Engineering in Healthcare Delivery

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Abstract — *Industrial Engineers (IE) are well suited to work in health systems such as healthcare delivery in hospitals. Kettering University students are required to co-op at industries for half of their academic career. There are many opportunities for the students to apply what they learn in the classroom and bring back to the class what they experience at work. Students are required to complete a thesis project on an issue within their workplace, with oversight provided by their work supervisor and a faculty advisor. Beaumont Hospitals of Michigan has been a co-op sponsor for over 20 years. The partnership has generated numerous senior theses that resulted in improved healthcare systems. Such areas include an increase in number of orders processed, reduction in technicians' travel time within the facility, better load balancing, and more efficient processes. Other areas are based on lean principles resulting in effective evaluation of return on investment of using a new RFID technology for tracking resources in a busy emergency center. The findings showed that the new technology would reduce non-value added time, increase in volume of patients treated, and consequently an increase in revenue. The benefits to the hospital and to the students are diverse. The continuous study and co-op work rotations provides IE students with the necessary real-life reinforcement of lessons learned in the classroom. The close relationship with industry enhances the students' learning, comprehension, skill retention, and ability to apply what they have learned. This is the strength in the partnership between Kettering and Beaumont.*

Index Terms — *healthcare, delivery, engineering, IE tools, electronic record*

BACKGROUND

'The healthcare industry is the largest in the world, responding to the needs of millions of people worldwide. The United States is at the forefront of this global industry, leading the way in many fields of clinical research, training, and practice. However, the American healthcare system is in crisis involving accessibility, safety and cost-effectiveness', as stated in the website of Purdue University on Healthcare Engineering [1].

Although engineering and healthcare do not seem natural partners to the general population, healthcare delivery brings multiple situations and problems to be solved through engineering methods. A recent study conducted by the National Academy of Engineering and Institute of Medicine [2] pointed out that the application of engineering methods that have transformed manufacturing and distribution in other industries have great potential to do the same in healthcare. '… the knowledge/awareness divide separating healthcare professionals from their potential partners in systems engineering and related disciplines' must be bridged. *Building a Better Delivery System* describes opportunities and challenges to harness the power of systems-engineering and other high-tech tools. Regenstrief Center for Healthcare Engineering of Purdue University [3] and at University of Michigan the HealthE Lab [4] are example centers to address these aspirations.

Traditionally, healthcare engineers serve the medical community through the management and maintenance, service and training of its vital biomedical and related "high technology" equipment and their safety procedures and precautions. The myth that healthcare delivery does not equate to engineering is a paradigm that needs to be shifted towards meaningful partnership. Engineering /manufacturing can be paralleled to healthcare delivery. External influence (oil shortage) in the mid'70s ushered in foreign low-cost fuel-saving competitive products. This prompted U.S. manufacturing to respond with automation. The early '90s brought in higher quality foreign products. U.S. reacted with statistical quality controls (SQC) and standards. The 21st century saw high quality, and low-cost foreign products. U.S. had to learn to run systems LEAN as well. Many engineering disciplines were brought together to provide the solutions. For healthcare, aside from hospital-to-hospital competition, the external force comes with the changing health bill. Healthcare delivery has to run lean with high quality, effective shorter delivery time and cost effectiveness. This effort has to span from patient safety [5, 6], to doctor's quality time and nursing care [7], to family engagement.

HEALTHCARE DELIVERY ENGINEERING FOR IE

Automation, SQC, and Lean are established IE tools. They apply to many components of the healthcare delivery systems such as medical diagnostic, treatment protocols, devices as well as healthcare delivery. They involve ergonomics and design, environmental ergonomics, work physiology, occupational biomechanics, cognitive engineering, safety engineering, human factors in engineering and design, system theory, decision theory, industrial cost analysis, productivity and performance improvement in an organization, statistical data analysis, total quality system, workflow/critical path analysis, as well as and management science with project management and implementation. Experts, who are IE's, Jean Ann Larson and Junell Scheeres [8],[9] have stated that there needs to be collaboration between IE's and hospital or clinical operations. With the advent of rising healthcare costs [10], IE's are known to be able to drive systems operations leaner, more value-added, higher quality and at lower relative costs.

