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Challenges and Opportunities in Design of Highrise Healthcare Buildings in Saudi Arabia: An Overview

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Abstract

The high-rise healthcare design has a particular set of benefits. This paper aims to illustrate the design consideration of facilities in urban areas because of their increasing land values at the same time healthcare demand not only a prospect for better planning flexibility, safety, and security but also an opportunity to achieve improved air quality, efficiency, reduced noise as well as a better healing environment. However, the main challenging aspects of high-rise healthcare design are vertical transportation, planning, life safety, noise and vibration, temperature, and airflow. To ensure the success of a vertical project, innovative approaches are essential in vertical design. This encompasses inventive facade design, standard frame construction techniques, and the effective operation of Facility Management Systems. Achieving this success demands infrastructure expertise, creative solutions for vertical transportation, and robust structural engineering capable of supporting heavy loads, including HVAC, electrical, low-current IT, and medical equipment that may weigh several tons. Also, Segregation of circulation, well-defined access, wayfinding, and the flow of services must be considered for patient/staff workflow. This paper employs a qualitative research methodology, utilizing a case study approach and physical observations to gather qualitative data. The analysis is conducted with the aim of identifying and addressing factors that influence design challenges in high-rise healthcare facilities. The ultimate goal is to propose a roadmap for mitigating space constraints, optimizing efficiency, and enhancing patient care within healthcare facilities.

Keywords: Healthcare Design, Architectural design, High-rise, Hospital buildings, Saudi Arabia

1. Introduction

With the ongoing rapid urbanization of the global population, over half of the world's inhabitants currently reside in cities. Projections indicate that by 2050, this percentage will rise to 70%, emphasizing the urbanization trend. This phenomenon places increasing pressure on healthcare facility development due to the limited availability of land, necessitating the efficient utilization of space in both the redevelopment of existing facilities and the creation of Greenfield projects. High-rise hospitals are not a recent innovation; they have been employed as a solution to address space constraints, optimize operational efficiency, and enhance patient care for many years. Dating back to the nineteenth century, large hospitals were designed with a compact, barracks-like layout. As the twentieth century progressed, the development of high-rise hospitals became more prevalent, especially in response to the substantial rise in land costs in urban centers. The proliferation of high-rise hospitals globally underscores their well-established presence, and today, taller and larger hospitals are being constructed more than ever before [1].

In the healthcare industry, when we monitor various aspects of the physical environment such as

patient satisfaction, infection control, optimized circulation, and patient fall rates, there is a growing need to design and develop facilities that enhance patient outcomes beyond what traditional hospital designs can achieve [2]. The National Fire Protection Association (NFPA) defines a high-rise building as a structure with an occupied floor that is situated 75 feet or more above the level where firefighting operations would typically be staged. This relatively low threshold necessitates the incorporation of specific safety features in high-rise buildings to ensure the protection of lives and the efficient response of emergency personnel, thereby saving both lives and valuable resources [3]. Horizontal expansion in healthcare facilities often results in increased travel distances between buildings and campuses, leading to inconvenience and reduced productivity for staff. In contrast, vertical growth can significantly improve the overall experience by minimizing patient movement within the building, bringing essential equipment and services closer to patients, and making a wider range of services accessible to diverse populations. High-rise healthcare buildings introduce unique challenges not typically encountered in traditional low-rise structures. These challenges encompass longer egress times and distances, specialized evacuation strategies, ensuring fire department accessibility, addressing smoke movement, and enhancing fire control measures [4].

