National Institute of BUILDING SCIENCES

The Academy for Healthcare Infrastructure

Collaborative Research Program

RESEARCH TEAM 2:

Developing a Flexible Healthcare Infrastructure

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Team 2
Developing a Flexible Healthcare Infrastructure

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Foreword

In 2013, the National Institute of Building Sciences established a collaborative research program to bring leading healthcare professionals together to address industry challenges at a national level. The Academy for Healthcare Infrastructure (AHI) would focus on improving the processes to create and maintain the complex built environment required to support America's healthcare mission. It would serve as a collaborative network with the purpose of exploring large, comprehensive ideas.

Upon establishing its charter and selecting Research Governors, AHI began the process of setting up Interdisciplinary Research Teams to identify current best practices; envision the future of the healthcare infrastructure industry; and engage appropriate industry leaders to develop new approaches for solving critical problems. Each of the resulting five teams consisted of leaders from the healthcare facilities industry and related subject matter experts, as well as an academician to facilitate the process who would be responsible for compiling the data and developing a white paper for publication.

The Academy's research methods were formulated to utilize the power of interdisciplinary collaboration to actively break traditional professional boundaries. Each of these small, focused teams of industry experts have committed to envision materially improved approaches to a specific critical industry issue. The structure is designed to result in breakthroughs in the creation, management and repurposing of healthcare infrastructure.

Each team focused on a specific topic: Owner Organization for Successful Project Outcomes; Developing a Flexible Healthcare Infrastructure; Speed to Market Strategies; Defining the Next Generation's Focus; and Reducing Initial Capital Costs.

Over the course of 2015, the facilitators coordinated with the healthcare facilities industry leaders and related subject matter experts, and began the process of compiling white papers with their findings.

This paper, "Developing a Flexible Healthcare Infrastructure," is the result of Team 2's efforts.

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Introduction

There are times when systemic incremental improvement is desirable. This is not one of those times. Affordable, quality healthcare is essential to sustaining a vibrant society. And yet, the American healthcare industry is facing overwhelming uncertainty in almost every segment.

The Academy for Healthcare Infrastructure (AHI) was established to materially improve the processes used to create and maintain the incredibly complex built environment required to effectively support America's healthcare mission. This collaborative research program is designed to focus on issues that are vital to improving the performance of the healthcare facilities industry, while avoiding the temptation to repeatedly address the same old issues.

American healthcare is experiencing unprecedented uncertainty. Infrastructure must effectively and flexibly respond to change. AHI's Interdisciplinary Research Team 2 explored current issues and success factors. This included defining what the team meant by flexibility in healthcare infrastructure, and then determining why flexibility and the ability to accommodate changing needs are important by identifying the forces of change in healthcare. The team also explored when and where flexibility was most critical and to what degree. Then, through feedback from the team, in combination with a literature search and best practice case study review, the work of the team culminates with outlining concepts for achieving flexibility and recommendations on how to optimize flexibility in healthcare infrastructure.

Methodology

The process consisted first of identifying a team of industry leaders and subject matter experts that represented a cross section of healthcare industry constituencies, including healthcare provider organizations; design and engineering professionals; and construction industry professionals with extensive and diverse experiences in healthcare facilities operations, planning, design and construction. A preliminary literature and best practice case study review was initiated and several foundational readings were recommended to the panel. This was followed by the preparation of an interview questionnaire. Interview questions covered the definition of flexibility; the forces that drive the need for flexibility; where they found that change occurred in healthcare infrastructure and to what degree; recommended strategies for achieving flexibility; and tools and processes for implementing a flexible healthcare infrastructure. The facilitator interviewed team members individually by phone. The literature and best practice case study review then continued. The findings from the interviews, literature and best practice case study reviews were then compiled into this white paper.

Need For a Flexible Healthcare Infrastructure

With few exceptions, hospital and healthcare building projects have historically been designed and built primarily based on immediate and, at best, predictable near-future needs. Total life-cycle costs linked to initial capital investments are difficult to quantify and are rarely fully considered in the project budget and design decision-making on capital projects, given the pressures to contain initial construction project costs. Yet, industry experts indicate that the cost of initial capital investment in infrastructure is exponentially smaller that the life-cycle cost of the delivery of care, operating, maintaining and renovating a building after occupancy over its entire functional life. Spencer Moore shared what is a commonly stated ratio of capital costs equaling about 10-20% and operating costs equaling 80-90% of total life-cycle costs. Other sources indicate staffing costs alone represent 60-75% of costs over the life of a healthcare facility (Carr, 2014). Facilities that cannot accommodate changing needs and operations efficiently are not a wise investment for the long run.

Healthcare infrastructure typically has a lifespan of 50-100 years or more. A fair number of hospitals in the Eastern United States are still operating at least partially in facilities constructed in the early 20th century. A significant number of facilities still in operation today were built during the Hill-Burton Act funding cycle for hospital construction beginning in 1946 (Currie, 2007, p 158). The changes in healthcare that have occurred over the past 50-100 years are immense and how healthcare is delivered today could not be imagined when many of the healthcare facilities currently in operation were conceived and built. At the same time, the rate and scope of change in healthcare is rapidly accelerating and it is impossible to imagine what, how and where healthcare will be delivered over the 50-100 year lifespan of the infrastructure being built today. Therefore, it is even more important that the healthcare infrastructure built in the future is designed to flexibly accommodate changing needs, including both those that can be anticipated and those that cannot even be imagined.

Drivers, Dimensions and Locations of Change

The forces that influence the need for flexibility are numerous and ever-evolving. They include advances in basic and medical science, new medical and communication technologies, changing care or treatment practices and locations, evolving demographics and markets, reimbursement patterns, regulations and standards. Care and treatment that was once delivered on an inpatient basis in the hospital is inevitably moving more and more toward ambulatory and home care. These trends are being enabled by advances in medical science, technology and care practices, and driven by managed care. At the same time, regulations and a focus on accountability are increasing. Reduced and conditional reimbursement is driving providers to do more with less, faster, better and with fewer resources. At the same time those patients left in hospitals are sicker, more acute, older and poly-chronic. Consumer satisfaction and reimbursement is simultaneously driving the move toward more patient-centered care. The era of the patient as a passive recipient of care and an indifference to the care experience is ending. Technologies are advancing at such a pace that it is difficult for healthcare organizations to keep up. As a result, the very nature of what occurs in various healthcare settings and how it needs to be accommodated in the healthcare infrastructure will obviously be very different tomorrow than it is today.

These forces are impacting the healthcare infrastructure in different ways, ranging from the simple repurposing of existing spaces (as they are with minimal cosmetic renovation), to the wholesale gut renovation and/or expansion of departments, addition of service lines or the complete replacement of a given infrastructure. Areas of high volatility and a typically high cost of change include heavy equipment-intensive diagnostic and treatment services such as surgery, interventional medicine, imaging, radiation oncology and emergency departments. Areas of high volatility but relatively low cost of change include pharmacies and clinical laboratories, as change in these areas typically occurs more often at the level of fixtures, furnishings and equipment (FFE) rather than the reconfiguration of space. They may also be moved off site and provide space for expansion of other services. Research labs also experience relatively high volatility, but if designed properly with module casework and proper planning of hoods, can easily accommodate change.

Changes in areas made up of repetitive cellular spaces, such as inpatient units and ambulatory care clinics, often occurs within their cellular structure, whether or not flexibility is considered in the original design. Examples of this include the conversion of semiprivate rooms to single-patient rooms, the addition of monitoring to convert an acute care room or unit into a step-down unit, re-assignment of an exam room or clinic module, etc. When more significant change is needed in these areas, beyond what the existing infrastructure can accommodate, they tend to be expanded or replaced with new construction.

Low-volatility areas typically include the power plant, kitchens, central stores and administrative areas. Power plants and kitchens tend to be hard and stable, in that they are very difficult to relocate, so the location and sizing of these areas is critical. These service areas and the pathways that connect them to the rest of the facility must not impede the growth and reconfiguration of treatment areas. Areas such as central stores and administrative areas are low-cost and tend to be considered soft. They can be relocated relatively easily if needed and can provide growth space for other highly volatile services. These spaces may often move or be located outside of the core building or campus, as they do not need to be built to Hospital I occupancy standards, if properly zoned and designed as separate structures.

Recommendations

The following recommendations come partially from the team members and also the literature and best practice review. The fundamental principles outlined follow a conceptual framework laid out by Steward Brand, organizing building elements in such a way as to accommodate shearing layers or change (Brand, 1994). This means designing and positioning the most stable elements, i.e., the structure; building envelope; primary mechanical, electrical and plumbing (MEP) systems; and primary circulation in such a way as to not impede the more frequent change of volatile and dynamic elements (the space plan of functional areas and FFE). Another way to visualize this is through a systems separation framework that organized these elements into three basic levels: System Level 1 – base building; System Level 2 – tenant upfit or space plan; and System Level 3 – fixtures, furnishings and finishes, as originally captured by Stephen Kendall et al (Ball State University, 2002).

