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TRANSFORMATION OF HOSPITALS THROUGH COVID-19 PANDEMIC

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ABSTRACT

TRANSFORMATION OF HOSPITALS THROUGH COVID-19 PANDEMIC

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Disasters around the world are extraordinary situations that are unavoidable for centuries, and humanity is looking for solutions. Disasters on a large scale deeply affect human health, community psychology and the country’s economy. One of the disasters that have an impact around the world is infectious contagious diseases, and these diseases are called pandemics when they affect world communities. Pandemics that negatively affect human health can cause accumulation in hospitals, as they increase the need for treatment. In cases where hospitals can be inadequate at such critical times, the transformation of hospitals becomes of great importance. Covid-19 is the latest pandemic in today’s world that has a global scale impact. In order to prevent the spread of Covid-19 and improve the treatment process, interest in hospital/ward design and in-hospital conversions has increased worldwide. Since Covid-19 is not believed to be the final contagious health threat for communities of the world, to examine the available adaptations and derive further planning and design strategies for treatment and well-being areas is crucial to study on.

This thesis aims to make constructive suggestions for pandemic processes based on interior space zoning and mechanical ventilation zoning, which can be applied for in-hospital transformations and modular hospital designs. For this purpose, this study focuses on examining the published guidelines (DIN 1946-4, ASHRAE 170-2008, Phoenix Controls Healthcare Sourcebook, Guidelines of The Turkish Ministry of Health) for hospitals in preventing the spread of infection and the studies in the literature, investigating the applicability of modular hospitals designed around the world during Covid-19 pandemic, and explaining the steps that can be applied in hospital transformations through two private hospital design cases in Turkey.

The data in the study were obtained by qualitative (literature review, standards review, as-built document review, on-site observations, and interviews) and quantitative (statistic evaluation of survey analysis, generating variations for case study examples) approaches. Information obtained from literature review, guidelines, and interviews with architects and engineers specializing in hospital design are the basis of the evaluation criteria of this study.

As a result, a study has been completed that can play a role in ensuring the consistency of mechanical and interior architectural planning in order to successfully implement hospital transformation practices with the aim of preventing the spread of infections in pandemic processes. Scenarios have been created after all the analysis and synthesis of hospital interiors progressed during Covid-19 pandemic.

Keywords: hospital transformation, mechanical ventilation, modular design, transformation of space, Covid-19 pandemic, infection control, aligning mechanical and interior space design

ÖZ

HASTANELERİN COVID-19 PANDEMİSİ İLE DÖNÜŞÜMÜ

Sönmez, Nurefşan
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Nisan 2021

Dünya genelinde meydana gelen afetler yüzyıllar boyu engellenemeyen ve insanlığın çözüm arayışı içinde olduğu olağanüstü durumlardır. Afetler geniş çapta insan topluluğunun sağlığını, toplum psikolojisini ve ülke ekonomisini derinden etkilemektedir. Dünya çapında etkisi olan afetlerden biri de enfeksiyonel bulaşıcı hastalıklardır ve bu hastalıklar dünya toplumlarını etkileyince pandemi olarak adlandırılır. İnsan sağlığını olumsuz yönde etkileyen pandemiler tedaviye olan ihtiyacı arttırdığından hastanelerde yığılmaya sebep olabilmektedir. Bu tür kritik zamanlarda hastanelerin yetersiz kalabildiği durumlarda hastanelerin dönüştürülebilirliği büyük önem kazanmaktadır. Günümüz dünyasında küresel boyutta yaşanan ve etkisi uzun süren son pandemi Covid-19 salgınıdır. Covid-19'un yayılmasını önlemek ve tedavi sürecini iyileştirmek için ise hastane/koğuş tasarımına ve hastane içi dönüşümlere olan ilgi dünya çapında artmıştır. Covid-19'un dünyadaki topluluklar için son bulaşıcı sağlık tehdidi olduğuna inanılmadığından, mevcut hastane uyarlamalarını incelemek ve tedavi ve refah imkânını arttıran daha çeşitli planlama ve tasarım stratejisi geliştirmek üzerine çalışmak büyük önem taşımaktadır.

Bu tez çalışması, pandemik süreçler için hastane içi dönüşümlerde ve modüler hastane tasarımlarında uygulanabilecek alan içi zonlama ve mekanik havalandırma bazında yapıcı önerilerde bulunabilmeye yöneliktir. Bu amaçla, bu çalışma, enfeksiyonun yayılmasını önlemek için hastaneler için yayınlanan kılavuzların (DIN 1946-4, ASHRAE 170-2008, Phoenix Controls Healthcare Sourcebook, T.C. Sağlık Bakanlığı yönetmelikleri) ve literatürdeki çalışmaların incelenmesine, Covid-19 pandemisi sırasında dünya çapında tasarlanan modüler hastanelerin uygulanabilirliğinin araştırılmasına ve Türkiye'de iki özel hastane tasarımı ile hastane dönüşümlerinde uygulanabilecek adımların alan çalışmasıyla açıklanmasına odaklanmaktadır.

Çalışmadaki veriler, nitel (literatür taraması, standart incelemesi, inşa doküman incelemesi, yerinde gözlem, ve röportaj) ve nicel (anket analizlerinin istatistiksel değerlendirmesi, alan çalışması örnekleri üzerine varyasyonlar türetme) yaklaşımlarla elde edilmiştir. Literatür araştırması, standartlar, ve hastane alanında uzmanlaşmış mimar ve mühendislerle yapılan röportajlardan elde edilen bilgiler bu çalışmanın değerlendirme kriterlerinin temelini oluşturmaktadır.

Sonuç olarak, pandemi süreçlerinde enfeksiyonların yayılmasının önlenebilmesine dair hastane dönüşüm uygulamalarının başarıyla sonuçlanabilmesi amacıyla mekanik ve mimari planlamaların tutarlılığının sağlanabilmesinde rol alabilecek bir çalışma tamamlanmıştır. Covid-19 pandemisi sürecinde gelişen analiz ve sentezler sonucunda çeşitli hastane iç mekân dönüşüm senaryoları oluşturulmuştur.

Anahtar Kelimeler: Hastane dönüşümü, mekanik havalandırma, modüler tasarım, mekân dönüşümü, Covid-19 pandemisi, mekanik ve iç mekân tasarımının paralel tasarlanması

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I sincerely thank my dear sister Merve SÖNMEZ, who encouraged me to step into academic life, followed my works with excitement and took care of me.

Nurefşan SÖNMEZ
İzmir, 2021

TEXT OF OATH

I declare and honestly confirm that my study, titled “TRANSFORMATION OF HOSPITALS THROUGH COVID-19 PANDEMIC” and presented as a Master’s Thesis, has been written without applying to any assistance inconsistent with scientific ethics and traditions. I declare, to the best of my knowledge and belief, that all content and ideas drawn directly or indirectly from external sources are indicated in the text and listed in the list of references.

Nurefşan SÖNMEZ
20.04.2021

TABLE OF CONTENTS

ABSTRACT v

ÖZ vii

ACKNOWLEDGEMENTS ix

TEXT OF OATH xi

TABLE OF CONTENTS xiii

LIST OF FIGURES xvii

LIST OF TABLES xxiii

SYMBOLS AND ABBREVIATIONS xxv

CHAPTER 1 INTRODUCTION 1
1.1. Theoretical Perspective 1
1.2. Problem Statement 4
1.3. Methodology of the Study 6
1.4. Scope and Limitations of the Study 9
1.5. Research Questions and Hypothesis 10

CHAPTER 2 LITERATURE REVIEW 11
2.1. Method 11
2.2. Search Strategy 12
2.3. Information Extraction 16
2.3.1. Air Quality 16
2.3.2. Layout 17
2.3.3. Interior Design 18
2.4. Standard Reviews 18
2.5. Results and Future Studies 21

CHAPTER 3 MODULAR HOSPITAL PROPOSALS 23
3.1. Modular Hospital Proposals 23
3.1.1. Layout Created by Combining Modules that Have Individual Filtration 24
3.1.1.1. Staat Mod Units 25
3.1.1.2. Cura Pods 27
3.1.1.3. Losberger Emergency Modular Hospital System 31

3.1.1.4. Covid-19 Hospital Ship 32
3.1.2. Layout Created by Combining Modules that Have Common Filtration 35
3.1.2.1. Emergency Modular Hospital 35
3.1.2.2. Field Rescue Center 38
3.1.2.3. Mobile Modular Hospital 39
3.1.3. Self-Standing Modules with Own Filtration 41
3.1.3.1. Modular Hospital Ward Prototype 41
3.1.3.2. Qure Circular Negative Pressure Quarantine Unit 43
3.2. Eliminated Hospital Proposals 46
3.2.1. Mobile Hospital 47
3.2.2. CAMP-15 47
3.2.3. Kaksh 49
3.2.4. CNC- Medical Emergency Module 50
3.3. Results 52
CHAPTER 4 CASE STUDY: EXAMINATION OF TWO HOSPITAL LAYOUTS WITH THEIR MECHANICAL SYSTEM PROPERTIES 59
4.1. Surveys 60
4.1.1. Answers of Hospital Management 60
4.1.1.1. Isolation Steps 61
4.1.1.2. Patient beds 61
4.1.1.3. Ventilation 61
4.1.1.4. Sampling for Covid-19 61
4.1.1.5. Hospitalization 62
4.1.1.6. Disinfectants 62
4.1.1.7. Overall Results 62
4.1.2. Answers Of Hospital Personnel 63
4.1.2.1. Resting Areas 64
4.1.2.2. Working Areas 65
4.1.2.3. Infection Risk 65

4.1.2.4. Disinfectants 67
4.1.2.5. Isolation and Safety 67
4.1.2.6. Precautions Inside the Hospital 68
4.1.3. Survey Results 68
4.2. Interviews 69
4.2.1. Interview With Ekrem Evren 69
4.2.2. Interview With Gonca Ateş Öztürk 73
4.3. Hospital Transformations 74
4.3.1. Examination of Hospital A 74
4.3.2. Transformation of Hospital A 77
4.3.3. Examination of Hospital B 90
4.3.4. Transformation of Hospital B 91
4.3.5. General Interpretation about Transformation Proposals of Hospital A and Hospital B 98
CHAPTER 5 CONCLUSIONS AND FUTURE STUDIES 101
5.1. Generic Transformation of Typical Standard Hospital Rooms 102
5.2. Generic Transformation Overall Results and Future Study Opportunities 106
5.3. Modular Hospital Planning Scenarios for Hospital Extensions 107
5.4. Concluding Remarks 111
REFERENCES 112
APPENDIX 1 – INTERVIEW 118
APPENDIX 2 – INTERVIEW 119
APPENDIX 3 – SURVEY 120
APPENDIX 4 – SURVEY 124

LIST OF FIGURES

Figure 1.1. Number of Covid-19 Patients in Hospitals 4

Figure 1.2. Number of Intensive Care Unit (ICU) Admissions for Covid-19 5

Figure 1.3. Applied Methods in the Study 7

Figure 2.1. Brainstorming Strategy 12

Figure 2.2. Grouping the Effects of Hospitals and Healthcare Facilities on Patients 13

Figure 2.3. Healthcare Environment and Hospital Environment Findings 13

Figure 2.4. Overview of the Searching Process 14

Figure 2.5. Number of Papers in the Context of Infection and Covid-19 16

Figure 2.6. A Patient Room Designed for Pandemic 20

Figure 2.7. An Isolation Room with an Entree which has Negative Pressure 20

Figure 2.8. The Use of Valves 21

Figure 3.1. Categorization of the Analyzed Hospitals 24

Figure 3.2. STAAT Mod Units Self-sufficient View 25

Figure 3.3. STAAT Mod Units Adjacent View 25

Figure 3.4. STAAT Mod Units Layout Design 26

Figure 3.5. STAAT Mod Unit Interior View Zoning 26

Figure 3.6. HVAC System of STAAT Mod Units’ HVAC Design 27

Figure 3.7. CURA Pods Adjacent Option 28

Figure 3.8. CURA Pods Self-sufficient Option 28

Figure 3.9. HVAC Unit Inside the Pod 29

Figure 3.10. Axonometric Section View of the CURA Pods 29

Figure 3.11. Installation of the CURA Pods 30

Figure 3.12. CURA Pods with Transition Module 30

Figure 3.13. Losberger Emergency Modular Hospital Placement 31

Figure 3.14. Losberger Emergency Modular Hospital System Exterior and Interior View . 31

