Appendix: Health Care Systems

> The provision of high-quality health care in the United States and globally will challenge financial, technical, and human resources in unprecedented ways over the next three decades. The cost to the U.S. economy is expected to double by 2015, approaching 20% of GDP (Borger et al., 2008). *
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> * First two sentences of "Envisioning the Health Care Initiative at Lehigh"

The financial, technical and human resource challenges pointed out by the white paper result *primarily* from the size, complexity, and "high-tech" nature of the health care system. This complexity is evident at any scale of the health care system—globally, nationally, regionally, in the insurance industry or within a single hospital or clinic—and in every aspect—health care delivery, disease diagnosis, goods and services distribution, drug and device development, and so on. For the health care system to function efficiently and effectively, researchers, planners, legislators and practitioners must take a systems approach, thinking about the system's multiple disciplines, functions, and modes as a whole rather than as individual components.

Industries and fields with similar levels of complexity such as communications, automobile manufacturing, financial services, transportation and logistics and the military have all benefited enormously from the systems approach and systems engineering research over the past decades. More recently, interest in, and funding for research in health care systems has exploded. For example, at the most recent INFORMS (Institute for Operations Research and Management Science) 2008 annual conference, 62 independent sessions were devoted to systems research in health care. "Improving health care with whole systems thinking and simulation" is the cover title of the December 2008 issue of the "Industrial Engineer" magazine, the popular press publication of the Institute of Industrial Engineers.

This appendix is intended to add a systems perspective to the perspectives on the Health Care Initiative already represented in the main document. Systems research and analysis will play a key role in the future evolution of health. Further, Lehigh University is in a good position to contribute significantly to this effort. By incorporating a systems approach to health care, the HCI will include a broad range of disciplines from all four colleges, encourage interdisciplinary collaboration, and avoid reinforcing functional "silos" within the university. In addition to the many departments and centers at Lehigh that study and teach the individual components of health care systems (biology, chemistry, economics, electrical engineering etc.), many groups at Lehigh routinely deal with the design, analysis, and management of large-scale and/or complex systems themselves. These include departments, such as Industrial and Systems Engineering, Economics, Finance, Management, Mathematics, Civil Engineering, Computer Science, and others, and Centers, such as the Center for Value Chain Research, the Enterprise Systems Center, the Energy Research Center, ATLSS, the Martindale Center, the Center for Social Research, and others.

We believe that both themes discussed in the main document can benefit from a systems approach. However, many important areas of Health Care Systems research do not fit neatly into either of the two themes. Thus we propose a third theme "Health Care Systems". We further explain and illustrate this theme with examples in the sections that follow.

Research in health care systems can be broken down into the following three main areas:

1) Health care operations; 2) Health care policy; and 3) Health care treatment.

Health Care Operations

Clinics, hospitals, hospital networks, logistics networks supplying hospitals, pharmaceutical manufacturers, and health insurance providers are but a few examples of entities that provide key goods and services with in the health care system. It is crucial that the operations of these entities be conducted in an efficient, effective, and cost conscious manner. Examples of research in this area include:

- *Optimization of health-care operations:* The single biggest issue in the health care field is probably the exploding cost of health care delivery. While much of the problem is driven by baby boomer demographics and high costs associated with advanced technology and the growing complexity of health care systems, there remain myriad unanswered research questions in health care systems operations that can help decrease costs, streamline operations, improve the quality of care, and design information, logistics, and planning systems to handle the growing demands that patients place on the increasingly complex health care system throughout the life course.
- *Information technology integration:* The healthcare sector is comprised of complex (and frequently changing) data management requirements. The growth and development of Enterprise Resource Planning tools and industry-specific technology applications have not specifically addressed the needs of the health-care industry as completely as those of other sectors. As a result, the integration of technology is characterized by a limited number of applications, often requiring complex customization and on-going updates/maintenance. In addition, the healthcare world continues to operate in a paper environment, with forms completed by hand and keyed manually into multiple systems. Huge improvements are possible in this arena, but current practices are entrenched. Solving these problems will require the contributions of computer scientists, economists, and data-management specialists.
- *Health care insurance operations:* Operational issues in the insurance industry include developing methods to detect redundant and fraudulent claims, and pricing problems, both pricing of policies and reimbursement for treatments. Dealing with these challenges require the design and maintenance of on-line information systems, designing and installing security systems that ensure security and address privacy concerns and regulations. Solving these problems require research and path-breaking advances in computer science, information systems, cryptography, accounting, statistics, data mining and data classification, optimization and high performance computing.
- *Real-time system optimization and stakeholder acceptance:* Hospitals and other health-care delivery institutions are complex systems that must make instantaneous decisions using real-time input. Most normative models use static snapshots and may not be effective in real-time settings. In addition, stakeholders often do not buy in to new procedures or rules. For example, mathematical optimization tools have been applied to operating-room scheduling, but physicians do not always accept the new schedules; those who do not may force suboptimal rescheduling or may even open stand-alone surgical centers and therefore act as direct competitors. Psychology, sociology, engineering, economics, finance, and other fields will all be able to contribute to this research topic.