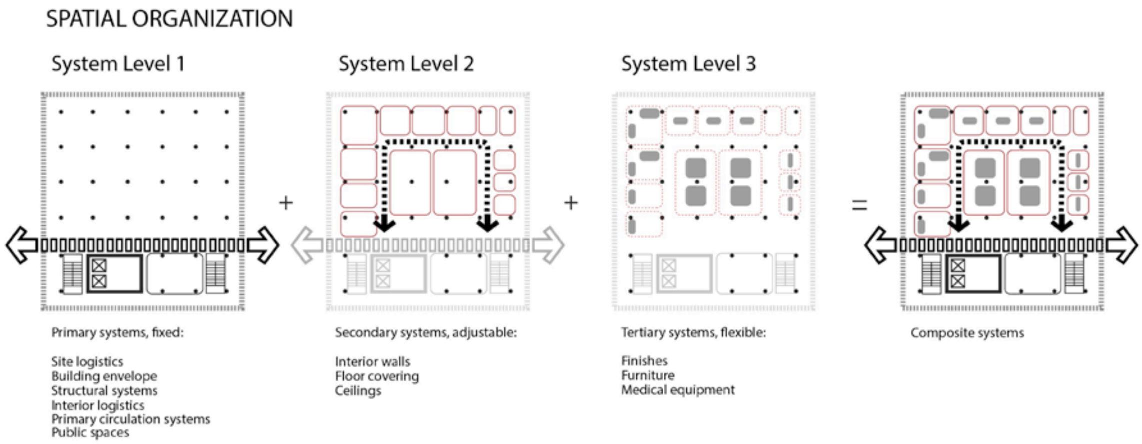

Figure 1: Systems Separation Framework

Within this framework, specific recommendations for creating a flexible healthcare infrastructure follow:

1. **Plan for expansion and provide open space:** This includes providing adequate site area(s) whenever possible, and organizing logical movement and system spines with growth corridors for expansion or the sequential replacement of infrastructure that can no longer accommodate changing needs. Expansion ideally needs to be able to occur through both the growth of existing services in place and the replication or addition of new elements. Locate and size the physical plant and primary MEP distribution systems to accommodate expansion without disruption or relocation of primary movement patterns and functional areas.
2. **Organize and align infrastructure and major circulation pathways as stable elements:** Primary public and back-of-the-house circulation pathways (both horizontal and vertical) should be aligned with both structural and primary MEP distribution elements (trunk lines, equipment rooms) in such a way as to create large unimpeded functional blocks of space. These elements should be planned as stable elements that should not need to be moved as needs change.
3. **Size and design structural elements for flexibility:** Structural column spacing and bays should be sized to accommodate multiple space configurations. Whenever possible consider long span systems to create column-free zones in highly volatile areas. Allow adequate floor-to-floor height and/or interstitial zones to accommodate ample systems distribution, expansion, replacement and maintenance.
4. **Size and design MEP/IT systems for change with minimal disruption to patient care and operations:** Provide accessible MEP and information technology (IT) pathways and systems with routing to avoid disruption of functional areas and other critical building services. Provide added capacity in the main plant, risers, trunk lines, electrical and IT closets to accommodate increased equipment loads and expanded demand.
5. **Provide flexible space fields to accommodate variable uses and spatial configurations:** Diagnostic, treatment and clinical areas should be located within open reconfigurable areas free of primary public and service pathways and primary MEP shafts, systems and trunk lines. These zones or blocks can work with a narrow dimension of approximately 100-120 feet wide and still allow the efficient functional layout of various diagnostic and treatment

departments. This dimension also enables efficient distribution of MEP systems from the periphery and access to daylight within departments.

6. **Provide flexible planning modules that can be re-purposed or reconfigured with minimal change:** Organize departmental areas around flexible modular groupings of diagnostic and treatment spaces. Suite modules may be interchangeable between operating and interventional room around a central core, for example. Different modules may be designed to accommodate various imaging modalities around a staff work zone. Standardized clinic modules may be used for various primary and clinical specialties. Standard modules should be easily converted or reassigned as needs change over time.
7. **Provide universal spaces that can be re-purposed without physical re-configuration:** Provide universal patient rooms that can be employed as acute care, step-down or intensive care over the life of a patient stay or the life of the room. Provide standardized sizes of rooms for exam, support and office spaces in clinic areas that can be converted or re-assigned as needs change over time.
8. **Provide pre-manufactured modular casework and partition systems:** These elements should be easily replaced, relocated, repurposed and re-used with minimal construction and disruption. Labs, pharmacy and staff work areas that are casework-intensive are likely locations. Highly repetitive spaces like patient rooms and exam rooms that may have changing uses are also good locations for these systems.

Tools for Creating a Flexible Healthcare Infrastructure

Project delivery processes being employed today have the potential to enable the construction of a more flexible healthcare infrastructure. Integrated project delivery (IPD) processes and building information modeling (BIM) can be much be more effective and efficient at designing, and coordinating a systems approach to building if employed with life-cycle flexibility in mind. They also have the potential to enable more effective management and tracking of changes in after initial configuration and occupancy if the capacity exists within the healthcare system to use them in this manner. BIM also has the potential to enable the design, coordination and organization of building systems too tightly if it is only used to minimize system conflicts in the initial configuration.

Advances in prefabrication technologies and their increasing application in the healthcare construction industry also have the potential to make healthcare infrastructure more flexible and changeable over time. Everything from headwalls, to casework to wall systems and entire room modules are now being regularly employed in the construction of healthcare facilities. These elements naturally work within a systems separation approach to building, as they exist at the tertiary systems level and have the potential to be designed to be plug-and-play ready, and then relocated or removed and replaced when they become obsolete, with less disruption to higher order systems and facility operations. As utilization increases and mass customization capabilities advance, the limitations and initial cost differentials now associated with many prefabricated systems should be reduced.

Conclusions and limitations

Change in healthcare is occurring at an ever-increasing rate and scope due to the myriad of forces that influence it in science, technology, culture, economics and politics. Healthcare today is quite different than what and how it was delivered when much of the U.S. healthcare infrastructure still in use today was initially built. Change in healthcare is not only accelerating, but it is increasingly becoming unpredictable. Therefore the healthcare infrastructure we build and renovate today needs to be highly nimble and flexible. One thing is fairly certain. The economics of healthcare will continue to demand that it delivers more, better, faster and with fewer resources than in the past, not only initially but also over the lifespan of the infrastructure being built today and tomorrow. Initial capital investment decisions need to not only consider first costs, but life-cycle costs that take into account all measures, including material costs, functional costs and environmental/health costs. Several conceptual and implemented frameworks exist that can enable a more flexible healthcare infrastructure are outlined in the body of this report. These models need to be implemented more consistently in the industry.

The limitations today, and with this report, is that the healthcare industry today does not systematically measure, track or fully understand life-cycle costs. Limited research exists on flexibility in healthcare infrastructure. In order to make better investment decisions for the long term, we need more and better information on the actual cost of designing and building for flexibility. Systematic research needs to be funded and executed that documents where change occurs in our healthcare infrastructure, to what degree, how often and at what cost. The industry needs a better understanding of the ratio of initial capital costs to life-cycle costs when healthcare infrastructure is designed for flexibility and when it is not.

Flexibility Defined

The first critical step for the work of Team 2 was to agree on a working definition of flexibility. The team began with Miriam Webster's online dictionary definition of flexibility[1] as, "Easily changed: able to change or do things differently" and "Characterized by a ready capability to adapt to new, different or changing requirements." In healthcare infrastructure, "easily changed" needs further clarification. The goal of a flexible healthcare infrastructure is to make change easier or at least possible, as it is not often easy or simple. Change is also a critical word in the definition, and the forces that drive change in healthcare are numerous, complex and often in conflict.

There are differing views on the use and meaning of the term flexibility. Flexibility and adaptability are often used interchangeably for differing, and at times alternating, conditions. Flexibility narrowly defined might be considered the ability of a given spatial or system configuration to accommodate changing needs without or with only superficial reconfiguration. Adaptability, on the other hand, involves elements at various scales explicitly designed for easy physical reconfiguration at some level. Expandability involves both the expansion and/or replication of existing buildings, departments, systems, etc. in place at various scales. **For the purposes of this report, flexibility will actually refer to all three critical abilities applicable to healthcare infrastructure: flexibility, adaptability and expandability.**

The team went on to state that flexibility in health facility infrastructure included both building systems and spatial conditions being able to accommodate changes in facility usage, clinical modalities, medical equipment, system loads, etc.

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[1] http://www.merriam-webster.com/dictionary/flexible

Drivers for Change in Healthcare Infrastructure

The scope of change in healthcare practices and healthcare delivery over the past 50-70 years is truly astounding. Healthcare providers in 1945 were practicing medicine and delivering healthcare in a very different way and in very different physical settings. The Hill-Burton Act was passed following World War II and many of the hospitals in the United States were built or expanded in the following decades based on federal guidelines set by the standards of care and technologies available in the mid 20th century. Many of those facilities are now at, nearing or past their functional life, yet are still in use. Their designs were based on formulaic templates recorded in a publication titled, "Elements of the General Hospital" (Bugbee, 1952). This document came to be termed by some the "cookbook," as it included very specific templates based on accepted practices at the time. Even though intended to provide guidance, they were "often simply adapted to a particular site by architects" (Currie, 2007, p. 158). Hill-Burton era hospitals were often designed and built fast and without much understanding of the changes that would occur in healthcare over their operational life.

Inpatient care since the mid 20th century has moved from multi-bedded wards, to semiprivate patient rooms to all-private patient rooms. Toilets and showers in each room became the standard rather than the exception. Progressive patient care introduced intensive care units and step-down units. Birthing units evolved with LDR and LDRP rooms replacing the factory model of obstetrics that existed mid-century. Women's health anticipated a broader patient and family-centered care movement that has continued to transform the size and outfitting of inpatient rooms and other spaces throughout the hospital. Concepts of therapeutic environments have been rediscovered, widely adopted and have begun to be validated through an expanding body of research. The patient who was once a passive recipient of care is now more likely to be an engaged and educated consumer of care, with higher expectations both on the quality of care and the care experience. These forces have fundamentally transformed the design of hospitals and other settings.