Figure 3.15. Layout of a Module Interior 32

Figure 3.16. Covid-19 Hospital Ship Exterior View Proposal 33
Figure 3.17. Covid-19 Hospital Ship Modules Placement Proposal 33
Figure 3.18. Covid-19 Hospital Ship Module Components 34
Figure 3.19. Covid-19 Hospital Ship Zoning Proposal 34
Figure 3.20. Emergency Modular Hospital Exterior View..35
Figure 3.21. Relation of Emergency Modular Hospital with Existing Hospital....................35
Figure 3.22. Schematic View of a Module 36
Figure 3.23. Axonometric View of Module 36
Figure 3.24. Technical Section of the Module 37
Figure 3.25. Ventilation System of Modules...37
Figure 3.26. Field Rescue Center Adjacent Option 38
Figure 3.27. Field Rescue Center Self-sufficient Option...38
Figure 3.28. Field Rescue Center Section Drawings of Modules..39
Figure 3.29. Mobile Modular Hospital Exterior View 40
Figure 3.30. Mobile Modular Hospital Interior View 40
Figure 3.31. Covid infection treatment configuration 40
Figure 3.32. Modular Hospital Ward Prototype Interior View..42
Figure 3.33. Modular Hospital Ward Prototype Exterior View 42
Figure 3.34. Location Option on Open Land for Modules 43
Figure 3.35. Location Option on Top of an Existing Building for Modules 43
Figure 3.36. Covid-19 Prototype of Emergency Quarantine Hospital Building....................44
Figure 3.37. Systematical Features of the Covid-19 Prototype of Emergency Quarantine Hospital...44
Figure 3.38. Structure of Circular Negative Pressure Quarantine Unit 45
Figure 3.39. Air flow in the Module..45
Figure 3.40. Mobile Hospital Proposal by VHL Architecture + Da Nang Architecture University 47
Figure 3.41. CAMP-15 48

Figure 3.42. CAMP-15 Dorms Layouts 48

Figure 3.43. CAMP-15 Office Layouts 49

Figure 3.44. Kaksh Quarantine Hospital/ Testing Lab/ Shelter 49

Figure 3.45. Kaksh Design Materials 50

Figure 3.46. Structure of Kaksh 50

Figure 3.47. CNC- Medical Emergency Module Sketch View 51

Figure 3.48. CNC- Medical Emergency Module Render View 51

Figure 3.49. Structure of CNC-Medical Emergency Module 51

Figure 3.50. Layout Types of the Modular Hospitals 53

Figure 3.51. Percentage of Preferred Filter Types 53

Figure 3.52. Filtration Type of Modular Hospitals 54

Figure 3.53. Pressure Directions 55

Figure 4.1. Actual Placement of Disinfectants 62

Figure 4.2. Adequacy of the Resting Areas for Personnel 64

Figure 4.3. Safety of Ventilation and Mechanical Conditions of the Resting Areas 64

Figure 4.4. Safety of Ventilation and Mechanical Conditions of the Working Areas 65

Figure 4.5. The Risk of Increase of Infection due to Personnel Duties 65

Figure 4.6. Cautiousness of Patients about Infection Control 66

Figure 4.7. Easy Access to Disinfectants 67

Figure 4.8. Evaluation of the Effect of Providing an Isolated Environment on the Sense of Safety 67

Figure 4.9. Assessment of Precautions Taken Inside the Hospital 68

Figure 4.10. Required Air Flow Direction among Spaces in Hospitals 70

Figure 4.11. Air Inlet and Outlet Placements for Isolation Rooms 70

Figure 4.12. The Control of Pressure through Automation in a Isolation Room of Hospital A 71

Figure 4.13. Need of HEPA in accordance with the Number of Isolation Room 72

Figure 4.14. Removing Air via Jetcap 73

Figure 4.15. Left Side of the 6. Floor and AHUs' Locations 75

Figure 4.16. Right Side of the 6. Floor and AHUs' Locations 76

Figure 4.17. AHUs Located on 1. and 3. Floors 77

Figure 4.18. Defined New Entrance to the Isolated Areas in Hospital A 78

Figure 4.19. Transformation of 2. and 3. Floor 79

Figure 4.20. Transformation of Rooms Located on 2. and 3. Floor 80

Figure 4.21. Transformation of a Patient Room into the Personnel Room 81

Figure 4.22. Transformation of a Patient Room into the Sterilization Area 82

Figure 4.23. Transformation of 5. Floor 83

Figure 4.24. Transformation of Room-1 on the 5. floor 84

Figure 4.25. Transformation of Room-2 on the 5. floor 85

Figure 4.26. Transformation of Room-3 on the 5. floor 86

Figure 4.27. Transformation of Room-4 on the 5. floor 87

Figure 4.28. Transformation of Room-5 into the Personnel Room 88

Figure 4.29. Transformation of Room-6 into the Sterilization Areas 89

Figure 4.30. Air Handling Units of Hospital B 90

Figure 4.31. Defined New Entrance to the Isolated Area in Hospital B 91

Figure 4.32. Transformation of 2. Floor 92

Figure 4.33. Transformation of Room-1 on the 2. Floor 93

Figure 4.34. Transformation of Room-2 on the 2. Floor 93

Figure 4.35. Transformation of Room-3 on the 2. Floor 94

Figure 4.36. Transformation of Room-4 on the 2. Floor 94

Figure 4.37 Transformation of Room-6 on the 2. Floor 95

Figure 4.38. Transformation of Room-7 on the 2. Floor 96

Figure 4.39. Transformation of a Patient Room into the Personnel Room 97

Figure 4.40. Transformation of a Patient Room into the Sterilization Room 97

Figure 5.1. Transforming a Patient Room Defined in Turkish Standards to an Isolation Room 102

Figure 5.2. Transforming a Patient Room Defined in Turkish Standards to a Personnel Room ... 103
Figure 5.3. Transforming a Patient Room Defined in Turkish Standards to a Sterilization area ... 104
Figure 5.4. Transforming a Two-person Patient Room Defined in Turkish Standards to an Isolation Room ... 105
Figure 5.5. Transforming a Two-person Patient Room Defined in Turkish Standards to a Personnel Room ... 105
Figure 5.6. Transforming a Two-person Patient Room Defined in Turkish Standards to a Sterilization Room ... 106
Figure 5.7. The Proposal to Use Modular Hospitals as Adjacent Building ... 107
Figure 5.8. Self-standing Layout for Modular Hospitals ... 108
Figure 5.9. Own Entrance for Each Module ... 108
Figure 5.10. Buffer Zone (Sluice) for Each Module ... 109
Figure 5.11. Clean and Dirty Pathways for Modular Hospital ... 109
Figure 5.12. Air Inlet and Outlet Placement ... 110
Figure 5.13. Curved Edges and Corners for Module Interiors ... 110

LIST OF TABLES

Table 3.2.1. Characterization of the Eliminated Modular Hospitals.................................... 46

Table 3.3.1. Characterization of the Modules 56

Table 3.3.1. Characterization of the Modules (continued)... 57

Table 3.3.1. Characterization of the Modules (continued)... 58

SYMBOLS AND ABBREVIATIONS

ABBREVIATIONS:

AC	Air Conditioning
AHU	Air Handling Unit
ASHRAE	The American Society of Heating, Refrigerating and Air-Conditioning Engineers
BAF	Bio-architecture Formosana
COVID-19	Corona Virus Disease-2019
CURA	Connected Units for Respiratory Ailments
CDC	Centers for Disease Control and Prevention
CNC	Computer Numerical Control
DCM	Decontamination Module
DIN	Deutsches Institut für Normung
EPDM	Ethylene Propylene Diene Monomer
HEPA	High Efficiency Particulate Arresting
HVAC	Heating, Ventilation, and Air Conditioning
ICU	Intensive Care Unit
IEQ	Indoor Environmental Quality
IP	Infection Preventionist
LAF	Laminar Air Flow
LED	Light Emitting Diode
MERS	Middle East Respiratory Syndrome
MERV	Minimum Efficiency Reporting Value
MV	Mechanical Ventilation
NCKU	National Cheng Kung University
NV	Natural Ventilation

PET	Polyethylene Terephthalate
PVC	Polyvinyl Chloride
QURE	Quarantine Units for Recovery, Emergency, and Ecology
SARS	Severe Acute Respiratory Syndrome
STAAT	Strategic, Temporary, Acuity-Adaptable Treatment
TEU	Twenty-foot Equivalent Unit
UK	The United Kingdom
USA	The United States of America
WHO	World Health Organization

SYMBOLS:

Pa	Pascal
°C	Celsius
m^3/h	Cubic meter per hour

1. CHAPTER 1
INTRODUCTION

1.1. Theoretical Perspective

People spend most of their time in indoors (Bluyssen, 2019), and it is known that indoor quality has an impact on human health, productivity (Asadi et al., 2017; Heinzerling et al., 2013; Mujan et al., 2019; Seppänen & Fisk, 2006), behaviors (J. Kim et al., 2017) and satisfaction (De Giuli et al., 2012; Humphreys, 2005; Lai et al., 2009). Indoor Environmental Quality (IEQ) refers to the provided quality of a building's environment for occupants (Piasecki et al., 2017), and covers the living conditions inside a building (US Green Building Council, 2014). IEQ contains several components such as, lighting quality, air quality, acoustic quality, thermal comfort, and also vibration, water quality, ergonomics, micro-organisms, odor, hygiene, electromagnetic radiation (Abdul Mujeebu, 2019). In these components, it is observed that mainly four of them have been the topic in literature: Acoustic comfort, lighting comfort, thermal comfort, air quality. Besides human health, productivity, behaviors and satisfaction, it has been a subject to many studies that these factors also have an impact on human comfort, well-being (Al horr et al., 2016; De Giuli et al., 2012) and performance (Haverinen-Shaughnessy et al., 2015; Seppänen & Fisk, 2006). For this reason, when examining the quality, livability and impact of an interior space on human activities, it is considered whether these conditions are provided or not.

One of the criteria that has direct impact on human beings in interiors is air quality (Tham, 2016). The correlation between air quality and humans has been proven and emphasized in several studies by examining the impact of air quality on attention (H. Kim et al., 2020), behaviors (Lin et al., 2017), productivity (Kosonen & Tan, 2004), well-being (Schmitt, 2013), and human health (Jones, 1999). Indoor air quality is expected to be acceptable in a way that positively affects and does not endanger human well-being and health. Therefore, ensuring indoor quality with the help of improved natural ventilation (Lei et al., 2017) and proper mechanical ventilation (Leung & Chan,

2006) in order to remove polluted air and harmful particles through filtration (Vijayan et al., 2015), and provide distributing of fresh air into the interior (Chao & Hu, 2004) are necessary. When outer conditions enable the use of natural ventilation and mechanical ventilation is not favorable, the use of natural ventilation is acceptable. This could also enable less energy consumption. However, especially in areas requiring thermal control and contamination control, such as hospitals, mechanical ventilation can be more favorable.

Although leaving the environment is seen as a solution for people, who are uncomfortable with a not sufficiently ventilated environment, this is unlikely in environments such as hospitals visited for mandatory reasons and cannot be easily abandoned. For this reason, extra care is taken to ensure air quality in such environments. As hospitals are vital for human health, it is very important to ensure appropriate conditions. Especially, because the hospital environment is conducive to the spread of diseases / infection (Annis, n.d.; Özcan, 2014; Öztürk, 2006; Spagnolo et al., 2013), extra attention should be paid to air quality, and dirty air should be easily removed without interfering the circulation. In this case, the use of natural ventilation may be inefficient due to the fact hospital rooms that are lack of operable windows and continuous ventilation of the room causes unstable thermal conditions needed for patients. Natural ventilation is recommended by the World Health Organization to reduce the risk of airborne infection spreading in health facilities. But it is said that hybrid ventilation (the use of natural and mechanical ventilation together) is necessary when natural ventilation alone is not sufficient. It is expected that where negative pressure should be provided, it will also be designed in acceptable conditions that will positively affect health and not lead to danger (World Health Organization, 2020a).

Correct ventilation strategies are of great importance in indoor spaces, since it is easy to spread diseases through air as a result of breathing, coughing, or sneezing (Tellier, 2009), and we often encounter such disease from the past to the present (Brachman, 2003). The systematic and accurate functioning of mechanical ventilation is very convenient both for ensuring clean air circulation and for filtering polluted air and take it out. Therefore, it is mandatory to follow mechanical ventilation standards such as applying negative pressure, providing sufficient air exchange, using HEPA filter, checking filter loading (World Health Organization, 2021) and to apply proper spatial layouts consistent with mechanical system within the hospital (Cheong & Phua, 2006) are strongly recommended to prevent airborne disease in hospital interiors.

In order to prevent the spread of disease or infection in hospitals, the guidelines issued by the Turkish Ministry of Health are applied by the hospital managements, and these follow-up audits are carried out by the Ministry. In addition, inspections and control measures tested are being increased to prevent diseases that spread in country basis or around the world from becoming a threat within the hospital. Diseases that spread around the world, which are easily transmitted (Morens et al., 2009), caused by infection due to a virus or a bacteria, and result in multi-deaths are called as pandemic (Felman, 2020). Since these diseases are available to be transmitted by contact, droplet and airborne (Centers for Disease Control and Prevention, 2020a), serious measures must be taken to prevent their spread. These diseases are deadly dangerous until their spread is prevented and treatment is found. When the history of the world is examined, it is seen that there have been many pandemic that hit hundreds of thousands or even millions of people in the world, such as, Justinian Plague in 541 AD, The Black Death in 1350, Cholera outbreak in 1817, The Third Plague Pandemic in 1855, Spanish flu in 1918, and the final pandemic was appeared Chinese coronavirus in 2019 (History.com Editors, 2020).

