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The Regenstrief Center for Healthcare Engineering: Designing, Implementing, and Sustaining Interdisciplinary Solutions to Transform Healthcare Delivery Systems

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Abstract: With start-up funding provided by the Regenstrief Foundation, Purdue University has created the Regenstrief Center for Healthcare Engineering (RCHE) to design, implement, and sustain interdisciplinary solutions to improve the safety, quality, efficiency and accessibility of healthcare delivery systems. RCHE's primary goal is to bring a systems-analysis approach to improving the processes of healthcare delivery, not to provide tools or techniques for medical research, diagnosis, or treatment.

This article will describe RCHE's business model; that is, how RCHE "engineers" interdisciplinary solutions, using the multiple perspectives of healthcare and multiple project time scales to organize and leverage healthcare delivery transformation. We then illustrate the model through the description of projects conducted with RCHE's "partnerships" with various healthcare delivery organizations. We conclude with a discussion of future directions for RCHE.

Keywords: Regenstrief Center for Healthcare Engineering (RCHE), interdisciplinary, healthcare delivery, systems analysis, metrics, transformational.

The Regenstrief Center for Healthcare Engineering will catalyze the transformation of health-care delivery systems by applying the principles of engineering, management and science.

1 Introduction

With start-up funding provided by the Regenstrief Foundation, Purdue University created the Regenstrief Center for Healthcare Engineering (RCHE) in 2005 to design, implement, and sustain interdisciplinary solutions to improve the safety, quality, efficiency, and accessibility of healthcare delivery systems.

RCHE's primary goal is to bring a systems-analysis approach to improving the processes of healthcare delivery. While the diagnosis and treatment of patients must remain in the hands of healthcare professionals, the application of engineering, management, and scientific principles has the potential to reshape the healthcare delivery landscape as they have in the automotive, transportation, and retailing sectors. Indeed, healthcare delivery has basically the same goal as these business sectors: to serve their clients' needs rapidly, efficiently, effectively, and safely.

RCHE's position as a "center" within Purdue's Discovery Park facilitates interdisciplinary research and leadership across all 13 colleges. In turn, the Center's partnerships with healthcare organizations such as Indiana University School of Medicine, Ascension Health, St. Vincent Health, the Indiana Hospital&Health Association (IHHA), and the Regenstrief Institute promote collaboration on cutting-edge projects to transformation the delivery of healthcare.

Despite complex issues challenging the healthcare delivery system, RCHE is committed to achieving a future as described in its vision statement, "a transformed delivery system providing services that optimize quality, cost-effectiveness and access for all persons with healthcare needs. RCHE identifies its contribution to the achievement of this future vision in the above mission statement.

2 Background

Samuel (Sam) Nathan Regenstrief was born in Romania in 1910. His family emigrated to the United States when Sam was 9 years old, settling in Indianapolis. Sam began his business career as a time-keeper (Real Silk Hosiery Mills) and a CPA (Spradlin, Carter, and Jordan) before taking over management of Rex Manufacturing, Connersville, Indiana. After Rex Manufacturing was acquired by Philco, Sam was named its president. In 1958, Sam founded the Design & Manufacturing Corporation, which, by the mid-1970's employed 2,000 people and produced 37% of the world's dishwashers.

Recognized as an authority on industrial production techniques, Sam Regenstrief believed that engineering and production concepts applied to healthcare delivery would provide better care at lower cost. In 1967, Sam and Myrtle Regenstrief created the Regenstrief Foundation to pursue this goal, creating the Regenstrief Institute for Healthcare in 1967 in Indianapolis. To complement the Institute's work in healthcare informatics, the Regenstrief Foundation solicited proposals from several universities in 2003 to develop a new research

center that would translate research in these disciplines into recognizable, long-term transformation of healthcare.

Purdue recognized the potential for Discovery Park, its campus of cross-disciplinary research centers, to develop, house, and support such a center. Integrated through Discovery Park and taking advantage of its infrastructure, Purdue offered world-class resources in the areas of engineering, management and science as a complement to medical school-based research at places like RCHE's core partner, Indiana University School of Medicine.

Because of the University's unique resources, leadership commitment, and overall vision, the Regenstrief Foundation awarded financial support for three years to establish the Regenstrief Center for Healthcare Engineering at Purdue University. After three years, the Center is eligible for increased funding in perpetuity (with periodic review), provided that several metrics had been successfully met. These include strong connections with healthcare leaders to create a climate of change and sustain positive momentum in healthcare.

Prior to the Center's official opening in January 2005, seed and core grants were offered to establish the Center's initial research projects. Proposals were reviewed through a competitive process and grants were awarded. These 2005 projects formed the nucleus from which future projects will be developed.

New projects were also generated by strategic partners in the healthcare industry. Initial industry partners, Ascension Health and St. Vincent Health, provided collaboration, funding, and access for Purdue researchers.