Are College Graduates Ready to Tackle the Challenges?

What have universities done to address this need? A number of universities have excellent graduate programs with research centers. Examples are shown in Table 1.

University	Type of program (minor, concentration)
Purdue University – College of Engineering	Healthcare Engineering Signature area (Healthcare Engineering)
Texas Tech University – White College of Engineering	Master of Engineering with an option of Healthcare Engineering (MEHE)
NC State University – Edward P. Fitts Dept of IE	Masters of Engineering with an option to study Healthcare Engineering
University of South Florida	Has Academic collaboration with Discovery Park
NC A&T State University	Has Academic collaboration with Discovery Park

Table 1: Graduate Programs

Only a few prominent undergraduate programs have established minors or an option of study (Table 2).

University	Type of program (minor or concentration)	Degree program
NC State University – Edward P. Fitts Dept of IE	Bachelor of Engineering with an option to study Healthcare Engineering as minor	Undergraduate
University of Michigan – IOE	Option of study in Healthcare for IOE program	Undergraduate
University of Arkansas	Bachelor of Engineering with an option to study various Healthcare logistics subjects	Undergraduate

Table 2: Undergraduate Programs

Healthcare System Engineering at Kettering University

Kettering University is one of few universities introducing an undergraduate concentration in Healthcare System Engineering for IE. With the appropriate pre-requisites, Healthcare System Engineering is offered as a minor to other disciplines. In addition, offerings will be extended to graduate certificate programs and a Master degree program as well.

Four courses are specific to the program. The "Supply Chain" course is one of the IE required courses. The other three courses are new to the IME Department and the Department of Business.

Course title: *Designing Value in the Supply Chain*

This course examines concepts of value including (1) value engineering, (2) value chain (including supply chain and logistics) analysis, and (3) value stream mapping. Value engineering considers how systematic methods are used to improve the "value" of goods or products and services, including optimizing the value of a system's outputs by crafting a mix of performance (function) and costs following a structured thought process based exclusively on function. Value chain analysis looks at the chain of activities that a product passes which gives the product more added value than the sum of added values of all activities. "Primary activities" (inbound logistics, operations (production), outbound logistics, marketing and sales (demand), and services (maintenance)) and "support activities" (administrative infrastructure management, human resource management, technology (R&D), and procurement) are both covered. The costs and value drivers are identified for each value activity. Value stream mapping, analyzes the flow of materials and information currently required to bring a product or service to a consumer.

Course title: *Six-Sigma Lean Systems*

This course examines techniques to maximize production efficiency and to maintain control over each step in the process. The structured problem-solving methodology DMAIC (Define-Measure-Analyze-Improve-Control) will provide the framework for the course.

Course title: *Healthcare System Engineering*

This course examines the technical structure of the healthcare delivery system and the role that industrial and systems engineering (ISE) plays in its design and improvement. Included will be how healthcare systems work in hospitals, medical offices, clinics and other healthcare organizations. Traditional ISE methods for improving quality, patient safety, and employee productivity and satisfaction will be presented within a systematic application of value chain engineering designed to produce lean processes.

Course title: *Healthcare System Management*

In this course students gain a broad understanding of the organization, financing and issues in healthcare delivery systems in the US. Students will apply core business skills and knowledge of healthcare unique functional areas in analyzing healthcare case studies. Students will critically evaluate healthcare issues and polices and their effect on healthcare system performance.

University and Hospital Collaboration through Co-op Program

Prior to establishing this concentration/minor, Kettering has been engaged in educating and training IE's in healthcare professions through its unique co-op program. Kettering University is ranked 1st in IE by US News & World Report in undergraduate programs. Kettering students are required to co-op at industries as ½ of their education, namely, they study for three months, work the other three months and repeat the cycle for 4½ years till they graduate. There are many opportunities for the students to apply what they learn in the classroom and bring back to the class what they experience at work. Before graduation, a senior capstone design project, usually from industry, is required. The senior thesis that the students write delve on topics within their workplaces, supervised by their work supervisor and a faculty advisor.