Within the same period, medical science and technologies advanced at a lightning pace. New diagnostic technologies and procedures such as computerized tomography (CT); positron emission tomography (PET) and single photon emission computed tomography (SPECT); magnetic resonance imaging (MRI); and ultrasound became available. New treatment modalities evolved, including radiation and chemotherapy, proton beam therapy, open-heart surgery, angiography and cardiac catheterization, laparoscopic surgery, robotic surgery and, increasingly, ambulatory surgery. None of these diagnostic and treatment modalities existed when many hospital settings still in operation today were built. In addition, both old and new procedures that once required days in the hospital are now becoming routinely performed in hours between admission and discharge.

The rate of change in healthcare is only accelerating; and the scope of change is both significant and influenced by a wide range of forces. Advances in basic and medical sciences are transforming disease diagnosis and treatment protocols. Minimally invasive and image-guided surgery is becoming the norm. Advances in genetic medicine and pharmaceuticals are also transforming the nature of healthcare. More and more procedures are moving out of the hospital to a myriad of ambulatory care settings and from ambulatory care to home care. Healthcare is also being delivered differently through collaborative teams of caregivers and structured around the medical home. These different models of organizing and delivering healthcare, in combination with electronic medical records, digital imaging and point of care lab testing, are transforming the functional relationship within and beyond traditional healthcare settings, and thereby have the potential to alter the physical organization of space within those settings that was once driven exclusively by time, motion and physical proximity.

Significant demographic forces are also at work and have the potential to drive changes in the healthcare infrastructure. The move to expand market shares and evolving market demographics, including age, health status and cultural makeup, will drive the need for different types of settings. The growth of vertically integrated service lines and centers of excellence are oriented towards providing more patient-focused care. As more and more health care is delivered outside of the hospital, inpatient care will continue to become increasingly acute and complex, and a higher percentage of the inpatient population will be sicker, older and poly-chronic. While the inpatient population is becoming more acute, the healthcare provider workforce is becoming older and there remain concerns that there will be persistent provider shortages that will require new work patterns and incentives to attract and retain high-quality staff. A greater diversity of clinical care providers and younger generations coming out of medical education have been trained differently, will work differently and have different expectations. Older facilities that have evolved over time to become less efficient, less safe and less desirable places to work will be at a competitive disadvantage. At the same time, reimbursement patterns and consumerism are driving the need to create settings that are far more efficient; safer; support better health outcomes; and improve patient satisfaction. As needs change, healthcare settings must be able to transform without negatively impacting these increasingly important measures of quality.

The complexity of these forces, coupled with the magnitude and accelerating rate of changes in healthcare, makes the ability to accommodate change imperative in the design and construction of healthcare facilities. The rationale for a flexible healthcare infrastructure is now only greater, given the degree of uncertainty in predicting what the context for healthcare will be even five to 10 years out and more so over the life of the facilities built today.

The Scope, Rate and Locations of Change

A flexible healthcare infrastructure must endure and ideally accommodate constant change across multiple dimensions and to varying degrees throughout a given facility over time.

> *"In the early years of a hospital, issues tend to focus on what I would call 'tuning' of the building, mainly those involving communication systems and other electronic issues. As the building ages, there is a need to expand some areas and relocate others as experience dictates. Provisions for new equipment or updated equipment must be accommodated. New medical techniques, energy reduction imperatives or social standards can trigger the need for renovation. Generally, the older the building, the greater the need for periodic renovation to prevent premature opalescence and decrease operating costs. These changes most often involve all utility systems, space configuration and other changes. Normally the biggest impediments to change are the utility systems."*
>
> *(Tib Tusler FAIA, FACHA)*

Change occurs within healthcare facilities across multiple dimensions, from simply replacing furnishings and finishes, to the complete renovation or reconfiguration of whole areas or departments within a facility, to the expansion or replacement of entire buildings. Some changes can be met with minimal spatial reconfiguration and simply new furnishings, equipment and finishes. The ideal goal should be to accommodate as much change as possible at the lower ranges of physical reconfiguration. Highly cellular and repetitive areas, such as inpatient units and clinic areas, often change with little or no physical reconfiguration to their cellular structure. An example of this would be the conversion of semi-private rooms to private rooms. Or, an acuity-adaptable or universal patient room might transform from intensive to acute care (or vice versa) over the life of a patient stay, or over the life of the room, The conversion of a clinic area from one specialty to another is another example of this level of change. This type of change is, however, constrained when the cellular structure of these areas is inadequate to meet new functional needs; requirements dictated by updated codes and standards; or building systems capacity.

Changing needs will, at times, require more substantive renovation and reconfiguration of a department or area over the life of a structure. This often occurs when departments need to expand in place, or are entirely relocated in an existing structure when they cannot expand in place. This may require the partial reconfiguration of the floor plan and MEP systems or the complete gut renovation of a space to the base structure. The degree to which the overall building and its systems were designed for flexibility when built will impact this level of change. When the building structure and infrastructure is not adequately designed to accommodate change, it can be both expensive and disruptive to accomplish. It can also have negative consequences for wayfinding, and the overall functioning of care delivery.

Most large healthcare facilities are expanded at some point, and usually multiple times over their life, unless it is simply impossible due to site or structural constraints. Expansion can be particularly expensive; disruptive to operations during construction; and compromise the overall functioning of the facility when the original building is not designed and built to adequately anticipate both future expansion and change within. Many healthcare facilities suffer from a cancerous form of growth and transformation that leads to incoherent wayfinding, less-than-ideal functional relationships and movement patterns, along with compromised efficiencies. At worst, the oldest and least-functional parts of a facility are completely encapsulated by newer construction, making removal of the heart of the facility difficult, expensive and/or impossible to achieve.

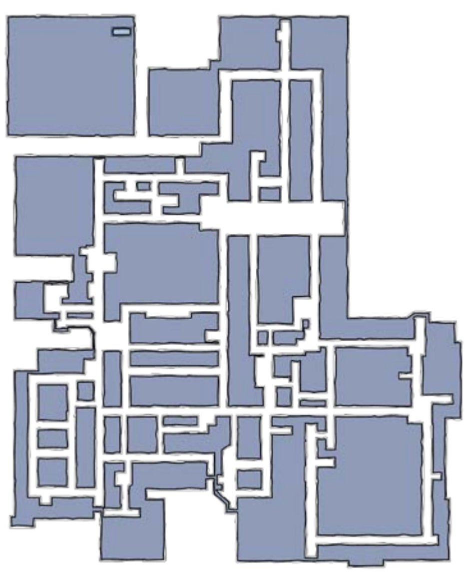

Figure 2: The Impact of Unanticipated Renovation/Expansion

Clay Seckman pointed out that cost and disruption, with the advent of Hospital Consumer Assessment of Healthcare Providers and Systems (HCAPS) survey and safety-based reimbursement, are two of the most significant dimensions of change. However, there is very little empirical data in the literature that documents the overall scope, rate and cost of accommodating changing needs and programs in healthcare settings. This was confirmed by the experiences of the team members. Team members had little or no access to comprehensive data on change, the cost of disruption or the cost of change and the cost of inflexible environments in their facilities or with their clients. Healthcare organizations typically do not track these measures systematically or consistently in ways that can be compared and studied. It is, however, generally understood that certain areas in healthcare facilities have a relatively high volatility and high cost of change, such as imaging, surgery and other technology-intensive diagnostic and treatment areas. Other areas may have high volatility but, if designed properly, a relatively lower cost of change such as labs and pharmacies. Some areas have low volatility and/or relatively lower costs of change over the life of the infrastructure. These areas include the power plant, dietary, central stores and other support spaces and administrative areas. The study team reported to what degree change occurred and/or need to be addressed in the following areas.

Surgery and Interventional Areas: There was general consensus that surgery and interventional areas changed or needed to accommodate change frequently. However some reported that while procedures and technologies changed, this did not necessarily involve much physical reconfiguration of the department or operating rooms within it. Changes reported included the growth of hybrid operating rooms (ORs) and image-guided procedure rooms. ORs were also reported as being too small for the growing amount of equipment in them and, in some cases, this required enlarging ORs into adjacent support spaces.

Imaging and Radiation Oncology Areas: There was consensus that imaging had the highest rates of change. Most change was the result of adding or replacing new and updated modalities and equipment. One respondent indicated that his facility had a seven-year rotation with new equipment. Spencer Moore at MD Anderson reported radiation oncology areas as also having high rates of change, again due to equipment upgrades. New equipment typically had greater and/or different mechanical and electrical loads, resulting in upgrades to those systems.

Emergency: There was mixed response from team members on the amount of change and the need for flexibility in the emergency department (ED). Some team members responded that they experienced a great deal of change in this area and others reported low rates of change. The greatest physical transformations that were reported were in the expansion of the department. Changes also included reorganization of registration processes and intake spaces and the drive to minimize or eliminate waiting and the need for fast track or clinical decision units. Changes were also reported to flexibly accommodate the highly variable ebb and flow of patients and improve utilization and throughput.

Clinical Labs and Pathology: Reports from team members on the rate of change in these areas were mixed, but there was general agreement that changes in lab areas rarely require the physical reconfiguration of space. Many labs are now typically organized in flexible modules and/or have modular casework. This also reflects the findings of a Clemson University study, “Nature and

Rate of Change in Clinical Labs," executed in 2002 (Battisto & Allison, 2002). It found that minor renovations of casework and reorganization of workstations occurs about every five years and that the addition or replacement of automated equipment occurred with similar frequency. Some team members indicated that labs were moving off site.

Research Labs: Respondents associated with institutions affiliated with teaching and research enterprises indicated that research labs had a high rate of change. These areas were also reported as employing modular casework and workstations that could be reconfigured as needed by changing research studies and research teams.

Acute Inpatient Units: There were varying reports on change in inpatient areas, with some reporting low rates of change and other reporting moderate to higher rates of change. Changes in inpatient units typically resulted from the increasing acuity of patients and the need for acuity adaptability. The move to all-private patient rooms and providing accommodations for families were also reported as drivers for the renovation of patient rooms and inpatient units. Renovations were noted as either the replacement of fixtures, furnishings and finishes. The replacement or expansion of inpatient areas in new construction was another trend identified by the team.