3 The Current Status of United States Healthcare

Healthcare is being challenged on its ability to meet public expectation on several fundamental policy issues. There has yet to be an effective response providing solutions to these challenges.

The growth in consumption of resources to provide healthcare services is at a level that defies financial sustainability. Healthcare now consumes an unprecedented amount of resources as measured by the Gross Domestic Product (GDP). This level of resource consumption exceeds the average of G7 countries (Canada, France, Germany, Italy, Japan, United Kingdom and United States).

Paradoxically, the costs of purchasing healthcare services are creating financial barriers to access care. Over 45 million are uninsured (IOM, 2004) and those who have health insurance are paying more in the form of co-payments and deductibles. Populations covered by governmental programs are finding that the failure of Medicare and Medicaid reimbursement to keep pace with the inflation impacting healthcare providers is causing practices to be closed to them.

Adding to the issues of rising costs and reduced access are concerns pertaining to the quality and safety of healthcare services. The 1999 Institute of Medicine report, *To Err Is Human: Building a Safer Health System*, started widespread public discourse on safety in healthcare services. Combined public concerns about healthcare quality, costs and access require solutions in a complex environment that seems to defy effective response. Sources of complexity include:

1 History. Disparate influences such as the strong compassionate roots of healthcare and corporate tax deductibility of health benefits compete for priority.

2 Expectations. Advances in technology inspire hope against medical conditions that have afflicted previous generations.

3 Culture. In the current system, treatment decisions must be made with incomplete understanding of what is needed (e.g. certain kinds of cancer) and sometimes in a time critical setting (e.g. emergency department).

4 Specialization. The ability to deliver effective care requires the implicit interaction of many highly specialized disciplines across the entire healthcare supply chain.

5 Indispensability. Everyone requires at least a certain level of healthcare, which sets a standard of accessibility that few other industries must meet.

6 Dynamics. We live in a world of constantly changing social factors, technology, demographics, and natural challenges (e.g. AIDS, SARS, Avian Flu, etc.)

The growing complexity of the healthcare system has led many to believe that it is the most difficult industry to change.

Amidst these challenges and complexities, RCHE asserts that solutions reside in applying systems analysis and "engineering" improved healthcare delivery systems. By working to integrate multiple perspectives, RCHE can achieve holistic and interdisciplinary solutions and catalyze transformational improvement throughout the healthcare delivery system.

4 RCHE's Business Model for "Engineering" Interdisciplinary Solutions

The Regenstrief Center has been organized based upon key concepts and relationships included in its business model (Figure 1).

4. 1 Partnership with the Healthcare Delivery System

RCHE views healthcare delivery as the result of actions among interdependent parties working together for the ultimate goal of delivering care to those with health needs. These parties are engaged in a range of activities from the production and distribution of goods and services, to the assembly and delivery of healthcare. The model recognizes these interdependencies as a supply chain in the healthcare delivery system. Representation from key portions of the supply chain as partners with RCHE is essential for comprehensive and sustainable solutions.

While the specific nature of each relationship is unique to the partner, RCHE pursues some common goals as it establishes its partnership network.

1 To understand the real world of healthcare delivery as experienced by patients, healthcare professionals, and care-givers. RCHE faculty and students bring a unique perspective — systems analysis — and powerful engineering and management tools to address the problems in healthcare delivery. But first the problems must be understood.

2 To understand healthcare delivery from a systems-oriented, supply-chain perspective. RCHE leadership believes that each "link" in the "chain" of producers and service providers — from medical devices, pharmaceutical manufacturers, and medical schools through distributors, nurses, and physicians — is operating at its best within the current system. Thus, transformative change must begin at the system level in healthcare, as it has in manufacturing and distribution.

3 To form teams with healthcare professionals and develop interdisciplinary solutions. Given its home in a world-class, engineering-oriented university, RCHE can bring a vast array of knowledge and experience to the challenge of improving healthcare delivery. However, in "engineering" solutions, the knowledge and experience of healthcare professionals is essential.

4 To demonstrate improvements in the real world of healthcare delivery. RCHE is committed to identifying real-world problems in healthcare delivery systems and demonstrating results in practice.

5 To share what we learn with others. In line with the mission of Purdue University, RCHE is committed to generating knowledge and sharing it with anyone who seeks it. Our strategic partnerships help us share research knowledge with healthcare professionals.

4.2 Interdisciplinary Collaboration

Within RCHE, interdisciplinary collaboration starts with leadership. The leadership team includes experts in hospital administration, systems engineering, management, public health, and medicine. This diversity translates into strong networks with the healthcare delivery system and a strong potential for innovation.

Interdisciplinary collaboration extends beyond the Center's leadership to include researchers and graduate students throughout Purdue. Consistent with the fundamental philosophy of Discovery Park at Purdue University, RCHE draws upon an extensive depth of talent to provide a holistic systems approach to healthcare delivery research.

Interdisciplinary collaboration within Purdue is reinforced by its president, Martin Jischke who serves as RCHE's Principal Investigator, sending a strong message about his commitment to the success of the Center's mission.