Beaumont Hospitals (from here on, it will be referred to as "Beaumont") is in the forefront of conducting studies that will improve healthcare. It is a non-profit organization. It's emphasis is customer satisfaction based. Beaumont's motto is "The Patient is the Center of All We Do". It is striving to sustain lean systems in the hospital to provide value-added, cost-effective and high quality care to the patients. Beaumont values employees that are diverse in age, but trained and experienced professionals who could help sustain this system. It is under these premises that Beaumont became a co-op sponsor for Kettering University students. Students generally enter Beaumont and rotate through different projects in the department(s). The rotations culminate in a senior thesis project. To provide a view of the scope of university-hospital projects, four thesis project summaries are listed. Two example theses are described in more detail to show the work, development, planning, implementation, results and conclusions.

Thesis Project Summaries

Theses that are summarized cover (1) process improvement for implementing EMR (electronic medical record) and practice management (PM) which is the non-medical processes. OneChart (customized electronic medical record system developed by EPIC) is used at Beaumont Hospitals and its ambulatory sites, (2) infrastructure building for supply chain, (3) improvement of communication of customer-staff interaction through helpdesk changes, (4) involvement in EMR development.

(1) Beaumont is implementing oneChart into a Beaumont Owned, Clinical Services Outreach, and Private physician office ambulatory sites. Information Services (IS) Ambulatory teams needed a standard process of obtaining and organizing required information from the ambulatory sites for an implementation. This causes difficulties in implementation of Practice Management and Electronic Medical Record modules due to employee dissatisfaction and confusion and lack good communication protocols and channels, and assessment criteria, scheduling strategies and clear oneChart system documentation and training. The software system was made more user-friendly, documentation was simplified and made more comprehensive. Management structure was streamlined, team roles were made accessible to all team members and changes were documented. The ambulatory team was to implement a standard appointment method that would improve communication between team members and information management. Customer service survey results were captured and sent to employees. The top five actions recommended were: increase time and content of training, unsatisfied with system functionality, increase internal knowledge, and increase preparation. Yearly surveys will serve as continuous improvement guidelines.

(2) The result of this thesis was the development of business processes and technology infrastructure requirements which support an order-entry based supply orders system to reduce or eliminate verbal, free-text and paper-based ordering of ad-hoc supply requests at Beaumont Hospital, Royal Oak. The replacement system additionally allows for integration to the revenue cycle system to automate the billing processes.

(3) The focus of this thesis is the off-site technician group which resolves technical work orders for the William Beaumont Hospital Help Desk. The PC Technician group is a small subset of the Help Desk but can greatly affect the image that the Help Desk projects onto customers. Help Desk Management lacked an effective technique to

monitor the Help Desk processes and staff members. This prohibits management from identifying improvement opportunities and forces them to rely on anecdotal or subjective information when Help Desk operations are scrutinized by outside departments or customers. In order to offer a solution to management, the author collected field data, complied suggestions for process flow improvements, and piloted those suggestions with the off-site group. The results of the pilot showed a 15% increase in the number of work orders that did not require traveling. It is projected that the change could ultimately reduce technician travel by 29%. It is recommended that the off-site group adapt to the suggested process change and that management use the report template given to have immediate access to the performance of the group.

(4) Co-op projects have contributed to the implementation of integrated Electronic Medical Records (EMR). These information technology systems, specifically Health Information Technology or HITECH, allow hospitals and healthcare practitioners to eliminate paper, chart electronically, e-prescribe medications, amongst many other functionalities. In tandem, patients reap the benefits when the continuum of their care is met from admission to discharge or better yet, across a lifetime.

In his campaign trail, President Obama shared, '…We will make sure that every doctor's office and hospital in this country is using cutting edge technology and electronic medical records so that we can cut red tape, prevent medical mistakes, and help save billions of dollars each year.'

Two Thesis Projects Brief Descriptions

The two theses illustrated here are in areas of: (1) quality assurance continuous improvement, (2) improvement on the ROI for patient and staff with reduction in non-value added time.

(1) Fundamental industrial engineering concepts like continuous quality improvement, process design/re-design, and business/operations analysis are illustrated in practice in a non-traditional engineering environment. This thesis offers a unique opportunity to understand the important role industrial engineers have and how each aforementioned concept can be applied across any industry. This thesis addresses the needs of Beaumont Hospital Royal Oak in identifying a process for reviewing and analyzing Alaris pump CQI data.

