Open Architecture for Healthcare: Case Study of Hospital Change in Practice

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Abstract
Sustainable hospital architecture requires a design strategy for future change. A whole life-cycle approach to the hospital operation must take into account the constant and rapid change of healthcare environments resulting from transformations in medicine, technology and sociology. The open building theory proposes a strategy to design hospitals for flexibility by system separation of the primary system “base building”, the secondary system “tenant fit-out”, and the tertiary system of “FF&E” (furnishings, fixtures and equipment). This method recognizes the different life spans, investment and decision making processes related to each system level. Many studies have documented the design theories and methods for planning hospitals to accommodate future change by designing for flexibility, adaptability and expansion, as well as the open building approach to the design process. Only a few of these studies, however, have evaluated these strategies in practice over time. This paper explores the open building theory in the context of the Sammy Ofer Heart Building at the Tel Aviv Sourasky Medical Center in Israel. The research documents the evolutionary process of the building over the last decade from its initial design in 2005, and illustrates the changes that were made to the spatial environment resulting from demands for specialized medical units, advances in medical technology, transformation in social healthcare norms, and adaptive health policy standards. The study classifies each change by its typology, the level of the change, the reasons for the change, and the consequences of the change on hospital operations based on an analysis of architectural documents, hospital data collection, field observation and expert interviews. The hospital design strategy, following the open building theory of system separation, is analysed and evaluated to determine whether the design methods were sufficient to support the hospital's need for change. The study presents the importance of system separation used in the design for hospital flexibility as it enabled significant changes during all phases of the project (design, construction and occupancy), and points out the drawback of the system that occurs when decision making in the design of one system level restricts the flexibility of the other system levels requiring constant collaboration between interdisciplinary project teams.

Keywords: Hospital Design, Open Building, Flexibility, Evaluation, Change over Time

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1. Introduction

Healthcare facilities are in constant change. Advances in all areas of healthcare - science, medicine, technology, economy, politics, and social - are transforming the healthcare environment. In many cases it seems that hospitals are in a race for change while the pace of change is accelerating. As a result, many hospitals have become obsolete and face demolition after only a few decades. Since the 1960s, architects have developed theories and methods to anticipate, to the greatest degree possible, where changes are most likely to occur and to design hospitals for maximum flexibility and expansion. The open building theory, developed for housing and implemented in the healthcare sector, recognizes the different life spans, investment and decision making processes related to the built environment, and proposes a strategy of system separation. The theory addresses the conflict between functionality and flexibility and argues that hospital should be designed to accommodate a variety of functions in order to gain value over time.

While many studies research the theories of hospital design for future change, only a few document how hospitals actually change over time and if the theories stand in practice. Previous studies revealed that some hospitals that were designed to be ‘infinitely’ flexible and dynamic did not fulfill their original vision. They did not expand and their interior redevelopment was limited in scope. Pilosof, N. (2005). This study proposes to explore the open building theory, which is increasingly being recognized as a prerequisite for architects to deliver sustainable healthcare facilities. The strategies of the open building are evaluated in the context of the Sammy Ofer Heart Building at the Tel Aviv Sourasky Medical Center in Israel that was designed by Ranni Ziss Architects and Sharon Architects in 2005 and is still under construction.

2. The Open Building Theory

The open building theory was developed as a response to the rigidity of a ‘whole’ design solution, a departure from the conventional functionalist thinking and architectural management practices. Johan Habraken first articulated the principles of open building in his book Supports: An Alternative to Mass Housing, published in 1961. Developed in the context of residential housing, the open building principles were also recognized in shopping centers and office buildings, and more recently also in healthcare facilities. The term ‘open building’ is used to indicate a number of different but related ideas about the making of environments: (1) The built environment is in constant transformation and change must be recognized and understood, (2) it is a product of an ongoing, never ending design process, in which environment transforms part by part, (3) designing is a process with multiple participants including different kinds of professionals, and (4) users may make design decisions as well as professionals.

