C A S E S T U D Y P R O J E C T

Macau Island Hospital, Pediatric Clinic.

Innovation in the Healthcare Industry

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Healthcare challenges are faced by every country, and even more so in the face of the ever changing technological and social landscape. Asian countries are no exception to these challenges. While developing countries like Cambodia struggle to improve public access to basic healthcare services, addressing contagious diseases and infant mortality, developed countries like Japan battle challenges of a rapidly ageing population together with a rise of illnesses such as diabetes, cancer and cardiovascular diseases.

Addressing these challenges calls for innovation: to manage healthcare with greater efficiency, ensuring better healthcare quality for a greater number of patients, and for reduced costs. Innovation is not confined to technology, but extends to design, research, financing, regulations and partnerships.

In this paper, our aim is to explore ways to advance the quality of patient care by creating and embracing healthcare innovations and developing scientific knowledge in which design and technology play a central role. As architects, designers and medical planners, we envision design as good platform to innovate and also provide patients with better healthcare experiences. This paper outlines the top five trends in innovation – Clinical Lab Design, Emergency Disaster Preparedness, Clinical Care Team, Neuro-Architecture, Lean Design Process, each illustrated using the new Macau Island Hospital as a case study.

CLINICAL LAB DESIGN

Healthcare design has always focused on the patient-centred spaces such as patient rooms. On the other hand, clinical laboratories are among the hospital's most important spaces where specimens are tested, and are gaining increased attention in terms of architecture and design planning. The objective is to design a clinical lab environment that is more efficient and effective in managing the flow of staff and specimens.

Open plan design

The latest lab design concept is the Open Plan, or Big Room concept, featuring wide open spaces with no interior walls. This allows greater flexibility and the layout to be reconfigured as necessary. Power, data and gases are mounted overhead, rather than provided through the floor or walls. Modular case-work, which is often equipped with wheels for easy relocation, is used instead of fixed cabinetry. Sinks and floor drains, which cannot be moved without major construction, are placed in areas that are unlikely to change, such as along aisles and walkways. Drains are also installed in a regular grid formation throughout the lab, then capped or uncapped as needed.

This arrangement is especially useful with analyzers that require a de-ionized water feed, and need access to a nearby drain to discharge waste water. Using this type of design, a lab director and technician could reconfigure a portion of the lab themselves over a weekend to add an analyzer, and have it up and running for testing on Monday. There's no need to engage a contractor or the hospital's construction services department to put up temporary barriers, cut down gypsum board and stud walls or reroute plumbing. Hospitals don't have to develop phasing plans or suspend operations to update lab workspace. This gives the advantage of flexibility, efficiency, as well as saves great amount of time, money and unnecessary manpower.

Automated testing

Automated testing systems are an advancing lab technology that is facilitated by open plan lab design. With traditional standalone analyzers, technicians tend to batch specimens until there is enough for a full load, before placing specimens onto each analyzer, run a batch, then unload the analyzer when testing is done. Standalone instrumentation often requires a high number of technicians, as one technician can only load, unload and monitor a small number of analyzers at any one time.

In an automated system, analyzers are arranged along a robotic track that operates much like a conveyor belt. Technicians load individual specimens onto the track in real time as they arrive at the lab. The automated system handles everything from de-capping and re-capping tubes, allotting specimens and labelling the new tubes, delivering them to centrifuges as necessary, loading them onto the appropriate analyzers for testing and automatically storing and archiving them until they are ready to be disposed of. Such automated systems are able to retrieve a specific specimen often days later and re-run it for additional testing, all without a technician ever having to touch the specimen again.

Depending on the number of analyzers, automated systems may involve 50 to 60 feet of linear track that is bolted to the floor. This automation line functions as the backbone of the lab. It should be located where it won't act as a barrier or bisect any traffic or work flow to other more manual testing areas of the lab. In addition, the front end, or pre-analytic section of the line should be placed as close as possible to where specimens come into the lab. Ideally, a specimen processor sitting next to the lab's pneumatic tube station will be able to take specimens out of the tube and simply turn in his or her chair to drop the specimens directly into the inlet of the automated testing line, with no wasted movement or time.

Because most automated lab systems are scalable, they function well in labs with open plan designs. A lab can start, for example, with two chemistry analyzers; in a few years, the lab could easily extend the line to include a third analyzer. Or, the lab could replace an analyzer with one that can perform a higher number of tests per hour. The open plan design allows for future modular growth with minimal readjustment needed to the lab layout. For the most part, the more you can automate, the better.

Almost every time you have a technician doing something manually by hand, it slows down the procedure and increases the error rate. By automating repetitive processes, you can make the most of the intellectual capital of highly skilled, highly trained technicians. Instead of spending their time preparing specimens or slides—mechanical duties that can consume their work days—they are able to do what they do best, which is using their cognitive problem-solving skills to analyze results.

Genomics

Another potential healthcare revolution is developing within the world of genomics, a genetic discipline that applies recombinant DNA, sequencing methods to sequence and assemble genome structures. It is found that genetic factors play a role in nine of the ten leading causes of death in the United States.

Popular biotech and pharma companies are concentrating on certain diseases such as acute lymphoblastic leukemia, breast cancer, cystic fibrosis, heart disease and diabetes, all of which have genetic components which could be addressed with a genomic approach. Investment entry-points include biotechnology, pharmaceuticals and research and testing facilities. Genomic studies in cancer treatment, for example, can be used to develop clinically validated tests providing the genomic profile of a patient's tumor and can help understand whether patients are likely to respond or benefit from cancer treatment and therapies. This could help healthcare providers better treat patients and manage their disorders with greater understanding.

Future growth and change

Well-designed clinical labs provide an ample amount of space for maximum flexibility that enables labs to grow, change and adapt for the future. It also provides the infrastructure needed to take advantage of the latest developments in technology and medicine. Sufficient power and data, robust heating and ventilation, careful design of engineering systems, smart selection of appropriate materials and finishes are critical to create conducive clinical laboratories for relevance of use in the long term.

Case Study: Macau Island Hospital

With relevance to the above consideration in clinical laboratory design and planning, similar concepts are adopted as part of the architecture and interior planning of the new Macau Island Hospital in Macau, SAR.