These Alaris pumps are the first of its kind and are a relatively new technology that provides the opportunity to avoid medication errors related to administration of intravenous infusions. The Alaris pump technology allows the hospital to program drug administration parameters in the drug database.

With well over 1,000 Alaris IV Pumps distributed throughout Beaumont Hospital Royal Oak, a large amount of medication administration data is collected. With this data and this investment, a defined process was established in order to increase reviews of medication alert data from yearly to quarterly. In return, the hospital is able to continually assess the drug database parameters to better suit the actual administration environment and even further, become aware of any potential hazardous administration that may occur.

Table 3 shows a direct import of the data that is collected by the Alaris drug pumps. This screenshot does not capture all the data, every column and every row. With this in mind, the imported data amounted to well over 3,000 rows and naturally, was not in a format that was easily dissectible and made it quite difficult to manage and analyze the data for the hospital.

Ultimately, the hospital needed a more efficient, more accessible way to analyze and review this data in meaningful reports. By means of Visual Basic macros, the imported data above was "cleaned up," deleting unnecessary columns that were non-value added, blank rows and columns, and copying the appropriate information into cells with quotation or "ditto" marks.

With the data cleaned up, additional macros were created and then organized into a user-friendly Excel sheet, housing different options to select from that would automatically produce pivot tables, detailed and condensed reports of the data. These reports were suggested reports that the hospital, specifically the pharmacy, requested to see.

Guardrails® Alerts - All Available Columns
Sep 26, 2008 2:31:04 PM

Group	ID	Clinician ID	Alert Type	Log Time	PC Unit #	Model	Sequence ID	Snapshot ID	Profile	PC Unit Version
69838	806484		Non-Infusion Resolution	9/26/2008 11:14	4078830	Alaris® System 8000	176	205		8.5.25.0
	94432		Non-Infusion Resolution	10/26/2006 16:20	"	Alaris® System 8000	176	258		8.5.25.0
33154	44507		Non-Infusion Resolution	12/6/2006 6:23	4074904	Alaris® System 8000	202	298		8.5.25.0
	704635		Non-Infusion Resolution	7/3/2008 20:57	"	Alaris® System 8000	202	321		8.5.25.0
36125	48461		Non-Infusion Resolution	12/9/2006 20:42	4074904	Alaris® System 8000	203	299		8.5.25.0
	704893		Non-Infusion Resolution	7/4/2008 5:35	"	Alaris® System 8000	203	322		8.5.25.0
36126	48462		Non-Infusion Resolution	12/9/2006 20:42	4074904	Alaris® System 8000	204	300		8.5.25.0
	711298		Non-Infusion Resolution	7/10/2008 20:02	"	Alaris® System 8000	204	323		8.5.25.0
46349	62095		Non-Infusion Resolution	12/12/2006 21:28	4074904	Alaris® System 8000	205	301		8.5.25.0
	712125		Non-Infusion Resolution	7/11/2008 12:06	"	Alaris® System 8000	205	324		8.5.25.0
46350	62096		Non-Infusion Resolution	12/12/2006 21:29	4074904	Alaris® System 8000	206	302		8.5.25.0
	716068		Non-Infusion Resolution	7/15/2008 9:50	"	Alaris® System 8000	206	325		8.5.25.0
46351	62097		Field Limit	12/12/2006 22:01	4074904	Alaris® System 8000	207	303	CRITICAL CARE	8.5.25.0
	62098		Resolution	12/12/2006 22:02	"	Alaris® System 8000	207	304	"	8.5.25.0
	717181		Non-Infusion Resolution	7/16/2008 7:46	"	Alaris® System 8000	207	326	"	8.5.25.0
46352	62099		Non-Infusion Resolution	12/18/2006 10:24	4074904	Alaris® System 8000	208	305		8.5.25.0
	719597		Stop Secondary	7/17/2008 22:16	"	Alaris® System 8000	208	327		8.5.25.0
	719598		Resolution	7/17/2008 22:16	"	Alaris® System 8000	208	328		8.5.25.0
515533	700177		Field Limit	6/30/2008 10:24	9964806	Alaris® System 8000	568	744	ONCOLOGY	8.5.25.0
	700178		Resolution	6/30/2008 10:25	"	Alaris® System 8000	568	745	"	8.5.25.0
	701256		Resolution	7/1/2008 7:30	"	Alaris® System 8000	568	747	"	8.5.25.0
517222	702366		Field Limit	6/30/2008 15:53	4079003	Alaris® System 8000	361	510	CRITICAL CARE	8.5.25.0
	702367		Resolution	6/30/2008 15:53	"	Alaris® System 8000	361	511	"	8.5.25.0
	702368		Resolution	7/1/2008 0:31	"	Alaris® System 8000	361	513	"	8.5.25.0
517539	702838		Field Limit	6/30/2008 16:54	4081759	Alaris® System 8000	495	702	Medical / Surgical	8.5.25.0
	702839		Resolution	6/30/2008 16:54	"	Alaris® System 8000	495	703	"	8.5.25.0
	702840		Resolution	7/1/2008 6:39	"	Alaris® System 8000	495	705	"	8.5.25.0
516415	701328		Field Limit	6/30/2008 17:26	4076312	Alaris® System 8000	661	885	CRITICAL CARE	8.5.25.0