Safe and cost-effective vertical hospitals have become increasingly crucial for maintaining a high quality of life in the world's most dynamic urban centers. While the pandemic may have prompted some individuals to leave urban areas, long-term trends indicate that cities will continue to attract top talent and companies vying to hire them. Young professionals are seeking live-work-play neighborhoods that also offer convenient access to healthcare facilities. Vertical construction also aligns with the evolution of healthcare service delivery. Many medical services have transitioned from inpatient to outpatient settings or require a combination of both. Hospitals and healthcare systems have acquired physician practices or established affiliations to generate referrals, necessitating the co-location of physician offices, examination rooms, and inpatient facilities within a single structure. This also includes the integration of a hospital pharmacy, laboratories, and other support services [5]. From a service planning perspective, the focus when designing and planning large, multi-level hospitals centers on patient safety, comfort, and security. Wayfinding and orientation must be carefully configured to ensure a satisfactory and pleasant experience for patients and visitors. Safety and security considerations are particularly pertinent for acutely ill or vulnerable populations seeking care in the hospital and become critically important in evacuation planning for fire or disaster scenarios. The rising demand and costs of healthcare place significant pressure on ensuring that the size, layout, and design of hospitals maximize the efficient use of limited resources and staff availability. Providing timely access to appropriate care settings, with well-defined boundaries between activities, is essential in a healthcare landscape where complex technologies play an increasingly pervasive role. It is equally important that patients do not have to travel excessive distances and are not subjected to redundant assessment and checking procedures by unfamiliar staff in unfamiliar environments [6].

2. Research Background

As urban population density continues to rise, so do land values, and the demand for outpatient care services also increases. Hospitals are consequently

facing growing challenges when it comes to finding space for expansion. This issue is particularly acute in urban and metropolitan areas, where the construction of vertical hospitals represents a practical and, in some cases, the only viable option for significant hospital expansion. Evidence from around the world supports the emergence of a global trend towards high-rise hospital design. This transformation in healthcare is guided by three primary objectives: ensuring easy access to healthcare services, enhancing the quality and efficiency of healthcare delivery, and preventing health risks. These objectives align with standards set by initiatives such as Saudi Arabia's Vision 2030 and the National Transformation Program. To illustrate this point, consider Saudi Arabia as an example. There is a pressing need to increase the number of hospitals in various healthcare sectors, including the Ministry of Health (MOH), the Other Governmental Sector, and the Private Sector. In particular, there has been a remarkable increase in the total number of hospitals across all healthcare sectors, amounting to a 38.64% rise in 2016 compared to 2002. Additionally, the number of hospital beds has seen substantial growth, with increases in MOH, Other Governmental Sector, and Private Sector beds totaling 50.48% in 2016 compared to 2002 [7].

3. Literature Review

The trend toward high-rise infrastructure, driven by urbanization and increasing property values, extends to various sectors, including healthcare facilities. Kamal and Saraswat conducted an analysis of emerging trends in tall building design, emphasizing environmental sustainability [8]. The insights gained from high-rise developments, while generally applicable, hold particular relevance for the healthcare industry. High-rise hospitals are not mere theoretical concepts; they are exemplified by several existing high-rise healthcare buildings. In this context, specific factors become increasingly significant in hospital planning. These include:

- Patient and Visitor Access and Movement: Ensuring convenient and efficient movement within the hospital for patients and visitors.
- Staff Access and Movement: Designing layouts that facilitate staff access to different parts of the hospital.
- Separation of Travel Functions: Creating distinct pathways for patients, staff, and the movement of goods and services to reduce congestion.
- Vertical Patient and Critical Care Traffic: Implementing designated rapid elevators for the vertical transportation of patients and critical care services.
- Models of Care Patient Flows: Establishing care models that support efficient and positive patient experiences.
- Organizational Zoning: Dividing the hospital into zones to enhance operational efficiency and wayfinding.
- Horizontal and Vertical Adjacencies of Departments: Strategically locating departments to minimize travel times and avoid traffic crossovers.
- Ventilation, Airflow, and Infection Control: Implementing systems that ensure air quality and reduce the risk of infections.
- Creative Use of Design Elements: Utilizing elements such as light, color, and interior design to create environments that reduce feelings of anonymity and depersonalization.
- Allocated Healing Spaces: Designating areas specifically for healing and incorporating elements of the natural environment.