Intensive Care Units: There were inconsistent responses by team members on the rate of change in intensive care units, with reports varying between reports of low, moderate and high levels of change. Most change resulted from increasing and changing monitoring technologies, increasing acuity of patient populations, accommodations for family members and changing facilities guidelines requirements (FGI). Respondents reported both cosmetic renovations, but when more extensive change needed to be accommodated, it was in the form of expansion or replacement of entire units in new construction.

Perinatal Areas: Most change reported by team members occurred in Neonatal Intensive Care Units (NICU) although labor, delivery, recovery (LDR)/labor, delivery, recovery, postpartum (LDRP) conversions were also reported. The conversion from open wards to private NICU rooms, with accommodations for families, generates significantly different space requirements and configurations. NICU spaces were reported as being too small. The replacement, relocation and expansion of services were cited as the typical modes of accommodating the need for change.

Ambulatory Care Areas: Surprisingly, while some responses indicated significant changes in ambulatory care spaces, most team members reported low rates of change in clinic areas. When it occurred, change occurred through the expansion and upgrade of aging space.

Public Areas: These areas, when noted, were reported to have low rates of change and, when these spaces were renovated or expanded, it was driven by the desire to improve the overall image of the facility.

Physical Plant: While these areas were reported as generally having low rates of change, there were noteworthy reports of significant change. IT and cabling upgrades were significant. The replacement of central energy plant equipment was reported in cycles, with plants in older facilities nearing the end of their functional life. Respondents reported the expansion of chillers, boilers and switchgear as a result of facility expansion projects, and the conversion of physical plants for improved energy performance and sustainability upgrades, including the conversion to district plants.

Concepts and Best Practices for a Flexible Healthcare Infrastructure

Buildings as Layers of Change: The study team was encouraged to review a framework for understanding and designing buildings to accommodate change, as outlined in the book, *How Buildings Learn: What Happens After They're Built*, by Stewart Brand. Brand expands on the conceptual framework of the English architect Frank Duffy to identify six shearing layers of change in buildings (Brand, 1994). While their work does not focus on healthcare facilities, it is particularly relevant, given that healthcare facilities are the some of the most-dynamic and ever-changing building types for the reasons, and in the ways, outlined above. Brand and Duffy's fundamental premise is that buildings are composed of various layers (or systems) with different rates of change. Buildings become obsolescent when the layers that are slow to change impede change in the layers where change occurs - or needs to occur - more frequently. Brand references Duffy, who claimed that renovations and alterations within a building with a 50-year lifespan exceed the initial cost of a building by three times (Brand, 1994). Again, his work was not based specifically on the study of healthcare facilities and, given the cost of construction and rate of change associated with healthcare facilities, it can be presumed that this ratio is even higher in healthcare.

Brand's six layers of change include **site, structure, skin, systems, space plan and stuff** (Brand, 1994). **Site** is the most stable element in that it is essentially permanent, with the exception of the ability to acquire additional adjacent land. The **structure** of a facility rarely changes over its life, except due to great need and at great expense. It is often the layer that ultimately limits the lifespan of a building. In healthcare this is commonly due to low floor-to-floor heights, column spacing or changing seismic regulations. The **skin** also rarely changes and, when it does, it may be due to the need to expand the building footprint, improve the energy performance of a structure or for an image makeover. Building MEP, life safety and communication **systems** change as a result of wear and tear, evolving load requirements and performance or technology improvements. These systems are typically replaced or upgraded on cycles of about 10-15 years, and at times more frequently in healthcare settings. The **space plan** includes the partitions; doors; floor and ceiling systems; and finishes, along with fixed equipment and fixtures. The **stuff** is all the movable FFE, along with all the things that the occupants bring into and out of the building every day (Brand, 1994).

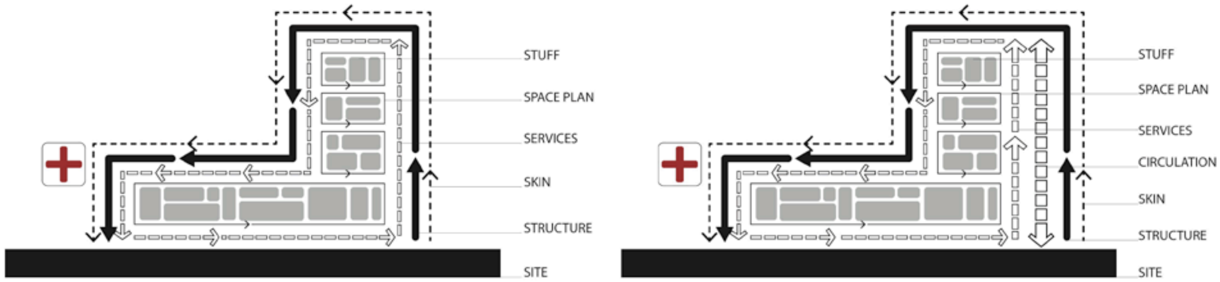

Figure 3: Shearing Layers of Change in Healthcare Facilities

One significant omission in the Brand/Duffy framework is building **circulation**, both horizontal and vertical. They identify elevators and escalators with moving parts as part of the "services" layer. However, this overlooks explicit and broader consideration of all vertical and horizontal circulation, including elevators; fire stairs and egress pathways; and public, staff, patient and service corridors. Primary circulation, especially physically "hard" elements, such as elevators and fire stairs must be considered similar to structure, essentially stable elements, as they are resistant to change and are never relocated except in extreme circumstances. Likewise, primary exit access, public and back-of-the-house circulation pathways that link main entry points, departments, elevators and stairs should also be considered and organized as stable elements. These pathways typically serve as the expressways through the building for the efficient movement of people and materials. Primary public pathways and landmarks are essential for legible wayfinding and should, therefore, be stable elements of the healthcare infrastructure. As in city streets, they may be separate but aligned with other service system pathways for the movement of energy, materials and information.

VA Hospital Building System: This work came to be known as the Integrated Building System (IBS) and was developed for what was then the Veterans Administration (VA). It remains the most thoroughly documented and systematic framework for the planning, design, construction and flexible accommodation of changing needs in healthcare facilities. It was the result of a VA-funded study, originally published in 1972 and executed by a joint venture of Building Systems Research and the architectural firm of Stone Marraccini and Patterson. The overall study involved a 'systems approach' that employed a concept of 'building systems integration,' with a kit of parts of coordinated component elements; a 'building system' that involved a process of design and construction; and a generalized 'prototype design' (Veterans Administration, rev. 1977, sec. 612.1).

The intent and benefits of the system went beyond simply designing for flexibility and included:

- *Reduction of initial project costs through standardization, prefabrication, reduction of change order costs and reduced construction time, especially in periods of rapid cost escalation*
- *Improved performance and reduction of life-cycle costs by reducing the cost of both routine maintenance and operations, and the physical alteration and reconfiguration of spaces and systems.*
- *Adaptability and prevention of obsolescence through open configurations designed to allow the widest possible range of design configurations over the life of the facility.*
- *Time reduction through efficient installation during the extended time period of construction, and time needed for maintenance or alterations after occupancy with minimum down time and minimum disruption of normal operations outside the immediate area of alteration.*

(Veterans Administration, sec. 621)

The IBS prototype design includes four distinct elements that can be designed and assembled in various configurations. Long-span **structural bays** provide a column-free zone for the flexible planning of various functional areas in **space modules**. Space modules are sized and organized to allow the flexible planning and transformation of functional or departmental areas over time. They are set within **service modules** that form functional areas with interstitial zone located overhead. The interstitial zone accommodates all horizontal ducting, piping, electrical and IT distribution in a highly coordinated layout to minimize system conflicts and enable easy access for service and modification without disruption to the functional areas below and above. Multiple space modules and service modules form **fire sections** as needed for smoke compartmentalization and fire separation. A **service bay** that houses air-handling units with major supply and return shafts, piping risers and electrical equipment is sized to serve maximum potential loads for the area and positioned along one exterior side of each space and service module, or on the roof overhead.