Table 3: Excel Sheet on Guardrail Alerts

Table 4 shows an example of one report that showed what kinds of actions were taken by the nurse administering certain drugs.

Drug Name	Therapy Name	Program Type	Infusion Program Type	Action Taken
DOBUTamine (STD)	No Therapy	(blank)	Continuous	CHANNEL OFF / Override / Reprogram
DOPamine (STD)	No Therapy	(blank)	Continuous	CHANNEL OFF / Override / Reprogram
epINEPHrine (STD)	No Therapy	(blank)	Continuous	Override / Reprogram
heparin	No Therapy	(blank)	Bolus Infusion	Override / Reprogram
			Continuous	Override / Reprogram
NOREPINephrin (STD)	No Therapy	(blank)	Continuous	CH DESLCT / Override / Reprogram
PHENYLephrine (STD)	No Therapy	(blank)	Continuous	Override / Reprogram
propofol	No Therapy	(blank)	Continuous	CHANNEL OFF / Override / Reprogram
vasopressin	CABG	(blank)	Continuous I	Override / Reprogram
	DI	(blank)	Continuous	Override
	GI	(blank)	Continuous	Override
	Shock	(blank)	Continuous	CH DESLCT / Override / Reprogram

Table 4: Critical Care Alert Field Limit

Even further, Table 5 highlights the actual administration dosages for Dobutamine and Dopamine. Both drugs were shown in the above table as being overridden at times by the nurses administering these drugs.

Drug Name	Above/Below	Alert Limit	Alert Value	+/- Limit	Times limit
DOBUTamine (STD)	Above Maximum	20	30	10	1.5
			35.842	15.842	1.792
			40	20	2
	Below Minimum	2	0.05	-1.95	0.025
			0.5	-1.5	0.25
			0.938	-1.062	0.469
			0.962	-1.039	0.481
			1	-1	0.5

			1.434	-0.566	0.717
			1.488	-0.512	0.744
			1.5	-0.5	0.75
			1.7	-0.3	0.85
			1.8	-0.2	0.9
			1.852	-0.148	0.926
			1.923	-0.077	0.962
DOPamine (STD)	Above Maximum	20	25	5	1.25
			30	10	1.5
			36.53	16.53	1.826
			50	30	2.5
			364.932	344.932	18.247
	Below Minimum	2	0.5	-1.5	0.25
			0.711	-1.289	0.356
			1	-1	0.5
			1.046	-0.954	0.523
			1.067	-0.933	0.533
			1.282	-0.718	0.641
			1.401	-0.599	0.7
			1.422	-0.578	0.711
			1.5	-0.5	0.75
			1.778	-0.222	0.889
			1.867	-0.133	0.933

Table 5: Critical Care All Fields Alert

With readily made, and easily accessible reports available, rather than a virtually meaningless amount of data imported directly from the pumps, the hospital is able to better assess their drug database. The hospital now has a defined process for reviewing and analyzing the Alaris CQI (continuous quality improvement) data. By means of an Excel import and an Excel home page document that automates customized pivot tables, the hospital/pharmacy can finally make sense of this vast amount of drug information and make information that is pertinent to the continual improvement of the hospital's alert database readily available. Envisioning what this can do for the hospital, they can easily produce and distribute summarized reports to all appropriate clinical care-givers. By making available Excel reports that summarize the Alaris CQI data, appropriate action plans can be made in order to continuously improve their drug database and drug administration practices.