4.3 Project Identification and Development

RCHE is designed to contribute a unique and rapidly evolving perspective on healthcare delivery through collaborative engagement of the healthcare system and RCHE's interdisciplinary research faculty. The basic unit of activity within RCHE is the project, which includes a set of specific goals, a project team, and a funding source. The majority of RCHE projects are identified and developed in conjunction with a partner. This partner then provides a "living laboratory" for collaboration and testing of research outcomes.

A complementary, but alternative approach to developing projects comes from the perspectives of the RCHE faculty who may see opportunities based upon their expertise in other industries or environments. In this alternative approach to project identification, Purdue faculty may develop and present project proposals for RCHE support. RCHE receives and evaluates the proposed projects based on their individual merits and their contribution to the RCHE portfolio.

Project proposals may address any topic that can catalyze improvement in healthcare, but each project proposal must be submitted by a multi-disciplinary team, must involve or agree to be matched to a strategic healthcare delivery partner, and must have the potential to be funded and scaled up by external entities.

Project development and implementation are supported within the RCHE model by a variety of standard activities.

1 Professional staff, RCHE leadership, and various subsets of project leadership meet weekly at a 1-2 hour operations meeting where project key points and fast- moving opportunities are discussed and developed. Participants in the weekly meeting are known as the RCHE operations team.

2 A group of campus and academic unit leaders as well as a subset of the operations team meets biweekly to develop opportunities, provide a multi-discipline network to new internal and external contacts, and help set RCHE's strategic direction.

3 Each project team is assigned a member of RCHE's executive team to facilitate project effectiveness and serve as an external resource.

4 In addition to regular project team interactions, RCHE meets quarterly with its partners to review projects as a portfolio and make connections among active projects and support the overall effectiveness of RCHE.

Project funding is derived from three sources. RCHE has some limited ability to nurture small projects with strong potential for improving the health delivery system. These funds are awarded competitively and intended to be seed funding. Researchers are expected to develop their projects with seed funds to the point that the project can be sustained with external funding. Projects typically are funded through an external entity. These entities include foundations and governmental grants. External funds may also be available from partners who are interested in collaborative projects with RCHE and willing to fund projects in which they have interest.

4.4 Project Implementation

RCHE pursues three general types of projects, each of which yield multiple types of findings that are implemented to improve processes for healthcare delivery. These three general types of projects include Healthcare Technical Assistance Program, research, and knowledge development, which result from structured interaction among RCHE and its strategic partners.

4.4.1 Healthcare Technical Assistance Program (TAP)

The mission of the Healthcare Technical Assistance Program is to design, implement and sustain short-term interdisciplinary solutions to transform healthcare delivery systems. Established in May 2005 through the strategic partnership with the Indiana Hospital&Health Association (IHHA), Healthcare TAP has worked with 15 Indiana hospitals on 24 training projects. Eighteen Purdue faculty, graduate students, and professional staff have participated. Schools represented include Pharmacy Practice, Nursing, Industrial Engineering, and Organizational Leadership and Supervision.

Interdisciplinary teams have completed projects in facilities planning, patient flow, continuous improvement methodologies, process improvements in registration and other departments, med safety, and scheduling. Healthcare TAP projects typically require a day to a couple of weeks to complete.

Although not foreseen at the founding of RCHE, Healthcare TAP has developed into a strategic program, helping RCHE connect with healthcare organizations and providing healthcare experience to researchers who have non-healthcare backgrounds. Furthermore, Healthcare TAP establishes partnerships with practitioners to quickly translate research results into practice.

4.4.2 RCHE research

The research program and implementation of research findings is RCHE's core activity. Through a systems-oriented approach, RCHE believes that transformation of the healthcare delivery system will occur. The broad objectives for RCHE's research are to achieve the characteristics of a transformed healthcare delivery system as conceptualized by the Institute of Medicine, a system that is safe, effective, patient-centered, timely, efficient, and equitable (IOM, 2001).

4.4.3 Knowledge development

RCHE uses the construct of a supply chain to view the healthcare delivery system and the interdependencies of the participants in this system. Implicit in this construct is the premise that new relationships within the supply chain are necessary for the highest level of system transformation. RCHE will catalyze the development of new knowledge pertaining to adaptive relationships among stakeholders in the healthcare supply chain. RCHE's research, coupled with Purdue University providing a neutral forum for collaboration, will enable strategic partners to work together to improve functional aspects of their interdependencies upon each other as parties in the healthcare supply chain. This setting provides a valued opportunity for participatory research across the entire healthcare supply chain, leveraging the strategic partners' investments while mitigating their risks. It also allows for larger variety and scope of projects than would be possible by these same healthcare organizations acting alone.