The physical design of the clinical lab and the quality of systems implemented are flexible and versatile enough to accommodate not only hematopoietic stem cell processing, but also adaptable to introduce a wide range of potential cellular and gene therapeutic projects and trials in the future. This facility is designed to be ready to apply for the following accreditations/certifications/registrations:

- CAP accreditation
- AABB accredited
- FDA registered
- FACT/ISCT accredited
- JACIE accredited
- ASHI/EFI accredited

***CTAG testing and processing areas*:**

The Cell Processing laboratory has been divided into three areas;

1. The first area is a GTP / GLP (Current Good Tissue Practice / Good Laboratory Practice) lab which is designed to accommodate all routine blood processing for both autologous and allogenic blood collection as well as Umbilical Cord Blood processing for cryopreservation.
2. The second area is a cGMP (Current Good Manufacturing Practices) Lab which is utilized for more advanced applications, such as cellular mediated immune responses and invetro immunological testing.
3. The third area is the Transplant Immunology laboratory, and is designed to test for histocompatibility between donors and recipients, along with more basic testing methodologies. It contains Flow Cytometry, a Molecular diagnostic and therapy lab, including Genetic Pathology, Cytogenetic, and HLA (Human Leukocyte Antigen) testing. Because all these functions are highly related to each other, the Transplant Immunology laboratory has been designed as one large open laboratory space, which facilitates staff interaction & cross training besides providing a flexible space which is easily reconfigurable as testing methodologies and equipment continue to evolve and change in the future.

***The cGMP Laboratory consists of*:**

- "Clean Rooms" for Routine Cell Processing. Each Processing room is Positive pressure; ISO-Class 8 (Class 100,000) accessed via ISO-Class 8 (Class 100,000) Ante-Rooms shared between the two processing rooms. The ante rooms are positive pressure relative to the surrounding corridor, but at negative pressurecompared to the Cell Processing rooms.
- "Clean Rooms" for Cell Therapy, these rooms will be at Positive pressure, ISO-Class 7 (Class 10,000) accessed via an ISO-Class 8 (Class 100,000) Ante-Room.
- And two negative pressure "Clean Rooms"; one for Gene Therapy and one for Viral Vectors.
- A dedicated specimen reception area is provided for incoming materials. Staff Lockers are built for gowning & de-gowning. A Decontamination Room and dedicated Housekeeping Room are also part of the cGMP Suite.

***The Cytogenetics Laboratory includes*:**

- A Tissue Culture Room (Positive pressure ISO Class-8/Class 100,000)
- A Cell Harvest Room (Positive pressure ISO Class-8/Class 100,000)
- A Dark Room
- Routine Karyotyping, including human chromosome analysis, Karyotype characterization of new cell lines, confirmation of cell line identity or integrity and high resolution chromosome analysis.
- A Banding Zone
- Workstations for Genetic Analysis
- BAC Array Workstations
- CGH (Comparative Genomic Hybridization) utilizing Conventional Chromosomal CGH and BAC Array CGH FISH validation.
- FISH (Fluorescence in situ hybridization) Processing
- Various assorted Immunological and Serological testing
- Tissue Storage/Cryopreservation

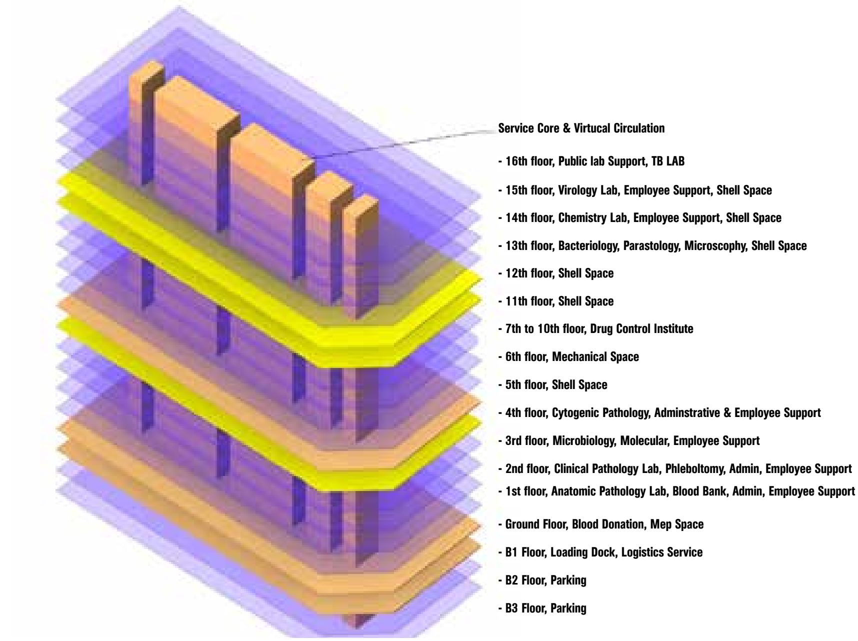

Fig.1: Lab Building, Open Plan Design

EMERGENCY DISASTER PREPAREDNESS AND PANDEMIC OUTBREAKS

At the frontline of Emergency and Disaster Preparedness with a Spotlight on Potential Pandemic Outbreaks around the Globe

Emergency and Disaster Preparedness have become significant drivers affecting emergency and hospital design across the world. Events ranging from tsunamis, tropical storms, potential terrorist attacks and pandemic/contagious disease outbreaks have impacted the design of physical facilities and hospital operations in order to safeguard the public during quarantine and pandemic events.

Today Health Systems and Hospital Facilities across the globe are challenged with the issues associated with pandemic events that are becoming more common and could have significant impacts on large segments of the population. Events over the course of the last decade, including outbreaks of H1N1, SARS and the recent outbreak of Ebola, have raised considerable concerns about how to control and isolate patients with potentially highly contagious diseases.

The CDC (Centre for Disease Control) and other worldwide health agencies have helped to define recommended protocols that establish infection control measures for varying levels of control of health related transmittable contagions and diseases. New recommendations are being formulated and developed to respond to constantly evolving infectious diseases and knowledge gained from the treatment of these health issues. Agencies around the world are re-evaluating the level of infection control and isolation based on worldwide concern over the transmission of potential pandemic diseases.

The recent media exposure around the Ebola outbreak in West Africa has only highlighted the need for sophisticated solutions effecting infection control operations and facility designs to support the operations. HKS has been at the forefront of emergency preparedness issues and its impact on facility design for the last decade. Many of the ideas that were conceived in the design concepts of the Washington Hospital ER One project in Washington, DC are still being implemented and improved upon today. Project ER One was the first of its kind in the United States and was on the leading edge of design for the time.

The ER One concept focused on three goals: scalability that conforms to fluctuating patient volumes, medical consequence management to allow continued operations in the midst of unknown events, and threat mitigation to help prevent and mitigate the effects of intentional harm or adverse natural events. Each of these concepts have been influential in helping to define how we begin to consult with our clients on the design of facilities and how these design solutions can promote safety, efficiency and complement the efforts of the care givers during difficult emergency scenarios.

Macau Island Hospital Pandemic Outbreaks Readiness

HKS was engaged by the Macau Health Bureau in the winter of 2014 to consult on the design of a new 1200 bed Macau Government Hospital Complex in Macau, SAR. As the HKS team began to conceive the design and planning for the new hospital complex, emergency and disaster preparedness were key elements of discussion during design phases.

The new facility was designed with several key elements that support the hospital's objectives for meeting emergency and disaster preparedness initiatives.