(2) Many hospitals currently do not have a formal method of justifying a wireless patient tracking tool (e.g. InnerWireless) in the healthcare community

The need for the pilot comes from the fact that once a patient is roomed, no further patient movement is recorded until the patient is admitted or discharged. This current process is confusing and disjointed for employees and can produce problems for visitors if they are trying to find particular patients. A pilot study was initiated and results showed that wireless tracking is cost effective for the hospital. The GOAL was to find pre-implementation metrics and analyze potential savings and improvements made with the implementation of the InnerWireless system. This thesis established the metric for improvement to project revenue. There had been a lack of return on investment analysis for a patient and staff ultra wideband badge tracking pilot in William Beaumont Hospitals Royal Oak Emergency Center. Pre-implementation metrics for patient care and patient tracking process inaccuracy were established through work sampling and time study data. The pilot will reduce more than 74 hours (corresponding to $1,800) of non-value added time annually and allow 19 additional patients to be seen annually, who would have otherwise left without being seen, bringing in an additional $12,500 per year of revenue. In addition, for the future, the system will collect and report on metrics which have never been studied at Beaumont, allowing further improvements to be made.

Customer satisfaction was put into the forefront of the study through reduction in confusion of destinations, efficiency and ease of patient flow, data accuracy and patient locating. A RFID badge was issued to patients for tracking in Pediatrics and Prompt Care units. A clinical and technical house of quality (Figure 1) was built to evaluate the relationships between the two characteristics and displays which requirement for the patient tracking system should have the highest priority. Time studies were conducted for patient tracking to find the efficacy of the metrics. As an example, the first order of patient tracking is when the ID'ed patient enters or exits a room. Assumptions made were: use of absolute values of data, use of Anderson-Darling (A-D) test for normality (bell curve), use of α of 0.05 (95% confidence in findings), use minutes for data intervals (Figure 2).

The standard deviation of the Enter Room data is almost as great as the mean of the data, which implies there is a fair amount of variability on the track board. The p-value of Enter Room Time Difference (TD) data is less than 0.05 which indicates that the sampled data are not normally distributed. There were many other such tests for nurses' and physicians' action times conducted as part of the pilot study. Another aspect of the study is the improvement of accuracy

of self-assigning process of nurses and physicians (originally a manual operation) to the patients. Random work sampling method was used.

The results of this study:

- outdates the current track board
- Reduces 37.1 combined hours of non-value added time annually from the combined nurses' and combined physicians' workflows; translating to ~$2,000 of time savings annually.

