Background Report

Industrial and Systems Engineering and Health Care: Critical Areas of Research

Prepared for:
Agency for Healthcare Research and Quality
U.S. Department of Health and Human Services
540 Gaither Road
Rockville, MD 20850
www.ahrq.gov

Contract No: 290-09-00027U

Prepared by:
University of Wisconsin-Madison
3270a Mechanical Engineering Building
1513 University Avenue
Madison, WI 53706

Authors:
Rupa Sheth Valdez
Patricia Flatley Brennan

AHRQ Publication No. 09-0094-EF
September 2009

Agency for Healthcare Research and Quality
Advancing Excellence in Health Care • www.ahrq.gov
HEALTH IT

This report is also available as Appendix A in the printed Final Report (available from the AHRQ clearinghouse) and on the AHRQ NRC Web site at http://healthit.ahrq.gov/engineeringhealthfinalreport (AHRQ Publication No. 10-0079-EF, May 2010)

Background Report

Industrial and Systems Engineering and Health Care: Critical Areas of Research

Prepared for:
Agency for Healthcare Research and Quality
U.S. Department of Health and Human Services
540 Gaither Road
Rockville, MD 20850
www.ahrq.gov

Contract No. 290-09-00027U

Prepared by:
University of Wisconsin-Madison
3270a Mechanical Engineering Building
1513 University Avenue
Madison, WI 53706

Authors:
Rupa Sheth Valdez
Industrial and Systems Engineering
University of Wisconsin-Madison

Patricia Flatley Brennan
Professor and Chair
Industrial and Systems Engineering
Professor, School of Nursing
University of Wisconsin-Madison

AHRQ Project Officer:
Teresa Zayas-Caban

AHRQ Publication No. 09-0094-EF
September 2009

Suggested Citation:
Valdez RS, Brennan PF. Industrial and Systems Engineering and Health Care: Critical Areas of Research: Background Report. (Prepared by the University of Wisconsin-Madison, Madison, WI under Contract No. 290-09-00027U). AHRQ Publication Number 09-0094-EF. Rockville, MD: Agency for Healthcare Research and Quality. September 2009.

None of the investigators has any affiliations or financial involvement that conflicts with the material presented in this report.

Acknowledgments

We would like to recognize the sustained help of Teresa Zayas Cabán, Ph.D., Senior Manager, Health IT at AHRQ.

Contents

Executive Summary

Introduction

There is no question that the current health care delivery system is suboptimal. Problems related to the system's efficiency, effectiveness, accessibility, safety, and other characteristics have been copiously documented in reports issued by both public and private agencies and in numerous journal articles. Acutely aware of the current political climate surrounding health care reform, the popular press daily inundates the public with stories of yet another deficiency in, or failure of, the system. In just one day (September 7, 2009), three prominent news sources reported the following shortcomings:

Chicago Tribune: There is concern that the proposals in Congress for health care reform will threaten the funding and future of the country's safety net hospitals (Johnson, 2009)

Wall Street Journal: A child died from a medical error caused by a lack of communication between physicians (Landro, 2009)

New York Times: Sixty-two percent of bankruptcies this year will be medical. Of those, three-quarters had insurance, at least when they initially got sick (Underwood, 2009)

Leaders in the health care community are deeply aware that change is necessary. Myriad approaches to improving the health care delivery system have been offered and remain at different stages of implementation. Prominent solutions to improving health care delivery include suggestions grounded in education, incentives, research funding, information technology, and systems engineering. Yet, despite consciousness of the problems and the many initiatives targeted at addressing them, the health care delivery system remains replete with flaws.

Purpose of This Meeting and Report

Beginning with the report *Building a Better Delivery System* (Institute of Medicine and National Academy of Engineering, 2005), there has been heightened interest in solving problems in the health care delivery system using industrial and systems engineering tools. Approaches to date envision improvements in the known health care system though the application of industrial and systems engineering approaches. However, the absence of progressive improvement in health care suggests the need to reframe the discussion, beginning first with a vision of an optimal health care system then specifying the industrial and systems engineering methods needed to insure the realization of that future.

The primary purpose of this meeting is to develop a research agenda at the intersection of industrial and systems engineering and health care. To achieve this primary purpose, meeting participants will be asked to engage in three activities:

1. Define a vision of an ideal health care system.
2. Critically examine the reasons for which fundamental change to the health care delivery system, including through the use of industrial and systems engineering tools, remains intractable.
3. Develop a prioritized list of new industrial and systems engineering tools that must be developed to realize the vision of an ideal future.

This background report provides a critical summary of the discourse salient to each element above. Documents generated by conferences, workshops, and working groups sponsored by various national bodies (National Academy of Sciences, Institute of Medicine, National Academy of Engineering, National Science Foundation) serve as the corpus upon which this report rests. By providing an overview of the main themes and identifying points of inconsistency and limitation in the current disquisition, this report seeks to provoke discussion among meeting participants. As such, it seeks not to be exhaustive but stimulating.

There are 13 reports that form the basis for this background report. These reports may be conceptualized as belonging to three categories: (1) reports that “set the stage” for discussions about improving the health care delivery system by drawing national attention to the need for change, (2) reports that directly explore the intersection between industrial and systems engineering and health care delivery, and (3) reports that represent the discourse related to specific mechanisms for improving the health care delivery system. Reports belonging to this final category primarily advocate one of three solutions to the deficiencies of the health care delivery system: (1) information technology, (2) evidence-based medicine, or (3) a "microsystems" approach. We purposely excluded reports that focused on a narrow aspect of the health care delivery system. Thus, for example, we excluded reports that focused solely on documenting specific demand for evidence, adoption challenges related to electronic health records, and a research agenda for consumer health information technology.

