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Evaluation of Operating Room Units within the Context of Green Design Criteria

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Abstract

The economic problems multiplying due to the deterioration of environmental conditions and the exhaustion of fossil based energy sources in today's world brings into question endeavors' towards designing environmentally compatible hospital buildings that causes less carbon emissions to the nature and that reduces the construction and management costs of the buildings and that considers energy efficiency for the hospital buildings as well covering different functions and requirements. However, in the operating room units where the hospital comfort requirements have been utilized to the utmost level, endeavors' for providing green criteria and energy efficiency have remained limited. The objective of this study is to determine other studies to be undertaken in compliance with green building criteria in the operating room units having complicated design characteristics in relation to the other hospital units. The green design criteria for operating rooms in line with national and international studies were researched within the context of this study and the raise in efficiency was explained using examples.

1. INTRODUCTION

It is required to keep the air quality of the indoor spaces inside the hospitals at a high level for the patients and the staff and to dispose-off the waste material appropriately. Research shows that units that consume the highest amount of energy and produce the greatest amount of hazardous waste inside a hospital both during its construction and during its management are the operating rooms. This fact leads us to consider the importance of green operating room design within the context of green hospitals. The objective of this study is to establish green operating rooms within the context of criteria such as the correct construction of operating room units starting from the architectural design in terms of their functions; the selection of installation systems that are fit for the purpose and thus decreasing the consumption of energy; providing energy efficiency; waste management; using water efficiently; availing air quality, and using green materials in consideration of the requirements that have been determined through regulations, standards, guidelines and on-site visits for the green design of operating units. As a result of the evaluation of green building criteria within the context of the study; the data that have been obtained in respect of the architectural design of operating room units, HVAC systems design and the air quality of the indoor spaces, water management, energy consumption and lighting, and waste management had been challenged on-site at the operating rooms of the hospitals that have been evaluated, then the data obtained had been compared and suggestions have been made.

2. OPERATING ROOM UNITS

Operating rooms are the areas where the patients who cannot be treated using medication are treated through surgical interventions. The operating rooms should be separated for aseptic and septic (aseptic: germ and infection free; septic: made up of germs and toxins [2]) interventions and should meet the sterilization conditions [1, 7, 19]. The performance of surgical interventions in these spaces obliges the comfort conditions of the indoor spaces to be maintained fixed to certain conditions mentioned within the standards. In this respect, the required standards in terms of ventilation, humidity and sterilisation

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should be conformed to [1, 3, 5, 7]. The comfort conditions and design parameters of operating rooms have been shown in Table 1.

Table 1. *The Comfort Conditions and Design Parameters of Operating Room Units [6, 7, 10, 19]*

Temperature	Humidity	Air Flow Type	Air Flow	Filter Type
21 ˚C ± 3 ˚C	30 % - 65 %	Low Turbulence-laminar flow from the ceiling	Mean value of airflow 0.24 m/s	Minimum 3 Phased Filters (F7-F9-H13)

2.1. Overview of Design Requirements for Operating Room Units

The service areas and inpatient bed availability of the operating room unit should be arranged in accordance with the expected surgical intervention load of the hospital [6, 8, 10, 18, 19, 25, 26]. In the architectural layout of the hospital, the operating rooms should be placed away from the intense circulation of people, with due diligence to be paid for being protected from the possible outside noise and negative effects of possible wall fractures that have an opening to the outside, appropriate for the sterile air flow direction for the transfer of patients and sterile materials and also for the removal of soiled materials, and providing opportunities for the establishment of the required mechanical systems that would provide meeting the heat loss and heat gain loads most efficiently. [6 - 8, 10]. The operating room units consist of soiled, semi sterile and sterile spaces (Figure 2.1) [1, 6 - 10]. In these spaces the direction of the traffic should always be from the semi sterile space to the sterile space and from the sterile space to the semi sterile space and from there into the soiled space (Figure 1).

[7, 9, 10].

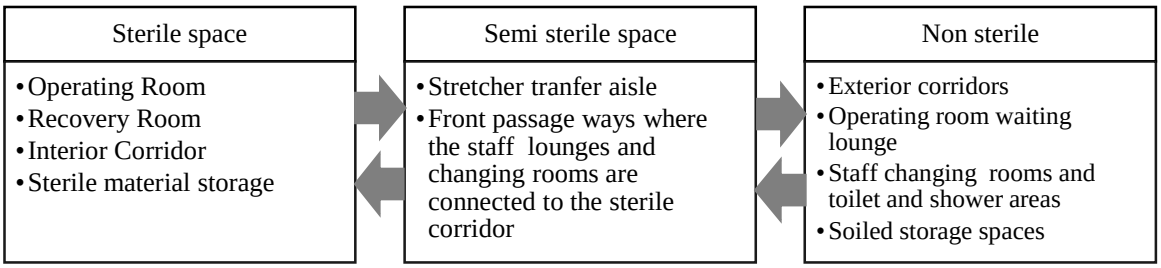


Figure 1. *Operating room spatial passage construction [1, 7, 9, 10]*

3. GREEN OPERATING ROOM UNITS

Operating room units form approximately 33 % of the total cost of the health institution in order to be able to provide all of the indoor conditions that have been claimed [3]. This fact underlines the importance of green design and energy efficiency in operating room units. As a result of the studies and research undertaken for the purposes of green operating room design, the actions to be taken in respect of the architectural design of operating room units in compliance with green criteria, HVAC systems design and the air quality of the indoor spaces, energy management, water management, lighting, material management and waste management have been provided below:

<u>Architectural Design;</u>

While selecting a space for the operating rooms, the core of the building or the middle floors should be preferred in order to keep the heat loss and gains at a minimum, and lifts should never be foreseen within the sterile space where the operating rooms are located [7, 11].