In December 2019, China reported that a virus identified as new coronavirus spreads out in Wuhan. In January 2020, China shared the genetic sequence of COVID-19 the new coronavirus in the light of the experience with SARS and MERS, and WHO (World Health Organization) published a guidance to protect health workers from infection and prevent transmission of viruses via droplet (World Health Organization, 2020a). The fact that it is transmitted by air, as well as contact, has made this outbreak even more dangerous and has increased the degree of measures taken. In addition to the mask, it was recommended to use of gloves, protective clothing, eye protection in hospitals (Cao et al., 2020), and minimize people's close interactions with each other (Harvard Health, 2021). However, since the virus is transmitted by air, although the contact is reduced, it is not enough to reduce the transmission of the virus to the desired degree. For this reason, stricter measures started to be taken to clean the virus in the air. In this direction, proper ventilation, proper decomposition of polluted air and clean air circulation, ensuring clean area circulation to protect non-infected health workers and other patients in the hospital from the disease, providing sufficient space for inpatient admission in the pandemic process, using Merv and HEPA filters (Salonen et al., 2013), low-level extraction (Cheong & Phua, 2006) are strongly recommended, and guidelines and checklists have been published by several health organizations, such as WHO (World Health Organization, 2020b) and CDC (Centers for Disease Control and Prevention, 2020b) for hospital administrations and healthcare professionals to make such necessary regulations.

1.2. Problem Statement

During Covid-19 pandemic process, it is observed that the number of patients exceeds the capacity of the hospital (Cavallo et al., 2020; Weissman et al., 2020). This situation causes a lack of treatment areas and endangers the lives of both patients and hospital workers.

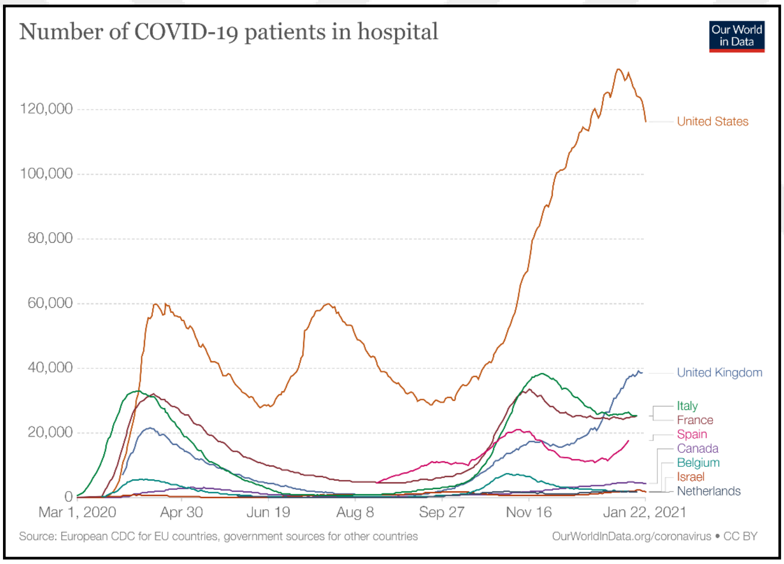


Figure 1.1. Number of Covid-19 Patients in Hospitals (Our World in Data, 2021a)

Figure 1.1 shows the number of Covid-19 patients in hospitals between 1st March 2020 and 22nd January 2021 around the world. According to the obtained data, the number of Covid-19 patients is too large to be underestimated, and although there are decreases from time to time, the number increases overall.

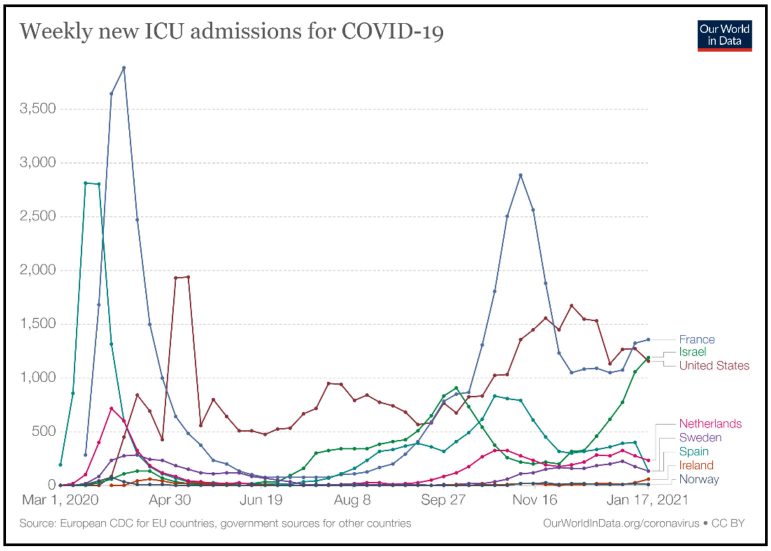


Figure 1.2. Number of Intensive Care Unit (ICU) Admissions for Covid-19 (Our World in Data, 2021b)

Figure 1.2 shows the number of Intensive Care Unit (ICU) admissions for Covid-19 between 1st March 2020 and 17th January 2021 around the world. According to the obtained data, there is almost no Intensive Care Unit (ICU) admissions in some countries for Covid-19 treatment such as Norway and Ireland. While in some countries there is quite a lot of Intensive Care Unit admissions such as France, Israel and United States. In addition to this, when the given two charts compared, it is seen that while USA has the highest patient numbers, the ICU admissions of USA for Covid-19 is lower than France and Israel. The change of ICU admission numbers may depend on several reasons, such as the severity of disease, strict precautions taken in the countries. There may also be a reduction in admissions due to the capacity of hospitals being full.

The increase of ICU admission numbers affects patient density in hospitals. Along with filling hospital capacities, it also increases the need for the built of extra treatment areas. For this reason, more than one hospital has been built or transformed during pandemic in many countries and also in Turkey. For instance, several hospitals, Professor Murat Dilmener Emergency Hospital, Dr. İsmail Niyazi Kurtulmuş Hospital (Daily Sabah, 2020), Başakşehir Çam and Sakura City Hospital, Marmara University Prof. Dr. Asaf Ataseven Hospital, Konya City Hospital (Usul, 2021) were opened and began to accept patients in 2020 in Turkey. However, because of the long duration of hospital construction and the fact that such initiatives are quite costly, modular hospitals are built in some places or in some hospitals in-hospital transformations are being carried out as a solution. As treatment spaces inside of hospital capacities become inadequate, if there is no time to build new hospitals and there is no place to build any hospital during pandemic process, in-hospital transformations needed to be gradually increased.

In order to prevent spread of diseases by providing effective hospital transformations, it is need to develop proper strategies by considering healthcare environment standards. Given the presence of pandemics in the last years, Covid-19 is not believed to be the final contagious health threat for the communities around the world. Therefore, hospitals are required to make suitable for transformation in order to take the necessary measures before possible future outbreaks.

As a problem statement of this thesis, when the literature was examined, it was found that the resources that could help in this regard (Chen & Zhao, 2020; Pandey et al., 2020; Robbins et al., 2020; Zhang et al., 2020) were quite few and not enough. It is thought that zoning proposals made without closely examining the ventilation and layout in the literature. The alignment of interior and mechanical design should be better understood for hospital conversions. More realistic suggestions should be made over existing hospital plans, and in the meantime, recommendations should be made taking into account hospital standards. It is believed that this study will fill this gap in the literature by helping to improve hospital transformations in the alignment of interior and mechanical design to prevent the spread of the disease.

1.3. Methodology of the Study

This thesis contains both qualitative and quantitative data which are based on, *reviews* of academic papers and designs, *interviews* with professionals, *observations* of mechanical systems, *collecting and analyzing the data* obtained from hospital managements and websites, in order to define the possible ways of in-hospital transformations for pandemic processes, as is shown in Figure 1.3.

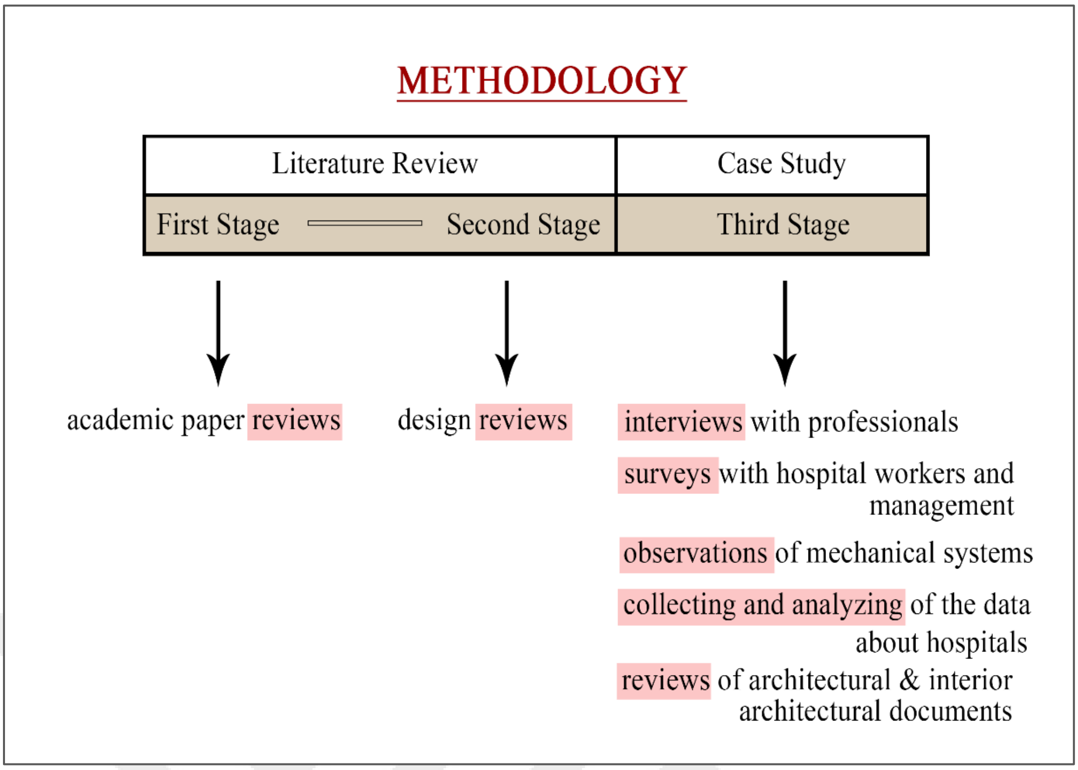


Figure 1.3. Applied Methods in the Study

A systematic and extensive literature review is the primary research step and analysis method of this study on pandemic needs for mechanical and physical zoning. Two main methods used for this extensive literature review consists an academic paper search with keywords defined throughout literature, and a design review of modular pandemic hospital units recently designed throughout the world with the threat and urgency of Covid-19 pandemic. For this purpose, first, academic papers were searched by using the Scopus Database about ensuring patient well-being and satisfaction in hospital and healthcare interiors. Based on the healthcare environment and hospital environment, the words interior design, lighting design, air quality, natural ventilation, thermal comfort, noise control, design, greenery, layout, infection and Covid-19 identified in the context of indoor environmental quality were searched in title, abstract and keywords on Scopus from 1998 to 2020. Second, design reviews of the proposed modular hospital ideas for Covid-19 pandemic process from all around the world were made, and similarities, differences, pros and cons of the hospitals were analyzed by looking at their layout strategies, building features, ventilation systems and filtration usages. Hospitals were examined in three groups, taking into account the forms of ventilation: Layout Created by Combining Modules that have Individual Filtration, Layout Created by Combining Modules that have Common Filtration and Self-

Standing Modules with Own Filtration. Layout planning and ventilation features of these hospitals were accessed on the web, and then their images and descriptions were analyzed and compared in accordance with the recommendations in the literature and the guidelines set by the World Health Organization (WHO), Centers for Disease Control and Prevention (CDC), DIN 1946-4 Deutsches Institut Fur Normung E.V. (German National Standard), The American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE).

