Title: **Challenges and Opportunities in Vertical Healthcare Design**

Author: Douglas King, Principal, VOA Associates

Subject: Architectural/Design

Keywords: Façade
Fire Safety
MEP
Structural Engineering
Vertical Transportation

Publication Date: 2016

Original Publication: CTBUH Journal, 2016 Issue II

Paper Type:
1. Book chapter/Part chapter
2. **Journal paper**
3. Conference proceeding
4. Unpublished conference paper
5. Magazine article
6. Unpublished

Challenges and Opportunities In Vertical Healthcare Design

Douglas King

Author

Douglas King, Principal
VOA Associates Inc.
224 S. Michigan Avenue, #1400
Chicago, IL 60604
United States
t: +1 312 554 1400
f: +1 312 554 1412
e: dking@voa.com
www. voa.com

Douglas King
A principal with the design firm VOA Associates, Douglas King is an instrumental leader in VOA's global healthcare practice, with a particular emphasis on the design of large-scale mixed-use healthcare projects. Mr. King was the technical director for the iconic US$732 million Feinberg/Galter Pavilion and for the US$500 million Prentice Women's Hospital at Northwestern Memorial Hospital in Chicago.

Mr. King serves as the lead peer review planner for several of the largest Veterans Affairs (VA) projects currently under construction in the United States. He has peer-reviewed large scale, private high-rise healthcare projects including the recently completed NMH Outpatient Care Pavilion.

In recognition of Mr. King's expertise on large-scale high-rise healthcare projects, the Chicago Committee of High-Rise Buildings (CCHRB) elected him to membership. Mr. King is active with the CCHRB in the promotion of research and education on the unique challenges of high-rise design. Mr. King supports the education and mentorship of architects, has served on advisory committees for two architecture schools offering Master's concentrations in healthcare design, and regularly serves as guest critic for the University of Illinois' healthcare design studios.

Vertical healthcare design is an emerging field with its own particular set of benefits and challenges. This building type will become more desirable and popular, particularly in North America, due to the location of healthcare facilities in urban centers, escalating land values, and demand for reimbursable healthcare services, but also because of numerous, little-explored advantages that the high-rise building type offers to healthcare providers. These advantages can include planning flexibility, security, and efficiency, as well as improved air quality and reduced noise, which can benefit healing.

However, vertical healthcare buildings, with their caregivers and vulnerable patient populations, require special sensitivity to the challenging aspects in healthcare design – noise/vibration control, air quality, temperature and airflow, vertical transportation, planning, and life safety and security among them. It's clear the high-rise healthcare typology is due for more detailed study and investigation.

Healthcare Grows Up

Where healthcare lives

Major urban medical centers in North America are typically located on the edge of, but rarely in the middle of, downtown, where land would be prohibitively expensive. Healthcare campus settings typically grew horizontally, with additional buildings connected by bridges and tunnels as healthcare organizations focused on maximizing outpatient service.

As cities grew, many medical centers found themselves surrounded by dense urban development. Leading examples include Northwestern Memorial Hospital in Chicago's Streeterville, as well as Barnes-Jewish Hospital in St. Louis and Texas Medical Center in Houston. Skyrocketing land prices made it impossibly expensive to expand by acquiring nearby lots; urban medical centers became "landlocked" (see Figures 1 and 2).

> "The structural grid or module in a healthcare facility varies by medical modality. Exam spaces in an ambulatory care setting prefer grids of roughly 9-by-9 meters, to around 9.75-by-9.75 meters."

A new mandate

In the United States, the desired program for medical centers has changed in recent decades. In the past, inpatient care had accounted for the lion's share of hospital space. Patient bed floors with diagnostic and treatment support space were the key components in hospitals; doctor's offices might be scattered across adjacent facilities.