4.5 Evaluation of Demonstrable Improvement

The fundamental measure of the success of the RCHE business model will be the demonstrable improvements in healthcare delivery resulting from collaborative efforts with partners. RCHE places emphasis upon the evaluation of its work in the context of demonstrated improvements. As a result, RCHE expects the variation in operations across institutions to cause site specific modifications for the successful implementation of research findings. RCHE will document these conclusions to assist in research application and resulting system improvement.

4.6 Knowledge Dissemination

The commitment to improve healthcare delivery requires the public dissemination of research findings and their effect on transforming the healthcare system. RCHE absolutely respects any proprietary information associated with a partner and will not disseminate information that would compromise a partner. This commitment has not limited the ability to disseminate useful

information having general impact upon healthcare delivery improvements. The conduct of research projects as well as the dissemination of research findings is based upon the principle of collaboration. By seeking partners' input into information dissemination, RCHE has not found that proprietary concerns have limited the ability to disseminate information to groups that could benefit from its research. RCHE views the publishing of academic papers in refereed journals to be of particular importance as it helps reinforce research rigor and builds upon the knowledge advancing healthcare delivery and the practice of healthcare engineering.

The RCHE model views the processes of project identification, development and implementation as providing a forum for constant interaction for people from multiple disciplines who would not normally meet, and do so in a way that keeps the meeting burden low on individual research participants. The primary benefit is the ability to create interdisciplinary collaboration among the healthcare supply chain and RCHE faculty in a process oriented to demonstrate improvement in the healthcare delivery system.

5 A Portfolio Approach to Transformational Change

The RCHE model has been designed to provide interventions to improve the healthcare delivery process from a variety of stakeholder perspectives and multiple time parameters (Figure 2). The parameters of perspective and time combine to strategically organize RCHE's work for rapid and effective system transformation. Using stakeholder perspectives to organize RCHE's work recognizes the need to understand these perspectives and enables RCHE to build necessary collaborations and consensus to implement findings. Projects organized by time parameters allow the ability to build research upon findings of successive scale and importance.

The short alpha-numeric codes in Figure 2 indicate individual RCHE research projects as of mid-2005 and the skewing of the project portfolio towards short-term projects. This represents RCHE's startup strategy to strongly engage partners. Over time this diagram is expected to be uniformly distributed in the subject areas and across time.

5.1 A Variety of Stakeholder Perspectives

The following examples of RCHE's projects addressing the perspectives of major stakeholders within the healthcare system illustrate progress to-date in building a portfolio to enable system transformation.

5.1.1 Patient perspective

A systems approach can help maximize the benefits an individual patient receives from the healthcare system by identifying the behaviors, skills, resources and capabilities necessary to successfully engage with the system.

As an example, in 2005 RCHE participated in the re-branding process of a local mental health clinic concerned with the stigma of mental health limiting access to their services. Specifically, the clinic wanted to ensure that consumers would react positively to the new brand. A team of RCHE researchers assembled to examine possible stigmas of mental illness and produce favorable responses through the new brand. The team included expertise in brand auditing, consumer behavior, and development of communications in the context of stigma.

Focus groups and interviews with clinic stakeholders (i.e., patients, families, general public, staff and management) revealed that while stigma was present among all groups, it decreased when familiarity with mental illness increased. Marketing consultants use the team's findings to create a successful roll-out campaign under the new name. The re-branding of the mental health clinic, and subsequent reduction of public sigma surrounding mental health services, has improved access and utilization of a critical community service.

5.1.2 Healthcare provider perspective

The Indiana University School of Medicine, its associated healthcare facilities, and the Indiana University Medical Group have become core partners in RCHE research. Due to their size and predisposition to healthcare engineering, several projects have been undertaken. Their prominence in healthcare attracts attention to these projects and provides opinion leadership in other healthcare organizations. Some of the projects involving these partners include the following.

1 Physician-assisted three-dimensional content-based image retrieval for medical diagnosis. Content-based image retrieval (CBIR) is based on the premise that patients with visually similar scans are afflicted by the same disease. While two dimensional scans have been sufficient for emphysema-type diseases of the lung, this is not expected to be the case for other diseases. In collaboration with a local radiologist, an RCHE team developed a three dimensional CBIR system that results in double the diagnostic accuracy, according to a clinical evaluation.

2 Patient-flow and scheduling process. Key insights from Factory Physics and Six Sigma principles in the improvement of manufacturing processes were used by an RCHE team to analyze and improve patient flow at an outpatient clinic. An animated simulation model of the patient flow process was developed, validated and used to test various potential improvements and develop an optimal system configuration. The overall results were a significant reduction in both the mean and the standard deviation of patient wait times, higher utilization of physicians' time, and increases in clinic utilization. Physicians and staff were highly supportive and receptive to the principles and tools used.

3 Provider-centered resource foraging. This project aimed to develop the capacity to model task- and information-flow factors between providers that affect productivity in healthcare delivery. Such modeling explores how physicians, nurses, and medical or clerical assistants manage the tasks associated with patient care, and provides for improved taxonomies and descriptions of resource access, sharing and use in the healthcare setting. The pilot phase has focused on outpatient clinic care, but has direct potential to address team-level coordination across healthcare settings.