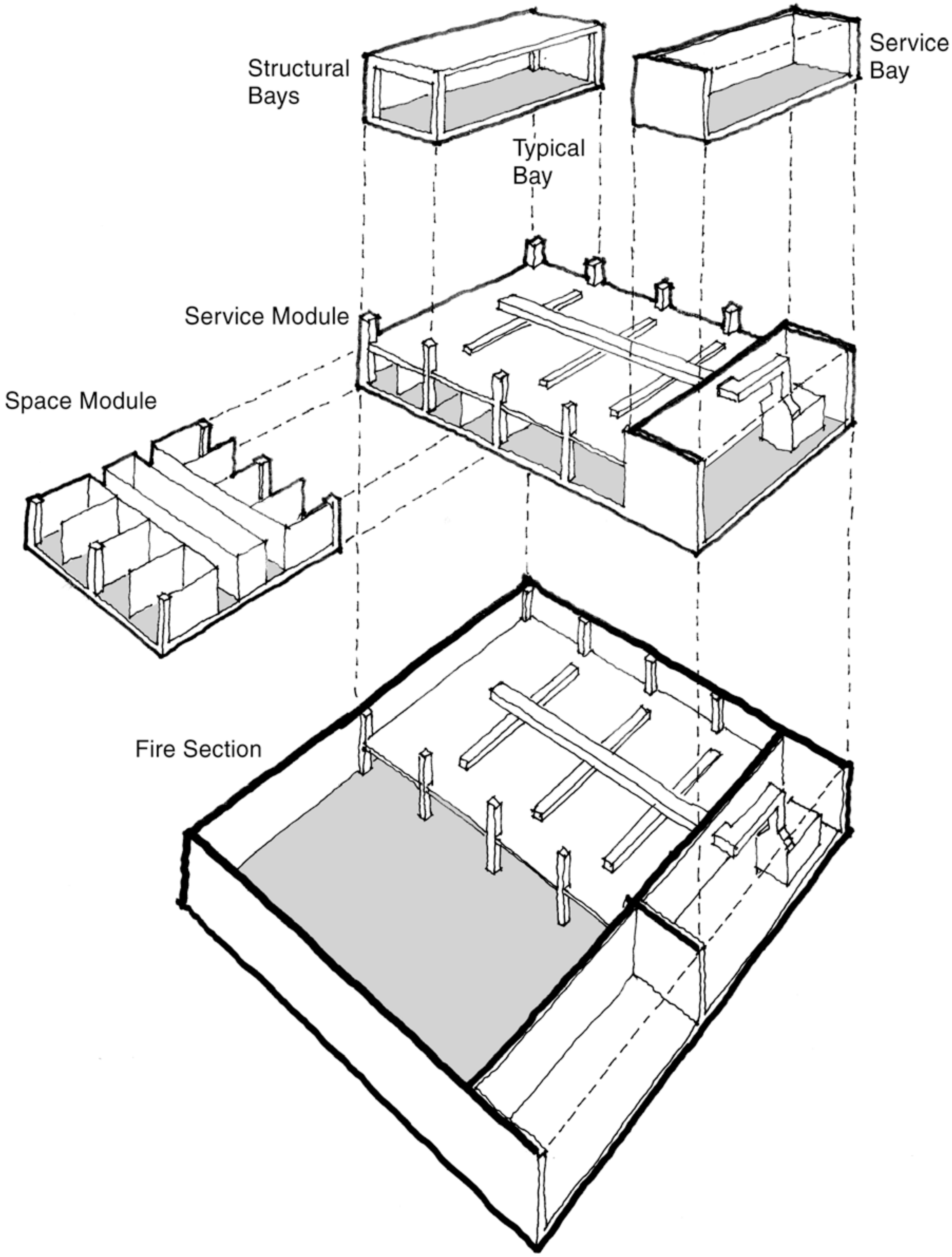

Figure 4: VA Building System Planning Modules
(Redrawn from Veterans Administration, Fig. 110-1)

Open Building Systems and the INO Hospital: Professor Stephen Kendall and a study team from Ball State University, TU Munich and BSA Design in Indianapolis documented the framework and execution of an open building system for the INO Hospital expansion in Bern Switzerland (Ball State University, Building Futures Institute, 2002). The Canton Bern Building Department was responsible for delivering an expansion project for the INO Hospital. The planning process was frustrated by the inability to fix a building program for the hospital expansion. As a result they conceived an alternative planning process that the Ball State study team ultimately termed "Open Building." The process was designed to enable the multi-year design and construction process to proceed through implementation in three stages by separate design teams at three distinct levels of design. The first phase was executed as a competition and included **primary systems**, essentially the core and shell base building, designed for an approximately 100-year lifespan. The second phase and **secondary systems** were also designed though a competition with different architects, and essentially involved the tenant up-fit or medical and space planning of the building interior. The secondary systems were expected to have a lifespan of approximately 20 years. The third phase was conceived as the design of the fixtures, furnishings and equipment installation with an intended lifespan of 5-10 years.

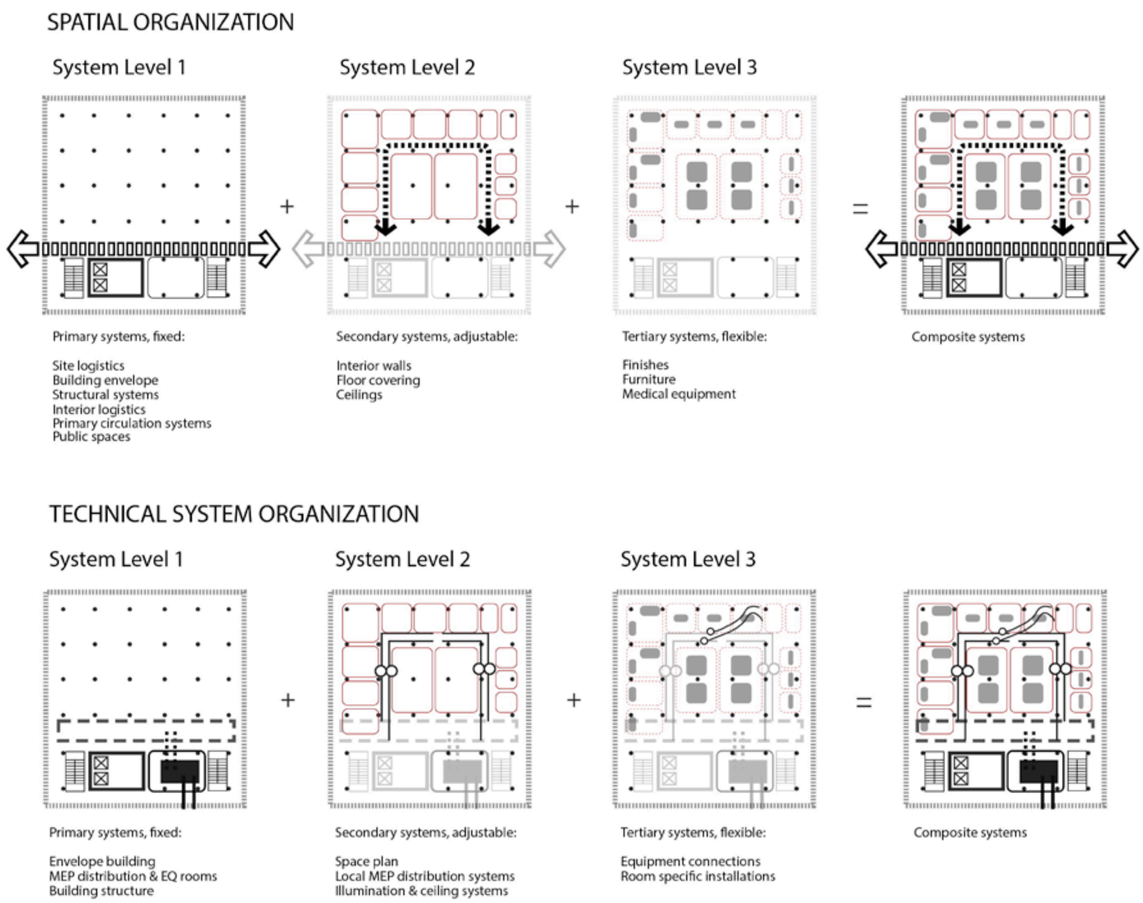

Figure 5: Open Building System Levels

Primary | Systems Level One: The primary system includes the structural frame. The primary systems also include core mechanical risers and distribution systems, along with the most-stable vertical circulation elements organized and located outside the primary planning footprint. It the case of the INO project, the structural frame consisted of precast concrete columns and a cast-in-place concrete two-way flat slab given the floor-to-floor height was low in order to align with an existing structure. A 3.6-meter square knockout section was located in the center of each structural bay to allow for the flexible positioning of vertical penetrations, including mechanical shafts, vertical circulation and light wells designed to allow daylight to penetrate the deep 80x90 meter floor plate of the expansion project. The concrete slab and reinforcing in the center of the bay was designed so that it could be cut so that openings in the slab could be determined upon design of the initial space planning that would follow (Ball State, 2002, p19). In addition to openings defined during the initial configuration and construction, additional openings could be cut as needed over time due to changing needs and reconfiguration of the space plan. The flat concrete slab system and floor-to-floor height employed at INO would not be ideal for contemporary hospital construction in the United States, but the framework of structure as part of a primary system works across a variety of structural systems.

The primary system at INO also included a double envelope exterior wall system with an open air space of .7 meters between the in inner and outer wall assemblies. The double envelope was driven in part by the desire for energy conservation and to enable the building to “breathe naturally,” given that access to daylight and fresh air is generally of greater importance in Europe than the United States. The exterior layer of the wall system is composed of glass panels with operable sun control blinds and the interior wall system is composed of wood panels and operable wood windows that span from floor slab to floor slab (Ball State, 2002, p 20). Again, the exact double envelope system can vary. The exterior wall assembly can be designed to the performance characteristics needed for the solar orientation and environmental conditions and image of any given context. The interior wall system can be fabricated with metal studs, and/or a variety of glazing, interior finish and cladding systems common to institutional construction in the United States. An additional novel benefit of the double wall system is that it provides a stable exterior façade that can accommodate changing configurations in the floor plan. The exterior assembly is not intended to change frequently, although it can be changed if needed. The inner layer, given the nature of its construction, can be easily reconfigured as needed, without impact to the exterior assembly or building image. Window locations can be added, removed or relocated for views, daylight and ventilation, as the needs and layout of interior spaces and location of interior walls that engage the exterior façade are repositioned over time.

Secondary | Systems Level Two: The secondary systems include the space planning of interior functional areas, including the layout of walls, doors, floors, ceilings and some fixed equipment for each floor or departmental area. The functional program specified at INO for the secondary systems included surgery, radiology, nuclear medicine, emergency, intensive care, laboratory, pharmacy, central sterilization and several support functions. The primary systems configuration was tested against multiple configurations of the secondary systems for these functional areas (Ball State, 2002, pp 20-29).

Tertiary | Systems Level Three: Tertiary systems generally refer to FFE, and include either built-in but removable items, such as casework, with or without plumbing, or completely movable items, such as furniture and medical equipment. Demountable partition systems would also be included as FFE. These items are often purchased outside of a basic construction contract, whether installed by the contractor, owner or a third party. They are recognized as having a short life cycle and are generally considered depreciated assets. These elements and systems are already widely recognized and treated in healthcare construction as separate from base building and secondary systems. Victor Sanvido added another level that must be considered: models of care, which change even more frequently.