Key Design Elements

- Departmental Compartmentalization
- Expandable/Convertible exterior space
- Mass Casualty Decontamination Design Solutions
- Dedicated Patient Transfer Elevators
- Emergency Observation Unit Conversion to Pandemic Isolation Floors
- Mechanical System Infrastructure (Seasonal/Pandemic Exhaust Design)

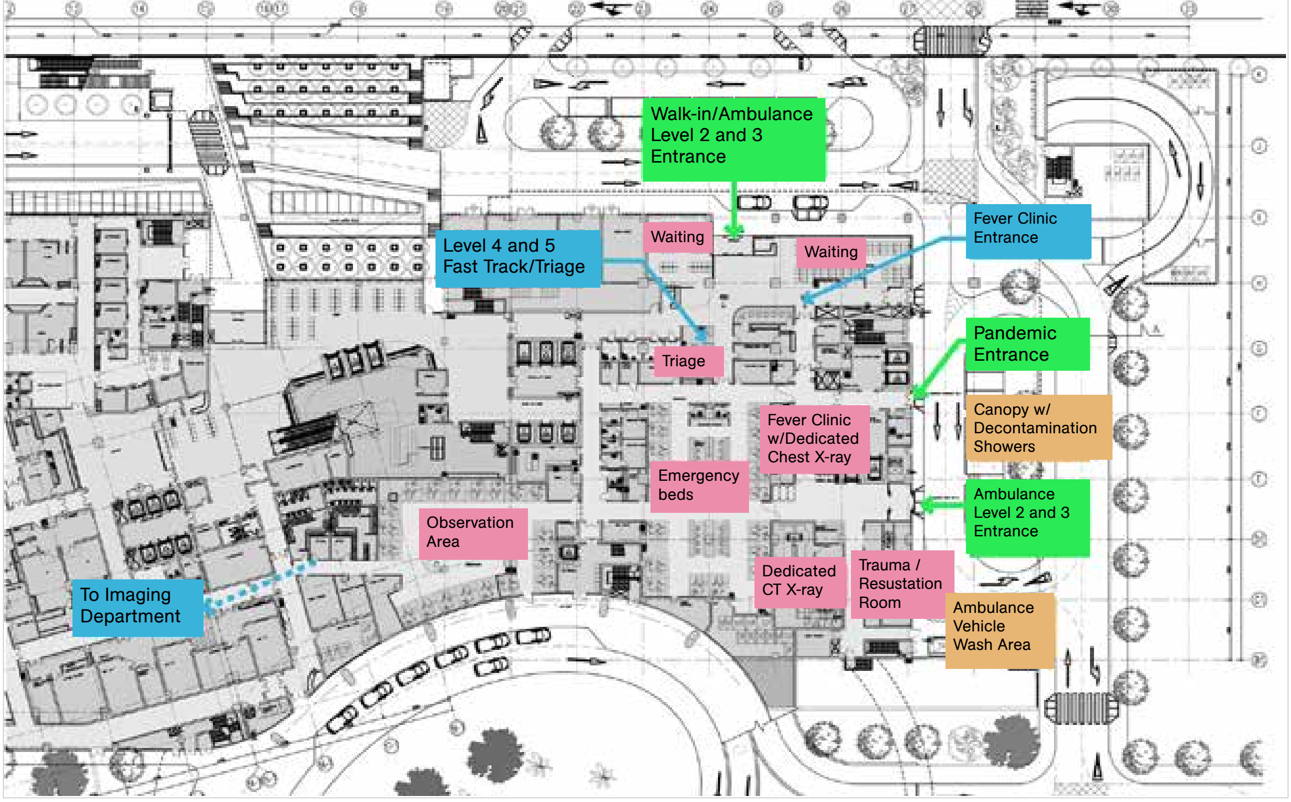

Fig. 2: Macau Island Hospital, Emergency Department

Emergency Department Design

The Emergency department was designed to operate under normal circumstances with 6 key zones including a Fever Clinic, multiple floors with 23-hour emergency observation, Level 1 Trauma/resuscitation rooms, Level 2 and 3 emergency room beds, Level 4 and 5 Fast Track/Triage area and dedicated CT and Radiology Imaging services.

The final design (figure 2) was developed to allow for compartmentalization into multiple zones which provide isolation and expandability during a mass casualty or pandemic outbreak. The department was designed in such a way to allow for a portion of the emergency department to be isolated for a mass casualty or contagious outbreak, while at the same time allowing for the main emergency department to remain operational. Both the interior of the emergency department as well as the exterior were designed to allow for expansion and compartmentalization.

Several design features (figure 3 a–b) are integral to allow for the expansion of exterior Emergency drop-off area into a temporary triage area and separate decontamination area that allows for the treatment of potentially contagious or contaminated patients.

- Structural davit connections or permanent ceiling mounted tracks can be provided to accommodate temporary fabric partitions or curtains.
- Strategically located hose bibs with shower heads for decontamination of patients
- Trench drains with dedicated plumbing diverted for decontamination

Fig. 3 a: Decontamination Shower

Fig. 3 b: Decontamination Shower Trench Drain

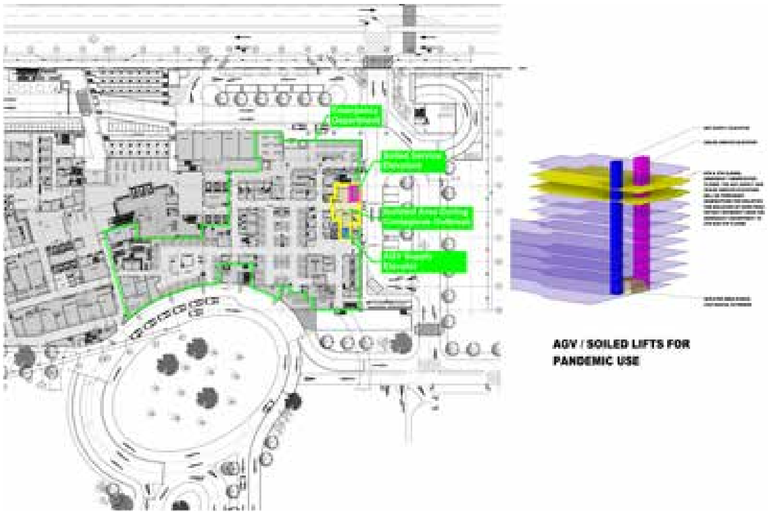

Fig. 4: Elevators.

In order to provide sufficient accommodations for isolation of large patient populations during quarantine events, it was necessary to provide dedicated vertical circulation access to multiple levels of the facility (figure 4). This access was coordinated to allow for the segregation of these isolated floors while also maintaining vertical circulation capabilities for the remainder of the hospital tower to allow for normal operations to continue during quarantine and pandemic events.