From a service planning perspective, patient safety, comfort, and security are central considerations when designing and planning large, multi-level hospitals. Effective wayfinding and orientation are essential to create satisfactory and pleasant experiences for patients and visitors. Safety and security are especially relevant for acutely ill or vulnerable patient populations seeking care in the

hospital and become critically important in emergency scenarios such as fire or disaster evacuations [1].

Designing high-rise healthcare facilities poses significant challenges during the planning and development stages. These challenges encompass various factors, including earthquake resilience, meeting user needs, addressing social considerations, evaluating economic feasibility, incorporating technological advancements, assessing soil conditions, maintaining appropriate building proportions, planning utility systems, considering life safety and fire hazards, managing logistics, handling waste disposal, ensuring infection control, managing airflow, accommodating MEP (mechanical, electrical, plumbing) equipment, and designing structural systems. Healthcare environments are also expected to undergo future expansion and adaptation, necessitating considerations such as load capacity in columns and floors, fireproofing, and the use of modular grids to ensure flexibility. Additionally, creative solutions are required for wayfinding, connections, and optimizing patient and caregiver flows within vertical healthcare environments. The technical challenges are substantial, with HVAC systems designed to reduce the risk of hospital-acquired infections through the use of air systems equipped with HEPA filters, negative airflow capabilities in infectious disease units and surgical suites, and positive pressure rooms for other patient types. Moreover, financial pressures, exacerbated by the pandemic, have highlighted the importance of cost control in healthcare construction, making smart engineering crucial for cost-effective solutions while optimizing available space for healthcare service delivery [9].

In a typical high-rise building, over 12% of the available space is dedicated to infrastructure, which includes mechanical, electrical, and plumbing systems (MEP), as well as fire protection (FP) systems. When you factor in structural elements such as stairs, elevators, and exterior walls, more than 25% of the total space is utilized for these essential systems and structures. To manage this effectively, it's common practice to prioritize planning for these "forgotten spaces" early in the design and development process. This proactive approach helps prevent costs from spiraling out of control and minimizes wasted space.

In healthcare facilities, the demands for infrastructure space are even greater due to the need for redundant HVAC, electrical, and IT equipment to ensure continuous operation. One of the significant challenges in MEP/FP planning is striking a balance between the cost of distributing equipment across multiple locations and the cost of creating horizontal connections between this equipment and its points of distribution.

To address these challenges cost-effectively, some strategies include placing equipment such as cooling towers, boilers, chillers, and other mechanical components in mid-level areas or on the roof. However, this should be done thoughtfully, incorporating safety enclosures and acoustical measures to mitigate noise from the equipment. Additionally, technology rooms, generators, fuel oil storage, fire pumps, and incoming water services can be strategically located in areas like parking garages or loading docks to reduce costs and minimize their visual impact on the overall building.

A notable advantage of vertical hospitals is that primary MEP/FP equipment can be positioned much closer to the areas they serve compared to horizontal facilities. This proximity offers flexibility, enabling facility managers to add equipment as needed in specific areas of the building, rather than requiring a larger system to serve the entire facility if service demands increase in a particular location [10].

4. Research Methodology

In this paper, a qualitative research method has been used. The systematic literature review explores the basic design concepts revolving around High-rise healthcare facility services and their parameters in terms of Architectural, Structural, Mechanical, Electrical, and Plumbing (MEP) and Clinical Engineering challenges through the relevant published academic and research literature from books, journal's papers and internet websites. These factors serve as the framework for an exploration of attributes of design prospects. This research also utilized the mixed method to collect qualitative data through case study and observation and analysis for user-centred evaluation of staff, patients, and visitors' perceptions of environmental and physical

infrastructural attributes of supportive design elements. The study is limited to private healthcare organization and their practicing trends in the Kingdom of Saudi Arabia. The need for High-rise facilities and vertical connections between departments and its high-level operational coordination among Outpatient departments, Emergency Departments, Diagnostic areas, surgical suites, and inpatient wards enable convenient access with decreased waiting times.

