS	Tool #1 Prediction: F2F Appt	"Gold Standard" (MD Feedback): CS	"Gold Standard" (MD Feedback): F2F Appt	Tool #1 Correct?	Cost Without Tool #1	Impact Using Tool: CS Cost	Impact Using Tool: F2F Appt Cost	Impact Using Tool: Total Cost using Tool	Impact Using Tool: Savings using Tool
1	✓		✓		Yes	$7,476	$40		$40	$7,436
2	✓			✓	No	$7,476	$40	$7,476	$7,516	- $40
3		✓	✓		No	$7,476		$7,476	$7,476	
4		✓		✓	Yes	$7,476		$7,476	$7,476	
5	✓		✓		Yes	$7,476	$40		$40	$7,436
⋮					⋮	⋮				⋮
89	✓		✓		Yes	$7,476	$40		$40	$7,436
90	✓			✓	No	$7,476	$40	$7,476	$7,516	- $40

Request Total	Tool: CS	Tool: F2F	MD: CS	MD: F2F	Tool Correct	Cost w/o Tool	CS Cost w/ Tool	F2F Cost w/ Tool	Total Cost w/ Tool	Total Savings w/ Tool
90	33% (30/90)	67% (60/90)	10% (9/90)	90% (81/90)	78% CS (7/9) 72% F2F (58/81)	$672,840	$1,200	$620,508	$621,708	$51,132 monthly

Fig 3: Results example (neuro referrals)

Core Project Area Summary (3 of 6)
Breast Milk Feeding

Focus

- Increase amount of in-hospital breast milk feeding in NICU and full term babies for health (babies and mother), flow, and cost benefits.
- *Applications*
  1. NICU and very low birth weight babies
  2. Normal newborns

Approach

- Implement and visibly measure ≥ 3 best practices with local track-run (e.g. rooming in, skin to skin, 1st feeding < 1 hour, etc.)
- Rapid cycle contrast surveys for barriers of low vs. high compliance mothers indicating BMF as preference
- Process redesign using HSyE reliability science tool
- Early identification triggers during hospitalization of babies not receiving BM or best practices
- Targeted interventions and heightened vigilance for most at-risk babies identified via data analysis (e.g. young, first time, non-Caucasian moms)

Measures

- Degree of implementation of above approaches (1-5 scale)
- Compliance/adoption rate of ≥ 3 Baby Friendly best practices
- Percent inpatient feedings via BM (or # orders for formula per "baby day" as surrogate measure).
- Percent feeding ≥ increase to 90% via breast milk at discharge (last 24 hours)
- Infection, NEC, and complication rates during LOS
- Average LOS (in NICU by gestational age) or additional days (in nursery)
- Cost avoidance from last 2 items

Figure 1. Solution approach

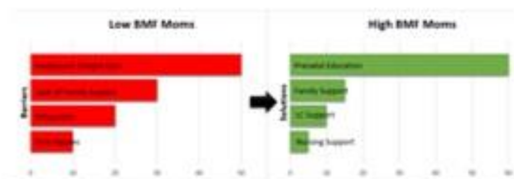


Figure 2. Barriers/Solutions contrast survey of mom's indicating EBMF preference prior to delivery

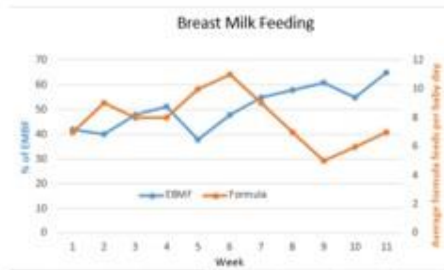


Figure 3. Results Run Chart

Core Project Area Summary (4 of 6)
Safety, Control Charts, and Reliability

Focus

- Reduce number of adverse events through assistance with statistical control charts, data analysis, reliability, engineering, and implementation science methods.
- *Applications*:
  Falls, medication errors, device associated infections (CAUTI, CLABSI, VAP), pressure ulcers surgical site infections, c.difficile, vein infiltration

Approach

- Develop statistical control chart tools for specific problem (Excel or Tableau based)
- Implementation in automated dashboard +/or provide ongoing analysis + interpretation support (+1 or -1 day workshop) if useful
- Map prevention process using reliability engineering design matrix model
- *Methods*:
  1. Statistical control charts
  2. Reliability design