4 Electronic medical records. RCHE has engaged other partners in provider-based research, including a current project examining the impact of an electronic medical record system in emergency rooms on efficiency and safety, specifically in the initial screening of patients by triage nurses and physicians in the ER. The research aims to determine whether availability and retrieval of a patient's electronic medication history translates into reduced screening time in the ER, reduced in-patient medication errors, and improvement of pharmacy reconciliations.

5.1.3 Healthcare organization perspective

Ascension Health and their largest ministry, St. Vincent Health (located in Indiana), are an excellent example of the ability to explore how research findings can be deployed in large healthcare organizations. Ascension Health (AH) is the nation's largest nonprofit healthcare system and has 67 hospital ministries. St. Vincent Health (SVH) includes a state network of 16 hospital ministries serving 45 of Indiana's counties. Driven by Catholic healthcare values, these strategic partners are outstanding collaborators and sponsors of RCHE. Initial research with AH/SVH has enabled significant progress on the following projects.

1 Operating room design and functionality. RCHE researchers analyzed sterilization and case cart preparation processes, which handle all sterilization, assembly and delivery of surgical instruments and supplies. After completing a detailed study of current processes through observations, interviews and documentation of cycle times, the team developed a simulation model incorporating equipment, staffing schedules and operational logic. Outcomes included identification of process bottlenecks, verification of proposed equipment configurations to handle workload, and prediction of queuing patterns in the system.

2 Evaluation of nursing work with the intent to increase caregiver time at the bedside. This study captures time (and type of effort) spent on documentation, sampling of tasks performed, tracking of motion through the unit, and physiological variables. With this data, it will be possible to evaluate the impact of different unit layouts, policies, and procedures on nursing workload, with the goal of improved healthcare, higher job satisfaction, and more effective use of skilled healthcare professionals.

3 Cost-effective supply chain strategies. With the intent to improve material management, this project looks at opportunities within healthcare organizations and between the organization and their external supply distributors. Comparisons between healthcare and several Fortune 500 companies' practices have identified opportunities for improvement.

4 Development, implementation and evaluation of telehome care services for patients with chronic heart disease failure. Major goals include improving the quality of care, reducing the length of stay and re-admissions, and developing a business case for further telehome care development.

5.1.4 Healthcare policy perspective

Policy formation also benefits from a systems-wide perspective. Multiple participants in policy discussions can improve content and assessment of options available in policy formation. However, the very nature of differences in perspectives makes it difficult to develop consensus and effective policy. In May 2006, RCHE will host a Healthcare Summit at Purdue University. Participants will include leadership in government, healthcare providers and large US businesses. The intent of this summit is to develop characteristics of a new, more functional healthcare system and to evaluate techniques to solicit information and to formulate effective input to the development of healthcare policy.

5.1.5 Healthcare supply chain perspective

In addition to addressing the perspectives representing specific segments of the supply chain, systems analyses need to focus on the interaction of these segments. Examples include supply chain research and systems training in process improvement techniques to improve interaction between segments.

1 Supply chain research. Many companies in the healthcare sector, including integrated care delivery networks as well as their distributors, suppliers and other supply chain partners are actively seeking ways in which to reorient the healthcare supply chain. However, the size and complexity of these systems, as well as the diversity of operations even within the same healthcare network rend this task difficult. To understand the implications of change on the system, it is important to consider the significant portions of the supply chain as a whole rather than implementing local solutions at individual facilities or firms.

One current project aims to determine the ability of mathematical modeling tools, similar to those that have been employed successfully in other supply chains, to provide insight into the operations of these complex systems and ultimately improve performance. Specifically, the project aims to develop network design models that can allow decision makers to estimate the financial consequences of opening or consolidating distribution centers, or changing distribution arrangements with service providers.

2 Lean Six Sigma. RCHE also provides Lean Six Sigma training to assist healthcare professionals with improving supply chain performance. As a part of training, Greater Lafayette Health Services assembled an internal improvement group to improve supply management and decrease unnecessary inventory, unidentified and hidden costs, loss of staff time, loss of revenues and loss of charges. The team developed a process map to identify opportunities for delays and improvements, and is now implementing pilot improvement strategies, such as color-coding of supply room bins to identify groups of supplies.

5.1.6 Creating Processes to Span Individual Perspectives

Under the auspice of the Indiana Hospital&Health Association (IHHA), an early strategic partner, RCHE is undertaking a project of significant importance and scope. The formation of the Indiana Center for Patient Safety (ICPS) incorporates all of the above perspectives and requires broad based support to collect, analyze and act upon patient safety information provided by IHHA members. The credibility of IHHA to its members and state government enables them to provide effective leadership in this unique approach to state patient safety programs.