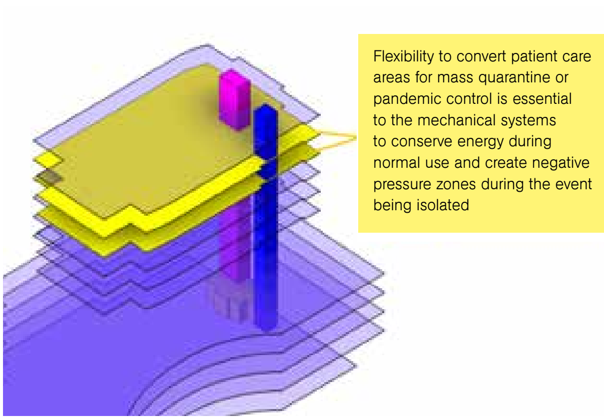

Figure 5. Flexibility for disaster preparedness.

The AGV Supply and Soiled Service Elevators will be temporarily quarantined for isolation of infectious patient movement from the emergency department to the isolated emergency observation floors on levels 8 and 9 (figure 5).

While the physical design and planning of the facility were instrumental in creating pandemic zones within the facility, it was imperative that a mechanical strategy be implemented to compliment the design and provide true isolated zones within an operating hospital. This required mechanical systems which were designed to allow for the compartmentalization and isolation of several zones during seasonal flu season or potentially pandemic events.

While providing flexibility to convert patient care areas to negative pressure zones during mass quarantine or pandemic events is crucial, the solution must also be designed to conserve energy during normal use. Areas programmed for quarantine isolation zoning are typically areas that are not fully exhausted during normal operation. Operating these areas with full exhaust during normal operation would increase the energy required to condition the necessary extra outside air. Using strategically placed dampers and direct digital controls energy can be conserved and the isolated areas can still be converted to negative pressure with minimal effort or disruption (figure 6).

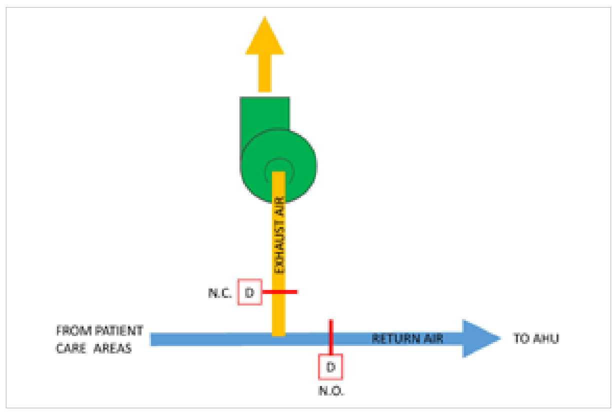

Fig. 6: Damper with Digital Control

During normal operation the return air damper is open, the exhaust damper is closed and the air handling unit is only bringing in the minimum amount of outside air required for the space. However, when the area is under isolation a command can be sent from the controls system to close the return air damper, open the exhaust air damper and also open the economizer damper in the air handling unit. When the damper positions are confirmed by the controls the exhaust fan starts, the area becomes negative pressure and is isolated from spreading contamination to adjacent patient care areas.

Conclusion

As the public's awareness and fears of the transmission of pandemic diseases grows there is sure to be a continued impact on how we design our health facilities to assist caregivers on the front line of defending against large outbreaks of contagious diseases in major metropolitan areas. Our hospitals and systems must be designed with the intent to provide greater assistance in the control and spread of such diseases while minimizing impacts on the existing operations of the facility.

CLINICAL CARE TEAM – Designing for a change-ready future (CADRE, 2015)

The rising healthcare costs in the United States have been an ongoing concern for policy makers, healthcare providers and patients. In a recent Commonwealth report[1] it was found that compared to 10 other developed countries the United States spent the most on healthcare, while the quality of care was rated amongst the lowest.

This finding, and many previous reports on escalating healthcare costs, have brought about an urgency to change healthcare and bring about systemic and system-wide reform. Needless to say the ripple effect of the systemic change has been felt in the design and construction industry as well.

The healthcare landscape is shifting, and one of the manifests of this shift is the growth in ambulatory care. According to a 2014 report from the Advisory Board (figure 7), based on feedback from 38 hospitals and healthcare systems in the United States, over the next 3 years construction in ambulatory facility (retail clinic, urgent care, free standing EDs, imaging centers or ambulatory surgery centers) construction is projected to grow by 71%, medical office buildings by 53%, inpatient towers by 41%, specialty hospitals by 15% and post-acute facilities (skilled nursing facility, long-term care hospital, hospice, rehab, and senior living) by 12% (figure 8).

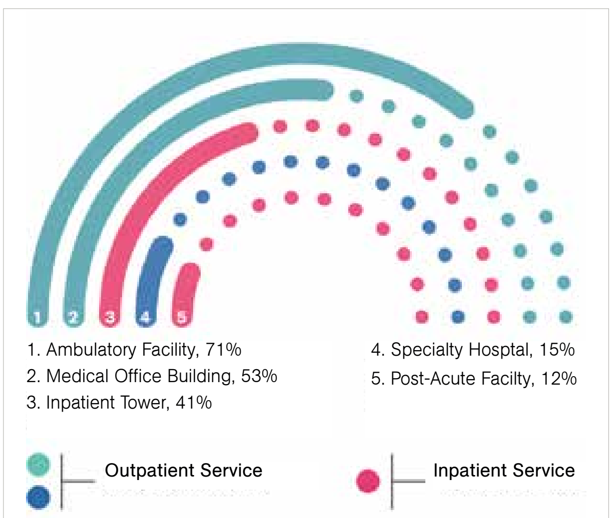

Fig. 7: Projected Growth in ambulatory care construction projects in the next 3 years.

Given the rise in outpatient care and overall construction, needless to say the A/E and construction industry is quickly assessing how they can respond to the shifting landscape. Many "ambulatory care of the future/ clinic of the future" reports are out there, and each provides a valuable insight for the industry. But what does "designing for the future" really mean? In an era of hyper-connectivity, personalized medicine and wellness initiatives on one end, and changing health management systems and insurance models on the other- what role do clinics play, and how will our facilities accommodate these roles? Will clinics be bigger or smaller, more specialized or diversified?

As diseases and their treatments get more complex, the core skillset of the physician has also needed to advance. Unfortunately, this has resulted in a growth of specialists disproportionate with the growth of primary care physicians, who are the first point of contact for a patient. This disparity, coupled with the growing shortage of physicians overall, has forced the provider model to change.

We are seeing a growth of new care team members, such as the physician extender/nurse practitioner (who can take on some of the physician responsibilities), and physician/medical assistants who team with the key care provider to provide team-based care. Additionally, with a focus on whole health, a growth in ancillary support for the entire team via health coaches, case managers and behavioral health specialists has increased. We also are seeing the need for more technical knowledge due to the advances in the field, technology and electronic health records.