In order to understand ways of new zoning/planning alternatives for transformation of hospitals for pandemic conditions, original zoning of hospitals according to mechanical and physical needs must be discovered. For this purpose, tape-recorded interviews were conducted as face-to-face with hospital designing architects and interior architects and mechanical engineering professional. Therefore, third stage consists of interviews, surveys, observations, collecting and analyzing of the data, and reviews of documents. Explanations and recommendations of architects and mechanical engineers summarized specializing in the field of the architectural and mechanical designs of hospitals. Then, the criteria to be considered in making hospitals suitable for transformation in pandemic processes were transferred to the study as both verbal references and schematic format. Also the as-built hospital drawings of multiple size hospitals were investigated accordingly. Colored as-built drawing sets helped to identify main zoning requirements. In this thesis, method to be followed for juxtaposing the original zoning needs with pandemic zoning needs is defined through case studies. As a case study, two private hospitals (which are continuously tested and controlled/commissioned by the Turkish Ministry of Health) were analyzed in terms of as-built architectural, interior design, and mechanical drawing sets. Zoning schemes were identified through colored drawings, space relation schemes of these hospitals. Use of space was also analyzed by online survey given out to healthcare personnel of one of the hospital case, which is occupied during this study. According to survey results, in detail survey analysis, and needs of pandemic defined by standards the new schematics for these two hospitals were generated. Recommendations have been made on how these hospitals can be made more appropriate for pandemic processes over their schematic plans. The recommendations were made in two categories: regulations that can keep pace with changes in the pandemic process and what to consider in the hospital’s planning process before it is built.

As a result, in the scope of ventilation strategies and layout planning, all the methods followed and accumulative information gathered were used for concluding generic schematic drawings of suggestions for future pandemic conditions for generic hospital typologies. Schematic transformation drawings give information about,

- dividing hospitals into zones as sterile, semi-sterile, dirty and buffer zone,
- creating isolation rooms,
- defining pressure changes and directions among zones,
- distribution of filters within isolated zones (common usage or self-usage),
- placement of filters in main inlets and main outlets in hospitals

1.4. Scope and Limitations of the Study

It is found that in order to be able to make constructive suggestions for pandemic processes, it is necessary to make examinations about in-hospital transformations first. For this purpose, a comprehensive literature review was done, strategic planning of proposed modular hospitals around the world was examined, and case studies were conducted on the transformation of two private hospitals in Turkey. In case of hospital capacities may be insufficient when we face pandemics and natural disasters, the need for in-hospital transformations increase. A comprehensive study that offers recommendations together with case studies to deal with such situations has not been found in the literature. As it is believed that this issue should be examined in detail, this study focuses on planning effective layout for hospital interiors and examination of the ways to follow for the most accurate ventilation strategy. In addition to the architectural planning proposals, the necessary mechanical recommendations were made with the support of experts in the field of mechanical engineering.

However, we are aware that this study has some limitations as noted below:

- This study addresses the topic that takes part in literature until September 2020, it is possible more literature work can be developed within time about in-hospital transformations and modular transformation alternatives.

- Although pandemics occur on a global scale, this study was carried out on the basis of the typology of Turkish hospitals. Nevertheless, it is desirable to note that the recommendations are applicable to other hospitals since this study contains general recommendations for hospital transformations and the necessary care has been taken to make this study a universal guide.

- Although it was desirable to be able to conduct investigations on a larger scale and work on City/State Hospitals, the necessary permissions were not provided to achieve hospital projects. For this reason, the studies were carried out on two different Private Hospitals in Turkey only. This limits the potential benefit of this study to be useful in City/State scale hospital typologies of Turkey.

- Because this study was carried out during pandemic, one to one interview with hospital workers could not be conducted due to the density of hospitals and the health restrictions applied within the hospitals.

1.5. Research Questions and Hypothesis

The research questions asked in this study are listed below,

- What are the retrofit options for transforming interior space of hospitals?

- What are the transformable proposals for hospital interiors in order to enhance indoor comfort and ensure better treatment under infectious disease conditions?

- Are transformation proposals suitable for all types of hospitals? If not, which proposals work for which kind of hospitals?

The first hypothesis assumes that hospitals are very active in pandemic processes, so there is a density of patients in hospitals, in-hospital transformations are necessary if there is no time to build new hospitals or hospital extensions in such processes.

The second hypothesis assumes that improving layout for transformation options with mechanical layout control in hospital interiors provides better air circulation, thus provides better air quality.

The third hypothesis assumes that hospitals should be divided into zones to prevent the spread of the disease/virus.

The fourth hypothesis assumes that the preference for individual filtration in treatment modules or hospital rooms provide better air quality, and it is more effective than the use of common filtration to prevent spread of disease.

CHAPTER 2
LITERATURE REVIEW

This chapter introduces the literature review that examines and groups the guidelines set out in the literature to prevent the spread of infection in hospital interiors and ensure patient health and well-being.

Since its emergence on December 14, 2020, Covid-19 has been a major threat worldwide. This airborne virus has spread very quickly. Therefore, in order to prevent its spread, strict measures have been taken in many public areas, especially in hospitals. For that reason, the WHO (World Health Organization) published a guidance to improve the suitability of the hospital environment for Covid-19 treatment and to prevent the spread of the virus and to ensure that health workers can be protected from transmission of the virus (World Health Organization, 2020c). In order to prevent the spread of the virus through the air, guidelines were published for the correct use of ventilation, ensuring sterilization, and proper interior layout. Since Covid-19 is not believed to be the final epidemic that threatens communities of the world, in order to easily deal with such epidemics, it is clear that the necessary measures should be taken in advance and hospitals should be prepared for emergencies. Because Covid-19's rate of spread and potential to negatively affect people is quite high, it requires an assessment of hospital interiors for suitability and an examination of whether the necessary measures have been taken. The existence of sufficient information and studies in the literature on this subject is also of great importance. However, it is found that there are insufficient number of studies in the literature that reveal the relationship between hospital and infection control by reviewing the available studies systematically.

2.1. Method

The literature review part of the study, is based on the review of evaluations on the satisfaction level in hospital and healthcare interiors, and conducting a systematic review by grouping the criteria considered in this research and related case studies in the literature. This review followed the guidelines of systematic literature reviews presented by PRISMA (Moher et al., 2015 as cited in Colenberg et al., 2020). Also hospital standards for infectious disease control is summarized to lead us to transformation opportunities for future steps of our case study.

2.2. Search Strategy

Studies in the literature were reached by using the Scopus database on 28 July 2020. Literature review was conducted by searching words in the context of title, abstract and keywords in the years from 1998 to 2020. The documents were examined according to their accessibility. Only abstracts of some documents were available. While some of documents could not be found and all the available ones read in detail.

At the stage of deciding on words to investigate, first, brainstorming was done. The words that are evoked by the word groups of *hospital environment, healthcare environment, hospital interior, healthcare interior* were identified. As is seen in Figure 2.1, the identified matchings are *layout, greenery, design, thermal comfort, well-being, lighting quality, air quality* and *satisfaction*.

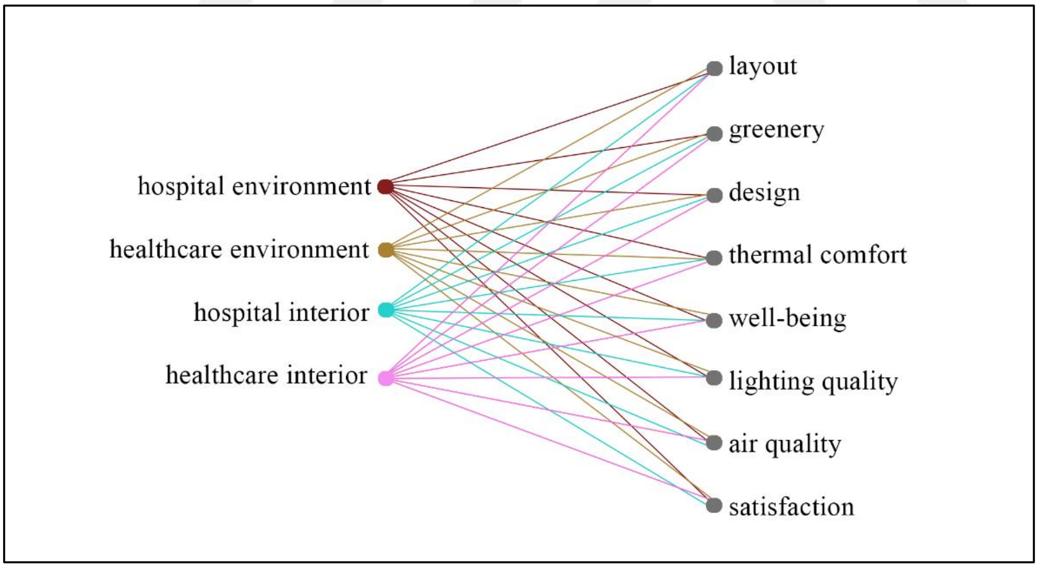


Figure 2.1. Brainstorming Strategy

Including these words, the possible effects of hospitals and healthcare facilities on people were grouped into physical and psychological terms, as is seen in Figure 2.2.

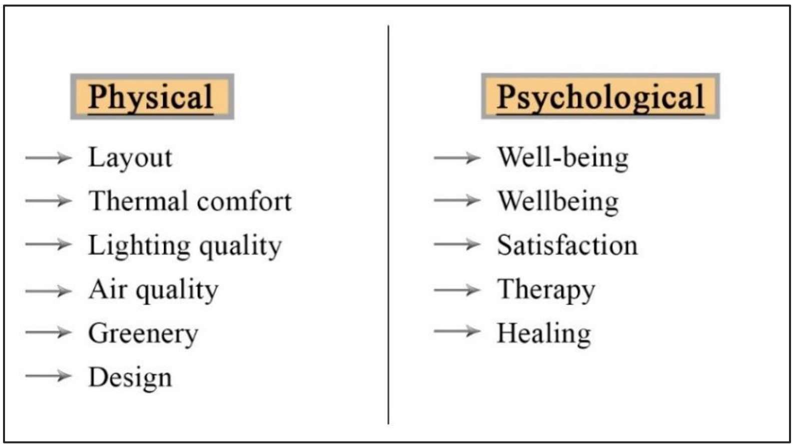


Figure 2.2. Grouping the Effects of Hospitals and Healthcare Facilities on Patients

Features of the hospitals and healthcare facilities that can be felt with one of the five senses were collected under the title physical. These are, layout, thermal comfort, lighting quality, air quality, greenery and design. While the possible effects of these places from a psychological point of view have also been collected under the title psychology. These are, wellbeing, well-being, satisfaction, therapy and healing.

Within these words, it was noticed that the word *wellbeing* is contained in two different ways in literature: wellbeing and well-being. In addition, it has been noticed that the way this word is expressed affects the number of papers that can be found in the literature, as is seen in Figure 2.3.

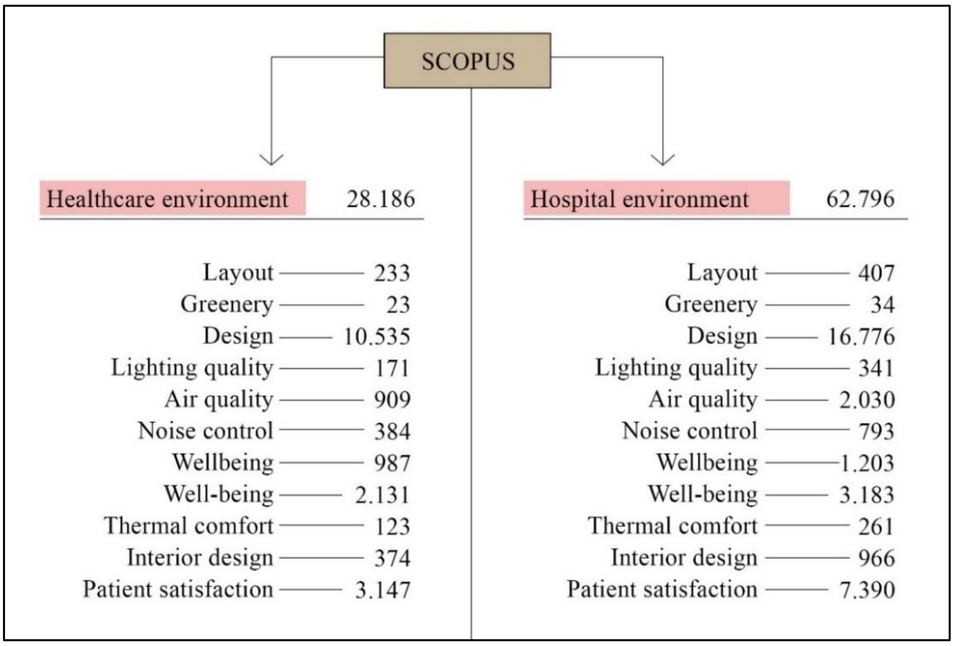


Figure 2.3. Healthcare Environment and Hospital Environment Findings

Figure 2.3 shows that when the identified words are searched on Scopus, different numbers are obtained under the name *healthcare environment* and *hospital environment*. Besides, the words *occupant satisfaction* and *patient satisfaction* refer different number of studies in literature. Considering this fact, the searching process for this literature review study is shown in Figure 2.4.