Case Study Summary: The Open Building framework employed on the INO hospital includes two basic attributes: a concept of systems separation, and distinct design and construction contract phasing and award. Likewise, the VA Building System also employs a similar but more-defined strategy of systems separation. The clear definition and separation of the systems in both models regulates the design of each system level, and all system levels as a whole, in such a way to flexibly accommodate changing needs over time. When the systems are clearly organized and separated, they can also be more easily executed in stages, either during the initial design configuration and construction, or at any point over the life of the infrastructure. The concept of systems separation mimics commercial high-rise building in the United States whereas the tenant up-fit (functional space planning and FFE) is separated from the base building design and construction. However, it was noted by some team members that healthcare design requirements, system loads and regulatory constraints are quite different than those in commercial construction. Both the VA Building System and the Open Building Framework employed at the INO hospital are systematically organized to accommodate the shearing layers of change that Brand identifies so that the stable elements do not impede change in functional areas.

Planning and Design Recommendations for a Flexible Healthcare Infrastructure

Plan for expansion and provide open space: Provide adequate site area(s) whenever possible and organize logical movement and system spines or growth corridors for expansion or the sequential replacement of infrastructure that can no longer accommodate changing needs. Flexible growth ideally needs to be accommodated through both the expansion of existing services in-place and the replication or addition of new elements. Locate and size the physical plant and primary MEP distribution systems to accommodate expansion, without disruption or relocation of primary movement patterns and functional areas.

Banner Estrella Medical Center in Phoenix, Arizona, by NBBJ was planned to accommodate the future expansion in place of diagnostic and treatment areas, as well as expansion or replication of additional diagnostic and treatment services and inpatient pavilions. The physical plant and materials delivery areas were located away from the initial phases of the hospital. A circulation and services distribution spine was organized as a stable element intended to link all initial and future phases on the campus. The main entry was also designed as a stable element (Martin C. NBBJ, Seminar PPT Presentations, 2005-2015).

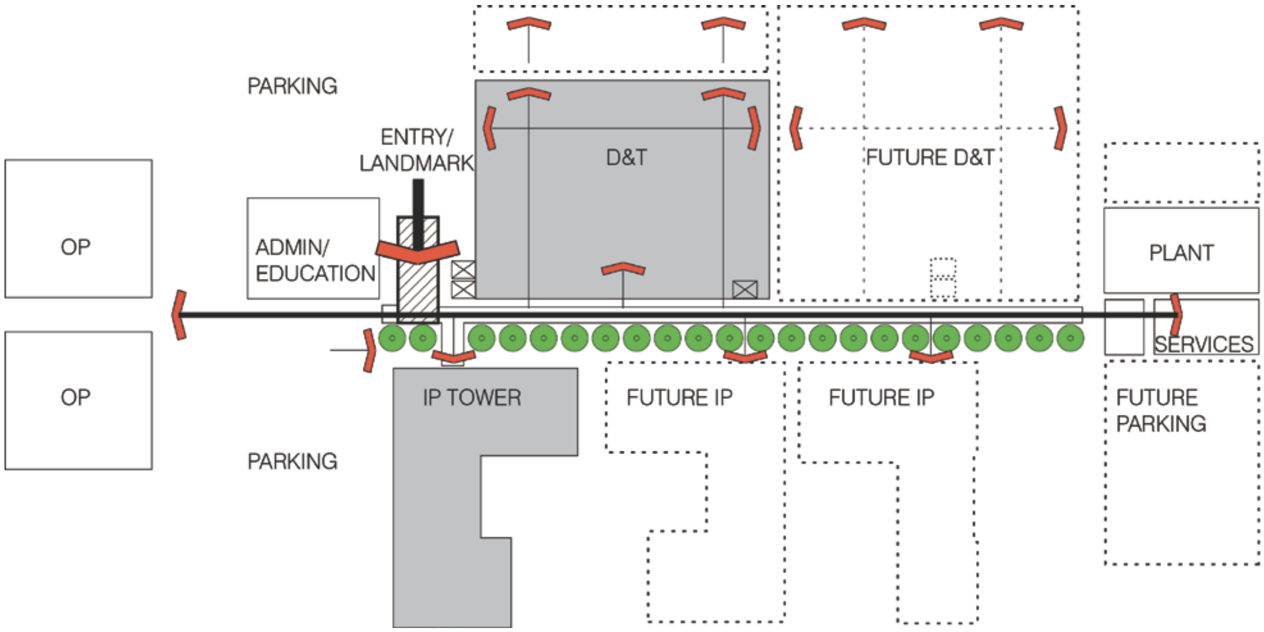

Figure 6: Banner Estrella Expansion Planning

Organize and align infrastructure and major circulation pathways as stable elements: Primary public and back-of-the-house circulation pathways (both horizontal and vertical) should be aligned with structural and primary MEP distribution elements (trunk lines, equipment rooms) in such a way to create large functional blocks of space free of physical interruptions. These elements should be planned as stable elements that should not need to be moved as needs change.

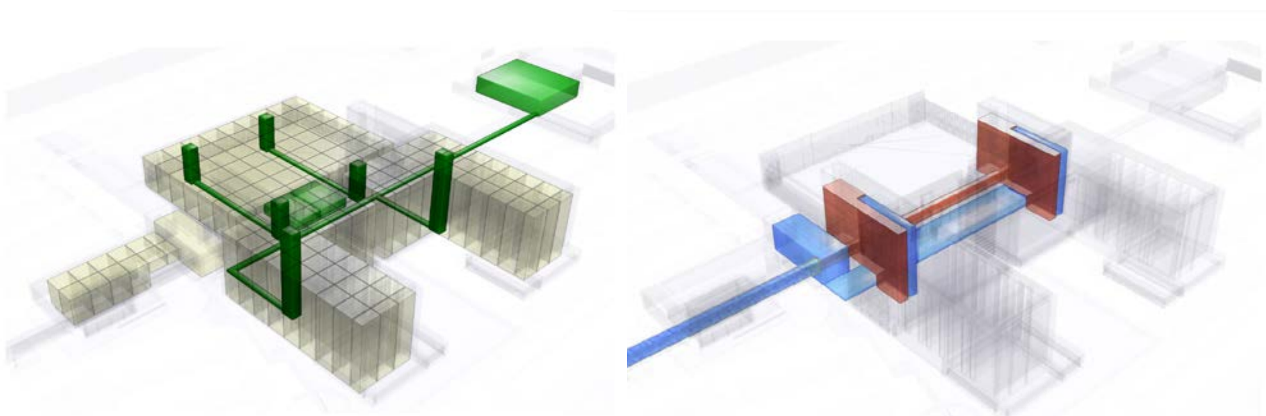

Figure 7: Banner Estrella Primary Infrastructure and Circulation
[diagrams courtesy of NBBJ]

Again, the Banner Estrella Medical Center campus in Phoenix (see Figure 7) was designed to accommodate various forms of expansion and change. The primary distribution of services, materials and people is organized along a central spine with diagnostic and treatment areas to one side and an initial inpatient wing on the other side of the spine. Ambulatory care facilities were planned for one end of the spine. The campus physical plant is located at the opposite end of the spine and positioned far enough away from the initial phases of construction to allow for the addition and expansion of both diagnostic and treatment areas and inpatient wings. The spine also includes a below-grade service tunnel that extends from a central receiving facility for movement of supplies. The primary distribution of MEP systems (shown in green) from the physical plant occurs within and below the service level of the spine (Martin NBBJ, 2005-2015).

Primary public circulation (shown in blue) occurs at grade in the hospital and links the main entry with the rest of the facility at public elevator cores. Horizontal primary public circulation was designed as a single loaded corridor along an exterior garden to promote wayfinding, along with connections to daylight and nature for patients and the public. Primary back-of-the-house circulation (shown in red) within the hospital was intended to occur on upper levels along the spine. The alignment and positioning of these elements creates open flexible space fields that can accommodate a range of departmental configurations, initially and over the life of the facility, without altering primary distribution and circulation pathways (Martin NBBJ, 2005-2015).

Size and design structural elements for flexibility: Structural column spacing and bays should be sized to accommodate multiple space configurations. Whenever possible, consider long-span systems to create column-free zones in highly volatile areas. Allow adequate floor-to-floor height and/or interstitial zones to accommodate ample systems distribution, expansion, replacement and maintenance. Vertical expansions can be complex and difficult, but have been accomplished with success if the original structure has been designed to accommodate additional floors. It is critical to have interstitial floors between existing functional areas and additions to minimize disruptions and maximize safety. Chip Cogswell shared information that Turner Construction has had deep experience (2.4 million SF in Middle Tennessee alone) in building on top of existing hospital construction while keeping the facility fully functional.

Structural column bays should be sized as large as possible, but a common minimum dimension between columns today is between 30-32 feet. Banner Estrella, for example, employs a structural bay of 32x32 feet in the open planning areas of the hospital. A structural bay of 32 feet square has been shown to generally accommodate the clearance and area requirements of both acute and intensive care patient rooms in a variety of configurations. It can also accommodate a range of the larger room configurations found in diagnostic and treatment areas, such as surgery, interventional and imaging rooms. It also accommodates groupings of 3 exam rooms per structural bay in clinical areas when exam rooms are about 10 feet wide, or two wider treatment rooms.