This background report has three parts. Chapter 1 presents a brief summary of each of the 13 reports that form the basis of this background report and presents a list of 7 themes common to these reports. Chapters 2-4 present summaries and discussion points related to the three meeting action items. Chapter 5 presents questions that may be used to instigate discussion among meeting participants, and Chapter 6 provides a conclusion.

Key Themes

Review of the 13 reports resulted in identification of seven common themes:

1. The current health care delivery system is both unsustainable in terms of cost and suboptimal in terms of value.
2. The current health care delivery system cannot adequately respond to changes in the larger environment and within the medical sciences.
3. Solving the problems of the health care delivery system is complex and will require approaches that are multidimensional, multileveled, and inclusive of multiple stakeholders.
4. Information technology will play a key role in the future health care delivery system.
5. Incentives are needed to promote change, including the use of systems engineering tools, information technology, and evidence-based medicine.
6. Opportunities are needed for cross-education and collaboration between health care professionals and scientific and technical professionals such as engineers and computer scientists.
7. Research funding is needed to explore the intersections between health care and the use of systems engineering tools, computer science methodologies, and information technology.

Additionally, review of the 13 reports resulted in a short summary and discussion related to each of the three meeting action items:

Define a vision of an ideal health care delivery system: Current visions of an ideal health care delivery system are primarily descriptive rather than prescriptive. When prescriptive guidance is provided, it is partial rather than comprehensive, focusing only on select aspects of an ideal health care delivery system such as the role of evidence-based medicine or information technology. If conceptualized in terms of an engineering design process, the vision or "design" of an ideal health care delivery system must be comprehensively specified prior to realization. Relying on only partial specification may be risky because it constrains the vision and increases the likelihood of unintended and potentially undesirable consequences.

Determine why fundamental change to the health care delivery system remains intractable: Solutions advanced to fixing problems of the health care delivery system are not aligned with the theoretical recognition that solving the problems of the health care delivery system requires a multidimensional solution not grounded in current realities. Furthermore, current approaches to changing the health care delivery system emphasize local optimization rather than system-wide optimization. Systems engineering tools have also been used to promote local optimization. This is reasonable, given the nature of systems engineering tools, the culture of health care, and the systems currently in place to support the use of systems engineering tools.

Determine what new forms of industrial and systems engineering tools are needed to arrive at the vision of an ideal health care delivery system: Although these reports mention several existing industrial and systems engineering tools that would be useful for local optimization, there is only minimal discussion of the new types of industrial and systems engineering tools that will be necessary. Those that are provided are a positive step in the right direction as they push the boundary beyond local optimization. One limitation of the new tools mentioned, however, is that they remain grounded in the current health care delivery system. What is needed is a set of new industrial and systems engineering tools that are grounded not in the current health care delivery system, but in the vision of an ideal health care delivery system.

Chapter 1: Summary of Past Reports and Identification of Common Themes

Report Summaries

In this section, a brief summary is provided of each of the 13 documents that form the foundation of this background report. The corpus is arranged alphabetically for ease of access to the source documents.

Commission on Systemic Interoperability. Ending the document game: Connecting and transforming your healthcare through information technology. Washington, DC: U.S. Government Printing Office; 2005.

This report advances the idea of information technology as a solution to many of the problems present within the current health care delivery system. Specifically, it is noted that increased interconnectivity will facilitate communication, security and confidentiality, and recordkeeping and prevent medical errors. Three steps are presented as a means of creating a nationwide system of health information: adoption, interoperability, and connectivity. The authors note that realization of such a system will involve multiple changes, including reformulated financial incentives, regulatory reform, changes in workforce requirements, data, privacy and authentication standards, a national health information network, and legal protections for consumers.

Donaldson MS, Mohr JJ. Exploring innovation and quality improvement in health care micro-systems: a cross-case analysis. Washington, DC: Institute of Medicine; 2001. A technical report for Institute of Medicine Committee on the Quality of Health Care in America.

This purpose of this report is to define the concept of a microsystem and to determine which characteristics of a microsystem enable it to improve the quality of care received by patients. The authors note that the concept of the microsystem is drawn for the manufacturing and service industry, where it has been successfully applied. In this report, the concept of the microsystem in health care is defined as a consisting of (1) a core team of health care professionals, (2) a defined population they care for, (3) an information environment to support the work of caregivers and patients, and (4) support staff, equipment, and a work environment. Examples of microsystems within health care provided by the report include a dialysis unit, an emergency room in a community hospital, and a hospice. Qualitative interviews with representatives of 43 purposely selected high-performing microsystems yielded eight themes which provide a framework for conceptualizing how microsystems function: (1) integration of information, (2) measurement, (3) interdependence of care team, (4) supportiveness of larger system, (5) constancy of purpose, (6) connection to community, (7) investment in improvement, and (8) alignment of role and training. The authors note that these findings may be used to develop tools, which may be used by other microsystems to replicate and extend the high levels of performance found within this sample.

Institute of Medicine. Crossing the quality chasm: A new health system for the 21st century. Washington, DC: National Academies Press, 2001.

This report serves as a complement to *To Err is Human* (Institute of Medicine, 2000), documenting not only quality concerns caused by errors but by an entire spectrum of causes. The authors acknowledge that although the health care system does, at times, perform admirably, there are large variations in care, and many do not receive the care that they need. Thus, there is recognition that “trying harder” within the current system is not the solution; a new system is needed. Recommendations include a systems approach to creating a health care system that is timely, effective, patient-centered, efficient, equitable, and safe. In advocating a systems approach, the authors acknowledge the need for change at the level of health care providers but also at the level of health care organizations, professional groups, public and private purchasers, and other government bodies. Environmental changes in four areas are proposed as a means of enabling larger system change: infrastructure that supports the dissemination and application of new clinical knowledge and technologies, the information technology infrastructure, payment policies, and preparation of the health care workforce. Funding for recommended to support projects targeted towards achieving the six aims and/or producing substantial improvement in quality for priority conditions.