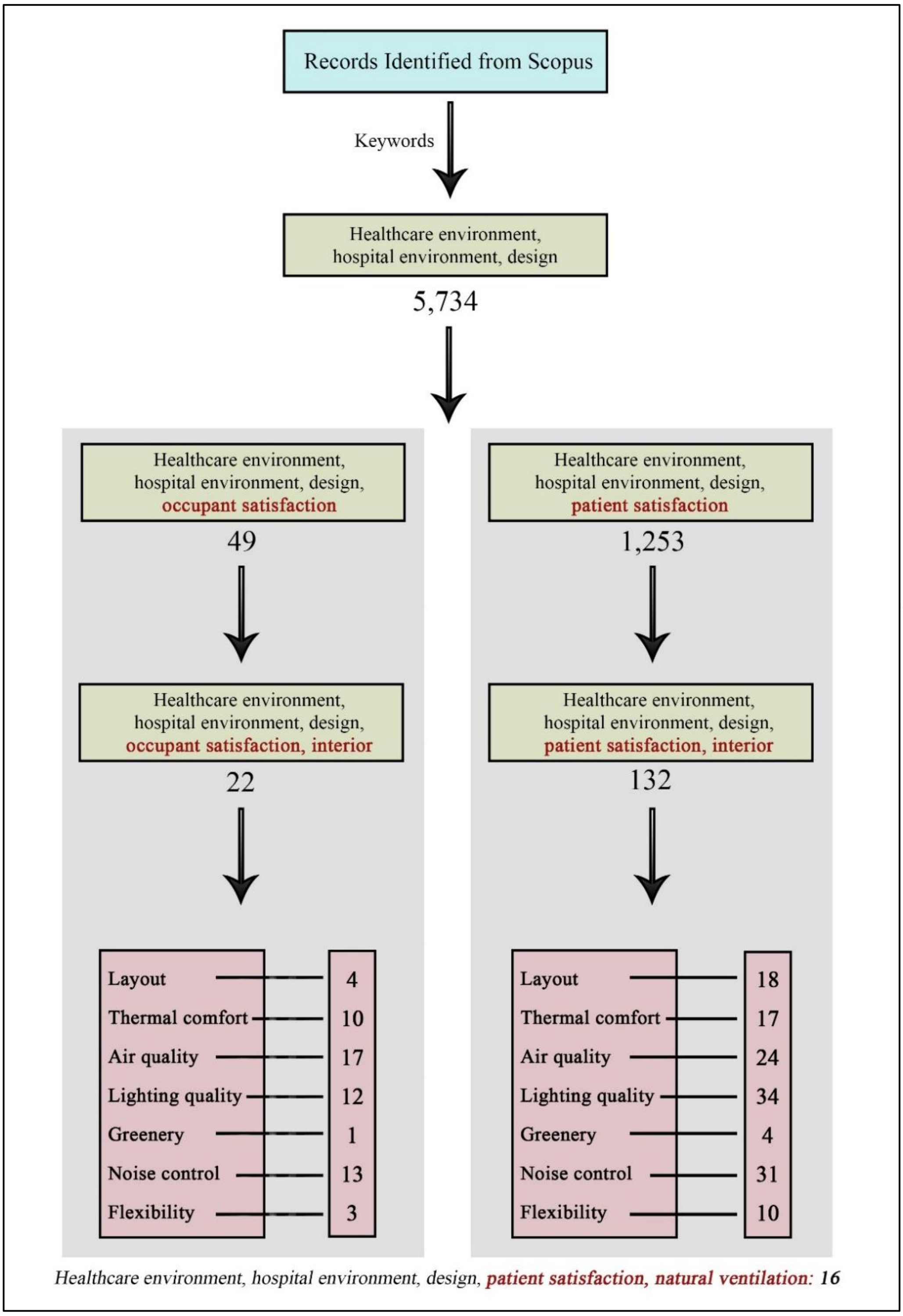


Figure 2.4. Overview of the Searching Process

When the keywords, healthcare environment, hospital environment, and design searched, 5,734 documents were found. Then, searching was categorized into two by adding occupant satisfaction and patient satisfaction. It is seen that in literature, looking for patient satisfaction (1253) enables more documents than occupant satisfaction (49). After adding the interior word, the number of documents decreased to 22 for occupant satisfaction and 132 for patient satisfaction. Due to the fact that we are searching for conformity of hospital/healthcare environments, the research focused on the part that includes patient satisfaction. Looking into literature, the relationship between hospital/ healthcare and patient satisfaction has been classified based on 7 features; layout, thermal comfort, air quality, lighting quality, greenery, noise control, flexibility. Through systematic review, in the context of patient satisfaction and interior design, it is detected that, 18 studies are related to layout, 17 studies are related to thermal comfort, 24 studies are related to air quality, 34 studies are related to lighting quality, 31 studies are related to noise control, and 10 studies are related to flexibility. While only 4 studies are related to greenery, and there is no study about proximity. The numbers show that great attention is given for indoor environmental quality parameters (thermal comfort, air quality, lighting quality, noise control) in studies. In addition to examined 7 keywords, natural ventilation was also searched by excluding ‘‘interior’’, and 16 documents were reached. Figure 2.4 shows the steps of the searching process.

In addition, 40 studies on *hospital environment* and *layout* were found. When *healthcare facilities interior* was searched, 96 studies found and only 42 of them could be reached. Then, 13 studies were eliminated because they have no meaning for this study. 16 full studies were examined, and only abstracts of 13 were read. To prevent the spread of the virus, two of the main criteria are to ensure proper *air quality* (ANSI/ASHRAE/ASHE, 2008 as cited in Spagnolo et al., 2013; ASHRAE 2003b as cited in Salonen et al., 2013; Nielsen et al., 2010; Cheong, & Phua, 2006; Spagnolo et al.,2013) and *layout* (MacAllister et al., 2016; Fay et al., 2017; Gharaveis et al., 2019). However, it is seen that air quality and layout of healthcare /hospital environment has been topics of only 42 studies in total.

In order to examine the literature in the context of infectious disease and hospital/healthcare environment, the keywords which are *hospital environment, healthcare environment, interior design, infection, air quality* were searched and 28 documents were found. While the keywords which are *hospital environment,* *healthcare environment, interiors, Covid-19* were searched, only 2 documents were found, as is seen in Figure 2.5. This elimination and review process shows that there is not enough academic study (indexed under Scopus) in literature that contains infection and Covid-19 topics related to hospital interiors.

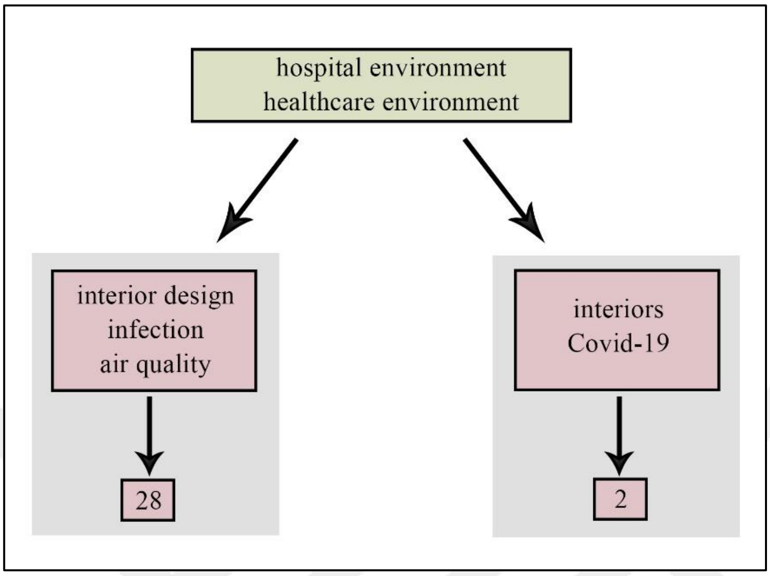


Figure 2.5. Number of Papers in the Context of Infection and Covid-19

2.3. Information Extraction

80 studies in indexed related to hospital design were read. 16 of these studies were about *indoor air quality of hospital interiors*, 23 of these were about *healthcare facilities interior*, 40 of these were about *hospital interior and layout* and 1 of the study was about *transformation of hospital spaces after Covid-19 pandemic*.

2.3.1. Air Quality

Natural ventilation is recommended to reduce the risk of airborne infection spread in healthcare facilities by WHO (Salonen et al., 2013). However, it is also stated that natural ventilation does not allow negative pressure in isolation areas. H13 and H14 HEPA filters (World Health Organization, 2021) and MERV 8, MERV 14 and MERV 17 (Salonen et al., 2013) are recommended for mechanical ventilation in healthcare facilities. ANSI/ASHRAE/ASHE Standard 170 recommends at least 20 total air changes per hour and at least 4 external air changes per hour in operating rooms (Spagnolo et al., 2013), at least 12 air changes per hour in Airborne Infection Isolation Rooms (AIIR) (Lee & Jeong, 2020), and at least 6 air changes per hour in patient rooms (Centers for Disease Control and Prevention, 2019). In addition, it is stated that the air comes from air ventilation and air-conditioning must not be recirculated and should be filtered (Evren, 2021; O’Connell & Humphreys, 2000).

Studies show that preference of high air change rate within spaces and the low location of return openings can reduce exposure to infection (Nielsen et al., 2010). For effective removal of pollutant in the isolation room of a hospital assert, low-level extraction is better than ceiling level (Cheong & Phua, 2006). For operating theatre rooms, the use of laminar airflow (LAF) rather than turbulent flow is suggested to prevent infection (Spagnolo et al., 2013).

According to the American Journal of Infection Control, Infection Preventionists (IPs) have an important role to prevent infections in healthcare facilities, to make collaboration with them is essential for protection from infection. For instance, as they indicate, patients must not be transported with other patients in the elevator (De Amaya, 2015).

2.3.2. Layout

It is expressed that layout, materials, equipment, and furnishings play a key role in facilitating or preventing transmission of pathogens (Zimring et al., 2013).

Separating hospital into zones is suggested to get under control infection. In order to inhibit infection and control airflow, a conducted study during Covid-19 pandemic in China suggests separating hospitals into three zones (clean zone, semi-contaminated zone, contaminated zone), and three channels (medical personnel channel, patient channel and simple delivery channel) (Zhang et al., 2020). Another suggestion for separating hospitals into zones is specified as, protective zone (reception, waiting area, trolley bay, changing room), clean zone (pre-op room and recovery room, plaster room, staff room, store), sterile zone (operating suite, scrub room, anesthesia induction room and set up room), disposal zone (sluice dirty utility and disposal corridor) (Chandrashekhar et al., 2005).

It is stated that there are 14 important criteria for layout design. These are, flexibility, environmental communication, information communication, monitoring communication, facility flow, material flow, cooperative use of human resources, space use, effective monitoring, accessibility, maintenance, proper decoration, material handling cost, shape ratio (Abbasi et al., 2017). Rather than ward size, open spaces defined for transition are stated more important to health workers (Pachilova & Sailer, 2020).

The results of a conducted research show that the centralized hospital layout design was found more effective on teamwork and patient care owing to the decreased walking distances than the decentralized layout (Fay et al., 2017). In addition, it is stated that minimizing the distance between patient room and nurse station can improve health outcomes (Fay et al., 2017; Gharaveis et al., 2019; MacAllister et al., 2016), and providing visual contact between rooms and nursing stations has importance for proper layout (Quan et al., 2017).

2.3.3. Interior Design

In order to prevent infection, it is suggested to minimize edges and corners, provide separated dirty and clean pathways, easily cleanable surfaces and areas, and safety patient flow (Spagnolo et al., 2013).

When it comes to patient satisfaction, interior elements such as, signs, maps, artwork, display boards, information counters, structural elements, furniture can be defined for wayfinding of visitors in healthcare environments (Pati et al., 2015). Besides, it is stated that closeness to nature and exterior spaces, having personal space, well-designed interiors, and provided leisure facilities positively affect patient wellbeing by increasing the satisfaction level of patients (Timmermann & Uhrenfeldt, 2014). Also, the use of an adequate number of seating elements for waiting area, and sufficient lighting are quite important for user satisfaction (Samah et al., 2012).

2.4. Standard Reviews

After the literature review, the standards were examined to determine the criteria to be taken into account for layout and ventilation when making in-hospital transformation, especially for Airborne Infection Isolation Rooms (AIIRs).

The criteria derived from the examined standards are listed below:

According to DIN 1946-4:2008,

- H13 HEPA filter should be placed in accordance with EN 1822-1 in the places required for suction of the isolation rooms,

- In order to prevent infection in the necessary areas, it is recommended to use an air lock at the entrances of corridors (İşbilen, 2013).

According to ASHRAE Standard 170-2017,

- If 100% fresh air cannot be delivered directly in the rooms converted from the standard patient's room, recirculation of air can still be provided with the air returned out from the room passes through the HEPA filter,
- All air coming from the isolation rooms must be discharged directly to the outside,
- Exhaust air grills in the patient room should be placed directly above the patient bed, on the ceiling, or on the wall near the headboard (ASHRAE, 2017).