The Indiana Center for Patient Safety was formed as a not-for-profit corporation through a partnership of the Indiana Hospital&Health Association, Indiana University School of Medicine, Indiana State Medical Association, Healthcare Excel, and Purdue University. The mission of the ICPS is to facilitate the development of safe and reliable healthcare systems that prevent harm to patients. Although carrying a similar mission as the 25 existing state patient safety centers in the United States, the ICPS integrates clinical and process research to target root causes that are beyond the reach of individual healthcare organizations. It is the only known state patient safety center that will have the depth of expertise and analytic capacity associated with two major universities. The ICPS will play a national leadership role by disseminating best practices, developing cooperative activities with national manufacturers and suppliers, and serving as a nexus for other patient safety organizations.

5.2 Multiple Time Parameters

The examples above illustrate how RCHE organizes its work using important stakeholder perspectives across the healthcare system. The organization of RCHE's research is also dependent upon the time parameter of the project. This orientation has been strategically effective in engaging partners during RCHE's first year of operation. This organizational approach has also been effective in creating interest and participation by Purdue University faculty in RCHE activities. An additional benefit of organizing research projects as short-term, medium-term, and long-term is the ability to build more substantive research upon early findings, thus leveraging research results.

5.2.1 Short-term projects

RCHE's short-term efforts engage interdisciplinary research teams to develop short-term solutions in clinical settings. These projects are particularly useful for introducing team members without healthcare background to the research possibilities within the healthcare setting. A key goal of short-term efforts is to establish ongoing mechanisms to drive research with a variety of clinical experience.

Healthcare Technical Assistance Program (TAP) facilitates the majority of RCHE's short-term projects. Results to date have been impressive. A productivity project for the toxicology lab of Witham Hospital has resulted in significant improvements and the development of plans for further progress. A facility planning project for a new obstetrics wing at King's Daughter's Hospital has been used to finalize plans that will significantly improve patient care, safety, and privacy. A simulation analysis of the emergency department at a St. Vincent hospital is being used to decrease the patient to physician time to a very short period. A list of Healthcare TAP projects that have been completed three months or earlier from the current date may be found at http://www.purdue.edu/rche.

5.2.2 Medium-term projects

RCHE utilizes the traditional masters and doctoral degree programs and post-doctoral and professional research programs of its diverse faculty members to encourage innovation on problems that are abstracted from recurring short-term challenges. RCHE strategic partners play an important role in longer-term research and often contribute to directing research to relevant and substantive problems. RCHE infrastructure and living laboratories are used to encourage translation of research to practice.

One such example is the patient-centered, facility design project. The goal of this project is to identify and leverage new evidence-based design principles and best practices in the development of patient-centered environments to improve patient satisfaction and safety.

The first phase of the project involved a current state analysis of a care environment, working with Ascension Health, one of RCHE's strategic partners, to a) identify high impact elements for patient safety in patient rooms, b) document a cross-comparison and validation of architectural design principles from key journals with AH-identified design criteria/goals; c) summarize current knowledge in patient-centered design for dissemination; and d) create a database of evidence-based literature for current "best practices" in psychology, nursing, architecture, interior design, engineering and business/management.

The team then worked to develop a photo-realistic three-dimensional model of a patient room using Virtual Reality Systems, allowing the user to navigate through, interact with and

customize room elements such as lighting, color, furniture layout and noise levels. Physiological and psychological data from the user can determine the impact of the environment on the patient.

The first phase of this project uncovered a number of design research opportunities, both to improve the current state of patient rooms and to design layout of future rooms. Future studies will include the return on investment for installing safe patient handling infrastructure and training of healthcare staff in high-risk units in nursing homes or hospitals where the majority of back injuries occur. In addition, the team will continue to improve Virtual Reality applications for patient-centered design.

5.2.3 Long- term projects

Education is a powerful catalyst for long term, transformational change in healthcare delivery. For this reason, RCHE is creating multidisciplinary educational programs aimed at developing current and future professionals with strong systems- analysis skills. RCHE supports the development of two multidisciplinary training programs at Purdue University, each offering substantial promise to provide new leadership in healthcare. These new leaders will receive training in systems analysis and will develop skills in effective multidisciplinary teamwork.

5.2.3.4 Healthcare engineering signature area

Purdue University's College of Engineering, which is composed of 12 schools ranging from Aeronautics and Astronautics Engineering to Nuclear Engineering, recently announced the creation of a healthcare engineering "signature area."

The vision is to improve healthcare delivery processes and to engineer systems that support and empower them. Faculty recruited within this new signature area will be positioned to pioneer processes and systems that can transform the present state of healthcare operations and to educate the professionals needed to sustain a revolution. This signature area will evolve as it matures, but many areas of concentration can already be identified:

1 Operations Management. Many of the inefficiencies and safety/quality hazards of current healthcare systems demand re-engineering of ongoing delivery operations at all levels including process flows; capacity management, equipment and materials supply chains, staffing and scheduling, and quality assurance. But progress also depends on enhanced sensing, communication, condition monitoring and information tools.