Institute of Medicine. Engineering a learning healthcare system: A look at the future/Preliminary draft. Work in progress, May, 2008.

The authors of this report note that systems engineering tools have transformed multiple industries and question whether these methods may be useful in creating a learning health care system. Ten common themes are documented in this report: (1) center the system's processes on the right target—the patient experience, (2) system excellence is created by the reliable delivery of established best practice, (3) complexity compels reasoned allowance for tailored adjustments, (4) emphasize interdependence and tend to process interfaces, (5) teamwork and cross-checks trump command and control, (6) performance transparency and feedback serve as engines for improvement, (7) expect errors in the performance of individuals, perfection in the performance of systems, (8) align rewards on key elements of continuous improvement, (9) develop education and research to facilitate understanding and partnerships between engineering and the health professions, and (10) foster a leadership culture, language, and style that reinforces teamwork and results. Finally, the report identifies five points of followup for members of the roundtable including clarifying terms, identifying best practices, exploring changes to health professions education, advancing the science of payment for value, and exploring development of a science of waste and engagement.

Institute of Medicine. The learning healthcare system: Workshop summary. Olsen L, Aisner D, McGinnis JM, eds. Washington, DC: National Academies Press, 2007.

The *learning healthcare system* is a system within which evidence is generated and applied within the decisionmaking process. This report highlights how evidence-based medicine could serve as a rigorous scientific basis for the medical profession and highlights approaches currently used by health care organizations to achieve this aim. Thus, the primary purpose of this report is to document how information could be better generated and applied to improving health care. Twelve needs are identified that must be addressed to move toward a learning healthcare system. These needs include: (1) adaptation to the pace of change, (2) stronger synchrony of efforts, (3) culture of shared responsibility, (4) new clinical research paradigm, (5) clinical decision support systems, (6) universal electronic health records, (7) tools for database linkage, mining, and use, (8) notion of clinical data as public good, (9) incentives aligned for practice-based evidence, (10) public engagement, (11) trusted scientific broker, and (12) leadership. Mechanisms of addressing these needs and current progress towards meeting these needs are presented, including realigned incentives, revised medical education, and building upon current infrastructure and resources. There is also a brief mention of the potential of methodologies such as mathematical modeling, Bayesian statistics, and decision modeling as effective mechanisms for assessing interventions.

Institute of Medicine. Learning healthcare system concepts v. 2008/Annual report. Washington, DC: National Academies Press, 2008.

This report presents a summary of the key issues identified during the first 2 years of work by the Institute of Medicine Roundtable on Evidence-Based Medicine. The authors emphasize that our Nation is failing to deliver the value that should be expected from received care and that the purpose of the roundtable is to accelerate the delivery of such value, particularly in terms of effectiveness and efficiency, by creating a learning health care system. There is mention of the fact that the context within which change to the health care delivery system is needed is daunting, given, for example, constantly changing medical interventions, the increasing complexity of decisions, and geographical variations in spending. A learning health care system within which new evidence is constantly produced and applied through real-time learning and use is presented as a solution to these problems. The report also documents the need to provide incentives for high-performing caregivers, to develop capacity to generate evidence, and to generate and disseminate high-quality data. There is acknowledgment that any effective solution will require the participation of multiple stakeholders, including caregivers, health care organizations, patients, health care product companies, researchers, regulators, and payers and purchasers.

Institute of Medicine. To err is human: Building a safer health system. Kohn LT, Corrigan JM, Donaldson MS, eds. Washington, DC: National Academies Press, 2000.

This report calls attention to the fact that between 48,000 and 96,000 individuals die each year as a result of medical errors in our health care system. Such errors are described as expensive to the system, resulting in rework and opportunity costs as well as intangible ones, such as those related to employee and patient satisfaction and morale. Multiple reasons are provided for the silence that surrounds the issue of medical errors: (1) consumers believe they are protected, (2) providers fear legal repercussions from systematically uncovering and addressing errors, (3) the fragmented system prevents an understanding of root causes, and (4) purchasers have not demanded better quality and safety conditions. This report states that success has been achieved by other industries in reducing errors and that the lessons learned in these industries should be applied to health care. In this report, the problem of medical errors is viewed as a systems problem, and one that can only be solved be implementing a multifaceted, multilevel response. Specifically, the report calls for the number of errors to be reduced through the implementation of regulatory, educational, and engineering mechanisms, and at the level of the provider, health care organization, and national agencies. Funding for a center dedicated to improving patient safety though goal setting, tracking, research, and dissemination is recommended.

Institute of Medicine and National Academy of Engineering. Building a better delivery system: A new engineering/health care partnership. Reid PP, Compton WD, Grossman JH, Fanjiang G, eds. Washington, DC: National Academies Press, 2005.

This report is divided into two sections: the consensus report and a series of individual articles by leaders in the fields of health care delivery or systems engineering. The authors explore the potential of systems engineering tools to the improvement of the health care delivery system. In the consensus report, a framework is presented in which the health care system is conceptualized at consisting of four levels: the patient, the care team, the organization, and the environment. Systems engineering tools are identified that could help the health care system overcome difficulties at each of these four levels. Additionally, action steps are presented which would promote both the awareness and use of systems engineering tools at each of these four levels. These action steps include the dissemination of current systems engineering tools by both governmental and private organizations, development of information and communication technologies, and multidisciplinary research and educational programs. The second half of this report contains short articles by leaders in the fields of health care delivery and systems engineering, each of which focus on a particular area of health or a particular class of systems engineering tools.