According to Turkish Ministry of Health,

- Isolation rooms should be at least 15 m2,
- The toilet should be at least 6 m2,
- Each of the isolation rooms should have an area for hand washing, dressing and placing clean/dirty materials just outside the entrance door of the room. Entree area should be at least 4 m2,
- Minimum total air change per hour should be 12. The air must be discharged directly. However, air can be recirculated in rooms where HEPA filters are used,
- Air-transmitted infection isolation rooms should have normal patient care conditions during periods that do not require isolation measures (The Ministry of Health of Turkey, 2010).

According to the Phoenix Controls Healthcare Sourcebook 5th edition,

- Isolation rooms are required to be negatively pressurized to prevent airborne infection from polluting adjacent corridors and other rooms, protecting personnel and uninfected patients from infectious diseases,
- Isolation rooms have two basic designs; a room with an entree or a room without an entree. An entree is a space between the patient room and the corridor. Placing an entree is required in case an immunocompromised patient also needs protection against airborne infection since the entree provides extra protection against infection when

doors are opened and closed. Figure 2.6 and 2.7 show the options for isolation room with entree or without entree,

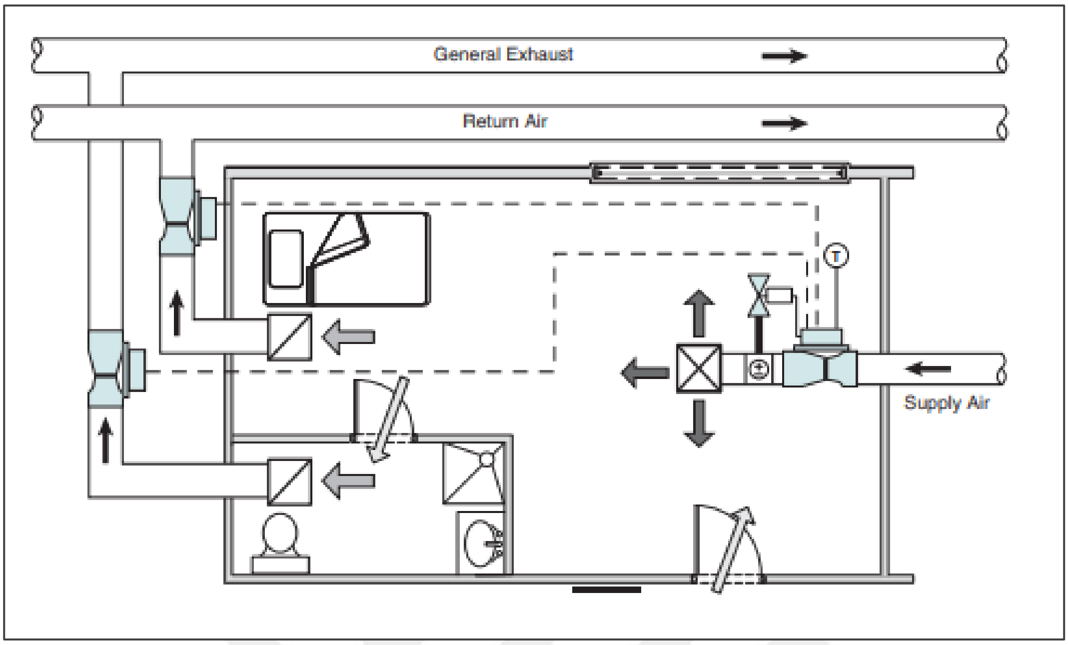


Figure 2.6. A Patient Room Designed for Pandemic (Phoenix Controls, 1999)

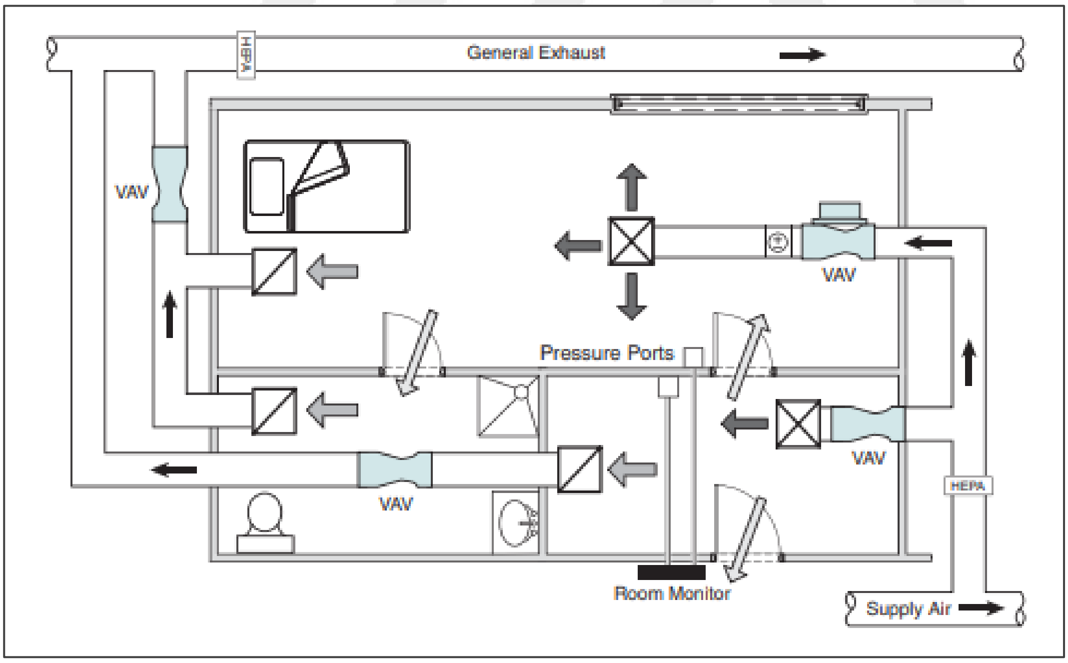


Figure 2.7. An Isolation Room with an Entree which has Negative Pressure (Phoenix Controls, 1999)

Figure 2.6 and 2.7 also show supply air and return air. Supply air is placed at the center of the both rooms. Figure 2.6 shows the room that has return air while the room shown in Figure 2.7 does not use filter in return air channels. This room is only given fresh air, and dirty air is sent to the exhaust while the room shown in Figure 2.6 uses both fresh air and return air.

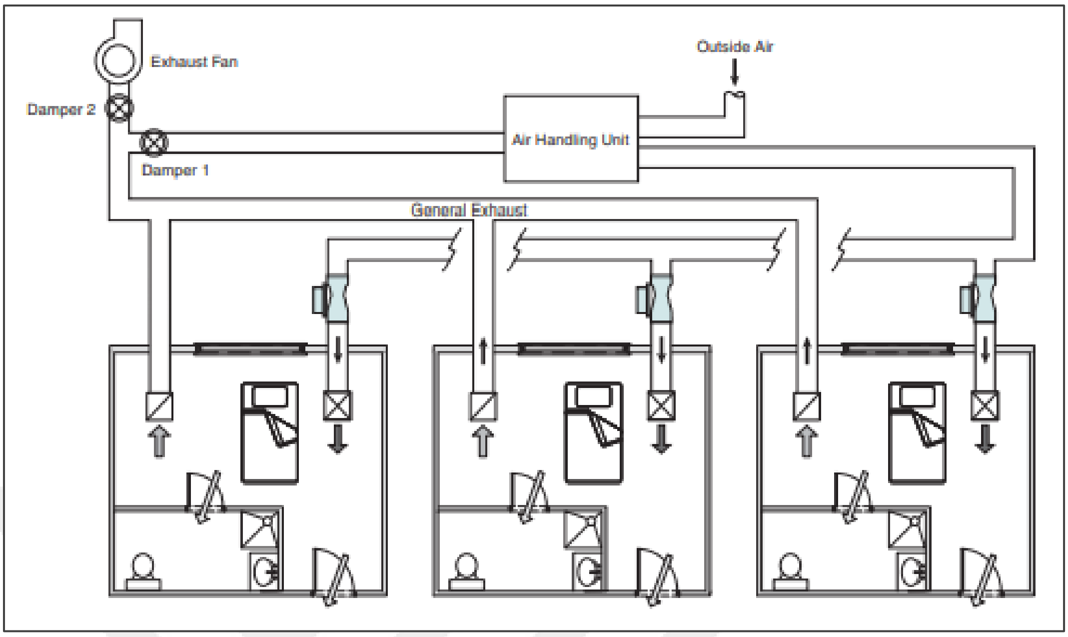


Figure 2.8. The Use of Valves (Phoenix Controls, 1999)

Figure 2.8 shows the use of valves for the rooms. Valves are used to transfer air and return %100 of air (Phoenix Controls, 1999).

2.5. Results and Future Studies

As a result of the literature review, it is determined that the criteria should be applied in the hospitals to prevent infection are effective layout, zoning interiors properly for transformation, effective filtration, and healthy ventilation. With this information, the efficiency on preventing infection of the modular hospital designs proposed during Covid-19 pandemic will be examined. Then, this information will be taken into account to create transformation proposals for two different case study hospitals in Turkey for Covid-19 isolation areas.

CHAPTER 3
MODULAR HOSPITAL PROPOSALS

As Covid-19 is a disease affecting the world, interest in modular hospitals in many countries has increased in order to prevent the spread of the virus and ensure an effective treatment process. In this direction, architects and engineers worked on the development of modular hospitals. Some modular systems are derived from shipping containers while some of them are made of steel, aluminum constructions or tent structures. Some are designed to be near or adjacent to the hospital, while others are designed to be located on a field independent from hospital area. In this chapter, modular hospital proposals from all around the world (AGX, 2020; Alter, 2020; Architizer, n.d.; CURApods, n.d.; Evolve Technologies Corporation, n.d.; Frida, 2020; Golden Hour MMH, n.d.; HAHA Architects Group, n.d.; Harrouk, 2020; HGA, n.d.; Losberger de Boer, 2020; National Cheng Kung University (NCKU), 2020; !NFEKT, 2020; QurE, 2020; Ravenscroft, 2020a, 2020b; VHL Architecture & Danang Architecture University, 2020) proposed during Covid-19 pandemic were examined according to the information obtained through websites in November 2020. All proposals aim to prevent the spread of Covid-19 and provide a healing environment.

3.1. Modular Hospital Proposals

In order to understand the approach for designing modular hospital layout and filtration, 9 proposed hospitals for Covid-19 pandemic were examined. These are STAAT Mod Units from the USA, Mobile Modular Hospital from Esthonia, CURA Pods from Italy, Losberger Emergency Modular Hospital System from the USA, Emergency Modular Hospital from the USA, Field Rescue Center from Poland, Modular Hospital Ward Prototype from Taiwan, CNC-Medical Emergency Module from Taiwan, Covid-19 Hospital Ship from UK. These proposals were analyzed in detail, respectively. Location of filter types, filtration system, direction of pressure and the used materials are factors to be analyzed and have great importance for contagious healthcare environments. In order to assess suitability of modules, these criteria will be considered.

Common features to ensure suitable pandemic environment in hospitals are considered in the design of new modular proposals: to minimize edges and corners, provide separated dirty and clean pathways, easily cleanable surfaces and areas, and safety patient flow (Spagnolo et al., 2013), providing effective spatial layout in hospital interiors (Fay et al., 2017; Gharaveis et al., 2019; MacAllister et al., 2016) with right zoning air system. Modular units either have self-sustaining air ventilation or combined air ventilation where mostly they have HEPA in air-inlet and MERV in air-outlet ideally.

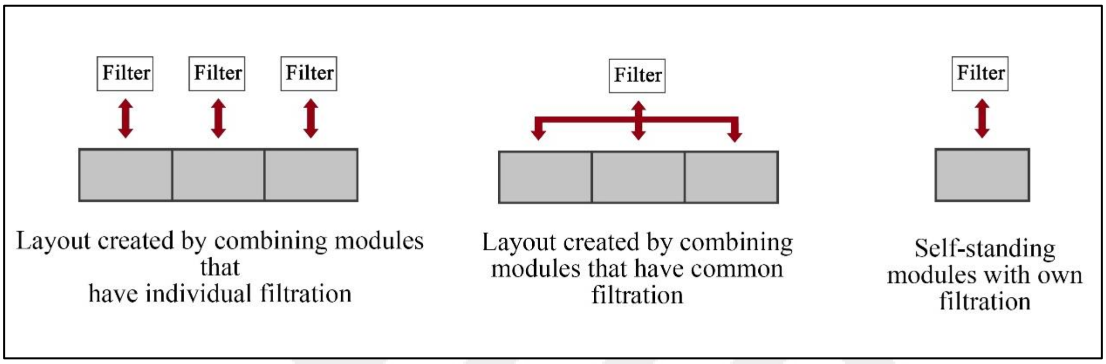


Figure 3.1. Categorization of the Analyzed Hospitals

According to the filtration and layout features of the analyzed 9 modular hospitals, they categorized into three as is seen in Figure 3.1. These are layout created by combining modules that have individual filtration, layout created by combining modules that have common filtration, and self-standing modules with own filtration, respectively.