According to a report from the Leonard Davis Institute of Health Economics, since the early 1980s, many surgical procedures have moved from the inpatient to the outpatient setting, with outpatient surgical visits now accounting for about two-thirds of all surgical visits in the United States. In part, this shift has been accommodated by the advancement in technology, including miniaturization of diagnostic equipment ranging all the way from handheld X-ray machines and portable ultrasounds to 3-D printing of medical (especially dental) implants. Smaller diagnostic equipment, wearable technology and the ability to remotely monitor health are transforming healthcare.

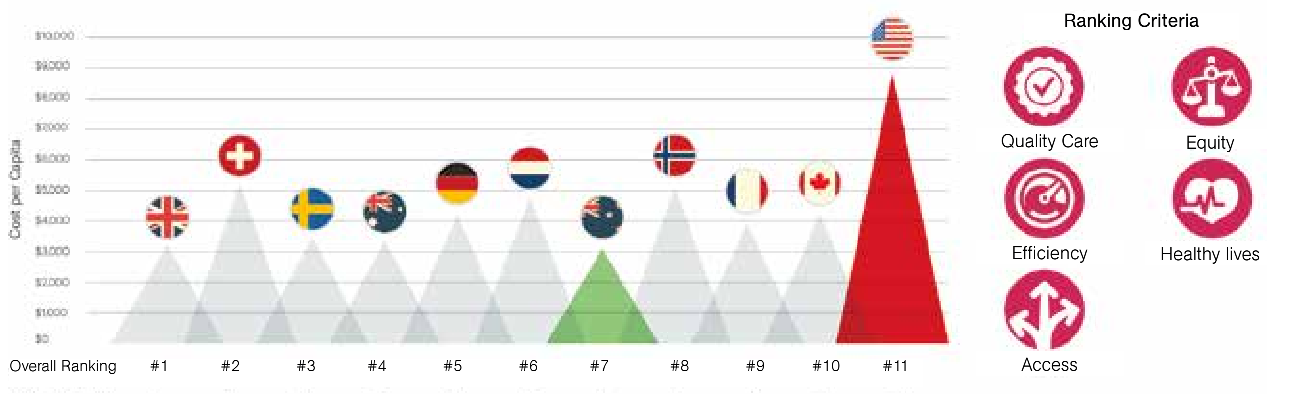

Fig. 8: Rising Healthcare Costs. / Source: Commonwealth Fund & CADRE 2015.

Care coordination

According to the AHRQ, "care coordination involves deliberately organizing patient care activities and sharing information among all of the participants concerned with a patient's care to achieve safer and more effective care (figure 9). This means that the patient's needs and preferences are known ahead of time and communicated at the right time to the right people, and that this information is used to provide safe, appropriate, and effective care to the patient".

AHRQ proposes two ways of achieving coordinated care: Using broad approaches that are commonly used to improve health care delivery and using specific care coordination activities[3].

This has strong implications for healthcare design because the healthcare delivery space must be considered a workspace that is conducive to care coordination. New trends in the healthcare workplace have been observed that include open office spaces for the care team to come together, touchdown and hoteling spaces to facilitate conversations, and emphasis on the consult space between patients and staff members to have better conversations.

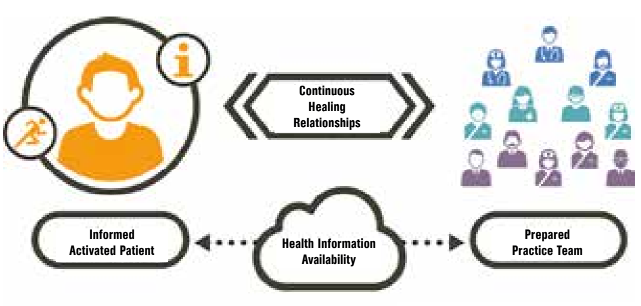

Fig. 9: Care co-ordination. / Source: (CADRE, 2015) & Improving Chronic Illness Care[2].

Examples of broad care coordination approaches include:

- Teamwork.
- Care management.
- Medication management.
- Health information technology.
- Patient-centered medical home.

Examples of specific care coordination activities include:

- Establishing accountability and agreeing on responsibility.
- Communicating/sharing knowledge.
- Helping with transitions of care.
- Assessing patient needs and goals.
- Creating a proactive care plan.
- Monitoring and follow up, including responding to changes in patients' needs.
- Supporting patients' self-management goals.
- Linking to community resources.
- Working to align resources with patient and population needs.

Evidence Support

- Care coordination is particularly critical for patients with chronic conditions and in the context of an aging population[4].
- Dysfunctional nurse-physician communication has been linked to medication errors, patient injuries and patient death[5].
- Studies in non-healthcare settings show that proximity among employees and visual contact affect the pattern of communication networks and the probability of communication[6].
- Presence of consult areas improves interpersonal communication[7].

Facility Implications

Open Office (figure 10): Getting physicians, case managers and other health professionals out of their individual offices to an open plan so they can connect with each other. This fosters collaboration between diverse care teams through informal work areas within ambulatory clinics. The Duke Primary Care Clinic prototype was designed to include Huddle Rooms, semi-enclosed areas within the work core for coordination meetings between staff members. The space allows all members of a patient's care team to collaborate on a care plan.

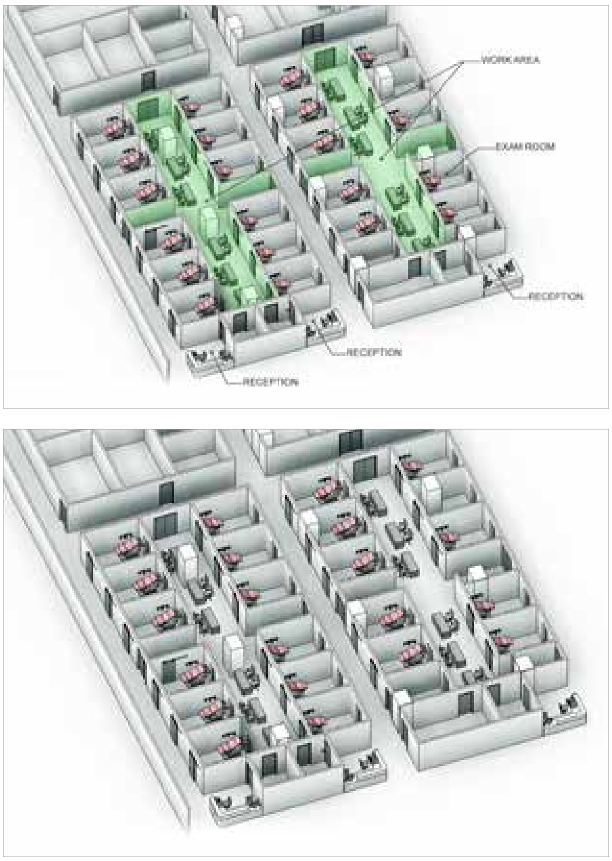

Fig. 10: Macau Island Hospital Outpatient Clinics.