McClellan MB, McGinnis JM, Nabel EG, et al. Evidence-based medicine and the changing nature of health care. Washington, DC: Institute of Medicine; 2008.

This report is the 2007 annual report of the Institute of Medicine roundtable on evidence-based medicine. It notes that there is a need for better evidence to guide health care decisions and that a mechanism is needed to both develop and apply evidence naturally during the care process. Nine common themes were identified related to the discussion of evidence-based medicine: (1) increasing complexity of health care, (2) unjustified discrepancies in care patterns, (3) importance of better value from health care, (4) uncertainty exposed by the information environment, (5) pressing need for evidence development, (6) promise of health information technology, (7) need for more practice-based research, (8) shift to a culture of care that learns, (9) new model of patient-provider partnership, and (10) leadership that stems from every quarter. It is noted that a multidimensional approach is needed to implement evidence-based care. Such an approach is described as involving multiple stakeholders such as patients, provider, payers, industry, and policymakers and involving realignment of incentives to support the use of evidence-based care.

National Research Council. Computational technology for effective health care: Immediate steps and strategic directions. Stead WW and Lin HS, eds. Washington, DC: National Academies Press; 2009.

This report centers around two questions: (1) How can today's computer science-based methodologies and approaches be applied more effectively to health care? and (2) What are the limitations of these methodologies? and How can they be overcome through additional research and development? Answers to these questions are obtained through site visits to eight medical centers, literature review, and committee expertise. The authors conclude that the current focus on information technology efforts within health care is insufficient to drive needed change. Recommendations include the implementation of both evolutionary and radical change and to expand research along two dimensions: (1) the extent to which new, fundamental, general-purpose research is needed and (2) the extent to which new research specific to health care and biomedicine is needed. As in other reports, there is acknowledgement that multiple stakeholders, including government, the computer science community, and health care institutions must participate for meaningful change to be realized. There is clear communication that the scope of this report is limited, focusing primarily on the role of clinicians in large health care institutions, and only peripherally touching on the larger economic, political, and cultural context within which health care reform must occur.

Nelson EC, Batalden, PB, Godfrey MM, et al. Microsystems in health care: The essential building blocks of high performing systems. Princeton (NJ): Robert Wood Johnson Foundation; 2001. RWJ Grant Number 036103.

This report presents the concept of the microsystem as an opportunity to think about transforming health care from the front line of service delivery. The authors note that the idea of transforming health care via optimization of the microsystem relies on three primary assumptions about the structure of the health care system: (1) bigger systems (i.e., microsystems) are made of smaller systems, (2) these smaller systems (i.e., microsystems) produce quality, safety, and cost outcomes at the front line of care, and (3) the outcomes of the macrosystems can be no better than the microsystems of which it is a part. Thus, microsystems are conceptualized as the building blocks of the health system. The authors note that the concept of the microsystem has been successfully been used by service organizations such as Federal Express, McDonald’s, and Nordstrom’s. This report then presents the results of a study in which 20 high-performing clinical microsystems were studied to uncover nine characteristics of success: (1) improvement methods, (2) staff focus, (3) performance results, (4) information and information technology, (5) patient focus, (6) leadership, (7) interdependence of care team, (8) culture, and (9) organizational support. The authors conclude that the role of the clinical microsystem has been ignored to date and should be attended to in the future as a means to transform the health care system.

Rardin RL. Research agenda for healthcare systems engineering/Final report. Arlington, VA: National Science Foundation, February, 2007. NSF Grant No. 0613037.

This report serves two primary functions: it (1) proposes a research agenda for health care systems engineering and (2) documents the funding challenges and potential funding solutions for health systems engineering. In this report, the health care system is conceptualized as consisting of six levels: patient, population, team, organization, network, and environment. The field of health care systems engineering is conceptualized as consisting of three domains: technology, model-based, and practice-based. A research agenda is outlined at each health care system level and the potential for advances is evaluated for each of the three health care systems engineering domains. Top research priorities identified include treatment optimization, personalized, preventive care, information rich and configurable operations management, collaboration within networks, and large-scale delivery system design. The report also notes that health care systems engineering has no funding “home” and calls for the establishment of a health care engineering alliance to support such research.

Roberts S, Uzsoy R, Ivy J, Denton B. Workshop: Healthcare engineering and health services research: Building bridges, breaking barriers/Final report. Arlington, VA: National Science Foundation, April, 2008. NSF Grant No. 0817223.

This report in organized around answering four questions at the intersection of health services research and health care systems engineering: (1) What do health services research and health care systems engineering have in common?; (2) What can health care systems engineering learn from health services research?; (3) What can health services research learn from health care systems engineering?; and (4) Why is the VA so important to health care engineering? Commonalities identified include shared understanding of problems, shared common intellectual assets, shared belief in data-driven analysis and decisions, and complementary research methods and tools. Seven recommendations to the National Science Foundation (NSF) are presented, which emphasize the need for NSF to encourage and fund interdisciplinary projects at the intersection of these fields. These recommendations include calls for both educational and research initiatives at the intersection of health care engineering and health services research.

Common Themes

The common themes presented below are not necessarily present in all of the 13 reports included in this background report, but may be found in a large majority of the reports reviewed.

- The current health care delivery system is both unsustainable in terms of cost and suboptimal in terms of value.