5. Kingdom of Saudi Arabia: Research Context

The KSA Vision 2030 and the objectives of transforming the healthcare sector emphasize the need for improving healthcare services' quality, consistency, and the performance and accountability of healthcare organizations. Achieving these goals requires a fundamental shift in our approach to physical and mental well-being and the supporting healthcare system. This transformation is essential if we aim to lead fulfilling lives in a vibrant society [11].

To promote patient safety, quality of care, and value in healthcare, continuous quality improvement is crucial. This study addresses the challenges and opportunities associated with high-rise healthcare facility design, aiming to enhance outcomes. The underlying principle is that a supportive physical, psychological, and social environment can significantly improve the overall experience for healthcare staff, patients, and visitors. This improvement is achieved by considering key elements of healthcare facility design that contribute to a positive healing experience. Furthermore, it's essential to remain responsive to the needs, values, and expectations of all stakeholders, including facility services. Gathering feedback from end-users on critical issues plays a vital role in the design process, ensuring that the resulting healthcare facility, such as Sehat Al Sharq in Al-Khobar, Saudi Arabia, aligns with the diverse requirements and preferences of its users [12].

5.1 Case Study: HMG Sehat Al Sharq, AlKhobar

The Al Habib Medical Group (HMG) Sehat Al Sharq Khobar is the first fully integrated digital hospital in the region, and expanding its services in order to meet a growing Urban population and continue to provide quality care it is known for with a high-tech Patient Centered healing environment with the capacity of 400 Inpatient Beds and approximately 300 Outpatient Clinics with total buildup area 290,000 Square meters. Digital hospital enables the patient to have access to medical consultations at work or home around the clock via visual communication services. Patients and Doctors/Staff communicate together continuously on medical consultations and doses. This also helps the patients not to visit the facility in non-emergency situations. There are #10 OR's, #2Equipped Cardiac Catheterization Rooms, #17 LDR, and 100 Beds for Intensive Care. Every aspect of the interior is designed around the user's welcoming environment to patient journey, from easy access down to grand spine corridors to appropriate circulations from Elevator Lobbies in such a way that patients, as well as family/visitors, orient themselves conveniently. Integrating new technologies and transformation of healthcare facilities, to create a progressive and accessible facility capable of integrating 21st-century medical advances and providing the highest level of patient-centered care [13].

HMG Khobar significantly reduced the admission waiting time for our patients and ensured their timely discharge from our hospitals enabling us to maximize resource utilization. Our Patient Care Technician Program is actively contributing towards our commitment to continuously enhance the efficient utilization of our nursing resources. Healthcare Digital Transformation Added Value, Enhanced patient engagement, Access to real-time healthcare information, Efficient Healthcare

Analysis, Increased efficiency and decrease in cost, Improved care to patients, Remote patient monitoring, Timely Assistance, Patient out-reach and live care expansion, Eliminate human errors and better communication with doctors [12].

6. Architectural Design Considerations

While designing a 21-story building with multiple connections like a Parking Area, Diagnostic zone, numerous Outpatient Departments, Operation Theaters, MEP Services area, Inpatient Department, and Staff Accommodations within the facility maximizing opportunities for future flexibility and safety with enhanced satisfaction and productivity. Kamal et al. analyzed the area requirement and zoning criteria for the architectural design of healthcare buildings [14]. While designing the High-rise facility, the project designing team considered many challenges including:

6.1 Structural Designing Coordination

Once initiating structural grids, columns, structural framing, and total building load shall be the most important challenge, considering dead and live load requirements for each area of the hospital. Moreover, loads range vary from Low to high in Office, Outpatient, Inpatient, Radiology equipment, and Helipad loads up to 7,000 Kg/m^2 for Structural Grids, Modularity and arrangements of Lower floor Parking lots, Outpatient clinic/examination rooms, mid-level operation theatre and critical care areas and upper levels patient's rooms.