Hoteling Spaces

These flexible spaces are favored as practice shifts from singular physician practices to multispecialty practices, providing unassigned spaces that can be used as needed by different team members.

Touchdown Areas

These areas provide the opportunity of impromptu information exchanges, in response to the increased level of communication between care team staff that is the cornerstone of ACOs and PCMHs. The Duke Primary Care Clinic prototype includes several areas within the work core where staff members can quickly coordinate care; they included transaction-height counters at workstations and standing desk space available for quick two-person meetings.

Proximity Across Specialties

Locating specialties close together encourage interdisciplinary collaboration. The rise of multispecialty ambulatory care centers (MACCs) supports this trend.

On-Stage/Off-Stage

This is a clinic module borrowed from Disney practice. The on-stage areas include space for the public, and the off-stage is reserved for the care team. The use of double doors in exam rooms is an effective use of the practice, as it minimized congestion at the front of the clinic improves privacy and reduces noise levels in the clinic[8].

Case Study: *Macau Island Hospital*
With relevance to the above consideration in clinical care team design and planning, similar concepts are adopted at the new Macau Island Hospital outpatient clinic department in Macau, SAR.

Prototypical Primary Care Clinic

Each primary care pod includes private exam rooms, consult room, private patient toilet, shared meds alcove, POC alcoves, physician dictation/ huddle areas and clinical work stations for teaming between every three exam rooms. Each pod was organized operationally to support physicians and a dedicated clinical support station for preparation and consultation between patients. The on-stage / off-stage concept is intended to allow for the public realm to be designed with a hospitality character, while keeping conveniently located clinical work areas hidden from public view. The design should assist in helping to reduce patient stress while allowing for private clinical work and collaboration areas. The Physician Pod is designed as a prototypical module, that could be combined in different arrangements depending of patient census and specific clinical practice needs. Each module is a kit of spaces that can be standardized within themselves and within the pod.

Prototypical Exam Room

A prototypical exam room was developed to provide direct access from the off-stage clinical support core, while allowing patients to circulate into the exam room from the public realm without crossing clinical work areas. The exam rooms were designed with the intent that the majority of the care should occur within the room and as much care as possible should be brought to the patient. The design accommodates direct access to the clinical care team work area and provides for family support zones, patient care zones and care giver work zones within the 120 sf exam room footprint. A modular systems approach was applied to the clinical sink and work area allowing for a flexible workstation to be used by the care giver to document with the patient in multiple zones of the exam room.

NEURO-ARCHITECTURE

Creating a responsive environment for the aging population:

According to United Nations, the Asia-Pacific region is currently home to over half of the world's elderly population. The unprecedented pace of population ageing is primarily due to the tremendous improvements in life expectancy combined with falling fertility rates in the Asia-Pacific region. The number of older persons in the region is expected to triple from 438 million in 2010 to more than 1.26 billion by 2050. Projections from the United Nations Population Division show the proportion of seniors aged 65 and older will surpass the proportion of children (aged 0-15) in South Korea, Thailand, and China by 2030. Vietnam and Malaysia, meanwhile, will cross this threshold by 2040 and 2050 respectively.

"Silver tsunami" is a term often used in the past decade to describe the rapid increase of people over the age of 60 as compared to the overall population in Western countries, but only recently has the term been heard more and more often throughout Asia.

This trend has created a rising demand for healthcare services for the ageing population, prompting both the public and private sectors in countries across the region to massively expand healthcare and healthcare technology infrastructure. With enormous investment in building new healthcare facilities and expanding or updating existing facilities across Asia, hospital asset owners are constantly looking for innovative ways to design health facilities to meet the needs of an ageing/increasingly urban and demanding population. Health facilities now need to be modern, comfortable, aesthetic, efficient, safe and accessible. These characteristics demand huge investment not only into new developments but also in renovating and retrofitting existing facilities.

Neuro-architecture is an emerging field. Understanding the aging brain and the impact of aging on sensory systems is key to developing responsive environments for the aging population. This paper will look at cutting-edge research in the field of neuroscience and psycho-physiology and translate the research findings into design and architectural language that can be widely applied, thereby translating our "design response" that goes beyond the functional and the aesthetic, to the "sensthetic."

Aging is characterized by many changes that are reflected in the body, the various sensory systems, and most critically, the brain itself. As the brain ages there are fundamental changes which include changes in the prefrontal cortex (responsible for key cognitive functions) and the hippocampus (responsible for memory and emotional processing) (Figure 11). The changes in the neurons and neurotransmitters, blood flow, and development of new cells, reflects in the ability to learn new things, remember names, perform complex tasks of attention etc.

Fig. 11: The prefrontal cortex and the hippocampus

However the brain, which is inherently plastic, compensates for its reduced ability in some areas by increasing abilities in others. Research study results suggest that low-performing older adults recruited a similar network as young adults but used it inefficiently, whereas high-performing older adults counteracted age-related neural decline through a plastic reorganization of neurocognitive networks. This ability for the brain to adapt and cope depends on lifestyle, overall health, environment and genetics.

As designers we focus on the environment – however – it is important to remember that as the brain is changing, there are simultaneous changes in the sensory systems: hearing (hearing loss, change in equilibrium), vision (sharpness, focus, toleration for glare, differentiation between colors, peripheral vision), smell and taste (atrophy in taste buds, reduced smell/taste perception), and touch (change in sensation and sensory thresholds). This implies that if we want to create environments for aging that promote a healthy brain- and look at Neuroarchitecture as a field, our "design response" must go beyond the functional and the aesthetic, to the "sensthetic".

All senses can be affected by aging, but hearing and vision are most affected.

VISUAL CHALLENGES

- There is an inability amongst older people to tolerate glare. Glare such as from a shiny floor in a sunlit room can make it difficult to get around indoors.
- One may have trouble adapting to darkness or bright light

VISUAL SOLUTIONS

- As one ages, using warm contrasting colors (yellow, orange, and red) can improve the ability to see.
- Keeping a red light on in darkened rooms, such as the hallway or bathroom, makes it easier to see than using a regular night light.

AUDITORY AND MOTOR BALANCE CHALLENGES

- Our ears have two jobs. One is hearing and the other is maintaining balance. As we age, structures inside the ear start to change and their functions decline. Our ability to pick up sounds decreases.
- We may also have problems maintaining our balance as we sit, stand and walk. Motor performance deficits for older adults appear to be due to dysfunction of the central and peripheral nervous systems as well as the neuromuscular system. Motor performance deficits include coordination difficulty (Seidler et al., 2002), increased variability of movement (Contreras-Vidal et al., 1998; Darling et al., 1989), slowing of movement (Diggles-Buckles, 1993), and difficulties with balance and gait (Tang & Woollacott, 1996) in comparison to young adults.
- Gait and balance problems are of particular interest as falls are a major source of injury and morbidity in older adults: 20–30% of older adults who fall suffer moderate to severe injuries that limit mobility and reduce quality of life (Alexander et al., 1992). Older adults exhibit greater spatial and temporal movement variability, resulting in less consistent actions as compared to young adults (Contreras-Vidal et al., 1998; Cooke et al., 1989; Darling et al., 1989).