- The current health care delivery system cannot adequately respond to changes in the larger environment and within the medical sciences.
- Solving the problems of the health care delivery system is complex and will require approaches that are multidimensional, multi-leveled, and inclusive of multiple stakeholders.
- Information technology will play a key role in the future health care delivery system
- Incentives are needed to promote change, including the use of systems engineering tools, information technology, and evidence-based medicine.
- Opportunities are needed for cross-education and collaboration between health care professionals and scientific and technical professionals such as engineers and computer scientists.
- Research funding is needed to explore the intersections between health care and the use of systems engineering tools, computer science methodologies, and information technology.

Chapter 2: Vision of an Ideal Health Care Delivery System

Summary

In the current discourse, comprehensive visions of an ideal health care delivery system are descriptive rather than prescriptive. For example, in *Crossing the Quality Chasm* (Institute of Medicine, 2001), the ideal health care delivery system is described as embodying six attributes: safety, effectiveness, efficiency, equity, timeliness, and patient-centeredness. Other attributes of an ideal health care delivery system include the capacity to learn and therefore continuously improve (Institute of Medicine, 2007) and cost-effectiveness (Institute of Medicine, 2008a). Finally, an ideal health care system should also be able to accommodate both environmental changes, such as an aging population and the shift in disease burden from acute to chronic illness (National Research Council, 2009) and advances in both technology and medical science, including new medications, devices, diagnostics, biologics, and procedures (Institute of Medicine, 2008b).

Limited attempts have been made to prescriptively specify components of the ideal health care system. Such attempts have primarily focused on detailing the role of information technology in the future. For example, in *Ending the Document Game* (Commission on Systemic Interoperability, 2005), the authors advance a vision of the future in which information technology is used to manage health care information, enabling a medical record to be available wherever and whenever it is needed and authorized. Similarly, reports focusing on evidence-based medicine (e.g., Institute of Medicine, 2007, 2008b; McClellan et al., 2008) detail how a vision of a learning health care system may be achieved by promoting knowledge bases other than randomized controlled trials and by collecting and disseminating data in real-time via information technology.

In *Crossing the Quality Chasm* (Institute of Medicine, 2001), there is an explicit refusal to specify a vision not only of an ideal future health care system, but also of a 21st century health care system. The committee argues that such an exercise would be neither useful nor possible. They further argue that imagination and valuable pluralism abound at the local level and, consequently, offer a set of rules the may be used to implement innovation and achieve improvement at this local level.

Discussion

The potential risk inherent in the current approach of prescriptively specifying only select aspects of a vision of an ideal health care delivery system may be best explored by considering an engineering design process. At the beginning of a design process, a designer establishes an understanding of the functional requirements that a product, service, or system must be meet. This results in a uniquely descriptive vision of this product, service, or system. Endless possibilities exist as to how these functional requirements may be realized.

After exploring the infinite possible design solutions, a designer must create concrete alternatives, evaluate these alternatives, and choose one with which to proceed. Thus, the designer must select the means that will be used to achieve the functional requirements. There is definitive movement from a descriptive solution to a prescriptive solution. No aspect of the design solution is left unspecified.

There is a simple reason for which an engineering design process requires comprehensive specification before advancing to development. Partial specification is unpredictable. Without ensuring that all of the pieces of the final design fit together, there is no assurance that the bridge will not collapse, that circuit will not short. It is not enough to determine what material should be used to build the bridge or build the circuit. Such limited prescriptive specification only serves to constrain the final solution; it does not present a final solution.

The same principles hold for “designing” an ideal health care delivery system. A uniquely descriptive solution is important at the beginning of the process. It allows for application of “imagination and valuable pluralism” (Institute of Medicine, 2001). Yet, this phase of the design process cannot last indefinitely. To realize an ideal health care system, a prescriptive solution must be defined. Precluding a prescriptive solution, it is impossible to determine whether we are moving toward the desired destination. Furthermore, such a solution must be comprehensive. At present, the prescriptive solution is only piece-meal. There are loud calls for the use of evidence-based medicine and information technology and even many details about how these tools may be used to improve health care delivery (e.g., Commission on Systemic Interoperability, 2005; Institute of Medicine, 2007, 2008b; McClellan et al., 2008; National Research Council, 2009). At the same time, however, there is little prescriptive specification as to how other aspects of the health care delivery system will be redesigned, eliminated, or added to fit with these recommended improvements.

One final point should be made about the level at which a prescriptive solution for the health care delivery system is specified. In *Crossing the Quality Chasm* (Institute of Medicine, 2001), the authors imply that such prescriptive specification should take place at the local level. Yet, in other publications such as *Building a Better Delivery System* (Institute of Medicine and National Academy of Engineering, 2005), the ideal health care system is envisioned as something transformed from “an underperforming conglomerate of independent identities into a high-performance ‘system’ in which participating units recognize their interdependence and the implications and repercussions of their actions on the system as a whole (p. 2).”

We are not arguing that a comprehensive prescriptive solution is possible, or even desirable at present. It may be that, as a Nation, we still need time to explore options, to draw lines in the sand. We only wish to draw attention to two realities: (1) there is inherent risk in prescriptively defining only certain dimensions of the ideal health care delivery system, and (2) a comprehensive prescriptive solution is important for ensuring purposeful movement toward an ideal health care delivery system.