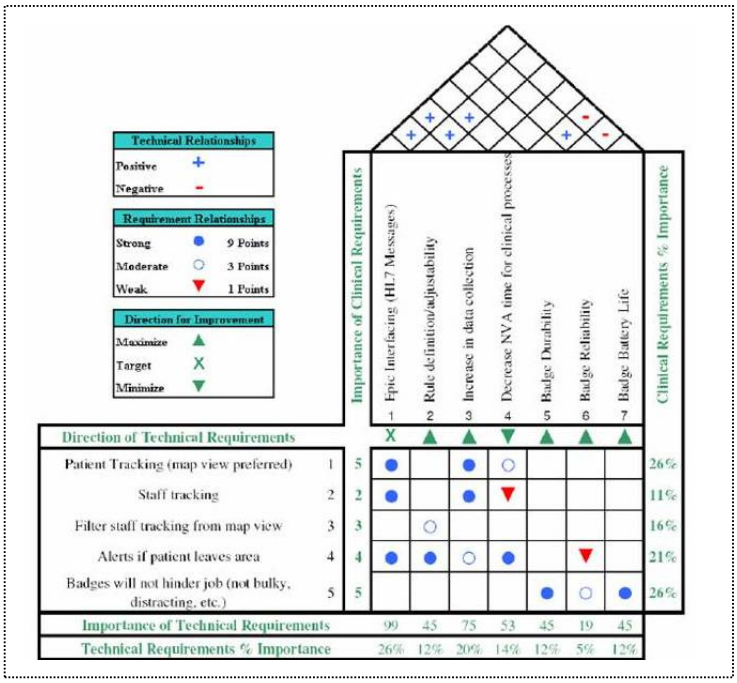

Figure 1: Clinical & Technical House of Quality

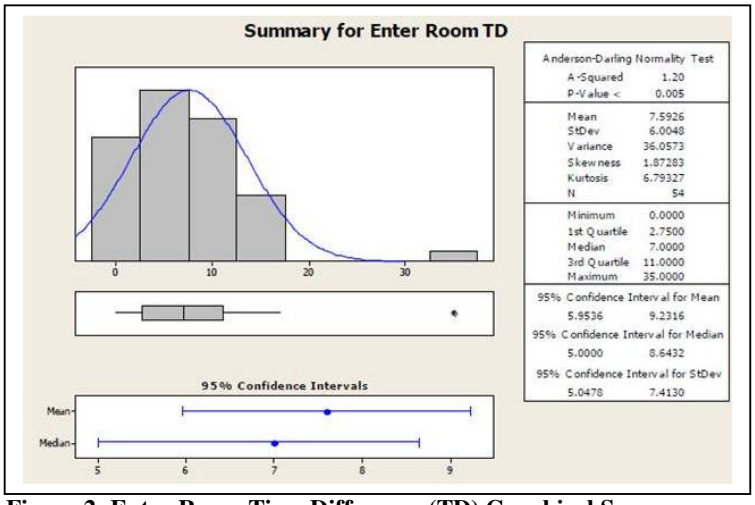

Figure 2: Enter Room Time Difference (TD) Graphical Summary

BENEFITS OF COLLABORATION BETWEEN KETTERING UNIVERSITY & BEAUMONT

Benefits of this partnership between Kettering and Beaumont Hospitals and clinics are numerous: (1) areas for process/business/system optimization were identified, (2) standardized LEAN, high quality, value-added systems and processes are created, developed and implemented with sustainability, (3) technical and Project Management skills such as Design of Experiments studies, critical path analysis, meaningful data collection and management tools have been

incorporated into the culture, (4) streamlined I.T. support services to internal/external customers were developed and appropriate documentation needs were addressed, (5) these processes, systems, tools and skills have been implemented, tested, validated, verified and put in place for everyday use, (6) standard service level agreements and consultation with healthcare providers on best practice recommendations were established, and (7) conduits of communication between technical and clinical staff were also enhanced.

Students realize there is a whole new world of applications for IE's other than Manufacturing. All the principles taught in the IE program can be applied to any industry, and in this case, to healthcare delivery. These principles include (or will be included in the new concentration) VE Structured Thought Process, information gathering, alternative generation (creation), evaluation and presentation of data, value Reference Model (VRM), value stream mapping, material distribution, design of products, services or processes. Research and development of production, marketing and sales, customer service are also part of the skills gained.

CONCLUSION

As illustrated with the summaries and case studies presented, IE principles are well adapted to the healthcare delivery system. The authors have worked together to help assemble the healthcare program for undergraduates. There is a need and an opportunity for universities to produce college graduates with healthcare delivery system experience. Kettering University and Beaumont Hospitals is partnering to provide the resources. These endeavors help establish connections between engineers and clinical practices, familiarize engineers with medical environment, actively involved in on-going research, and actively involve in practical healthcare processes and procedures.

As healthcare continues to evolve and with innovation driving change in today's hospitals, healthcare practitioners together with engineers face unprecedented challenges. Yet despite these challenges, there are opportunities. Professionals from both engineering and medicine need to "break the cycle" and downplay the myth:

Engineering ≠ Healthcare paradox.

There needs to be a cultural change to an acceptance attitude, flexibility and open-mindedness. Now is the time for non-traditional careers for the engineers and acceptance of their services by Healthcare professionals.

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