Advancements in less-invasive medical treatment, combined with limitations in insurance reimbursement, have fueled the growth in outpatient services and ambulatory care, which have lower overhead costs and generally shorter wait times. This has driven demand for spaces similar to an office building, in which a high level of medical treatment are performed. The National Fire Protection Association (NFPA) introduced an entirely new chapter to NFPA 101 (Life Safety Code) in 1992 to address these hybrid "ambulatory care" environments.

For many hospitals today, the ambulatory care component is now equal to, or larger than, the inpatient component. One example is the 25-story, 122-meter, 92,903-square-meter Northwestern Memorial Hospital (NMH) Outpatient Care Pavilion (OCP), which houses outpatient functions and support such as laboratory and research components. A primary driver for the growth in separate outpatient functions is the simple fact that it is cheaper to build an office building than a hospital.

Group practice

At the same time medical centers took on ambulatory care requirements, physicians began to develop larger practices, too. The 41,800-square-meter Northwestern Medical Faculty Foundation project, a group practice comprising a dozen floors in the Galter/Feinberg Pavilion at NMH is one example, as is Houston's Texas Medical Center. As these group practices became the norm, their program evolved from the traditional groupings of doctor's offices (each with their own waiting, reception, and infrastructure) in a shared office building, to shared waiting and reception functions and other common infrastructure, surrounded by scattered, modularized exam and office functions, all appearing as one branded environment.

Medical education and research

Today, academic medical centers embrace three roles – clinical services, education, and research – and their requirements include simulation centers as well as spaces for informal out-of-class learning and research. In 2015, Northwestern University broke ground on the new 55,741-square-meter Simpson Querrey Biomedical Research Center, which will rise 12 stories in Phase One, but is planned to comprise 45 stories in total in Phase Two, with an eventual buildout of close to 111,000 square meters (see Figure 3).

Figure 3. Simpson Querrey Biomedical Research Center. © Perkins+Will

Figure 1. Barnes-Jewish Hospital, St. Louis. © Washington University School of Medicine

Figure 2. Texas Medical Center, Houston. © University of Texas Health

Stacking

In designing the Feinberg Galter Pavilion at Northwestern Memorial Hospital in the 1990s, the author and design team pioneered the idea of a mega-healthcare structure by stacking the outpatient component on top of the inpatient component and leveraging common vertical transportation capabilities to co-locate the healthcare staff working in the hospital with their accompanying offices in their group practices. This "stacking" of inpatients and outpatients has taken hold in some denser urban environments.

Today, stacking has a natural ally in the trend towards minimal movement of patients within the hospital. In the new "patient-centered care model," clinical staff, nurses, specialists, and physicians come to the patient.

Conferencing and research

Twenty years ago when hospitals realized they were spending a lot of money on outside conferences, they began to construct larger conferencing capabilities within their facilities, which not only saved money, but actually became a profit center for some. Everything from grand rounds (lectures to doctors), to community health education, to vendor-sponsored PR events could be accommodated in this environment.

Additionally, the research element has expanded in buildings such as The Rehabilitation Institute of Chicago (RIC) pavilion, under construction as of the time of this publication. Within two individual floor modules, the RIC will contain space for inpatient treatment, research and development of prosthetics, and other rehabilitative modalities, as well as patient observation and education. The RIC embodies a growing trend in healthcare clinical research towards a "bench-to-bed" regime, in which the practitioner is also the educator and the researcher (see Figure 4).

What does this all mean for the high-rise hospital? As the programmatic uses within the