6.2 MEP, Low Current and Fire Fighting Coordination

Provisions and location routing shall be well-defined early for any project. These require space as well as routing shafts, Stairs, Elevators, and the exterior wall system in a high-rise healthcare project. Locations of the MEP main equipment are driven by balancing the cost for multiple main equipment locations against the costs of implementing a major horizontal connection between this equipment and the point of distribution. There are multiple locations within the building stack where the Air Handling unit with pumps and support equipment and main Electrical/ ER transformers / Generator and Panels are located (Figure 2) Typically the assumptions are that certain equipment will be located at the Service Floor, Basement. Ground Floor or on the Terrace. Redundancy, Flexibility, Adaptability, and Growth: Due to various MEP types of equipment and important application of machines harvests redundancy of its vertical routing in place of horizontal, so Redundancy can be determined not only for fixed servicing equipment but at the time of maintenance of major equipment and machines. Also, future expansion of the facility needs to be considered for flexibility, adaptability, and future growth of medical space and its MEP requirements. Usually providing extra space within risers and distribution of MEP services shall be helpful for future routing of service connections and for achieving quality models with various important design parameters (Figure 3).

6.3 Design of Building Façade

For main facade selection and type of Materials are mainly structural glazing, Aluminum composite panels, and Natural stones are commonly allocated materials because of aesthetics, constructability, energy efficiency, and ease of cleaning and maintenance [15]. Generally, selections of material and glasses are of different types according to shading coefficient, U value, and relative heat gain [16]. Thermal performance: Apart from comfort, control of internal pressure in the facility is critical for safety, health, and positive outcomes. High-rise facade and Stack effect: In high-rise buildings, the natural flow of warmer indoor air rising upward leads to the influx of cooler outdoor air, resulting in the creation of negative pressure zones on lower floors and positive pressure zones on upper floors within the building. This uncontrolled stack effect complicates several issues, including air quality, sound quality, security, containment, fire safety, and the potential for bacterial contamination. Hence, considering the issue around the stack effect should be a step in the right direction for their application of stack effect knowledge in specific healthcare projects.

6.4 Vertical Transportation

The means by which occupants access specific areas of a building including stairs, ramps; Elevators, and Vertical movement can also be visualized through the use of courtyards, balconies, atriums, and skylights. The space of vertical transportation

needs to be well-programmed with the context of Elevators/ Escalators, Service, Dumbwaiter, and Pneumatic tube systems. Moving Outpatients, Inpatients, logistics medical supply, and users and staff movement within the facility has Thirty-Six elevators and eight working escalators. In a high-rise facility, in Emergency cases every second counts, that's why this critical reason connection between the Helipad to the Emergency department and operation Theaters is very important without any hurdles. Figure 4 shows vertical transportation via Emergency Patient elevators serving once critical patients arrive on the Helipad and then transfer immediately to the Emergency Department without delay.

6.5 Life Safety

To promote specific enhancements in patient safety and ensure the delivery of safe, high-quality healthcare, the following objectives are pursued:

- Accurate patient identification.
- Enhanced communication effectiveness.
- Improved safety concerning High-Alert Medications.
- Ensuring the correctness of surgical site, procedure, and patient.
- Reduction of healthcare-associated infection risks.
- Mitigation of patient harm resulting from falls [17].

Additionally, in accordance with various Fire codes and NFPA guidelines related to Smoke compartments, it is essential for every zone to be coordinated across all MEP (Mechanical, Electrical, Plumbing) disciplines. Evacuation planning poses a significant challenge in the design of high-rise healthcare projects. Both the Saudi Building Code and numerous international regulators have highlighted the use of firearm elevators for evacuation in accordance with emergency guidelines. In certain situations, vertically evacuating patients may be a safer alternative to using stairwells.

6.6 Enhancing Patient and Staff Satisfaction

Several measures in Design and High-rise Connections between departments reduce waiting times and Travel distances. When we perceive the Patient's Journey from the registration desk to discharge, vital signs, Consultant visit, Diagnostics, Procedure, Medication, and post-screening follow-up, the interdepartmental communication is shown (Figure 4). Also, connection to the outdoors and Natural light with full-height glazing in Examination and Patient rooms is known to quickly heal the process and increase patient, family, and staff satisfaction.