The open building theory distinct between levels of intervention in relations to the hierarchical structure of the built environment in which higher levels serve as the setting and context in which lower levels operate. This approach is represented often by the terminology of ‘base building’ and ‘fit-out’ or ‘support’ and ‘infill’. The recognition that certain “clusters” of building elements have variable life-cycle value led to the definition of three levels of systems: Primary level of the “base building” (structure, envelope, public circulation, and mechanical and supply systems), Secondary level “fit-out” (function, interior walls, service systems), and Tertiary level of FF&E (furniture, fixtures and equipment). The primary level is expected to last 100 years and should be designed to provide capacity for a changing mix of functions. The secondary level in expected to be useful for about 20 years, and the tertiary level for 5-10 years. Since the life expectancy of each level differs and control over the different levels is distributed over time among different stakeholders and planners, decision making structures need to respond and become sequenced rather than an “all-at-once” decision making process.
3. Case Study: The Sammy Ofer Heart Center, Sorasky Tel Aviv Medical Center

The Sammy Ofer Heart Building at Tel Aviv Sourasky Medical Center was designed by Sharon Architects and Ranni Ziss Architects and was constructed in 2008-2011. The building, located in the center of Tel Aviv, was designed as a monolithic cube clad with climatic glass and prominent red balconies. The new structure was designed to connect to a historical ‘Bauhaus’ hospital building through an atrium with iconic red bridges (figure 1). The 70m high building consists of 55,000 sq.m and includes 13 medical floors of 3,100 sq.m per floor, and four underground parking floors designed with the possibility of conversion to an emergency 650-bed hospital. The 15,000 sq.m underground sheltered floors were innovatively designed to be resistant to chemical and biological warfare.

The building, defined as a cardiac center, was initially programmed to relocate all the hospital cardiac units, clinics and surgery division onto three main floors, and to include an additional two floors for internal medicine units and outpatient clinics. Seven floors were left for future programming and completion. Accordingly, the building was constructed in four main phases: (1) the underground emergency hospital, (2) core and envelope including a mechanical roof floor, (3) interior completion of floors 0-3, (4) interior completion of floors 4-6, and (5) interior completion of floors 7-10, currently still under construction (figure 4).

Fig.1. Design illustrations of the Sammy Ofer Heart Center, 2006. Source: Ranni Ziss & Sharon Architects.

The project was programmed and designed by the architects in collaboration with the hospital CEO, deputy director, heads of cardiology units, head nurse, and various internal and external consultants and project managers. Like most hospital facilities, the project was planned under tight budgetary, regulatory and environmental constraints. The design process, which began in 2005, reflected a variety of concepts. The realization of the project depended on finding a solution for an existing two story outpatient building that had been constructed on the site in the 1960s for use as an emergency room and had become obsolete. After much discussion, it was decided to demolish the building and not limit the project's potential by preserving the existing structure. Because the hospital management was undecided regarding their strategy and program, the design team developed a method of presenting and evaluating diverse design options.

Most hospital facilities in Israel are “tailor-made” designed for a specific functional program. The Sammy Ofer Heart Building had to challenge this traditional practice as seven out of its eleven floors were constructed for future interior completion. The challenge to design a base building as a “container” that would fit unknown functional programs led to the implementation of system separation (figures 2-3). Architect Arad Sharon declared that the building was designed to be flexible and to provide optimal space for future advances in medicine (2012). It is important however to state that the theory of the open building was not evident to the design team of the project during the design process. Only in retrospect did this case study recognize the similarities between the open building theories and methods and strategy used in designing the project. The comparison reveals what was considered simply ‘good practice’, and what was considered to be too controversial or a paradigm shift to be applied.
Fig. 2. Preliminary study of schematic typical floor plans illustrates the flexibility between two medical units on the same floor, 2005. Source: Ranni Ziss & Sharon Architects.

Fig. 3. The design of the hospital medical unit was analyzed to demonstrate its flexibility strategies, including modularity units, separation of functions and services, and levels of change. The primary level (1) consists of a 7.6m x 7.6m structural grid, central core, MEP shafts, and the building glass envelope. Secondary level (2) includes the MEP units and the interior walls. Tertiary level (3) consists of the ward equipment, including medical devices, furniture, and objects.
4. Method

In order to explore the open building theory in the context of the Sammy Ofer Heart Building this research documented the evolutionary process of the building from its initial design in 2005. The survey is based on primary data collected from the hospital and the two architecture firms that designed the building including architectural drawings, programs, and reports. The design process was analysed based on expert interviews including (1) the hospital Deputy Director of Medical Technologies & Infrastructure Development that was in charge of the project management since the very beginning, (2) Heads of medical units that were part of the hospital strategy team, (3) head nurses, (4) architect Arad Sharon and architect Ranni Ziss as well as other leading architects within the two architecture firms, and (5) the project managers from CPM and M.Iuclea that coordinated the design process and construction phases. The survey information was also obtained by site visits and observations of the unit’s performance from 2014-2017. It is also important to state that the initiative for this research was the author personal experience as the design project manager of the project, working at the Ranni Ziss Architecture firm in the years 2005-2009.