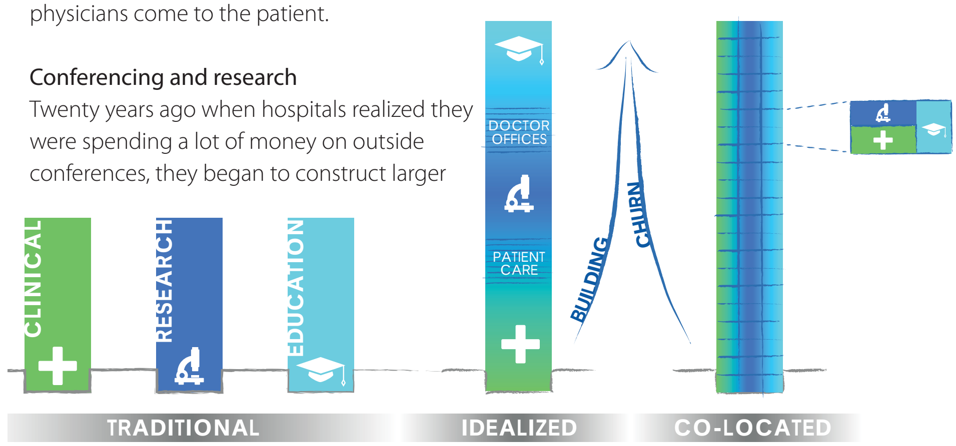

Figure 4. Idealized, bench-to-bed regime.

inpatient healthcare environment changes, the "stack" – the way space is organized – changes.

Treatment and reimbursement

Changes in healthcare delivery and industry reimbursement policies in the United States mean slimmer margins. Increased volume combined with efficiency has become the goal for practitioners. When this business model is considered alongside the trend toward outpatient treatment in a business occupancy setting, the taller hybrid structure becomes increasingly viable as a healthcare building type (see Tall Buildings in Numbers, page 44).

High-Rise Healthcare: Challenges

The challenges in achieving taller and more efficient healthcare structures are numerous.

Structural engineering

When conceiving a high-rise healthcare structure, establishing loading requirements is the initial challenge. Load key diagrams take into account the expected live and dead load requirements for each area of a hospital. Loading can range from as low as 293 kg/m^2 in outpatient areas to more than1,953 kg/m^2 in areas where MRIs or linear accelerators reside on elevated slabs. This challenging intensity is closely rivaled by the reconciliation of the grids established to respond to functional needs in the hospital. This grid establishment, along with core placement and exterior wall system selection, is determined to respond to criteria such as eccentric loading at the exterior, the response to probable circulation patterns, and requirements for lateral bracing.

Modularity

The structural grid, or module, in a healthcare facility varies by medical modality. Exam spaces in an ambulatory care setting prefer grids of roughly 9-by-9 meters, to around 9.75-by-9.75 meters. This module can be adapted vertically for inpatient rooms, intensive care units (ICUs), and diagnostic/treatment areas, such as operating rooms and imaging suites. Minor offsets in the grid can be accomplished by slightly angling columns, shear blocks, and column offsets with moment frames. Establishment of a universal grid is important in the accomplishment of flexibility and adaptability for future functional modifications in the high-rise healthcare project (see Figure 5).

Shifting grids

High-rise healthcare facilities have increasingly adapted parking requirements into the building stack. This introduces significant challenges for transfer of the grid from the parking structure to the health-care module; usually this is accomplished by transfer trusses or girders. Larger structural grids are also desired in the public spaces of high-rise hospitals. Frequently these facilities have larger concourses with retail and conferencing spaces, and larger spans are required to achieve the feeling of expansiveness that such uses mandate. However, these public areas are usually located in the lower sections of the building stack, so offsets are localized to that area.

Lateral systems

High-rise healthcare facilities have extensive vertical transport requirements. A good baseline rule is that a high-rise hospital will have one elevator for every floor served. Hospitals separate their circulation systems into three major groupings (staff, service, and patient) for privacy and infection control purposes, so elevators will often be grouped by function. These vertical elements provide ample opportunity for shear wall placement for lateral support. Shear walls are used frequently in healthcare, but occasionally X- or K-bracing or moment frames are employed where the design or construction methodologies dictate such uses.

Floor-to-floor height

Floor-to-floor height establishment in high-rise healthcare facilities is a blend of science with the art of applying past experience. Required floor-to-floor heights vary among the lower-level service areas, public spaces, diagnostic, and treatment floors, and those of the inpatient bed units/ICUs and the medical office or ambulatory care areas.