The waiting lounges and staff utility lounges and the corridors should be arranged as spaces that receive day light through a connection with the outside [7, 13, 14, 27].

The functional connections of the spaces should be provided with a rational planning considering the sterility conditions [7, 8, 10].

Extendable spaces with the required width in accordance with the regulations should be designed for the operating halls and the supporting facilities (Figure 3.1.) [1, 6, 7, 13].

The floor height in accordance with the regulations and foreseen by the selected system should be provided [8 - 11].

The construction materials used in the unit should be hygienic, antibacterial and without joint-fillers and should be as modular as possible and recyclable [6 - 10, 15, 25]. Figure 2

Starting from the entry into the unit, doors and passages should be selected in terms of the appropriate system for the location and the sizes [7, 11].

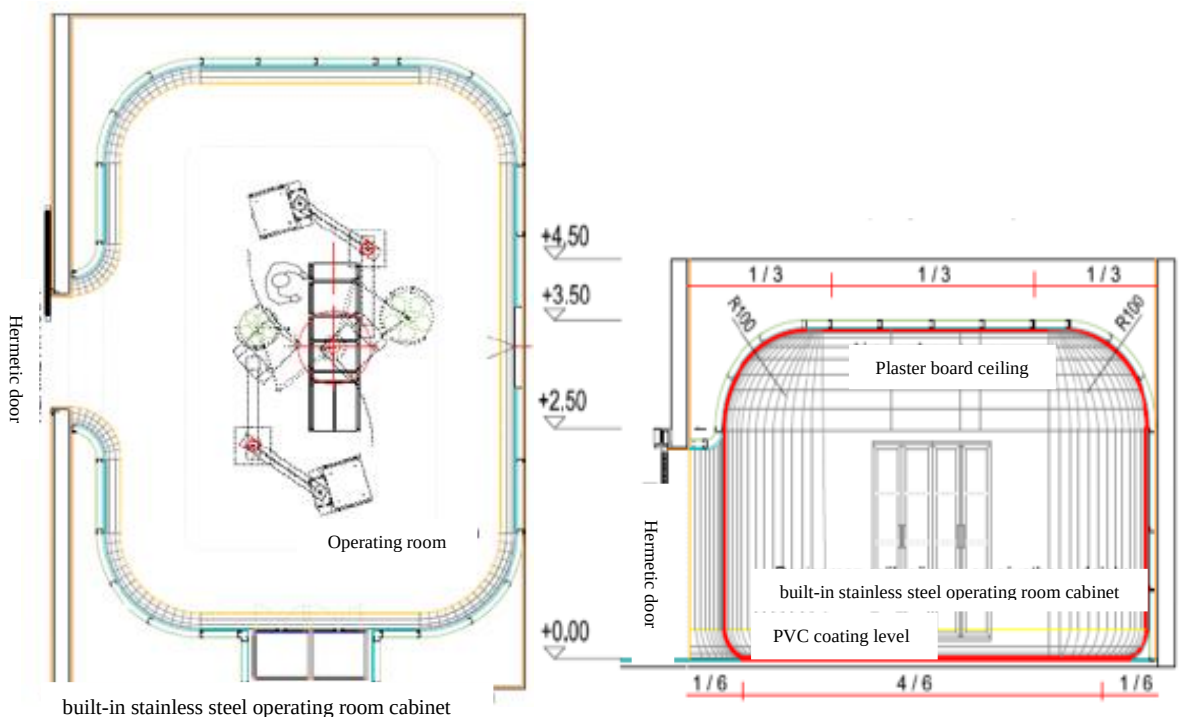


Figure 2. *Plan and Cross Section of Operating Room [18]*

HVAC Design and Indoor Air;

A technical space containing air conditioning devices, cooling devices and other groups of devices required for the processes of the sterile space should be planned to be located in close proximity to the operating room unit [10, 16].

It is important whether the operating room has got an outdoors façade and if so, considering the cool air requirement of the operating room, it should be located facing the northern direction so that it will be possible to use devices with smaller capacities and thus generating less management costs is significant from the point of view of HVAC design [10, 13, 17, 19].

During the hours when the operating rooms are out of use, the system air should be lowered without jeopardising the existing sterilisation [13, 17 - 20].

Feeding every operating room using an individual air conditioning switchboard should be preferred in order to provide the desired ideal conditions. However, on economic grounds, a single air conditioning switchboard could be used for two operating rooms of similar characteristics [7, 10].

Using a separate air discharging system or a special vacuum the anaesthetic gasses should be removed from the environment [15, 19].

Conduits in conformity with HVAC systems should be established, suitable materials for the conduits should be selected, non-leakage and insulation should be provided, and the efficiency of the materials should be provided as well [7, 8, 10, 15].

The outdoor air could be pre-cooled or pre-heated with the exhaust air that has been discharged through the air conditioning system or with an energy recovery unit to be added to the system during summer or winter air conditioning. [15, 17, 19, 21].

The maintenance of the system should be undertaken regularly. The filters should be replaced regularly [10, 11, 16].

The thermal capacities of the devices that have been used within the unit should be considered [6, 7].

Water Management;

The location of the unit and its required wet spaces should be determined.

A water valve and an installation must be specific for the unit.. The installation materials should be non-leaking and resistant [7, 23].