The study compared the documentation of the hospitals’ original design and its existing conditions. The information gathered in the survey is demonstrated by two documents: a list of the changes during the period 2005-2017 (Table 1), and architectural drawings and schemes (figures 4-5). The buildings’ change over time is analysed by the change typology, the level of the change, the reasons for the change, and the consequences of the change on hospital operations. The changes are also analysed by their stage in the design process and in relation to the construction phase. The change in practice is later evaluated in comparison to the open building method of system separation and management levels.

5. Change in Practice

The survey of the Sammy Ofer Heart Building documented the changes in the facility over the last twelve years. The changes examined were classified into five main categories: Time, Type, Cause, Project phase, Design stage, and System level (Table 1). The Time refers to the year of design change or the estimated year of construction. The Type defines if the change was a Completion of construction, Renovation of space, Expansion of unit, Addition of function or Relocation of function. The Cause specifies the driver of change, whether it was a health Policy driver influenced by demography, economy or politics, a Medical driver forced by advances in science, diseases and treatment, a Technology driver led by advances of digital systems, equipment or IT, or a Social driver forced by change of cultural norms and demands. Project phase relates to the five phases of the buildings’ construction as detailed in chapter 3 and illustrated in figure 4. Design stage distinguish between the Schematic, Preliminary, Bidding, Construction and Occupancy stages of the design process of the building, and the System level refers to the Primary, Secondary, or Tertiary level of the physical change.

The main force behind the design and construction of the building was the generous donation of the Sammy Ofer family to the Tel Aviv Sourasky Medical Center in 2005. Since hospital development in Israel relies mostly on private funding, hospital directors attempt to maximize the potential of each donation. In the case of Tel Aviv Sourasky Medical Center, it was clear from the start that the hospital would construct the largest structure possible even by applying pressure to the municipality planning guideline limitations. This strategy led to the design of a base building with five shell floors for future completion, and was even more tangible in the ‘last minute’ decision to add two more shell floors to the building just before construction began. The change of the buildings’ height required redesigning the primary system of the building including the structure, MEP systems and facades and caused a delay of a few month in the design and construction process. The survey justifies the addition of the two floors as all the seven shell floors have already been completed and the hospital is still dealing with lack of space and resources.
<table>
<thead>
<tr>
<th>Change</th>
<th>Year</th>
<th>Type</th>
<th>Cause</th>
<th>Project Phase</th>
<th>Design Stage</th>
<th>System Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shell floors 9-10</td>
<td>2005</td>
<td>Addition</td>
<td>Policy</td>
<td>2</td>
<td>Bidding</td>
<td>Primary</td>
</tr>
<tr>
<td>Emergency hospital floor -4</td>
<td>2007</td>
<td>Addition</td>
<td>Policy</td>
<td>1</td>
<td>Construction</td>
<td>Primary</td>
</tr>
<tr>
<td>Neurology on floor 4</td>
<td>2012</td>
<td>Completion</td>
<td>Medical</td>
<td>4</td>
<td>Construction</td>
<td>Secondary</td>
</tr>
<tr>
<td>Neurosurgery &amp; Neurology ICU on floor 5</td>
<td>2013</td>
<td>Addition</td>
<td>Medical</td>
<td>4</td>
<td>Occupancy</td>
<td>Secondary</td>
</tr>
<tr>
<td>Dermatology inpatient &amp; outpatient clinics on floor 6</td>
<td>2015</td>
<td>Addition</td>
<td>Medical</td>
<td>4</td>
<td>Occupancy</td>
<td>Secondary</td>
</tr>
<tr>
<td>Oncology inpatient &amp; outpatient units on floor 7</td>
<td>2017</td>
<td>Relocation</td>
<td>Policy Medical</td>
<td>5</td>
<td>Occupancy</td>
<td>Secondary</td>
</tr>
<tr>
<td>Oncology clinics on floor 8</td>
<td>2017</td>
<td>Relocation</td>
<td>Policy Medical</td>
<td>5</td>
<td>Occupancy</td>
<td>Secondary</td>
</tr>
<tr>
<td>Inpatient internal medicine units on floor 9</td>
<td>2017</td>
<td>Addition</td>
<td>Policy Medical</td>
<td>5</td>
<td>Occupancy</td>
<td>Secondary</td>
</tr>
<tr>
<td>Research labs on floor 10</td>
<td>2017</td>
<td>Completion</td>
<td>Policy</td>
<td>5</td>
<td>Occupancy</td>
<td>Secondary</td>
</tr>
<tr>
<td>MRI &amp; CT not in building</td>
<td>2013</td>
<td>Relocation</td>
<td>Policy Medical</td>
<td>4</td>
<td>Occupancy</td>
<td>Primary</td>
</tr>
<tr>
<td>Day rooms in inpatient units</td>
<td>2007</td>
<td>Relocation</td>
<td>Policy Social</td>
<td>3</td>
<td>Preliminary</td>
<td>Secondary</td>
</tr>
<tr>
<td>Doctors’ offices &amp; staff wardrobes location</td>
<td>2006</td>
<td>Relocation</td>
<td>Policy Social</td>
<td>3</td>
<td>Preliminary</td>
<td>Secondary</td>
</tr>
<tr>
<td>Number of ICU rooms</td>
<td>2012</td>
<td>Addition</td>
<td>Medical</td>
<td>3</td>
<td>Occupancy</td>
<td>Tertiary</td>
</tr>
<tr>
<td>Number of single patient rooms vs. two patient rooms</td>
<td>2013</td>
<td>Addition</td>
<td>Medical Social</td>
<td>4</td>
<td>Occupancy</td>
<td>Secondary</td>
</tr>
<tr>
<td>Patient beds in the corridors and day room</td>
<td>2012</td>
<td>Addition</td>
<td>Policy Medical</td>
<td>3</td>
<td>Occupancy</td>
<td>Tertiary</td>
</tr>
<tr>
<td>Conference rooms</td>
<td>2015</td>
<td>Addition</td>
<td>Policy</td>
<td>4</td>
<td>Occupancy</td>
<td>Secondary</td>
</tr>
<tr>
<td>Curtains in the intermediate patient units</td>
<td>2012</td>
<td>Addition</td>
<td>Policy Medical</td>
<td>3</td>
<td>Occupancy</td>
<td>Tertiary</td>
</tr>
<tr>
<td>Bathroom in all ICU rooms</td>
<td>2008</td>
<td>Addition</td>
<td>Policy</td>
<td>3</td>
<td>Bidding</td>
<td>Secondary</td>
</tr>
<tr>
<td>Monitoring system</td>
<td>2014</td>
<td>Addition</td>
<td>Technology</td>
<td>4</td>
<td>Occupancy</td>
<td>Tertiary</td>
</tr>
<tr>
<td>Mobile IT equipment</td>
<td>2014</td>
<td>Addition</td>
<td>Technology</td>
<td>4</td>
<td>Occupancy</td>
<td>Tertiary</td>
</tr>
<tr>
<td>Electrical medical equipment in corridors</td>
<td>2012</td>
<td>Relocation</td>
<td>Policy</td>
<td>4</td>
<td>Occupancy</td>
<td>Tertiary</td>
</tr>
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</table>