A typical range of floor-to-floor heights might be:

- Service areas – 5.18 to 5.48 meters

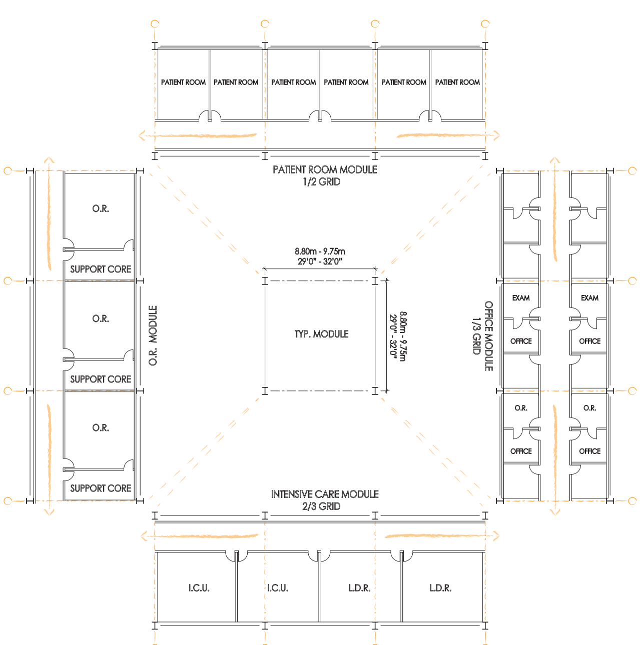

Figure 5. Example of a structural module in a healthcare facility.

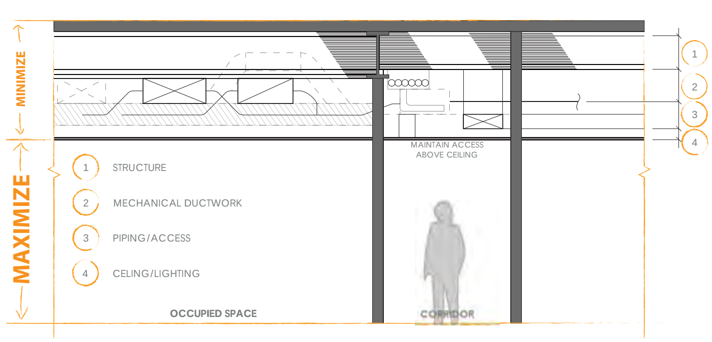

Figure 6. The challenges of establishing of floor-to-floor heights in a high-rise healthcare application.

- Public levels – 6 to 8.22 meters
- Diagnostic and treatment areas – 4.87 to 5.48 meters
- Patient room and ambulatory care or medical observation bay (MOB) areas – 4.26 meters.

Variables that affect these ranges include:

- Functions on the floor above and their impact on beam/girder depth
- Building structure (concrete or steel framing)
- Major piping from a floor above crossing the interstitial cavity of a particular floor
- Desired functional ceiling height below
- System for duct work distribution employed serving that particular floor

Figure 6 indicates the challenges of establishing of floor-to-floor heights in a high-rise healthcare application.

Flexibility

High-rise healthcare projects are likely to experience future expansion (vertical and horizontal), adaptation, and renovation. To future-proof the planning for these anticipated modifications, high-rise healthcare projects employ several common strategies. These strategies include building capacity in the columns for future vertical expansion (usually several floors); standardizing the loading capacity of floors to accept future uses (610 kg/m^2); fire-proofing the structure for the most restrictive use (usually type IA or IB under the International Building Code); oversizing shafts for future air systems (usually the most volatile of changes); and deploying a modular grid (as previously mentioned) to allow for more universal adaptability for future modularized uses.

Equipment/miscellaneous loading

Hospitals introduce a multitude of miscellaneous loading challenges.These initiate from the requirements of mechanical, electrical, plumbing, and fire protection needs; medical equipment requirements; and fire/life safety elements such as shutters, horizontal fire doors/walls etc., to achieve the occupancy separations found in high-rise healthcare applications.