The sinks inside the unit should be placed as not to effect the circulation within the corridor and should be designed so that touching them does not become necessary [7, 23].

The waste water should not be fed directly into the sewage; first its intensity levels should be decreased.

Precautions should be provided to avoid soiling in the water and installation components that have been used within the cooling systems [7, 20, 22].

Lighting and Energy Performance;

Spaces for making use of the day light should be designed throughout the unit [13, 14].

The lighting components should conform to the updated standards [24, 28].

The energy efficiency of the devices should be considered and the devices should be selected accordingly. Unnecessary devices should not be used other than their capacities [24].

Significant amounts of energy saving could be achieved as a result of establishing automatic control systems that avoid the systems working with their maximum capacities [7, 15, 28]. Figure 3.

Figure 3*. Lighting for OR Units [Personal photo archive of Arzu Yazıcı]*

Waste Management;

An independent waste management plan should be prepared for the operating room units [23, 29].

Only the required amount of materials should be purchased and the use of unnecessary materials should be avoided [7, 23].

The wastes should be sorted into different packages depending on their compositions [7, 23, 29].

Recyclable materials should be used [23].

The wastes should be collected and disposed-off in an appropriate manner [29]. Figure 4.

Figure 4. *Operating room waste bins [Personal photo archive of Arzu Yazıcı]*

All across Turkey, with the rise in the importance of green hospital certification systems especially in metropolises it is known that works are on-going for the integration of green building - energy efficient systems into the building constructions both in private health institutions and also in public and private sector partnerships with the efforts of the Ministry of Health. However, it has been found out that these are not considered to be extensive undertakings or being cancelled due to financial reasons.

4. THE EVALUATION OF GREEN BUILDING CRITERIA IN OPERATING ROOM UNITS

In the researches undertaken, the efficiency of the mechanical systems in general within the context of energy efficiency towards operating rooms is mentioned. However, starting from the location within the hospital building all of the installations and the control and management of the waste should be planned while the operating unit is being built. Since there are regulations and directives for private hospitals in Turkey, the research that had been undertaken throughout the study had been evaluated specific to the private hospitals. Thus access to tangible data had been provided.

4.1. Case Study

It has been ascertained that the capacities of the hospital buildings are determined on the basis of their inpatient bed capacities in accordance with the Private Hospitals Regulation. According to the data received from the Ministry of Health, Department of Private Health Facilities (Core Funding Management System data with the date 01. 10. 2014) the arithmetic mean value of the total number of inpatient beds in the private hospitals in Ankara is approximately 85. 11 hospitals have been ascertained to be above the arithmetic mean value of the inpatient bed capacity and the operating room units of these 11 hospitals that are in close proximity with each other in the newly developed districts of the city namely Private Memorial Hospital, Private Acıbadem Hospital, Private Bayındır Hospital, Private Medicana International Hospital, and Private TOBB ETÜ (Turkish Union of Chambers and Commodity Exchanges Economy and Technology University) Hospital had been researched on-site and used as the data for this study. At the end of the on-site research, the data that had been obtained had been compared and suggestions have been made.

A Green operating room evaluation form of a total of 45 questions 20 of which are open ended questions and 25 of which are yes or no answer questions in respect of architectural design, HVAC systems design and indoor air quality, energy management and waste management from amongst the criteria of green hospitals within the context of the evaluation. This evaluation form had been put together by making use of the regulations and green hospital certification systems published by the Ministry of Health, international publications on the subject of energy efficiency and various accreditation systems. On-site evaluations had been performed using this established form and the determinations had been made. The hospitals had been named as A, B, C, D and E and evaluated under the components of green design criteria which are of architectural design, ventilation and air conditioning system and the indoor air quality, water management, lighting and energy management, and waste management. Certain designations had been made after the assessment of different requirements (Table 2.) and improvement suggestions have been made in respect of the operating room units.

Table 2. *The Introduction of the Operating Room Units of the Evaluated Hospitals*

Hospital A

The building had been constructed as an office at the beginning and then been provided with a license as a hospital after providing the required physical conditions. The hospital has got a capacity of 150 inpatient beds and its operating theatre had been placed on the second floor of the building with 7 units. The passages from one space to another had been performed in accordance with the requirements of the soiled, semi sterile and sterile spaces within the architectural planning. The ceiling and the walls had been painted with antibacterial wall paint over reinforced concrete. As floor covering, easily cleanable vinyl material had been used.

Hospital B

The building had been constructed as an office at the beginning and then been provided with a license as a hospital after providing the required physical conditions. The hospital has got 103 inpatient beds and its operating theatre is placed on the second floor of the building with 4 units. The passages from one space to another had been performed in accordance with the requirements of the soiled, semi sterile and sterile spaces within the architectural planning. The ceiling and the walls had been painted with antibacterial wall paint over reinforced concrete. As floor covering, easily cleanable vinyl material had been used.

Hospital C

The building had been started construction as an office however completed as a hospital and had been provided with a license. The hospital has got 164 inpatient beds and its operating theatre is placed on the first floor of the building with 6 units. The passages from one space to another had been performed in accordance with the requirements of the soiled, semi sterile and sterile spaces within the architectural planning. The ceiling and the walls had been painted with antibacterial wall paint over a special steel structure. As floor covering, easily cleanable vinyl material had been used.

Hospital D

It has been built as a hospital. The hospital has got 105 inpatient beds and its operating theatre is placed on the ground floor of the building with 5 units. In respect of the soiled, semi sterile and sterile conditions, it has been detected that semi sterile passage ways had not been provided in front of the changing rooms and lounges for the staff and that the staff go straight into the sterile space. The ceiling and the walls had been painted with antibacterial wall paint over reinforced concrete. As floor covering, easily cleanable vinyl material had been used and it has been ascertained that in one unit the old style rubber gum covering material had been used.