The Sammy Ofer Heart Building, that was defined and designed as a cardiology center, has changed his functional program considerably. The cardiology division occupies less than 30% of the building. The current building contains neurology, dermatology, internal medicine and oncology units in addition to research labs and outpatient clinics (figure 4-5). The change of program can be explained by changing needs since cancer became the number one cause of death and statistically surpassed cardiac diseases. The logic of centralizing the oncology units in one location to enhance the hospital efficiency and health services, could have only been accomplished in the new building. The hospital management also decided to relocate other functions to the building since their previous settings needed renovation or extension, or because they received funds to reconstruct a specific medical unit. The hospital dynamic development plan is driven by forces of economics as well as internal and external organization politics.
Most of the changes took place after the building was occupied. Although this process of future completion was designed in advance, it still created a challenge both for the construction and the operation of the running units. The phasing stages, divided by the buildings’ floors, created a process of completion from bottom upwards. This strategy might be efficient in order to avoid interruptions of the construction to the operating units, but it limits the flexibility of the design process. In many cases the considerations in the construction phases overruled the importance of locating some medical close to other units for processes optimization. For example, the inpatient internal medicine units under construction on the 9th floor should have been located on the 4th floor above the existing internal medical units on the 3rd floor to centralize the internal medicine division and to enhance flexibility of staff and equipment among the four units. In addition, the hematology units were omitted from the cancer center in the new building. The oncology inpatient and outpatient units were moved to the 7th and 8th floors in order to centralize cancer treatment and care. Unfortunately, this left no space for moving the hematology division because the 6th floor was already occupied by dermatology inpatient and outpatients clinics.