2 Building and Facility Design. There is a growing opportunity to focus facilities research on efficient arrangement for staff interactions with patients, energy efficiency and flexibility for changing demands and patient loading.

3 Clinical Environmental Management. Healthcare engineering can build environmental management technologies to fully control viruses and bacteria that can lead to patient infections in clinical environments.

4 Medical Imaging. Continuing improvement in power and cost of medical imaging require attention to delivery throughput, sharpened resolution, laser-based patient positioning, biological/chemical markers, and autonomous image interpretation.

5 Pharmaceuticals. Advances in pharmaceutical care require a combination of pharmaceutical delivery technology with sensor and controls to assure patients receive safe doses of the intended medications.

6 Clinical Decision Support. Most of the technological tools of healthcare require enabling decision support software in order for clinicians to use them effectively.

7 Distance Health**.** Among the best ways to improve healthcare quality, reduce costs, and address shortages in many healthcare professions – particularly outside metropolitan areas – is to find ways to support safe monitoring and treatment in patient homes and rural clinics by clinician professionals physically located far away.

8 Patient Informatics. An element of a transformed healthcare system is seamless and efficient electronic patient records with fully adequate protection for patient privacy and sharing among treatment providers.

9 Assisted Mobility**.** Research on prosthetics, advanced wheelchairs, exoskeletons, robotics, and autonomous vehicles can play a crucial role in improving healthcare delivery and staff/patient safety while reducing costs.

10 Perception-Based Engineering. Perception-based engineering assists in the optimal design for the human-interface aspects of machines and environments in engineered healthcare systems.

5.2.3.2 Doctorate of Nursing Practice (DNP) Program

Purdue University's School of Nursing has developed a Doctor of Nursing Practice (DNP) program to deliver an innovative curriculum from post-baccalaureate to doctorate, emphasizing healthcare engineering and interdisciplinary collaboration among faculty, hospitals, community leaders, and policy makers (Wall, Novak & Wilkerson, 2005).

During the past several years, there has been an increased interest in developing a viable alternative to the research-focused degrees of Doctor of Philosophy (Ph.D.) and Doctor of Nursing Science (DNS, DNSc). The Doctor of Nursing Practice presents students with a degree centered on evidence-based practice.

Collaboration with other disciplines that are not commonly considered by nursing is one of the keys in the design of Purdue's DNP program. In particular, the School of Nursing is partnering with RCHE, Purdue's Homeland Security Institute, the Center on Aging and the Life Course, the Schools of Pharmacy and Management, and the College of Engineering in order to apply expertise from several disciplines to improve the delivery of healthcare.

The DNP program is designed to allow for three types of prospective students: post-baccalaureate RN, students currently pursuing a master's degree in nursing, and advanced-practice nurses who have completed their master's degree. Students are required to complete 83 post-baccalaureate credit hours of coursework, including over 1,500 hours of supervised clinical practice, a health-policy residency, and cognate residencies in an area of specialization. The following seven core competencies recommended by the American Association of Colleges of Nursing are incorporated into the curriculum: scientific basis for practice; advanced nursing practice; organization and systems leadership, and quality improvement; analytic methods for implementation and evaluation of evidence-based practice; information technology use in

healthcare delivery systems; development, implementation, and evaluation of health policy; and interdisciplinary collaborative practice models to improve client outcomes.

In addition to training new leaders for healthcare, RCHE has embarked on several long term research efforts that aim to adapt approaches from other industries to healthcare delivery. One common thread underlying these projects is the development of new information sources to support transformational change and promote the dissemination of information by focusing on how healthcare processes must adapt to make the best use of information.

1 Patient flow at St. Vincent's Birmingham. Working with locational software, St. Vincent's goal was to make the hospital patient flow transparent to doctors, nurses, administrators, and other staff. Digital displays are coupled with radio frequency identification and other sensor and data entry technologies to provide real-time patient tracking and bed allocation information at a glance. Departmental state sequences or "traces" are automatically saved to one or more databases as patients are admitted, discharged, and transported throughout the system. Ascension Health is now discussing pilot projects to implement these concepts at other Ascension ministries.

As part of this project, RCHE researchers will develop methods that use system information from state transparency technologies to help decision-makers more effectively manage patient flow and resource allocation. The first phase will include analysis of system traces, and the second phase will involve a broader study to identify additional relationships and dependencies between system dynamics as captured through trace data, system performance measures, and patient care and satisfaction. The final goal is a decision-support system that helps managers optimize system and patient performance measures by issuing alerts and making evidence-based recommendations using (a) the current hospital state and (b) the flow relationships and dependencies identified from the trace data.

2 Surgical robotics. Other long term projects include ongoing innovations in technologies that have not been advanced through typical technology development processes. Medical technology is a central part of healthcare delivery, enabling advanced diagnostics and treatment alternatives that improve patient outcomes. Often, these sophisticated systems introduce challenges as well: safety hazards can arise due to the complex interactions in the healthcare environment; clinical specialists must have training in technology as well as medicine; and the costs of these devices are ever increasing. To transform healthcare delivery, RCHE researchers are developing long-term guidelines to mitigate these complications for next generation medical devices.