Hospital E

The building had been constructed as an office at the beginning and then been provided with a license as a hospital after providing the required physical conditions. The hospital has got 208 inpatient beds and its operating theatre had been placed on the third basement of the building with 7 units. The passages from one space to another had been performed in accordance with the requirements of the soiled, semi sterile and sterile spaces within the architectural planning. The ceiling and the walls had been painted with antibacterial wall paint over reinforced concrete. As floor covering, easily cleanable vinyl material had been used.

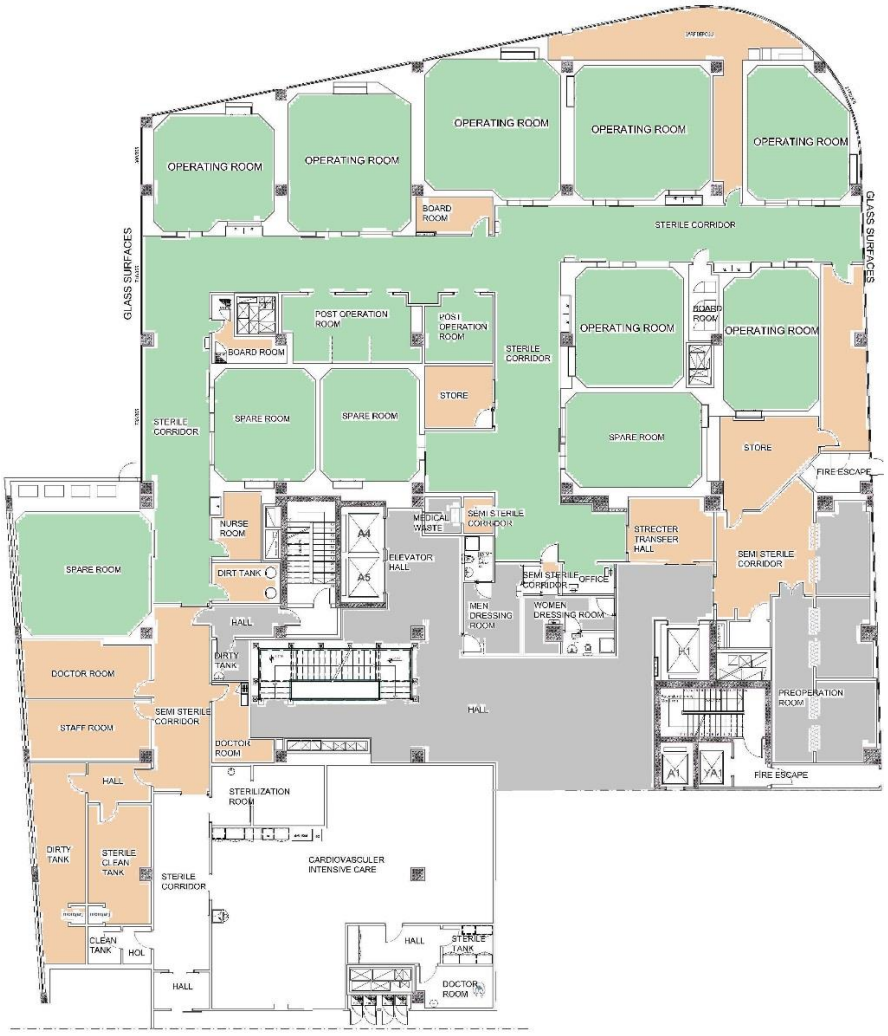


Figure 5. *Hospital A – Operating Unit Floor Plan*

Sterile space Semi-sterile space Non Sterile space

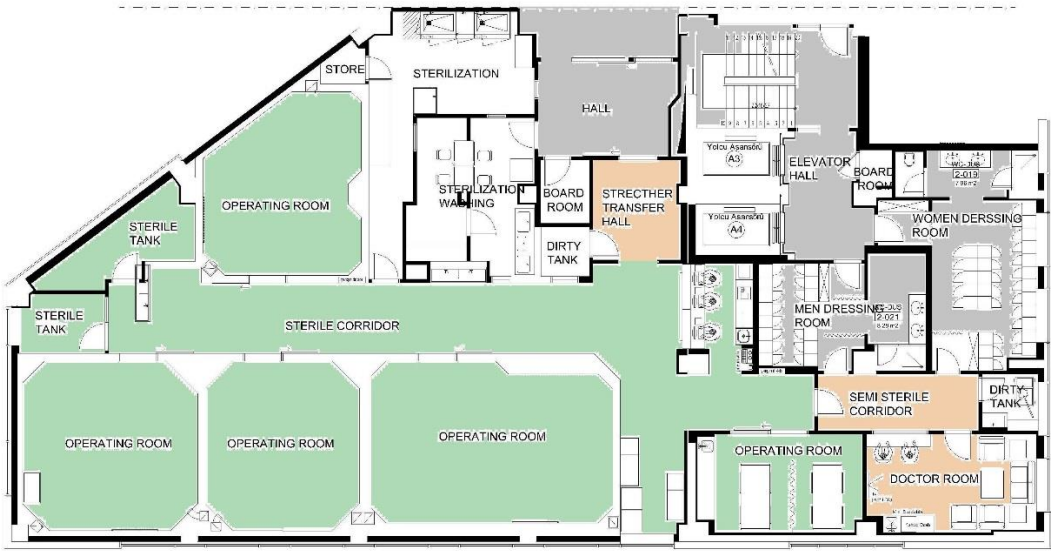


Figure 6. *Hospital B – Operating Unit Floor Plan*

Sterile space Semi-sterile space Non Sterile space

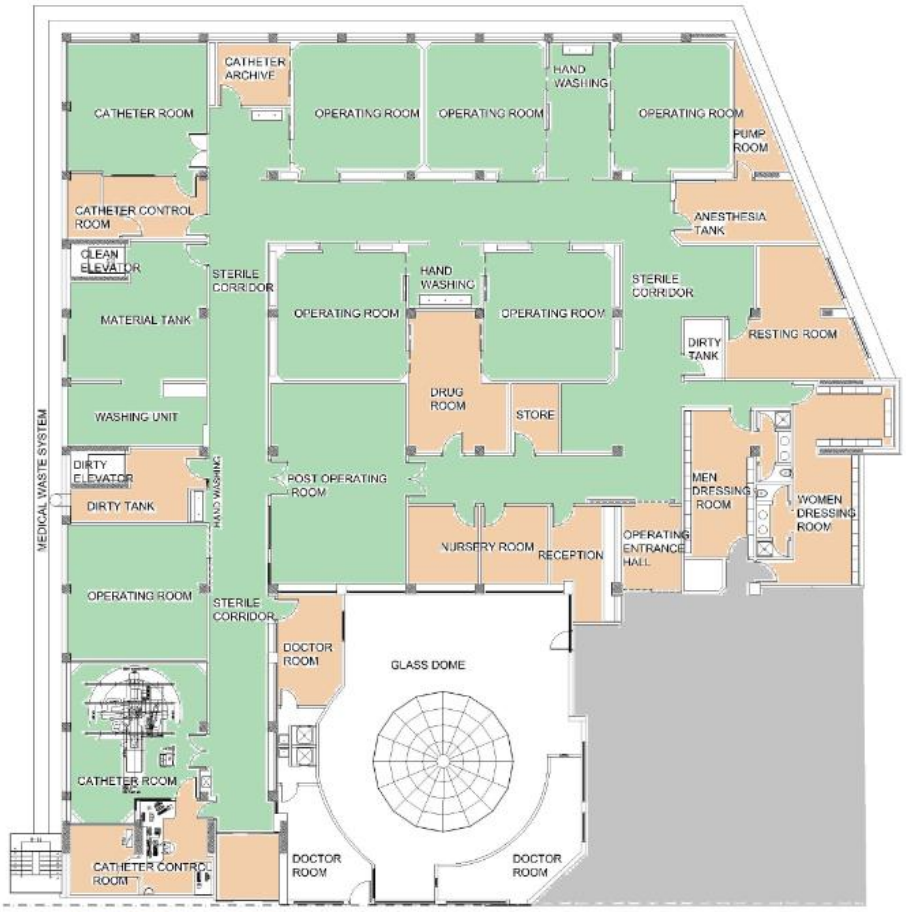


Figure 7. *Hospital C – Operating Unit Floor Plan*

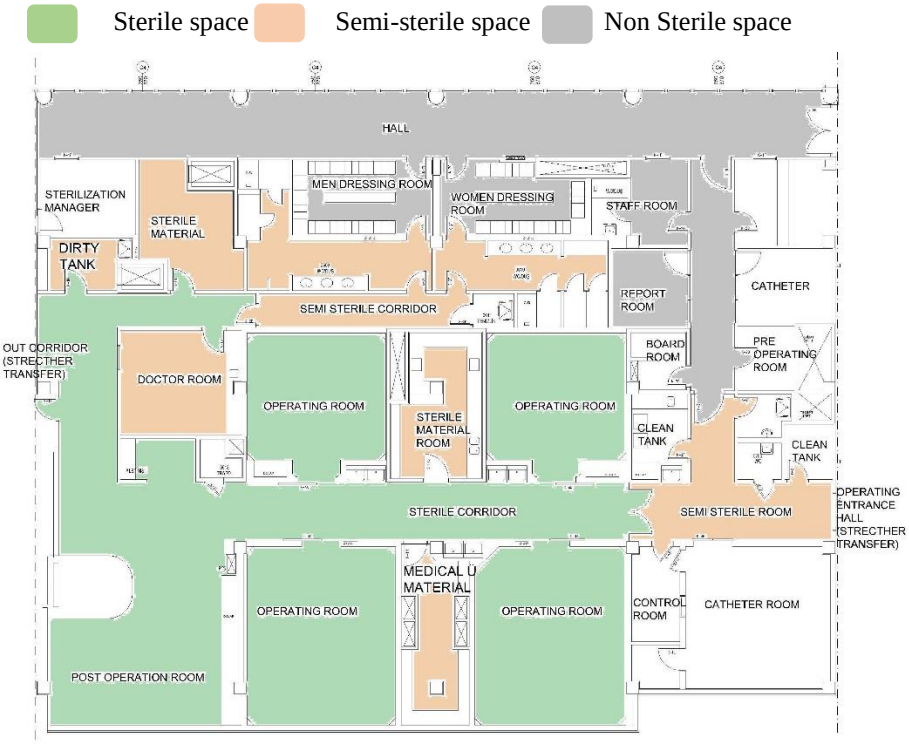
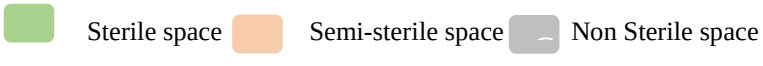