Fig. 4. Section of the building illustrates the five stages of completion and the current dynamic program. Source: Ranni Ziss & Sharon Architects.
The main limitation to the flexibility of the building was in the Cardiac Intensive Care Unit on the first floor. Following the requirements of the Israel Defense Force, the ICU was designed as a fortified space constructed with concrete envelope, special MEP systems and protected doors and windows. The specification of this one unit in the middle of the building restricts the potential of the unit to expand or connect to other units, and limits the possibility of changing its function or location. Experts predict that the future hospital will be transformed into an Acute-Care center, and all other functions will move to the community. This prediction stresses the need to design for ICU units' expansion and flexibility to change typical patient rooms into ICU patient rooms. In this sense, the need to shelter ICU patients in a “closed” protective environment contradicts the notion of the open building theory. Another limitation on the flexibility of the building is the depth of the structure that was defined by its square proportion. The internal spaces on the floors lack natural light and ventilation since most of the facades facilitate closed patient rooms, offices or clinics. The prominent red balconies on the west and north facades constrained the layout of rooms and open spaces in units that were designed in phases 4-5.
6. Discussion

The open building system separation supported the development of the building by phases. It enhanced changes in one system level with minimum impact on other levels. For example, a change of medical unit or change of technological systems could easily be implemented as the structure and MEP shafts were designed separately from the internal walls and envelope. In fact, most of the changes made were the completion of the secondary and tertiary levels, while the primary level was changed only before the construction of phase 1 and bidding of phase 2. The module of patient rooms, defined by the primary level, supported change in clinics, offices, and labs in the secondary and tertiary levels. Internal changes in all of the medical units, such as relocation of day rooms, doctors’ offices and staffs’ wardrobes, were possible and carried out efficiently because these changes did not require changes in the primary system.

The separation of the building into system levels was also useful as a management tool in the design process. The long design process of twelve years, which is still running, has encountered many different professionals and decision makers. Many of the project team members of the hospitals were replaced including the CEO of the hospital, heads of medical units and head nurses. Each change of personal resulted in reconsideration of the design and requests for alternative design options. The design team included a collaboration of two architecture firms, replacement of two project management firms, and different consultants along the way. The development of the project by phases, using the system levels method, allowed the architects to divide the workload between the two offices. Each office was responsible for the design of specific floors with minimal need for consultation and coordination.

The development of the project by autonomous levels differs from the design method of conventional hospital facilities, in which the building as a whole develops with all of its inter-dependencies, even if construction is realized in phases. This innovative approach presents challenges to the design, primarily at the level of decision making and coordination between the separate firms responsible for each level. Kendall, S. (2005). The shift to a serial rather than parallel decision making sequence following the realization of the separate levels is not a trivial task. Decisions made in early stages of the design are often necessary even though they might restrict future change, as each system level affects the flexibility of the other system levels. In addition, the design team is trained and expected to enhance a holistic approach to their design, developing the project from its conceptual scheme to detailed drawings. Leaving their design for future completion is often perceived as unprofessional. Furthermore, hospital managers, as all managers, tend to pursue control over their project, wanting to make a significant contribution under their name.

7. Conclusion

This case study demonstrates how the client’s demand for sustainability, a long-term value for their facility, assures optimized adaptability in the face of policy, medical, technology, and social transformation, impact the design and the decision making process. The open building theory of system separation and design management in different levels has proven to be efficient and productive. Although the theory wasn’t stated in the design process, its methods supported the construction of the project in phases, enabled the design of different functional programs, and enhanced the management of the design process by different consultants, designers and contractors. The controversial decision of the hospital management to maximize the building potential and build a base building for future infill at a high cost, provided the Tel Aviv Sourasky Medical Center with the possibility of promoting a dynamic, strategic plan for the entire campus.
While emphasizing the importance of the building’s flexibility for physical change (Form), we must recognize that it is only one part of the facility change over time. Many changes are made in the operation of the hospital units (Function) including adjustments of procedures or schedules, without any change to the physical setting. Other changes are made by the adaptability of the users to maximize their experience of the given environment. It is also important to acknowledge the evolutionary nature of change: one change may cause a reactionary chain of changes in the Form, Function or Use of the building. For example, the Sammy Ofer Heart Center, with its separated system levels, can easily support changes of patient room types: from double patient room to triple or single patient rooms, but the physical change is only one aspect to consider. We need to evaluate how such a change would affect the overall operation and performance of the unit. In many cases the greatest limitation for flexibility is not the physical space, but the lack of professional staff or the resistance of the organization culture.

This study documented changes over the last twelve years during the design process, construction and occupancy phases. While this time frame is significant, farther work is needed to evaluate healthcare facilities over longer periods of time. In retrospect, a study of the open building theory should be conducted after a full life-cycle of the hospital facility in order to evaluate the true value of its methods. An economic study of the Sammy Ofer Heart Building should also be conducted to determine whether or not the strategy of investing in an empty base building for future fit-out is feasible and profitable. More studies of healthcare facilities change over time from different environmental, cultural and economic context, will enhance future design of sustainable healthcare architecture.

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