3.1.1. Layout Created by Combining Modules that Have Individual Filtration

In this section, combined modules with individual filtration system are analyzed. Layouts of the module combinations are also part of the analysis and believe to lead us for future design / planning alternatives. In this context, module layout, pathways, entrances, air filtration, filter type, location of filter system, pressure direction, ventilation isolation are analyzed for each hospital. STAAT Mod Units, CURA Pods, Losberger Emergency Modular Hospital System and Covid-19 Hospital Ship are examined in detail, respectively.

3.1.1.1. Staat Mod Units

STAAT Mod Units were designed by HGA in USA in order to prevent infection, provide effective treatment for patients and safety environments for patients and healthcare workers during covid-19 pandemic. It is stated that while designing these units, the recommendations of CDC (Centers for Disease Control and Prevention) for Airborne Infection Isolation rooms were considered (HGA, n.d.). It is stated that the first STAAT Mod Units was built in Fort Washington, Maryland (Buckley, 2020).

Figure 3.2. STAAT Mod Units Self-sufficient View (HGA, n.d.)

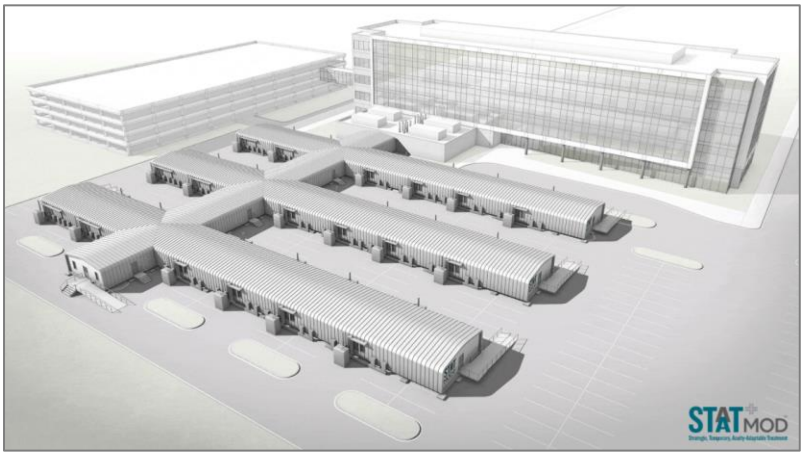


Figure 3.3. STAAT Mod Units Adjacent View (HGA, n.d.)

Figure 3.2 and Figure 3.3 show the installed units. It is suitable to use as either adjacent to existing building or self-sufficient. The capacity can be enlarged with end-to-end addition (HGA, n.d.). It is understood that the layout of STAAT Mod Units was designed to provide entrance from outside for each module. This is the right approach in terms of preventing infection and virus transmission. Figure 3.4 shows the layout of

STAAT Mod Units. It is seen that mid modules 1-2-3-4-5 are used only by staff and, patient rooms are located at the sides of the middle modules.

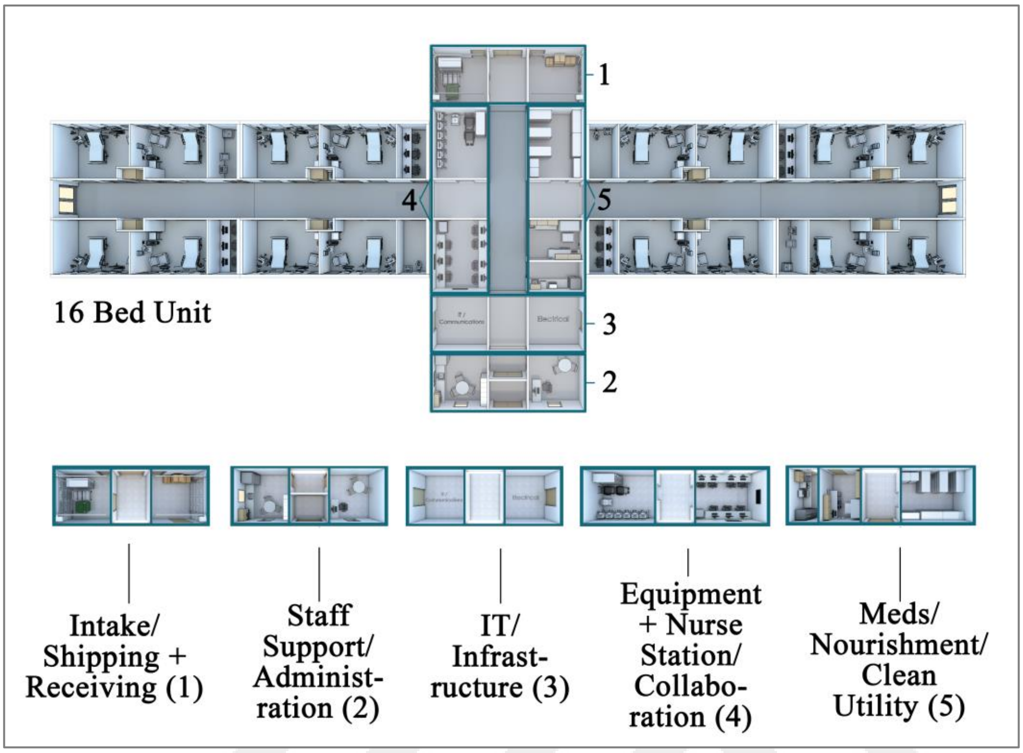


Figure 3.4. STAAT Mod Units Layout Design (HGA, n.d.) (Redrawn from info)

Figure 3.4 shows the layout of STAAT Mod Units. It is seen that mid modules 1-2-3-4-5 are used only by staff and, patient rooms are located at the sides of the middle modules.

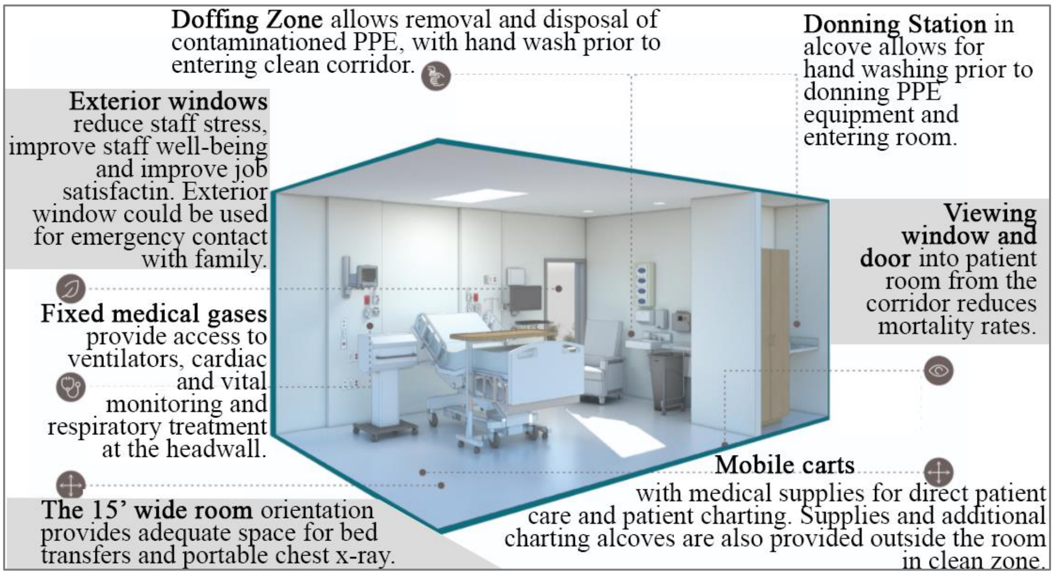


Figure 3.5. STAAT Mod Unit Interior View Zoning (HGA, n.d.) (Redrawn from info)

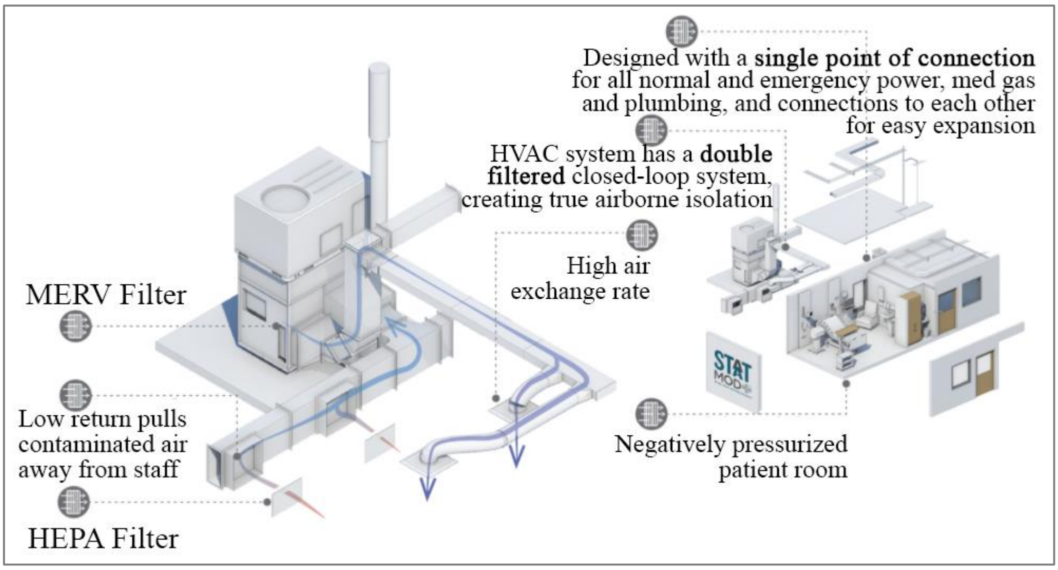


Figure 3.6. HVAC System of STAAT Mod Units' HVAC Design (HGA, n.d.) (Redrawn from info)

Figure 3.5 shows the interior view of the unit by zoning and placement of the equipment accordingly. Figure 3.6 shows the HVAC system of isolation rooms in detail with filters and pressurization methods. It is seen that double-filtered systems are used. Both HEPA in inlet and MERV filters at the outlet with a closed-loop HVAC system are preferred. Each module has own filter and negative pressure is applied in interiors. According to the given figures, it is seen that HVAC unit built next to the module at the ground level. It can be inferred that the air inlet mechanism is placed at ceiling level while outlet mechanism is placed at the ground level for each module. It is the analyzed as the right precaution to prevent cross-infection.

3.1.1.2. CURA Pods

CURA Pods were designed as an intensive care unit by Italian architects Carlo Ratti and Italo Rota during Covid-19 pandemic, and installed at a hospital in Turin. It is transformed from shipping container (Ravenscroft, 2020a).

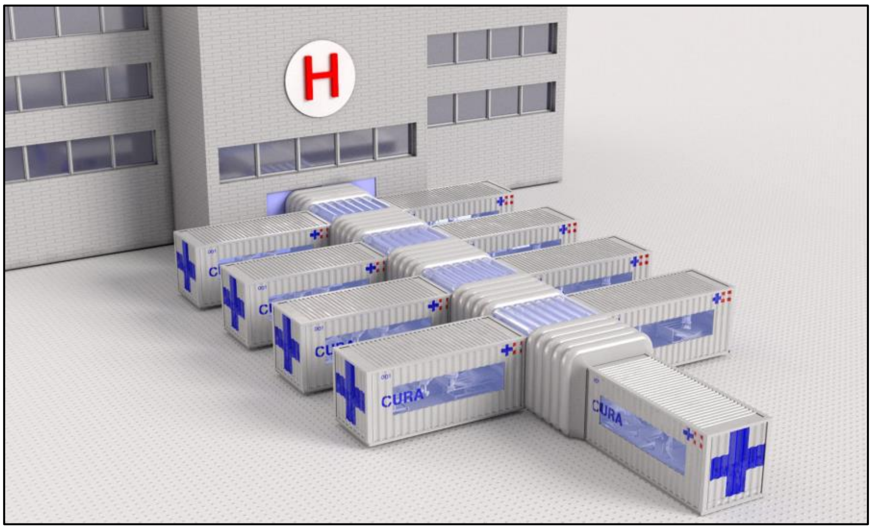


Figure 3.7. CURA Pods Adjacent Option (Ravenscroft, 2020a)

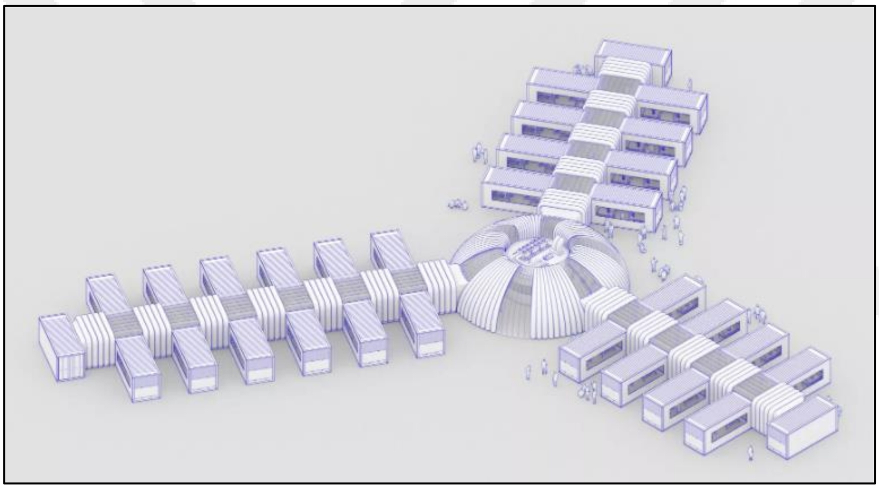


Figure 3.8. CURA Pods Self-sufficient Option (Ravenscroft, 2020a)

Figure 3.7 and Figure 3.8 show the placement of CURA Pods. They can be installed both adjacent to the hospital, and as self-standing field hospitals (Alter, 2020). CURA Pod can be easily installed and combined with quickly assembled hospital tents. It can be used as single or combined with inflatable tunnels (Ravenscroft, 2020a). As can be seen from Figure 3.7, the modules are not given separate access, and the modules use a common corridor. There is no given information about separating clean and dirty pathways. If they are not separated, the preference of the common corridor for modules would have a great potential to spread infection.