Figure 8. *Hospital D– Operating Unit Floor Plan*



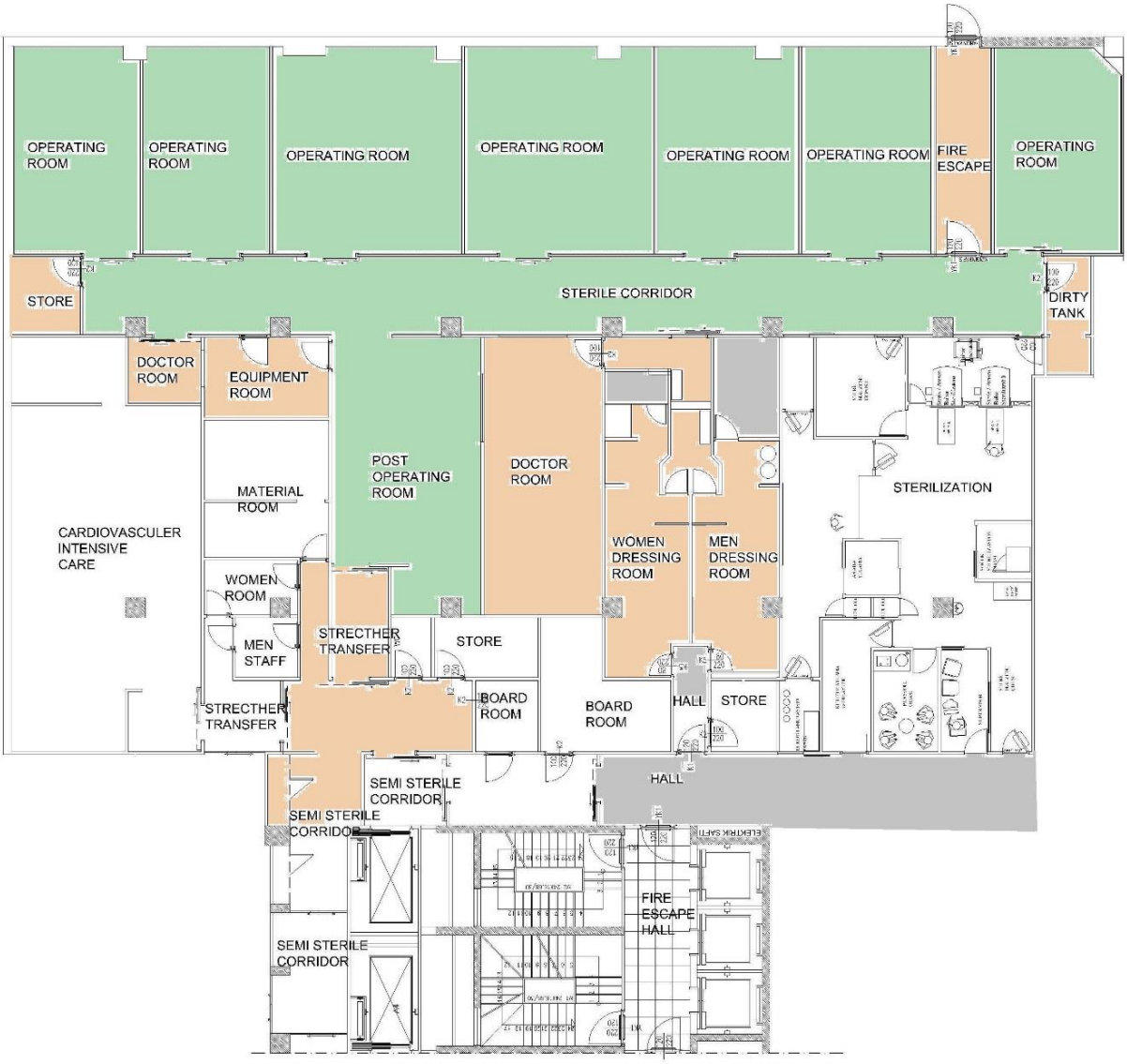


Figure 9. *Hospital E– Operating Unit Floor Plan*

Sterile space Semi-sterile space Non Sterile space

When we have a look at the partial floor plans for the operating rooms of private hospitals given in Figure 5, Figure 6, Figure 7, Figure 8, and Figure 9. It is observed that the operating rooms units are arranged either around I or L shaped corridors or on the façades facing outdoors. The data that have been obtained through the green operating room evaluation form during the on-site study had been examined under the titles of architectural design, HVAC design and indoor air quality, water management, lighting and energy management and waste management and then the positive and negative aspects of the operating room units had been ascertained and suggestions regarding the operating rooms has been presented. The comparison of the operating room units in accordance with green building criteria have been provided within Table 3.