A special emphasis will focus on design specifications for surgical robotic systems. These complex, electromechanical devices have the potential to transform the way surgery is performed, allowing surgeons to dexterously manipulate internal tissues through small incisions using computer controlled instruments. By bringing a computer "in the loop," advanced control algorithms can guide the surgeon's hand during intricate motions and avoid delicate tissues. Virtual training simulators and tele-mentoring will allow doctors to be properly certified and develop new procedures on computer generated patients. Ultimately, the rich information in three-dimensional medical image data will be combined with the precision and accuracy of the robot enabling an unprecedented level of treatment.

The field of surgical robotics is still in its infancy and proposes many challenges. While first generation robots in use today have demonstrated potential, they are expensive, large, and require extensive technical knowledge. In addition, the surgeon is removed from the patient with

no tactile feedback and the robotic mechanisms dominate the sterile field. Research is needed to ensure the added complexity does not introduce more hazards than benefits. A long-term focus will help us understand how the power of computer processing and system engineering can increase safety and efficiency.

6 Future Directions for the Regenstrief Center for Healthcare Engineering

The Regenstrief Center for Healthcare Engineering has learned much from its first year of research and partnerships. The conceptual framework provided by the RCHE model has been very effective with almost no apparent need to fundamentally change the basic tenets.

There have been operational issues and new opportunities for research that suggest RCHE's future directions. The interdisciplinary focus on the complex problems in healthcare is absolutely essential. While theoretical approaches to problems may be addressed by the perspective of a single discipline, implementation of tentative solutions and demonstrable improvements almost always require interdisciplinary coordination and typically represent the most difficult aspect of the projects. During RCHE's first year there has been an increase in the number of disciplines that have found robust academic material. By the end of the second year of operation, it is highly probable that RCHE will have active faculty from every college at Purdue University.

The interdisciplinary nature of RCHE's research will require increasing amounts of time to manage and coordinate interdisciplinary research teams. RCHE is developing internal processes to increase coordination across disciplines. It has become apparent that interaction among discipline-based researchers develops appreciation for the theoretical constructs of different disciplines, methodological synergies, and differences in technical language. It will take time to transition from an academic discipline-centric approach to a true interdisciplinary approach.

Partnerships are also essential. Healthcare systems are deceptively complex and knowledgeable people from those systems are necessary to assist in the identification of relevant work, participate in research, and provide leadership in the implementation of research findings.

RCHE will pursue additional strategic partners as representatives from a wider range of the healthcare supply chain. As these partnerships are established, RCHE will experience an increase in the scope of possible and/or expected research projects. Partnerships also enable research on the inter-relationships among participants in the supply chain, where there may be the greatest unrealized potential to improve the delivery system. These types of developments will continually raise the need for RCHE to be introspective about its scope of research and where there is greatest value for improvement in healthcare delivery.

RCHE has found that there are important differences between academic and healthcare organizations' cultures. Research projects tend to highlight these differences and may cause difficulties during projects. The challenge is to recognize the differences and understand how these differences enhance RCHE's research.

RCHE is very enthusiastic about beginning efforts to provide interdisciplinary training for tomorrow's healthcare leaders through the doctorate in nursing practice and engineering signature programs. The number of professions involved in these interdisciplinary training programs should expand to include physicians, pharmacists and health administrators. The

potential contribution of interdisciplinary training is the ability to teach systems analysis and improving inter-profession teamwork.

The role of the Healthcare Technical Assistance Program (TAP) is also expanding. Healthcare TAP will be able to translate complicated research finding into practice, and will also have an important role in the Indiana Patient Safety Center as a research translation agent. The Indiana Patient Safety Center will collect and analyze patient safety information. Advancement in safe practices will be dependent upon these research findings being implemented. Existing data suggests that the majority of safety improvement findings will occur in the areas of systems improvement. The technical assistance provided by Healthcare TAP will be an important differentiating characteristic of this state patient safety center.

Long-term transformation will rest on the Center's ability to promote the integration of engineering, science, and management expertise among Purdue's 13 colleges and 1,800 faculty. Modern technology, such as the internet and email, allows for rapid dissemination of information among students, researchers and practitioners. The true challenge is to facilitate effective interdisciplinary research and collaboration with healthcare organizations which results in cross-cultural experiences generating demonstrable improvements in healthcare delivery.

Purdue has embraced Sam Regenstrief's desire to improve and transform healthcare delivery. By tapping into the creativity and ingenuity of faculty and students, The Regenstrief Center will provide significant improvements to current healthcare delivery problems in the short term. The Center's long-term goal, is to fully realize the Mr. Regenstrief's vision of sustained improvements in healthcare efficiency, quality and accessibility.

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