The establishment of an early process for determination of structural parameters involving the design team, structural engineers, and MEP engineers can contribute to achieving a flexible structural system that responds to the myriad requirements in the high-rise hospital program.

MEP, IT, and fire protection challenges

Decisions about placement and routing of main MEP, IT, and fire protection (FP) systems in a high-rise healthcare project should be addressed early in project definition. These uses require space – and a lot of it. The space required in a healthcare facility for MEP/FP (with IT needs) – main equipment rooms, shafts etc. – can exceed 12% or more of the project program. The space needed to accommodate stairs, elevators, and the exterior wall system in a high-rise healthcare project for these nonmedical uses can exceed 22% of the program and 25% of the total area of the facility.

With these spatial demands, efficient planning is paramount for cost control.

1. *Main equipment locations*
   Location of the MEP/FP equipment is driven by balancing the cost for multiple main equipment locations against the costs for implementing major horizontal connections between this equipment and the points of distribution. Typically, there are multiple locations within the building stack where air handing units with pumps and support equipment and main electrical/emergency electrical transformers and panels are located. Typically, the assumption is that certain equipment will be located at the basement or ground levels or on the roof.

   Cooling towers, boilers, and chillers can be placed in mid-level mechanical areas or on the roof of a high-rise facility as a cost-effective alternative. Incoming technology rooms, generators, fuel oil storage, fire pumps, and incoming water services can also be strategically placed to reduce costs. This equipment can frequently be placed in locations that have minimum visual impact on the facility, such as within a parking or loading dock area.

   Mid-level placement of mechanical equipment is also a viable option, provided that careful detailing of the acoustical slabs and enclosures around the mechanical units occurs. This same care needs to be extended to the transformers frequently associated with larger MEP equipment, which produce low bass acoustics that need to be mitigated. The potential of electro-magnetic (EM) interference from this equipment also needs to be addressed within the surrounding spaces.

2. *Redundancy*
   Healthcare facilities are frequently considered "essential facilities" in most communities, and redundancy is mandated by regulatory requirements. A high-rise application enhances redundancy with its vertical routing, in lieu of horizontal. Redundancy can also be driven by the need for regular servicing of equipment. The design of HVAC, electrical, and IT equipment needs to consider downtime for maintenance of major healthcare equipment. Redundancy requirements add to the space needs of the high-rise healthcare environment.

3. *Flexibility, Adaptability, and Growth*
   Healthcare facilities are constantly evolving. New or modified healthcare modalities, healthcare regulations, and community growth contribute to the volatility of the healthcare program. In addition to the modular strategies discussed under the structural considerations, flexibility, adaptability, and growth need to be addressed in the MEP and IT systems.

   It is common to provide space within risers and electrical distribution rooms for additional equipment. Spare interstitial space can be identified for future routing of horizontal connections. "Strategic soft space, " including locker facilities, on-call suites, administrative space, and storage can be established adjacent to the mechanical/electrical locations. This soft space can be relocated to allow for future growth while maintaining usefulness for the current configuration.

One great payback of a vertical hospital application is that the main MEP equipment can be placed much closer to the spaces served than in horizontally oriented healthcare facilities. This allows for responses to growth on a more incremental level. In a high-rise application, equipment tends to be smaller in capacity, so growth and flexibility impact is contained within a building zone, more so than with conventional design.

Façade design

Façade design for high-rise healthcare applications commonly embraces aesthetics, constructability, energy efficiency, and maintenance. One major and often misunderstood consideration is the "stack effect" and its impact on building systems operations.

1. *Thermal performance*
   Control of internal air pressure in hospitals is critical for the safety, health, and comfort of patients, staff, and visitors. Controlled positive air pressure creates protective environments for patients who may have compromised immune systems. Conversely, negative pressure environments protect caregivers and visitors from the spread of infection in the hospital environment. Hospitals need both of these protective environments.

2. *Stack effect and the façade*
   The stack effect occurs in taller buildings when warmer air inside migrates upward, drawing cooler outside air inward. This creates negative pressure areas on lower floors and positive pressure at the upper floors of a building.