Measures

- Number of harm events of each type
- Compliance to prevention steps (composite score)
- Level of implementation of reliability approach (user-assessed subjective 1-5 scale)
- Associated reduction in costs and discharge delay

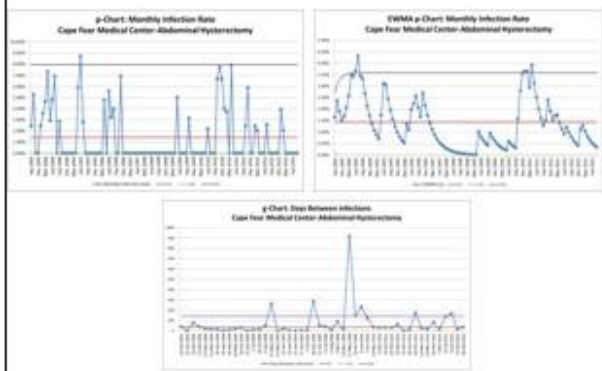


Fig 1: Duke Control Chart

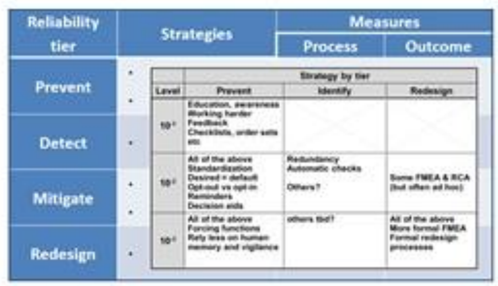


Fig 2: Reliability Process Design Matrix (reliability matrix)

Core Project Area Summary (5 of 6)
Macro System Design

Focus

- Optimize health system network design in terms of capacity and geographic location of care services relative to patient location to provide good access within a reasonable distance at minimal total cost.
- *Applications*:
  1. Design (and redesign) of overall inpatient and outpatient care network
  2. Location of specialized services across an existing network (e.g. ultrasound, mental health, sleep apnea facilities, etc.)
  3. Consolidations, merges, and partitioning of systems and accountable care facilities

Approach

1. Develop and validate optimization model of overall network
2. Conduct optimization, sensitivity, and scenario analysis elicited from health system
3. Interact with health system team to provide ad hoc analysis support to ongoing system redesign decision

- *Methods*:
  1. Service location-assignment and capacity optimization models
  2. Excel-based computer simulation and queuing models to account for demand and other variation
- *Implementation*:
  1. Excel based data analysis
  2. Mathematical modeling
  3. Scenario testing

Measures

- Average total distance and core access
- Resource utilization
- Patient satisfaction
- Total cost

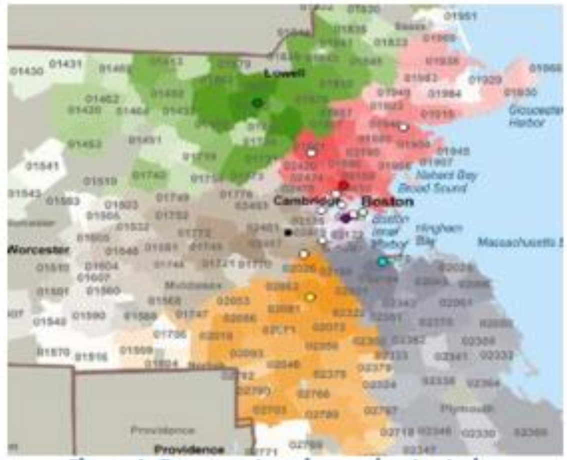


Figure 1: Resource location optimal solution

Objective Function	Minimize $\Sigma\Sigma P.E_i.D_{ij}.X_{ij}$
Constraints	$\Sigma X_{ij} \leq 1 \quad \forall i$
	$X_{ij} \leq Y_j \quad \forall ij$
	$\Sigma P.E_i.X_{ij}.t1 \leq C_j.N_j \quad \forall j$
	$\Sigma N_j = k \quad \forall j$
	$\Sigma N_j \geq 2 \quad \forall j$
	$N_j \leq k.Y_j \quad \forall j$
	$D_i = \Sigma X_{ij}.D_{ij} \quad \forall i$
	$\Sigma P.E_i.X_{ij} \geq \%P.\Sigma E_i \quad \forall j$

Figure 2: Resource location optimization model