Chapter 3: Barriers to Realization of This Vision

Summary

Unquestionably, "solving health care" is viewed as a complex problem. This complexity is recognized in each of the 13 reports that serve as the basis for this background report. Particularly within *To Err is Human* (Institute of Medicine, 2000), *Crossing the Quality Chasm* (Institute of Medicine, 2001), and *Building a Better Delivery System* (Institute of Medicine and National Academy of Engineering, 2005), there is recognition that improving the health care delivery system will require a multifaceted response, involving numerous stakeholders such as providers, health care organizations, public and private purchasers, professional groups, and national agencies. Mechanisms for change advocated in these reports include:

- Financial mechanisms. Create financial incentives, including payment reform, for the use of quality improvement techniques and evidence-based medicine. Implement financial penalties for preventable medical errors. Increase research funding to investigate potential solutions to problems in the health care delivery system.
- Educational mechanisms. Spread knowledge related to tools and techniques that may be used to improve safety, effectiveness, and efficiency. Ensure that all providers are prepared to respond to the changing environment. Create multidisciplinary learning environments to foster innovative solutions to the problems of the current health care delivery system.
- Engineering mechanisms. "Design out" problems that contribute to problems such as medical errors. Create new structures that support evidence-based medicine and the use of information technology.
- Regulatory and market-based mechanisms: Develop performance standards and expectations both for the health care professional and health care organization.
- Provider-based mechanisms: Rely on the intrinsic motivation of providers as a force for improving the health care delivery system.

Thus, philosophically, there is consensus that an ideal health care system will not be realized through incremental improvements of the current system. This sentiment is most directly expressed in *Crossing the Quality Chasm* (Institute of Medicine, 2001): "The current care systems cannot do the job. Trying harder will not work. Changing systems of care will" (p. 4).

A second common theme among the reports is that improving individual components of the health care delivery system will lead to improvement of the overall, or whole, health care delivery system. This theme is most clearly expressed within two reports (Donaldson & Mohr, 2001; Nelson et al., 2001) that detail the microsystem philosophy. In this view, smaller parts of an organization (microsystems) are seen as having semipermeable boundaries with other microsystems, the whole of which is embedded in an environment. This broader environment consists of dimensions such as the payment environment, the regulatory environment, and the cultural–socio-political environment (Nelson et al., 2001). Examples of a microsystem include a dialysis unit, an emergency room within a community hospital, or a hospice care center (Donaldson & Mohr, 2001). The microsystem philosophy states that (1) bigger systems are made of smaller systems, (2) the smaller systems produce quality, safety, and cost outcomes at the front line of care, and (3) the outcomes of the macrosystems can be no better than the microsystems that comprise it (Nelson et al., 2001). Thus, proponents of this philosophy maintain that improving individual microsystems will lead to improvement of the overall health care delivery system.

Finally, a third common theme among reports is that systems engineering approaches are a novel approach to changing the health care delivery system and should be adopted (e.g., Institute of Medicine, 2000, 2008a; Institute of Medicine and National Academy of Engineering, 2005; Rardin, 2007; Roberts et al., 2008). A common rationale presented for adopting systems engineering tools is that they have been successfully applied within other industries such as banking, manufacturing, and aviation. The reports reviewed suggest that the reason that systems engineering tools have not had a larger impact on changing the health care delivery system is that (1) knowledge of their existence is not widespread, (2) there are no incentives in place for either providers or health care organizations to use these methods, and (3) little funding exists to conduct research on the intersection of health care delivery and systems engineering. As a result, several reports advocate for increased cross-education between health care and engineering professionals (e.g., Institute of Medicine and National Academy of Engineering, 2005; Roberts et al., 2008) and incentives for implementing systems engineering tools within health care organizations (e.g., Institute of Medicine, 2008a; Institute of Medicine and National Academy of Engineering, 2005), and additional research funding (e.g., Institute of Medicine and National Academy of Engineering, 2005; Roberts et al., 2008) to encourage the use of these approaches.

Discussion

There is a contradiction between the philosophical view that solving health care is a complex problem that cannot have a solution grounded in the current system and many of the solutions presented. For example, there is a belief (although not shared by all) that certain solutions will be close to panaceas. In other words, there is a tendency to oversimplify the problem. Such sentiment is found, for example, in *Ending the Document Game* (Commission on Systemic Interoperability, 2005). In this report, the authors argue that many of the problems within health care, for example, problems related to cost, safety, efficiency, and effectiveness, could be solved through the adoption of information technology. The rationale behind this belief is that information technology will enable systems to fundamentally retain their current structure but better perform necessary tasks.

Furthermore, despite acknowledgement that fundamental changes to the delivery system are necessary, many of the changes proposed remain grounded in the current system. Thus, suggestions for increased research funding assume that Federal agencies will remain responsible for disseminating funds. Similarly, suggestions for the use of evidence-based medicine assume that care will primarily continue to be delivered in clinics and solutions for education assume that academic disciplines will, fundamentally, retain their existing boundaries.

A similar problem exists with the idea that implementing change at the level of the microsystem will result in meaningful change at the level of the macrosystem or the overall health care delivery system. Proponents of the microsystem viewpoint maintain that outcomes of the macrosystems can be no better than the microsystems that comprise it (Nelson et al., 2001). Although this is a reasonable statement, modest reflection reveals that its converse is more powerful. In other words, microsystems can be no better than the macrosystem in which they are embedded. It is the macrosystem which constrains what the microsystem is capable of achieving. Thus, the microsystem approach to improving the health care delivery system is also grounded within the current macrosystem reality.

The reflections above highlight that the solutions advocated contradict the understanding that improving the health care delivery system is complex and requires a fundamentally new solution. Answers proposed often either oversimplify the problem and/or remain grounded to current realities. Achieving true reform of the health care delivery system will require solutions that are true to our theoretical understanding of the problem as multidimensional and requiring a paradigm shift.

Unfortunately, the answer of systems engineering has, to date, also failed to yield any fundamental change. Common wisdom suggests that this failure is due to the lack of use, instead of any inherent limitation, of these methods. Failure to use these tools has been attributed to a lack of awareness, resources, or motivation to implement systems engineering knowledge.