RISK FOR FALLS

- Approximately one-third of community-dwelling older adults fall each year; the rate is doubled in senior group dwellings (Gillespie et al., 2001; Jensen et al., 2002). Even without injury, falls may cause a loss of self-confidence and result in reduced active behavior and increased dependency among older adults (Gallagher et al., 2001). Falls have been identified by the elderly as the most significant barrier to active behavior (Wilcox et al., 2003).
- According to a United Nations report, in the South-East Asia Region the incidence of falls amongst older adults varied from 31% in China, to 20% in Japan. The economic impact of falls is critical to family, community, and society. Healthcare impacts and costs of falls in older age are significantly increasing all over the world. Fall-incurred costs are categorized into two aspects: Direct costs encompass health care costs such as medications and adequate services e.g. health-care-provider consultations in treatment and rehabilitation. Indirect costs are societal productivity losses of activities in which individuals or family care givers would have involved if he/she had not sustain fall-related injuries e.g. lost income.

DESIGN SOLUTIONS FOR FALL PREVENTION

- Clear circulation/corridor systems should be applied in the building for older adults, as some of them may have memory impairment or suffer mental problems.
- Different function zones should be separated and applied with distinct design factors (e.g., colors and styles) to aid in place recognition.
- Corridors in the building for elderly people are suggested to be short, with uninterrupted visual destinations or environmental cues; short and clear corridors has been found to be more navigable for older adults than long corridors (AIA, 1985; Brawley, 1992; Goldsmith, 1996; Passini et al., 2000).
- The location of utility/service rooms in residences for older adults should receive special attention. The laundry room should be located on the bedroom or bathroom level of the residenc (Haslam et al., 2001). The location of a storage room may depend on its function.
- The usefulness of grab bars (figure 12) for fall prevention has been recognized (Sattin et al., 1998). In addition, door handles or push bars, instead of knobs, should be installed in residences for older adults (Gilderbloom & Markham, 1996).
- Irregular floor surfaces should be avoided and hard-surface flooring are recommended as it

Fig. 12: Grab bars and appropriate finishes. Source: HKS, Inc.

improves standing balance and postural stability (Redfern et al., 1997; Thies et al., 2005).

- High-density and low-pile commercial-grade carpeting has been suggested as a safe flooring material for healthy older adults (Dickinson et al., 2002).
- The bathroom has been identified by older adults and researchers as the most common site of environmental hazards (Carter et al., 1997; Huang, 2005). Besides slip-resistant floor surfaces, sliding glass shower doors should be avoided (Murphy et al., 2006). Walk-in shower stalls or bathtubs with rails, raised toilet seats, and wide clearances have been suggested for elderly users (Jenkins et al., 1997; Percival, 2002).
- Regarding the kitchen design, adequate spaces facilitating different eating routines are preferred (Percival, 2002). Square-shaped kitchens may seem more spacious, compared to linear-shaped kitchens. Boschetti (2002) recommended an L-shape (figure 13) layout for kitchens used by the elderly, as it affords a corner to lean against. Installing carefully designed stair handrails for stability is necessary; an appropriate height and a proper section size of the handrails should be applied. Closed risers, consistent riser heights, appropriate short riser and long tread, coarser tread surface textures are some of the key strategies for fall prevention in staircases.

Fig. 13: L shaped kitchens for elderly.

- An elevator or stair lift may promote independence when an individual becomes too disabled to use stairs, (Gilderbloom & Markham, 1996). However, Simoneau et al. (1999) found changes in stable visual anchors, as when exiting an elevator cage, may create risks for falls among older adults. This risk may be exacerbated by dim lighting in the elevator cage.
- Lack of illumination appears to be related to poor postural stability among older adults and may induce risks for falls (Brooke-Wavell et al., 2002; De Lepeleire et al., 2007). Furthermore, changes in light levels should be smooth, as older adults need more time to adapt to changes in light levels than younger adults (Brabyn et al., 2000).
- Visual spatial cues can help older adults with declining memory recognize places and respond to the surroundings. Sundermier, et al. (1996) noted that specially designed elements in the space can be used as cues by older adults while moving around and be helpful to prevent falls. sizes the edges of spaces and help older adults distinguish features of the environment.
- Research by Perritt (2005) on carpet patterns showed that that high contrasting patterns were associated with more incidents (stumbles, reaching for handrail, veering, purposeful stepping, pausing, stopping) than carpeting with low color contrast patterns. Bonato and Bubka (2011) found that viewing high contrast static patterns (black and white squares laid out in regular patterns on a rug) can induce motion sickness. In a recent correlation study by Calkins (2012), it was found that vinyl flooring with medium size pattern (1”- 6”) was associated with greater falls than no pattern, small pattern (6”). These few studies suggest that floor glare and pattern may contribute to falls. However, the underlying relationship, and ideal condition for each, demands more research.”

TACTILE CHALLENGES

- With aging, you may have reduced or changed sensations. These changes can be related to decreased blood flow to the nerve endings or to the spinal cord or brain. The spinal cord transmits nerve signals and the brain interprets the signals.
- After age 50, many people have reduced sensitivity to pain. Or you may feel and recognize

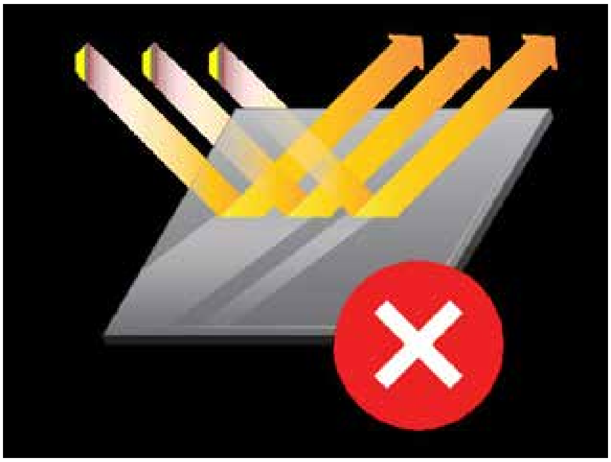

Fig. 14: Avoid reflective surfaces.

pain, but it does not bother you. For example, when you are injured, you may not know how severe the injury is because the pain does not trouble you. Older persons can develop an increased sensitivity to light touch because of thinner skin. Avoid reflective surfaces, Utilize Materials with texture (figure 14).