Long spans with interstitial zones over functional areas, as employed in the VA Building System, provide the greatest flexibility in functional planning, with minimal interference from columns, shafts and vertical risers. Long spans are particularly useful over highly volatile diagnostic and treatment areas. However, Tib Tusler stresses that optimal flexibility is only achieved when the entire integrated building system is employed universally throughout a facility. Palomar Pomerado Medical Center by CO Architects, north of San Diego, also employs a long-span, column-free zone over the surgery and interventional procedure areas of the diagnostic and treatment portion of the hospital. The 110-foot clear span at Palomar allows for the flexible arrangement of pods of procedure rooms organized around either clean or work cores and surrounded by a perimeter corridor. The span is achieved through deep roof trusses within an overhead interstitial roof zone. The truss top chords undulate and support a green roof assembly over the diagnostic and treatment platform.

The limited floor-to-floor heights common in many healthcare facilities built in the early to mid 20th century have proven to be significant barriers to flexibility. In large healthcare complexes with multiple building additions, the perplexing question that often arises is how to expand further and align floor levels without continuing a pattern of constrained infrastructure, or when to simply forgo attempts to align floors with older structures by skipping floors, abandoning older facilities or building a completely new replacement facility. Most conventional new hospital construction today is built with a floor-to-floor height of 15-18 feet. Even so, the density of MEP, IT and other systems can be such that routine maintenance is difficult and disruptive, and replacement is also costly and disruptive. These issues are a significant advantage of dedicated distribution zones (both horizontal and vertical) in the VA Building System. Whether or not a complete IBS system or interstitial floor system is employed, adequate vertical and horizontal zones within the building structure should be provided to accommodate a systematic layout and organization of primary distribution pathways, connection points and maintenance locations in order to to achieving a flexible healthcare infrastructure.

Size and design MEP/IT systems for change with minimal disruption to patient care and operations: Provide accessible MEP and IT pathways and systems with routing to avoid disruption of functional areas and other critical building services. Clay Seckman reported that inadequate space for, and the capacity of, major MEP and IT systems, and the distribution of these systems throughout the facility, was a common barrier to making changes and upgrades. Others reported providing additional capacity to MEP systems beyond initial design loads. Victor Sanvido, however, cautioned against oversizing mechanical systems to the point where they operate efficiently and experience increased wear and tear. He also encouraged moving as much thermal energy as possible via water rather than air. Kurt Stahl reported providing 30-40% extra capacity in electrical panels and upsizing low voltage areas and IT closets as examples of flexibly accommodating future needs in their projects at AECOM. Fiber and structured cabling was specifically pointed out as a major issue. Multiple team members reported that changing regulation, including ASHRAE standards and requirements in the FGI *Guidelines for Design and Construction of Health Care Facilities*, were significant drivers for upgrades and increasing robustness in MEP systems.

The VA Building System employs a robust and highly structured strategy for organizing and designing the distribution of MEP and IT systems. Each service module and its service bay are sized to accommodate the systems needed for the maximum potential load on any given system in that zone. In order to create a more flexible healthcare infrastructure, irrespective of the specific approaches employed, it is important to properly locate MEP services and outside of large open space fields. It is also important to provide added capacity in the main plant, risers, trunk lines, raceways, electrical and IT closets to accommodate increasing equipment loads, expanded demand and new system requirements.

Provide flexible space fields to accommodate variable uses and spatial configurations: Diagnostic, treatment and clinical areas should be located within open reconfigurable areas that are free of primary public and service pathways and primary MEP systems and trunk lines. Banner Estrella was designed with open space fields essentially free of interruption (Figure 7). At Palomar Pomerado, these zones or blocks have been shown to work with a narrow dimension of approximately 100-120 feet wide, and still allow the efficient functional layout of various diagnostic and treatment departments. This dimension also enables efficient distribution of MEP systems from the periphery and improved access to daylight for both patients and staff within diagnostic and treatment departments that are typically located in thicker floor plates. Team members also recommended building shell space whenever possible in strategic locations. These initially unoccupied spaces should also be designed for flexibility and free of interruption by infrastructure and primary circulation elements.

The Feinberg Galter Pavilion of the Northwestern Memorial Hospital was organized with a public zone including horizontal and vertical circulation along the north end of the two-city block long facility. A parallel primary back-of-the-house circulation corridor runs parallel to it along the long axis on all diagnostic and treatment (D&T) floors and is separated from the public zone by banks of patient, staff and service elevators that open to the south. This allows the remaining two thirds of the building footprint to flexibly accommodate a range of diagnostic and treatment departments free of interruption from public or private horizontal and vertical inter-departmental circulation. Ellerbe Becket's (now AECOM) conceptual model for the Gonda Building at the Mayo Clinic is organized in the same way. It is structured so that a flexible clinic zone is located between a stable public and patient waiting and clinic access zone with a stable staff access and support zone to the rear of the clinic zone.

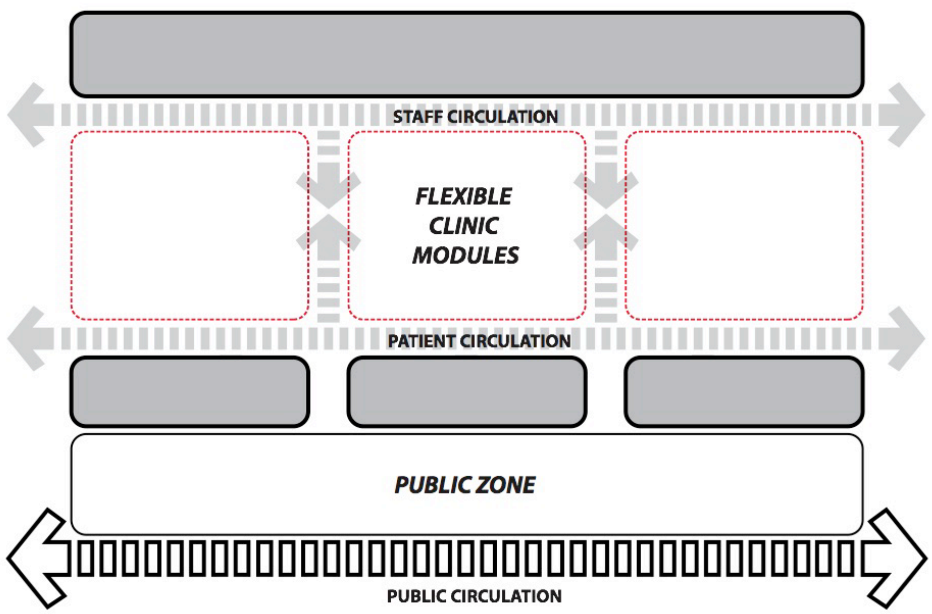

Figure 8: Conceptual Model for the Gonda Building at the Mayo Clinic

Provide flexible planning modules that can be re-purposed or reconfigured with minimal change: Organize departmental areas around flexible modular groupings of diagnostic and treatment spaces. Module dimensions and layouts should be coordinated with the structural grid so that columns, when present, occur in standardized locations for all modules. Surgical modules may be interchangeable between the operating and interventional room around a central core, as an example. Imaging modules may be designed to accommodate various imaging modalities around a staff work zone. Standardized clinic modules may be used for various primary and clinical specialties that might be used for different clinical practices on a regular schedule or be repurposed to another clinical specialty at some point in time. Standard modules should be easily converted or reassigned as needs change over time. Rick Harris with FKP reported employing clinic modules with standardized dimensions for exam and treatment spaces. Corridors were set as stable elements with plumbing for exam and treatment spaces located in corridor walls. Team members also encouraged the location of soft spaces or areas (faculty offices, administrative areas and small departments) that can be cannibalized and/or easily relocated.

Provide universal spaces that can be re-purposed without physical re-configuration: Provide universal patient rooms that can be employed as acute care, step-down or intensive care over the life of a patient stay or the life of the room. Also provide standardized sizes of rooms for exam, support and office spaces in clinic areas that can be converted or re-assigned as needs change over time. Modular room layouts can also allow the conversion of two smaller rooms into one larger room, or the subdivision of a larger room into a standardized smaller room. For example, size treatment rooms equal to two exam rooms. As clinical practices change, universal spaces based on standardized dimensions can be more easily repurposed. For example, physician offices and exam rooms can be converted from one use to another without the relocation of walls, when planned at the same size and with the same dimension. More ambulatory care exam encounters are now occurring as consultations across a table or desk, or on a couch in some practices, rather than traditional physical exams that occur on an exam table. This is fundamentally altering how exam rooms are used and how they are being designed and equipped. Universal spaces should be designed with a ‘plug-and play’ chassis so that casework, headwall assemblies, workstations, fixed and movable equipment, fixtures and accessories and furnishings can be easily reconfigured, replaced, removed or added.

Provide pre-manufactured modular casework and partition systems: These elements can be easily replaced, relocated, repurposed and re-used with minimal construction, disruption and down time. Team members reported that casework-intensive areas, such as both clinical and research labs, pharmacy and staff work areas are already common locations for modular casework. Highly repetitive spaces, like patient rooms and exam rooms that may individually or collectively have changing uses, are also good locations for these systems. The prefabrication of entire bathrooms, patient rooms, and diagnostic and treatment spaces are being employed in new healthcare construction to an increasing degree as well, although there was concern by some team members about the ultimate difficulty in changing out these spaces at some point in time.

Tools for Creating a Flexible Healthcare Infrastructure

There are a variety of tools, means and methods for delivering and managing the healthcare infrastructure available today that can support systematic design for flexibility. Integrated project delivery, building information modeling and prefabrication are being employed to eliminate waste, minimize conflicts, reduce change orders during construction, optimize decision making, promote collaboration, reduce construction time and accelerate revenue generation from capital investments. When employed with flexibility as a goal, they can be powerful resources.

However, the potential also exists to design too tightly for initial needs and, as Clay Seckman notes, they can be used to “actually reduce the flexibility over the life of the facility.