There is reason to believe, however, that this failure is also the result of a combination of assumptions about systems engineering tools, of the structures in place to support their use, and of the traditional focus of both systems engineering tools and the health care delivery system. Although each of these factors will be examined in turn, the primary problem seems to be that there has been a focus on local instead of system-wide optimization.

A pervasive assumption exists that systems engineering tools have been useful in solving problems in other fields and will, therefore, be successful in the field of health care. The determination of whether systems engineering tools have been successful in other fields may depend upon the level of examination. Thus, for example, it may be argued that systems engineering tools such as human factors engineering have been useful for the redesign of the cockpit, preventing some pilot errors. Yet, a more microlevel examination may lead to a different conclusion. Aviation, banking, and manufacturing, all industries for which there has been a claim of success for systems engineering tools, are suffering deeply. A more accurate assertion, therefore, may be that systems engineering tools have been successful in solving microlevel problems, but have not been successful at solving many of the microlevel problems pervasive in each of these industries.

The support structures that have been built to support the use of systems engineering tools are similarly focused on local optimization. For example, organizations such as the Institute for Healthcare Improvement and the Leapfrog Group advocate the use of systems engineering tools at the level of a practice or a health care organization. Both the measures and tools presented for use assume that the overall health care delivery system will remain constant, and that it is the prerogative of each individual practice or institution to optimize their performance within this relatively fixed environment.

The culture of health care also promotes local optimization. Silos exist both at the level of the practice, the "microsystem" or subspecialty, and at the level of the health care organization. Each practice has its own panel of patients, each "microsystem" or subspecialty has its own specialized knowledge, and each health care organization has its own market share. At each level, therefore, there is incentive to optimize locally to preserve whatever advantage one currently enjoys. Particularly at the level of the health care organization, there is little incentive to join with another health care organization and to optimize at the level of joint operations. Such a maneuver may be an anathema to profit-driven health care organizations, which, in a market-based health care system, compete with one another for survival.

Finally, by their very nature, systems engineering tools are best suited for local optimization. Although systems engineering tools are meant to provide a means for obtaining a holistic perspective about and solution to a given problem, the "systems" that these methods were originally designed for were relatively small-scale systems such as a manufacturing plant floor or perhaps even an organization. Thus, it could be argued that the use of systems engineering tools at the level of a practice, "microsystem," or even health care organization is sensible. The methods are being used at the level for which they were originally designed.

If this is the case, what is the role of systems engineering tools in creating a vision of the future that is not grounded in the current system? To date, the relationship between systems engineering tools and the health care delivery system has been to use current systems engineering tools to optimize the current health care delivery system. In the future, this relationship will need to change such that new systems engineering tools are developed to facilitate the creation of an ideal health care delivery system.

Chapter 4: New Industrial and Systems Engineering Tools To Realize This Vision

Summary

There is very little discourse related to what new industrial and systems engineering tools must be created to realize a vision of an ideal health care delivery system. Although several reports mention that systems engineering tools must be adopted for use in health care or that new systems engineering tools must be developed for health care (e.g., Institute of Medicine, 2007; Institute of Medicine and National Academy of Engineering, 2005) only one report (Institute of Medicine and National Academy of Engineering) contains an in-depth discussion related to this topic. This report, *Building a Better Delivery System*, is divided into two parts. The first part contains a consensus report and the second, articles written by individuals. Little is mentioned in the consensus report about the need for new systems engineering tools. Only in the individual articles is there some detailed discussion about the new types of systems engineering tools that must be developed to improve the health care delivery system.

Examples of the new industrial and systems engineering tools proposed are presented below. Many of these methods are presented as also necessary to address complex problems within other fields such as manufacturing:

1. Methods of modeling and optimizing supply chains where demand is a function of multiple variables. Within health care, demand is a function of multiple variables including the types of treatment available and the insurance coverage available. Models are needed which can account for demand that does not have a single determinant.
2. Models of modeling and optimizing supply chains within which the actions of one party affect the options available to other parties. The activities of stakeholders in the health care system are interdependent. For example, the coverage decisions made by an insurance company may affect the treatment decisions made by a provider.
3. Methods of analyzing large-scale systems. Industrial and systems engineering tools contain methods such as value-stream mapping and facilities layout tools that may be

used to analyze small-scale systems. These tools may be useful for optimizing a clinic or unit but are not as likely to be useful for optimizing an entire system.

4. Methods of modeling which replace the need for clinical trials. Developing knowledge via randomized controlled trials is considered time consuming and costly. Computer modeling techniques may be a useful means of generating the necessary evidence in a more efficient manner.
5. Methods of modeling and optimizing activities of multiple, independent agents. Health care consists of multiple, independent agents such as health care providers, health care systems, health care payers, and regulatory agencies working independently to optimize their position.

Discussion

The methods listed above provide a glimpse into the types of new industrial and systems engineering tools that may be needed to move beyond current improvement efforts. These methodological visions are a step in the right direction to move the tools available beyond local optimization. It should be noted, however, that many of these tools are also grounded in the assumption that the current health care delivery system will retain many of its features such as multiple, independent players and demand that is informed by the actions of insurance companies.

This latter point emphasizes the need also for new industrial and systems engineering tools that are grounded not in the current reality but in the vision of an ideal health care delivery system. The new tools created should be those that will be necessary to both create and optimize this vision. Thus, determining which new industrial and systems engineering tools are necessary must be the last step in the process. Without specifying a vision, it will be unclear what new types of tools will be needed to realize the vision.