   Air quality, sound quality, security, containment, fire safety, and bacterial contamination are all issues complicated by the uncontrolled stack effect. The stack effect in high-rise buildings can mean a loss of conditioned air, uncomfortable cold air coming in at lower floors, the whistling of air blowing around doors and doorways, suctioned doors that are difficult to close or open, and infiltration of undesirable odors.

   Addressing the stack effect in the design of commercial high-rises is not uncommon, but the application of this knowledge with research specific to healthcare has yet to emerge. Informing and educating all stakeholders in the design of taller hospital environments (owners, facilities managers, design team members, and contractors) on the issues around the stack effect would be a step in the right direction. Further collaboration between high-rise architects and healthcare designers is required to mitigate the stack effect.

Vertical Transportation

As moving inpatients, outpatients, materials and supplies, visitors, and staff within acceptable ranges of performance is critical to the success of a high-rise healthcare project, space for vertical transportation needs to be well-programmed. Elevator groupings frequently include banks dedicated to staff, patients, and the public, with specialty cars for food service movement, special patient populations (such as oncology), parking garage access, and medical office building functions (see Figure 7).

The forces of economics and functionality have mandated a reduction in elevator shaft size, while increasing cab size, performance, and ride comfort. Prior supertall building elevator research has advanced the technology in a manner that translates nicely to healthcare projects. New developments include destination dispatching, innovations to eliminate counterweights (allowing cabs to be larger), and intuitive elevator call systems using predictive technology. These innovations have increased ride quality, sped up response time, and reduced elevator shaft footprint requirements.

The next generation of destination dispatching technology allows elevators to be disengaged from the "elevator bank" concept entirely, which frees up design options with elevator cab placement. Fast-moving, energy-efficient elevators and systems, featuring two elevators sharing one shaft, are now available for high-rise healthcare. Horizontal transportation within buildings, which has recently received new design emphasis, would further free up design.

Life Safety and Regulation

Until recently, the regulatory world was the major impediment in the quest to build taller hospitals in the US, but few prohibitions exist elsewhere. In the US, the Center for Medicare and Medicaid Services had an informal decree that buildings of differing occupancies could not be stacked on top of the institutional occupancy. Thus, a facility with business, institutional, and assembly functions would not be considered a "mixed-use structure," and was prohibited. Instead, these uses had to be designed under the guidelines for hospitals.

Mixed-use/mixed occupancy challenge

Today, the idea of a mixed-use high-rise hospital is a viable option for medical centers. A typical high-rise stack might feature a lower-level floor of support functions, with several floors of public spaces/assembly, and the heart of the hospital (diagnostic and treatment functions) with inpatient units stacked above. In the past, outpatient functions have been designed separately, as have doctor's office towers, parking and

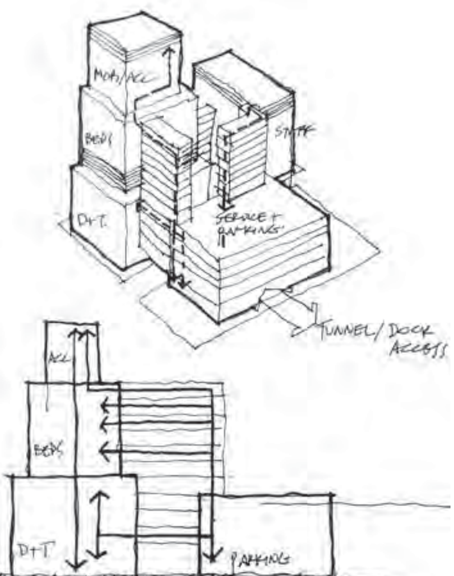

Figure 7. Elevator grouping concept.

sometimes staff accommodations. Today, the concept of a "super stack," where all functions could be placed in an optimal vertical environment, is achievable.