Health Care Policy

Health care policy issues are many and widely varied. They vary from local issues (for example the viability and effectiveness of a needle exchange program) to fundamentally important national issues (for example the most efficient and cost effective system to provide health insurance coverage to the citizenry). Examples of health care policy issues that require a systems view include:

- *Regulatory compliance:* Due to the mix of private pay and insurance, compliance with ever-changing regulatory requirements is key to the long-term success of the U.S. health-care system. Organizations face constant policy and process revisions to meet compliance requirements. The ability to monitor and respond to such changes is key to success and a critical component of an organization's ability to continue to deliver care while remaining profitable. Meeting these challenges will require research by legal scholars, policy experts, IT engineers, and business process specialists.
- *Risk of pandemic:* The globalization of corporations and reductions in the cost of global travel have "flattened" the world but have also left it more vulnerable to the rapid spread of diseases such as flu, as well as to man-made health disasters from bioterrorism. To mitigate these threats, and to counter them when they are realized, requires the dedication of enormous resources from governments, NGOs, aid organizations, and private enterprises. Systems analysis can address important research questions regarding the allocation, deployment, and effectiveness of these resources. For example, logistics models can determine the optimal pre-positioning of emergency supplies; economics models can analyze social and financial tradeoffs; biological models can simulate the spread of disease throughout the global population; and so on.
- *Food security:* The global food distribution system is enormously complex, critical to the survival of millions of people, and, at the same time, underfunded. The goal of the global food system is food security, which, according to the U.N. Food and Agriculture Organization, "exists when all people, at all times, have access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life." To ensure food security, planners must draw on diverse expertise from policy experts, economists, engineers, public health workers, medical practitioners, logistics providers, the military, and others. Important research questions include: how to identify and mitigate threats from malicious actors; how to distribute food and supplies to remote regions; how to finance farming operations during the current credit crisis; how to reduce the dependence of the food infrastructure on fossil fuels; and how to ensure equitable distribution across and within communities.
- *Organ Transplant distribution:* As organs become available for transplantation, a match must be made to a patient waiting for a transplant. The policy for making this assignment is a complex decision procedure based on many variables including the biological suitability (e.g. blood type), the criticality of the patient, the proximity of the patient and organ, and complex objectives seeking to maximize patient well being and some measure of fairness.

Health Care Systems: Treatment

Treatment technology in health care continues to advance at a rapid rate. Many treatment methods themselves pose complex systems problems the solution of which has the potential to greatly increase the effectiveness of the treatments. Examples include the following:

- *Treatment optimization:* The most transparent example of this area is radiation therapy treatment. Effective treatment of cancer requires patient examination, image processing and analysis, data mining and processing, and therapy calibration and implementation. These diverse components must be performed in concert in order to maximize the effectiveness of the treatment. Based on advances in medical physics, quantitative tools such as data mining, image processing, image registration, and mathematical optimization have begun to automate these components and streamline their coordination, enhancing patient care while optimally utilizing scarce M.D. and staff time. The availability of Intensity Modulated Radiation Therapy and the emerging area of Image Guided Radiation Therapy methodologies offer exiting multidisciplinary research opportunities for physics, mathematics, statistics, operations research, biochemistry, signal processing, medical and computational sciences.

- *Screening procedures and polices:* Screening for various conditions is important for patient well being and also impacts system costs. Screening procedures are often complex, involving many steps, and requiring many decisions. For example, at what age should patients start being screened, and how frequently should the screening be done? Given various screening test options with differing levels of effectiveness, false positive rates, costs etc., how can we best design a procedure consisting of a series of such tests that best lead to a definitive diagnosis in a timely way at minimal cost?
- *Computer assisted diagnosis:* Advanced imaging and diagnostic tools, such as X-ray, CT, MRI, and traditional laboratory and genetic test results provide a myriad of digitized data about individual patients and the population. Advanced signal processing and data-base methods are needed to handle, store, retrieve and mage the data. The digitized data bases allow to develop advanced data classification methods that enable to separate healthy from the unhealthy, e.g., to automatically evaluate X-ray images to diagnose cancer or other diseases. Systematic data analysis could result in early detection of trends or anomalies.