Chapter 5: Questions To Stimulate Workshop Discussion

1. Are current systems engineering techniques scalable to be effectively used at levels higher than an organization?
2. Are we asking the right question? Instead of asking how the health care delivery system should respond to environmental changes such as the rising need for chronic care, should we be asking why there is a rising need for chronic care? In an article in the *New York Times* this week, Michael Pollan noted that one reason for rising chronic care is the rise in obesity due to the American diet. Similarly, asthma has increased due to environmental conditions. Instead of placing such emphasis on redesigning the health care delivery system, should we instead focus on preventing these environmental changes?
3. There is a pervasive assumption that providers are intrinsically motivated to deliver the best possible care. There is also an assumption that financial incentives are needed for providers to implement systems engineering tools and to use evidence-based medicine. This suggests that providers are also driven by other motivations. What are the implications of this apparent contradiction?
4. Given that the microlevel system constrains the microlevel systems, is there reason to believe that creating change at lower levels will lead to fundamental change for the entire delivery system?
5. There is a tension between revolutionary and evolutionary change. Historically, systems engineering tools have been used within the field of health care to create evolutionary change. How can systems engineering tools be used to create revolutionary change?
6. Many hold fast to the belief that information technology will solve many of the problems inherent in the current health care delivery system. Why does such an assumption exist? What are the pitfalls of such an assumption?
7. What is the meaning of “best practice”? How should we define “best practice,” given that the definition may differ depending upon the point of view (patient, practitioner, payer)?
8. How do we systematically balance the need for evidence-based care and the individuality of patients?

9. Who will use the newly developed industrial and systems engineering tools? If they are not focused on local optimization, who will be responsible for implementing them in practice?

Chapter 6: Conclusion

There is consensus among the reports reviewed that change to the current health care delivery system is necessary. An understanding exists at a theoretical level that changes to the system must be revolutionary, not simply grounded in current realities. Visions of an ideal health care delivery system are primarily descriptive, although some elements of the vision, such as the role of information technology, have been prescriptively defined.

Efforts at change, including the use of systems engineering methods have, however, remained grounded in current realities. The focus has been on locally optimizing elements of the entire system, such as a practice, unit, or organization. The use of systems engineering tools in this context is understandable given that (1) the culture of health care emphasizes local optimization, (2) existing systems engineering methods were created for local optimization, and (3) structures supporting the use of systems engineering methods promote local optimization.

To create a revolutionary new future, however, there is a need for new industrial and systems engineering tools that have a focus beyond local optimization. The reports reviewed contain a few suggestions of new industrial and systems engineering tools that have this broader focus. Several of these tools, however, are still grounded in the realities of the current health care delivery system. There is a need to create industrial and systems engineering tools that are grounded not in the current reality, but in the vision of an ideal health care delivery system.

References

1. Commission on Systemic Interoperability. Ending the document game: Connecting and transforming your healthcare through information technology. Washington, DC: U.S. Government Printing Office; 2005.

2. Donaldson MS, Mohr JJ. Exploring innovation and quality improvement in health care micro-systems: a cross-case analysis. Washington, DC: Institute of Medicine; 2001. A technical report for Institute of Medicine Committee on the Quality of Health Care in America.

3. Institute of Medicine. Crossing the quality chasm: A new health system for the 21st century. Washington, DC: National Academies Press, 2001.

4. Institute of Medicine. Engineering a learning healthcare system: A look at the future/Preliminary draft. Work in progress, 2008.

5. Institute of Medicine. The learning healthcare system: Workshop summary. Olsen L, Aisner D, McGinnis JM, eds. Washington, DC: National Academies Press, 2007.

6. Institute of Medicine. Learning healthcare system concepts v. 2008/Annual report. Washington, DC: National Academies Press, 2008.

7. Institute of Medicine. To err is human: Building a safer health system. Kohn LT, Corrigan JM, Donaldson MS, eds. Washington, DC: National Academies Press, 2000.

8. Institute of Medicine and National Academy of Engineering. Building a better delivery system: A new engineering/health care partnership. Reid PP, Compton WD, Grossman JH, Fanjiang G, eds. Washington, DC: National Academies Press, 2005.

9. Johnson CK. Will safety net hospitals survive health reform. Chicago Tribune

10. Landro L. A fight against fatal error. Wall Street Journal September 7, 2009. Available at: http://online.wsj.com/article/SB10001424052970203706604574378762626910076.html. Accessed September 7, 2009.

11. McClellan MB, McGinnis JM, Nabel EG, et al. Evidence-based medicine and the changing nature of health care. Washington, DC: Institute of Medicine; 2008.

12. National Research Council. Computational technology for effective health care: Immediate steps and strategic directions. Stead WW and Lin HS, eds. Washington, DC: National Academies Press; 2009.

13. Nelson EC, Batalden, PB, Godfrey MM, et al. Microsystems in health care: The essential building blocks of high performing systems. Princeton (NJ): Robert Wood Johnson Foundation; 2001. RWJ Grant Number 036103.

14. Rardin RL. Research agenda for healthcare systems engineering/Final report. Arlington, VA: National Science Foundation, February, 2007. NSF Grant No. 0613037.

15. Roberts S, Uzsoy R, Ivy J, Denton B. Workshop: Healthcare engineering and health services research: Building bridges, breaking barriers/Final report. Arlington, VA: National Science Foundation, April, 2008. NSF Grant No. 0817223.

16. Underwood A. Insured, but bankrupted anyway. New York Times September 7, 2009. Available at: http://prescriptions.blogs.nytimes.com/2009/09/07/insured-but-bankrupted-anyway/?scp=1&sq=medical%20bankruptcy&st=cse. Accessed September 7, 2009.

17. Will safety net hospitals survive health reform? Available at: http://www.chicagotribune.com/news/chi-ap-us-healthcare-safety,0,5110897.story. Accessed September 7, 2009.