MULTI-SENSORY DESIGN SOLUTIONS

- It also appears that additional brain regions can be activated in older adults during cognitive tasks, such as taking a memory test. Researchers do not fully understand why this happens, but one idea is that the brain engages mechanisms to compensate for difficulties that certain regions may be having. For example, the brain may recruit alternate brain networks in order to perform a task. Multisensory integration becomes more important during aging as it helps to counteract the often-destructive consequences of unisensory deterioration. Mozolic et al. (2012).

AUDITORY AND VISUAL SOLUTIONS

- Use vision and sounds to direct:
- A "Sensthetic Model" – is a conceptual tool to think "across" modalities that can help professionals and students to design, study or experience sensory environments. It is a step beyond the aesthetics of appearance, towards a Sensthetics of Experience. (Nanda, Lee, & Wang, 2015).

Case Study: Signage as Visual Solution, Nature as Medicine

In large buildings, especially in hospital when we are not at our most alert state, finding our way around can boggle the most organized minds.

At Macau Island Hospital, we drew from the flora and nature that surround the city (figure 14), and applied them to a well thought out "way-finding" system (figure 15). We used yellows and reds which stimulate and are good for dining and social areas on the patient floor. As one ages, it gets harder to tell apart blues and greens than it is to tell apart reds and yellows.

Regarding interior colors, unsaturated and washed-out colors will be avoided in the environments for older adults, as it is difficult for them to discriminate these colors and color confusion may result in falls. In addition, an appropriate contrast between colors of the wall and the floor, and floor surfaces at different levels emphasizes the edges of spaces and help older adults distinguish features of the environment at the new Macau Island Hospital.

Fig. 14: Inspiration from flora and nature that surrounds the city.

Fig. 15: "Way-finding" system.

LEAN PROCESS DESIGN

Lean is a production practice that considers the expenditure of resources for any goal other than the creation of value for the end customer to be wasteful, and thus a target for elimination. Working from the perspective of the customer who consumes a product or service, "value" is defined as any action or process that a customer would be willing to pay for. A lean organization understands customer value and focuses its key processes to continuously increase it. The ultimate goal is to provide perfect value to the customer through a perfect value creation process that has zero waste.

To accomplish this, lean thinking changes the focus of management from optimizing separate technologies, assets, and vertical departments to optimizing the flow of products and services through entire value streams that flow horizontally across technologies, assets, and departments to customers.

Eliminating waste along entire value streams, instead of at isolated points, creates processes that need less human effort, less space, less capital, and less time to make products and services at far less costs and with much fewer defects, compared with traditional business systems. Information management becomes much simpler and more accurate.

Lean applies in every business and every process. It is not a tactic or a cost reduction program, but a way of thinking and acting for an entire organization.

"All we are doing is looking at the time line, from the moment the customer gives us an order to the point when we collect the cash. And we are reducing the time line by reducing the non-value adding wastes." Taiichi Ohno

The principles of Lean explain that every activity, in every business, started by people can generate more or less waste. It exists in all processes and it can be seen in various ways. Many forms of waste are obvious, but others are not easy to see without especially looking for them. It may be hard to identify it sometimes. In Japanese, waste is categorized into three different words; Muda (unproductive), Mura (inconsistent) and Muri (unreasonable).

Waste in Design and Construction

The Lean Construction Journal in a 2009 white paper pegs the ratio of non-value-added or wasteful activities in a typical construction project at 55% to 65%. While it is easy to pick on our construction friends when much of their waste is easy to see in terms of materials, motion and transportations on a interpretation, etc., the design team members too own a fair share of that percentage.

We need to think about every task that you do in terms of, is this value added to the project, and would the customer pay for this? We must ask team members what the tasks are to deliver the customer the value they request and try to produce only those tasks.

Fig. 16: Lift lobby signage

Macau Island Hospital LEAN Process Design

Real-time mock-ups
Many architectural processes involve a full-scale mock-up, usually in a warehouse or other large space on campus where users visit the mock-up and offer comments. While these mock-ups tend to be very helpful, one lean tool that can be even more helpful is the real-time mock-up (figure 16).

At Macau Island Hospital, mock-ups for typical patient room, typical ICU room, OR, typical exam room were built. This gave a more realistic evaluation of how the space would be used and nurses were able to start implementing processes and using the equipment planned for the new unit ahead of time.

Process Mapping
A clear departure from the traditional design approach, Process Mapping takes an in-depth look at existing and future hospital processes (figure 17). The teams examine each operational process from the point of view of the patient, staff and family members, highlighting value-added activities and non-value-added activities through observation and process mapping of the current state of operations. Each step in a process is mapped diagrammatically with additional layers of analysis, such as the time it takes to complete the task and the value of that task, and then added to the diagram. Once the current state maps for each area are completed, unnecessary steps and problems are discovered and solutions are brainstormed to create future state maps showing how processes will be done more efficiently at the new facility. This phase differs from the traditional design approach in that there is considerable effort in the early phases gathering information, defining value and reviewing processes to inform the program and design effort. □

> "The most dangerous kind of waste is the waste we do not recognize."
>
> Shigeo Shingo

Fig. 17: Process Mapping for Macau Island Hospital

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Successful design is the result of the harmonious relationship and balance between patient and user experience, form and function, budget and schedule, sustainability and sound business principles." Angela's 21 years of experience encompasses LEED and JCI Accredited medical projects ranging in size from 10,000 to 3.5 million square feet and bed counts from 30 to 1,650 beds, in the US and internationally. Her specialties include Healthcare Architecture and Healthcare Planning –she develops innovative, quality healthcare design solutions that meet the client's vision and embraces the challenges and complexities of healthcare design and creates quality solutions. Her projects range from 100-bed children's hospitals to 1,650-bed greenfield hospitals. She has worked with prototype healthcare facilities, healthcare guideline and references.

Kenneth Webb

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Kenneth is a senior planning and design architect with 16 years of experience focusing on conceptual design, master planning, schematic design and design development. His expertise includes working closely with medical professionals, physicians and consultants in planning state-of-the-art healthcare facilities. Kenneth leads design teams to develop innovative solutions that meet the client's needs without sacrificing functional and operational efficiencies.

Andrew Jaeger

Vice President, HKS Inc.

Andrew contributes 16 years of experience dedicated solely to the planning, programming, design and integration of state-of-theart medical technologies into the healthcare environment. His experience in healthcare design encompasses all hospital clinical areas and service lines including inpatient care units, surgical suites, pharmacies, diagnostic imaging and radiation and oncology. However, its Andrew's in-depth expertise in clinical laboratory operations and design that clients truly respect and appreciate the most about him. Utilizing his extensive expertise in laboratory design and processes, Andrew provides clients with state-of-theart, laboratory design solutions that enable and promote Lean/ Six Sigma lab processes and operations.