Table 3. *The Comparison of the Operating Room Units in accordance with Green Building Criteria*

The design criteria	Examined Characteristics / Hospital	A	B	C	D	E
Architectural Design	Is the building fit for its purpose?	-	-	+	+	-
	Are the surface areas of the units in conformity with the regulations?	+	+	+	+	+
	Are the floor heights in conformity with the regulations?	+	+	+	+	+
	Are there protrusions such as pillars, etc.. inside the units?	-	-	-	-	-
	Are openings such as doors, etc... are appropriate?	+	+	+	+	+
	Is the sterile passage ways in conformity with the standards / regulations?	+	+	+	-	+
	Is there an independent fire escape in the operating rooms?	+	+	-	-	-
HVAC Design and Indoor Air Quality	Is the technical area in close proximity of the unit?	+	+	+	+	-
	Is there a shared switchboard use?	+	+	+	+	+
	What is the HVAC operation principle?	*	*	*	*	*
	Is there a laminar flow unit?	+	+	+	+	+
	Does the number of filters meet the standards?	+	+	+	+	+
	Is calibration (measurement) performed regularly?	+	+	+	+	+
Water management	Had due diligence been paid to the design of the wet spaces?	-	-	-	-	-
	Is there a humidity issue in the operating room?	-	-	-	-	+
	Are there any on-going improvement works in water use?	+	+	-	-	-
	Is there a separate water valve for the operating room unit?	-	-	-	-	-
Lighting and Energy management	Are there any spaces capable of receiving any day light?	+	+	+	-	-
	Are there any on-going improvement works for the energy efficiency of the lighting components?	+	-	+	-	-
	Is there heat insulation in the operating room?	+	+	+	+	+
	Is there sound insulation in the operating room?	+	+	+	+	+
Waste Management	Is there a waste management plan?	-	-	-	-	-
	Are the wastes collected separately depending on their compositions?	+	+	+	+	+
	Is there any use of recyclable materials?	-	-	-	-	-
	Is there a separate system for liquid waste?	+	-	-	-	-

*: A system working with a half flow under recovery conditions and with 100 % fresh air.

- Since the staff changing rooms and lounges that are considered as soiled space in Hospital E which is example number 4 open straight into the sterile corridor, it has not been found to be appropriate in terms of planning.

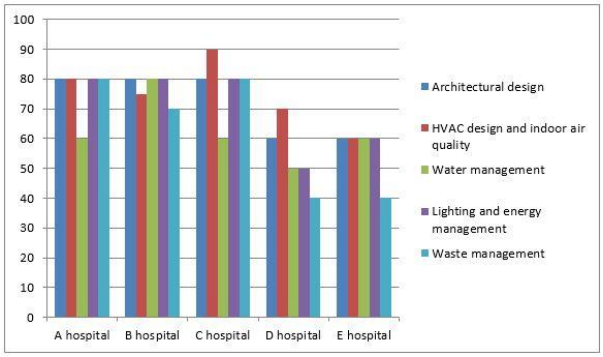


Figure 10. *The Comparison of the Hospitals in terms of their Compliance of Green Operating Room Criteria*

The following have been ascertained for the hospitals that have been evaluated:

Architectural criteria such as the surface areas (sqm), floor heights, and sterile space planning full compliance had been achieved since there are compulsions of implementation in the regulations as well,

A more diligent system selection had been made in ventilation systems as opposed to water and energy systems and the operating room indoor conditions are in compliance with the standards, however, energy efficiency had not been considered in the selection of systems,

There aren't any on-going works for the purposes of reducing the energy use of the medical devices in any of the hospitals,

The wastes are collected separately; however, no attention had been paid for using recyclable materials or materials with lower chemical properties.

The Comparison of the Hospitals in terms of their Compliance of Green Operating Room Criteria are shown in Figure 10. In this study where we had started from the concept of green hospital and researched the green operating room concept in accordance with the data that have been obtained and the research that have been undertaken the aspect that would have been benefited in energy efficiency in operating room units have been presented below:

The hospital building should be constructed in accordance with its functions. The operating room unit should be on the ground floor or the middle floor in consideration of heat requirements and heat loss. The non-sterile, semi sterile and sterile spaces should be defined, and the sterilization conditions should be established through appropriate rules and ventilation systems. The materials used indoors should be antibacterial, antistatic and modular type as far as possible.

A technical area should be established in the close proximity of every operating room unit. The arrangements should be made so that fresh air should be let in straight through the ceiling. The system should be designed so as to avail for the maximum conduit sizes and minimum conduit lengths.

In accordance with the functions of the operating rooms, one air conditioning device should be used to serve a single room or to serve two rooms. However, in case the required sterilisation is not provided or in case one device is connected to two rooms and the device is out of order it should be remembered that the activities of two rooms are going to be suspended.

Sinks for washing hands should be installed in a sufficient number and with suitable accessibility. The sinks and the disinfectants should be operated using elbows or knees to avoid the use of hands. The sinks should be placed so as not to effect the circulation in the corridor. In the water installation system, water control valves built independently for the operating room should be planned.

The design of areas that could receive day light should be foreseen within the operating units (staff lounges, corridors, etc.). In the selection of lighting components the lamps should be appropriate for the purposes and in compliance with the standards. In addition, the operating rooms should be painted or covered using materials with light colors.

It is known that in Turkey hospital waste is disposed-off by the city councils and the relevant authorities. Since the hospitals that have been evaluated are physically close to each other, the idea of establishing a common waste disposal facility through cooperation seems possible. In hospitals having a certain consumption capacity, in case the standards are complied with and in case the required permissions are granted, it is going to be more effective for the hospitals to establish their own facilities in terms of cost, time and efficiency. The separate storage of all the waste after being sorted, reducing the use of disposable products and replacing the products and drugs that are being used with products having higher efficiency could contribute to energy efficiency for the operating room units.

Along with the issues that have been mentioned, planning a multi-disciplinary and wholesome approach during the design, construction and management phases of the building bears great significance in terms of performance. During this process, the aspect that is as important as the selection of the systems is undertaking the energy performance analysis and the correct coordination of the management and the choice of system. In accordance with the data that had been researched on and obtained throughout the study the green design criteria for operating room units have been provided within Figure 11.