Building information modeling: Building information modeling (BIM) software now provides a potentially potent tool for implementing an open systems separation approach to the flexible design of healthcare facilities. It can enable better visualization and coordination of all building systems and elements, both during the initial design and construction process and as a facilities management tool over the life of the infrastructure. Team members reported that BIM is effectively becoming a standard operating procedure for project delivery.

In the past, the level of visualization and coordination of detailed and complex building systems integration that BIM now provides was rarely employed. Stone Marraccini and Patterson built highly detailed physical systems models and mock-ups in order to visualize, educate and coordinate the implementation of the VA Building System with all participants in the process. It proved very effective in educating the value of the systems approach to the contractor and subcontractors during construction. Physical modeling, however, is an expensive and time-consuming process, and suffers from resulting in a static physical artifact that can exist only in one place at a time. BIM enables virtual and dynamic modeling that can simultaneously be visualized and used in multiple locations and evolve as the original design develops, during construction and over the life of the facility as changes occur.

If developed and maintained properly, BIM can also minimize some of the uncertainty and unexpected cost and complications of remodel projects. However, Rick Harris with FKP cautioned about overselling BIM to facility managers that do not have the expertise or capacity to use it or maintain it. “BIM needs to be provided to the level it can be used.” Spencer Moore noted that the MD Anderson Cancer Center maintains a document library, but has not yet been able to transition from BIM to facility improvement measure (FIM). They are just getting started on how to use new tools that can be employed such as having maintenance personnel use BIM/FIM-capable tablets. Likewise, Cincinnati Children’s has yet to use BIM for routine maintenance. The relationship between facility management and equipment and systems providers is changing and with the proper tools it may help address the life-cycle facility management limitations of some health systems. George Sterling noted that Trane is moving from solely an equipment manufacturer to more of a solutions provider.

Given its ability to identify and resolve system conflicts during the design process, BIM also has the potential be used to design the initial configuration of systems too tightly and only for initial program needs. Buildings designed for change cannot be initially configured as tightly as systems are under the hood of a modern automobile. If used properly during design and construction, and in facility management, BIM can be an effective long-range tool for planning, documenting and managing change over the life of a facility.

Plug and play through prefabrication and modular design: The construction industry in the United States is still in the infancy stages of employing prefabrication and modular design of systems, assemblies and entire elements or spaces in healthcare construction, and significant increases in prefabrication are potentially on the horizon. Rick Harris reported that Nemours Hospital in Wilmington, Delaware, has employed prefab toilets, headwalls and utility assemblies in corridors. Walter Jones also stated Parkland employed prefab toilets and curtain walls. George Sterling with Trane mentioned that heating, ventilation and air conditioning (HVAC) units are routinely being prefabricated for controls and entire central plants are being created "in a box" pre-plumbed and prewired for installation next to an existing facility. Kurt Stahl reported prefabricated corridor racking improves "safety initially, and both safety and flexibility downstream." Victor Sanvido concurred that prefabrication leads to both reduced accidents and waste. Prefab can also help deal with a constrained labor market and improve efficiency in the construction process.

Mobile and modular technologies are commonplace today in many smaller hospitals where the cost and utilization of certain imaging technologies makes permanent installations prohibitive. STERIS deploys and operates mobile central sterilization units. However, rarely are healthcare facilities adequately designed for the need to plug and play mobile units. Mobile "ports" should be located and designed for the efficient, safe use of mobile and modular modalities, not simply accessed through the loading dock or nearest side entrance.

Prefabrication inherently works within an open building and system separation framework, where entire spaces have the potential to be designed, as system level 3 elements or FFE. It has the potential to help make a facility more plug-and-play. While modular casework is widely employed, and modular system components are routinely being adopted, some team members expressed concern regarding the ultimate ability to easily replace obsolete modular rooms, especially those with significant utility interfaces installed during initial construction and set deep within the building.

Integrated project delivery: Team members generally indicated that integrated project delivery (IPD) is becoming more common and being employed fairly regularly on the projects they have been involved with, although to varying degrees and through various contractual structures. Kurt Stahl noted that IPD helps establish a (collaborative) three-way relationship and allows thinking and visualization outside the box that can both anticipate future needs and right-sizing initially. Spencer Moore felt that IPD has the potential to help reveal future needs and identify potential flexibility strategies through the engagement of many different constituencies during the project delivery cycle. In addition to the project coordination benefits of IPD**,** it provides a project delivery model that can better conceive and implement open building and systems separation/integration concepts**.**

Conclusions and Limitations

> *"A building is like a musical instrument, for optimum performance it needs to have a tune up every so often."*
>
> *Tib Tusler*

Change in healthcare is occurring at an ever-increasing and accelerating rate due to a wide range of forces that impact the delivery of healthcare and healthcare infrastructure. The nature and scope of changes in healthcare over the 50-100 year lifespan of the typical healthcare facility built today is also increasingly unpredictable. **Our healthcare infrastructure therefore needs to be designed to be more flexible in order to remain optimally tuned for the safe, efficient and effective delivery of care over time.** However, given the increasingly constrained economics of healthcare today and in the future, a fundamental question remains unanswered; what are the initial capital investment premiums (if any) for building a more flexible healthcare infrastructure and how much will it save for an organization over the life of a given infrastructure investment?

Barriers to change: Rick Harris identified that societal and human forces are at times barriers to change. The biggest obstacles to change are people who are resistant to change. User groups involved in the design are often resistant to changing the ways they work. They know what they know deeply, and at times passionately, but they don't know or are not willing to accept things with which they have no experience. It is important to realize that the design of a given project is not only for the people involved at the conception, design and construction of a given project, but it is also for their successors over the life of the infrastructure. A significant challenge is that we are generally a first-cost, short-term-results culture and this has certainly been true in healthcare and is reinforced by the constrained economic context that it operates within today.

Tom Kinman with Cincinnati Children's noted that healthcare organizations generally do not have confidence in the claims about the life-cycle cost-benefit of flexibility strategies. Several team members also mentioned that some organizations have had problems with facilities in the past that have been designed for change that never happens, such as oversizing foundations or structures for vertical expansion. Budgets tend to be fixed, so often the project at hand involves compromise on project scope, unless a clear compelling case for flexible design can be considered early enough in the project delivery process. Proposals for flexible healthcare infrastructure should be client-specific, identified early in the decision-making and scope-setting stages of a project and focused on specific organizational goals, strategies or components.

Another barrier to designing for flexibility that Rick Harris noted was the general tendency to have misconceptions about how quickly and easily renovations can happen and how much cost and disruption will be involved in facilities that have not been designed for flexibility, or have not been designed for the nature of change that will ultimately occur down the road. There are always the hidden complications of renovation, "the surprises that happen."

The Cost-Benefit Equation: Team members were asked what premium (if any) would your organization, or the organizations you work for, be willing to accept in initial capital investment in construction to achieve greater flexibility over the life of the facility? Or, what would be an acceptable payback period? The responses varied from 2-5 years and, in some cases, seven years. On the low end, George Sterling indicated that the economic climate today emphasizes initial cost over life-cycle costs unless first cost investment provides a 2-year payback. Spencer Moore with MD Anderson indicated that a 3-5 year payback with a 3-5% premium on initial investment would be acceptable. Victor Sanvido indicated that clients were typically willing to accept 3 years automatically. Paybacks of up to 7 years needed discussion, and over 7 years was much harder to accept unless the program budget was already generous. Kurt Stahl with AECOM suggested at 5-7 year payback on a 50 year building. CEOs are building the least (dollars and scope) amount, given uncertainty, and there is a desire and increased pattern of moving clinical and non-clinical functions downstream to lower-cost infrastructure.

The Need for Better Data: There was consensus among the team members that that there is a lack of systematic, standardized and comprehensive documentation of change and the cost of change in healthcare infrastructure over its life. The following questions remain to be sufficiently answered:

- *Where does change occur, to what degree, how often and how much does it cost?*
- *What is the actual ratio of initial capital costs to the life-cycle cost associated with accommodating change?*
- *How can we consistently capture and measure the total life-cycle costs of operations in healthcare facilities including the functional costs of staffing and patient care that is impacted by the configuration and conditions of the physical care delivery environment?*

Public and private healthcare systems and providers, especially those with rapidly changing needs, multiple facilities and that build frequently, can benefit the most from investing in a flexible healthcare infrastructure and investing in research that provides a better understanding the cost-benefit ratio of building flexibly. We can no longer afford to make infrastructure investment decisions based on naked claims, or weak or incomplete information and data. Most healthcare organizations do not thoroughly or consistently track and document change or the cost of change in their infrastructure over its life. Some healthcare organizations collect and maintain some data. Most do not, at least not in any systematic and usable format. If longitudinal studies are to be conducted across multiple facilities, there needs to be a uniform and standardized model for collecting and organizing data on renovation, maintenance and replacement costs, as well as greater standardization on documenting the cost of initial capital investments so that data can be compared.

A comprehensive research agenda needs to be implemented and funded around the issues of changes and a flexible healthcare infrastructure in the United States. In order to be implemented comprehensively, this agenda needs to be adopted and supported by the entire cross-section of the healthcare industry including governmental agencies, large health systems, the product manufacturing and construction industries along with design, construction and healthcare provider professional bodies.

> "*The biggest area where we need to have flexibility is in our thinking – the process*."
>
> *Clay Seckman*

The healthcare infrastructure we build and renovate today needs to be highly nimble and flexible; even more so today than in the past. One thing is fairly certain. The economics of healthcare will continue to demand that it delivers more, better, faster and with fewer resources than in the past; not only initially, but also over the operational lifespan of the infrastructure being built today and tomorrow. Initial capital investment decisions need to not only consider first costs, but life-cycle costs that take into account all measures, including material costs, functional and operational costs, and social/environmental/health costs. The strategies, conceptual and implemented frameworks outlined in this report can help enable a more flexible healthcare infrastructure.

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