7. Conclusions

The reason for vertical growth and main drivers of high-rise healthcare buildings are efficient operation under one entity including Diagnostic, Outpatient, Inpatient, Administration, Services, and Support Ancillary spaces. The high-rise hospital not only offers the prospect for enhanced productivity via incorporating clinical spaces, and services with medical training and research functions in a sole entity but also positive outcomes with travel distance, waiting and transfer time, quality views, easy access to respite spaces, wayfinding, and nature are highly gained for patient experience, also by above parameters directly impact the overall duration and length of stay can be effected healing duration. Moreover, employees experience reduced workloads, which may allow them to utilize the extra time for specific tasks aimed at enhancing patient satisfaction. There is a further need to identify a policy strategy of shifting from horizontal to vertical growth and model of care as well as descriptions of resource utilization and their design outcomes.

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Figures

Figure 1

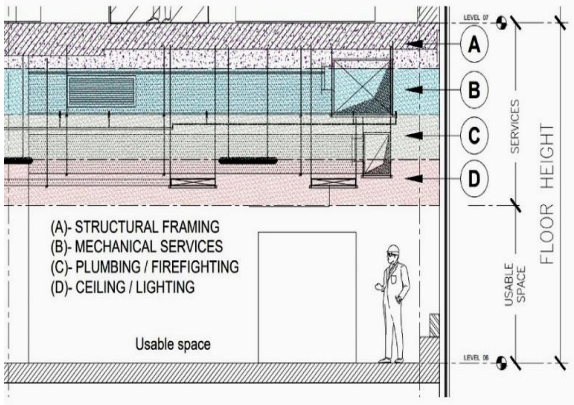

Figure 2

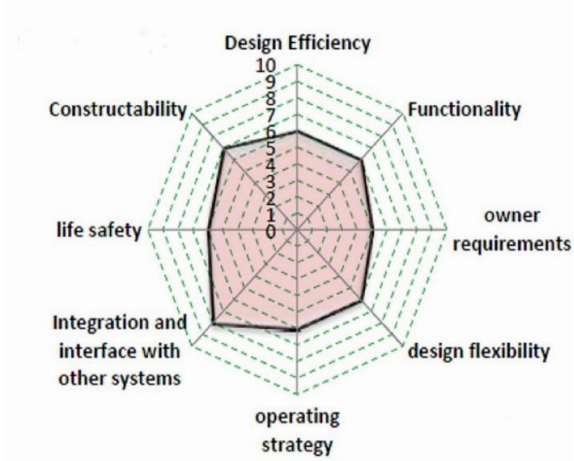

Figure 3

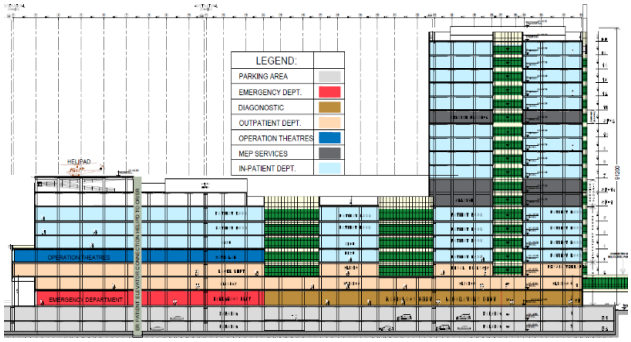

Figure 4

Figure Captions

Figure 1. Sehat AlSharq View at Alkhobar, Saudi Arabia

Figure 2. Typical Floor Ceiling MEP Services distribution

Figure 3. The quality model for Sehat AlSharq Hospital, MEP

Figure 4. Connection b/w Parking Area, Emergency Outpatient, MEP Services area, and Inpatient Area.