Compartmentalization

The healthcare industry's approaches to life safety have already been largely transferred to the commercial high-rise typology. Healthcare facilities are compartmentalized into separate smoke zones, with zoned MEP/FP systems for fire/life safety functions. This "coordinated fire-protection philosophy" as NFPA has called it, provides optimal horizontal migration for healthcare facility occupants.

Evacuation

Evacuation planning is a major challenge to designing high-rise healthcare projects. Regulators have identified the use of elevators for evacuation and have written guidelines for use of these in emergency situations. Vertical evacuation of patients in some cases is potentially safer than transport via stairwell.

Construction and Renovation

Movement of Materials and Workers

High-rise hospitals can pay dividends in the renovation of an existing facility. Placing functions on separate floors allows for positive logistics during renovation. Studies show that sick and infirm individuals are particularly susceptible to life-threatening diseases when they come in contact with construction dust. Hospital environment specialist Andy Streifel emphasizes the need for construction phasing and separation in minimizing risk for vulnerable patient populations during healthcare facility renovation (Streifel 1998).

The vertical renovation allows construction areas to be sealed off from operational healthcare zones.

ILSM and ICRA

In the 1980s and 1990s Infection Control Risk Assessments (ICRA) and containment of construction risks to the construction zone were defined, and approaches for mitigation were popularized in the United States. Today, the performance of an ICRA for each construction project in a hospital determines practices for occupant safety in the hospital, contingent upon the level of construction activity for each individual project. The most effective barrier is a permanent barrier: the floor plates of a high-rise hospital provide that barrier.

Limited floor plates accentuate safety in ILSMs and ICRAs

Along with ICRA analysis, American hospitals now perform Interim Life Safety System Measures (ILSM) analysis for each project, to determine the steps necessary to protect the life safety systems and patient support systems present in each area of a hospital affected by ongoing construction. Again, the stacking of medical functions promotes the segregation of these construction areas much more readily than does a more horizontal scenario.

Special populations in vertical hospitals

Planning spaces for the diagnostics and treatment of special populations within a hospital setting would benefit from going vertical. These special populations include patients in the oncology, hospice, pediatrics, mental health, geriatric care/continuum of care, and women's health departments. Identified, separate, and discrete locations and circulation paths are required to service the needs of each group.

Hospital regulators have responded to the notion of special populations by authorizing the "hospital within a hospital" licensing concept, whereby a branded hospital with a particular expertise can function within the hospital environment of another licensed facility. This raises the prospect of a healthcare environment in which different branded facilities run separate healthcare organizations within an umbrella hospital system in a high-rise.

Conclusion

Healthcare providers are experiencing increasing pressure to lower margins and maintain profits with less reimbursement. Drivers include increasing efficiency within their workflow processes and reducing waste. The high-rise hospital offers an opportunity for more efficient, healthful, and symbiotic placement of the clinical, education, and research elements of the healthcare function. A handful of building projects today suggest the efficiencies inherent in vertical healthcare design, but further study and design research is needed.

Changes in regulators' attitude towards stacked/mixed-use occupancies, and the introduction of elevatoring as an acceptable means of egress during an emergency have impacted regulators' attitude towards vertical healthcare. The vertical transportation industry is exploring ways to move more people within vertical structures.

The many areas where further research is needed in high-rises generally match up with future research opportunities for high-rise healthcare (Oldfield, Trabucco & Wood 2014). The healthcare profession will benefit from research progress on tall building design, especially when it is performed in conjunction with experienced high-rise designers and healthcare planners. ■

Unless otherwise noted, all photography credits in this paper are to VOA Associates.

References

OLDFIELD, P.; TRABUCCO, D. & WOOD, A., eds. 2014. ***Roadmap on the Future Research Needs of Tall Buildings.*** Chicago: CTBUH.

STREIFEL, A. J. 1998. "A Holistic Approach to Indoor Air Quality in Health Care." ***HPAC Engineering,*** October 1998: 3–12.

> "In a vertical hospital, the main MEP equipment can be placed much closer to the spaces served than in horizontal facilities."