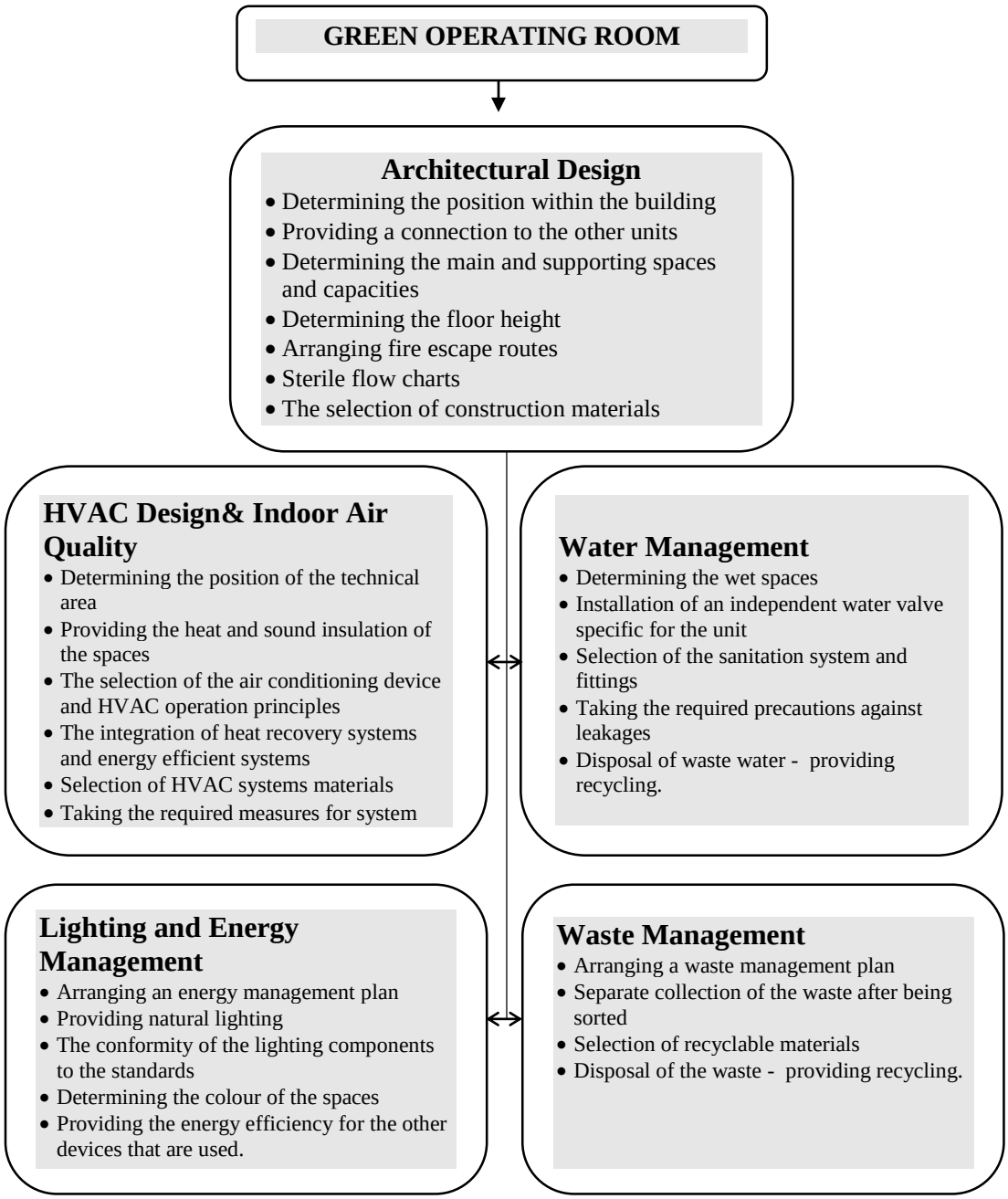


Figure 11. *Design of Operating Rooms in accordance with Green Criteria*

5. CONCLUSION

Due to the reason that surgical interventions are performed in them, operating room units are the most sensitive areas and since the risk of infections is high in such areas, and because providing the required sterile conditions increases the cost due to energy consumption, the concept becomes even more important for the owners of hospitals.

In this study undertaken on the operating room units, the physical conditions of the operating rooms foreseen within the Regulation on Private Hospitals which is a directive that is compulsory to be complied with had been taken as the standard showing the physical standards for private hospitals and green building criteria for the operating rooms had been evaluated and then the precautions for energy efficiency for the units and the practices to be adopted have been presented. Starting from the operating room units of five different private hospitals that have been evaluated within the study with different capacities and requirements, and on-site examinations had been undertaken for hospitals with different patient potentials and requirements the targets have been the correct positioning of the operating room units within the hospital building, its functional planning and selecting the energy efficient construction materials which is in accordance with such planning, and finally the establishment of green operating room units that are energy efficient.

Starting from the operating room units along with the study undertaken and the conclusions that we have arrived at, the requirements for the specialized units and the support units should be evaluated one by one and then in a holistic manner in the studies to follow such as the emergency room unit, intensive care unit(s), laboratory unit(s), inpatient areas, clinics, nuclear medicine, chemotherapy, etc. of the hospitals and starting with the architectural design and the selection of building components, evaluations should be made for energy efficiency and on-site visits especially should be emphasized. At the end, an integrated design by administrators, hospital designers and users should be accomplished and directly sustainable green hospital standards should be established for the existing hospitals in Turkey and for the ones that are going to be built in the future and the implementation of the same should be enforced by the administrators.

CONFLICT OF INTEREST

No conflict of interest was declared by the authors

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