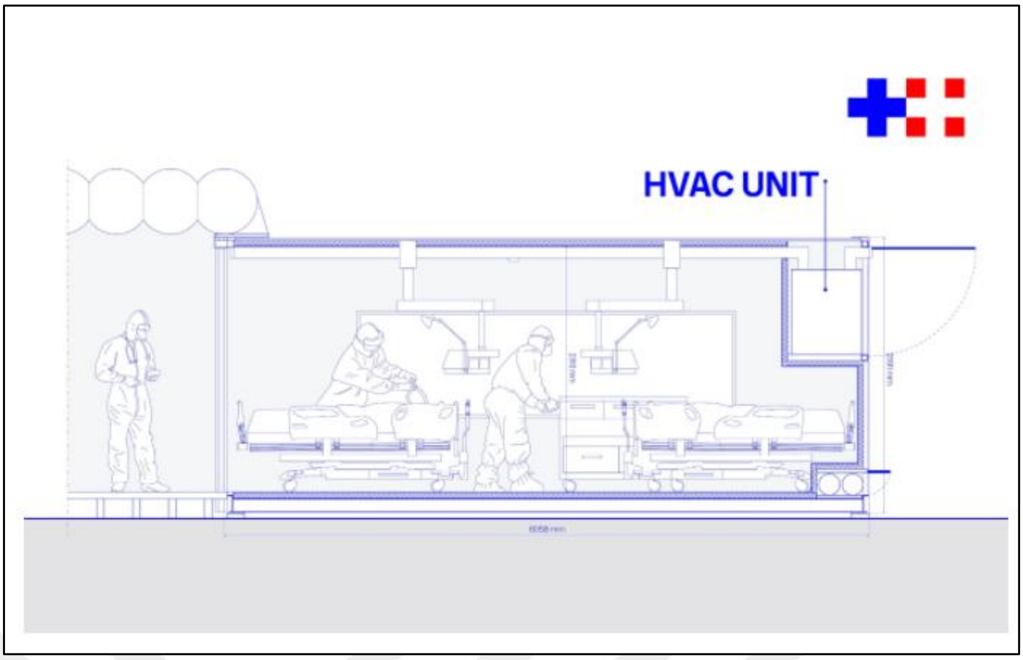


Figure 3.9. HVAC Unit Inside the Pod (CURApods, n.d.)

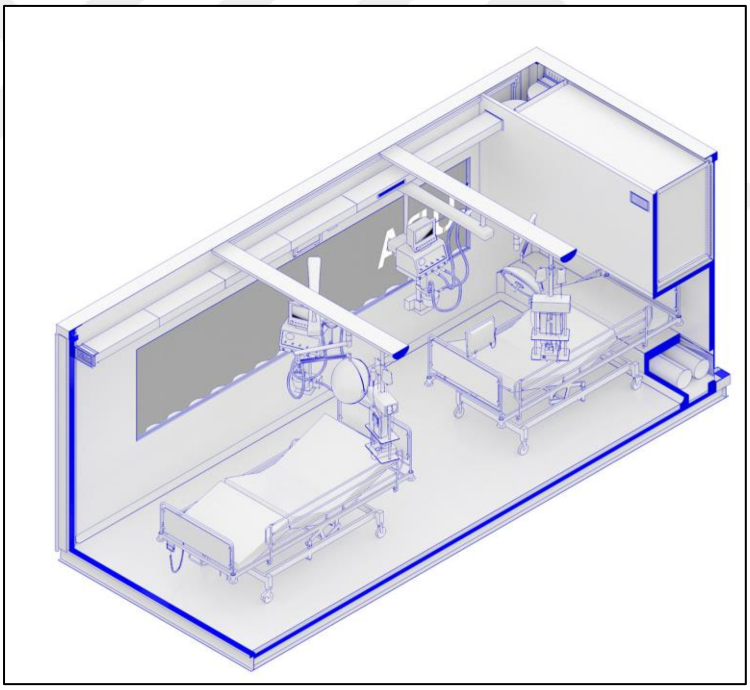


Figure 3.10. Axonometric Section View of the CURA Pods (CURApods, n.d.)

Figure 3.9 and Figure 3.10 show the HVAC unit embedded to the pod's wall. It is stated that each module uses its own HVAC unit. In addition, HEPA filter is preferred for the filtration at the inlet side. It is provided at least 12 air changes per hour, and there is negative pressure inside each pod (Ravenscroft, 2020a). These approaches are identical with set standards and other given example to prevent infection. According to mechanical analysis, it is observed from Figure 3.9 that the air inlet and outlet are placed at the ceiling level. However, it is expressed that low-level extraction is better than ceiling level (Cheong & Phua, 2006).

Besides, there is no information found about interior materials used. It is believed the materials will follow the hospital design standards set.

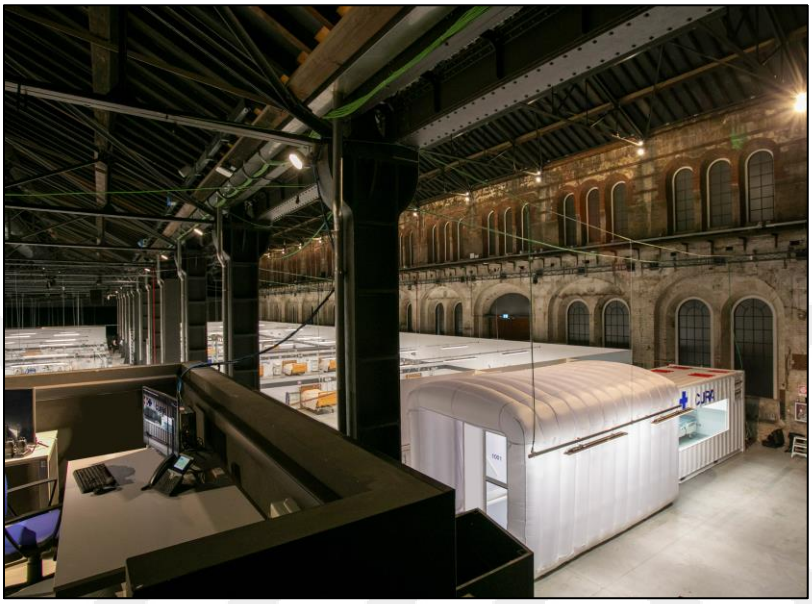


Figure 3.11. Installation of the CURA Pods (Ravenscroft, 2020a)

Figure 3.12. CURA Pods with Transition Module (Ravenscroft, 2020a)

Figure 3.11 and Figure 3.12 show the installation of the CURA Pod at a temporary hospital. It is built inside the Officine Grandi Riparazioni in Turin (Ravenscroft, 2020a), and this can be problematic in terms of interior air quality within the complex if the return air is not filtered by MERV filters and returned to interior space of the complex. No info related found.

3.1.1.3. Losberger Emergency Modular Hospital System

Evolve Emergency is a firm of the USA origin that specialized on designing technological products (Evolve Technologies Corporation, n.d.). Losberger de Boer produces Losberger Shelters and provides quarantine tents, triage tents, wards and morgues (Losberger de Boer, 2020). With the collaboration of Losberger de Boer and Evolve Emergency, a modular hospital system for the state of emergency is offered.

Figure 3.13. Losberger Emergency Modular Hospital Placement (Evolve Technologies Corporation, n.d.)

Figure 3.13 shows that according to the hospital placement, all modules have their own entrance, and the middle wards also serve as corridors. There is no given information about separation of clean and dirty pathways for corridor. It they are not separated, this situation may cause spreading of infection.

Figure 3.14. Losberger Emergency Modular Hospital System Exterior and Interior View (Evolve Technologies Corporation, n.d.)

Figure 3.14 shows the exterior and interior of the module. PVC coated fabric is preferred for shelters, and the use of hard flooring is offered optionally (Evolve

Technologies Corporation, n.d.). Preferring hard floor can help to sanitize ground easier.

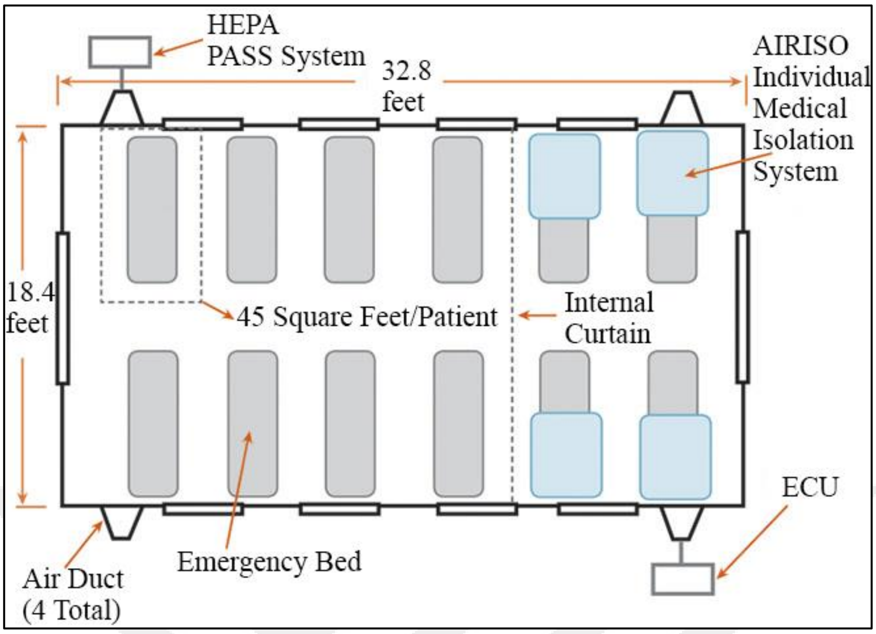


Figure 3.15. Layout of a Module Interior (Evolve Technologies Corporation, n.d.) (Redrawn from info)

Figure 3.15 shows the placement of 12 beds in a module. It is seen that HEPA filter is next to the module, and UVC irradiation and automatic pressure control system are preferred in HVAC system. Isolation in modules is provided with the use of internal curtains. It is stated that the use of individual HEPA filtration enables to maximize bed space for shelters provided (Evolve Technologies Corporation, n.d.).

3.1.1.4. Covid-19 Hospital Ship

Covid-19 Hospital Ship modular hospital is the other proposal against Covid-19. Weston Williamson + Partners from UK proposed the use of ship as a modular hospital. In countries that do not have easy access to clean water, where hygiene and social distance are difficult to implement, such as Africa, India, it was thought that the use of the ship as a hospital would eliminate these problems (Iype, 2020).

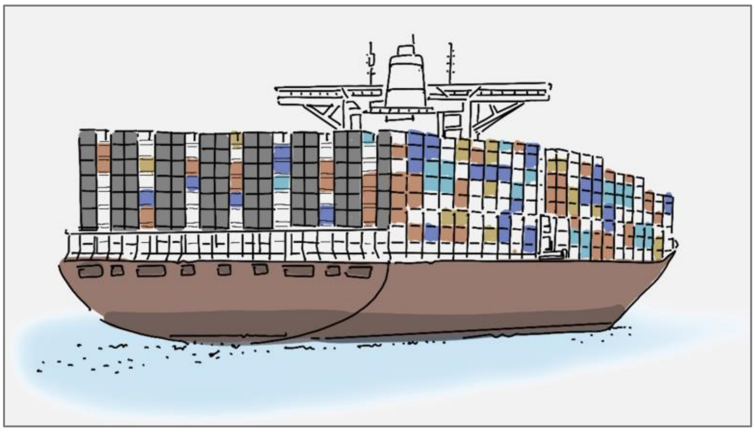


Figure 3.16. Covid-19 Hospital Ship Exterior View Proposal (Iype, 2020)

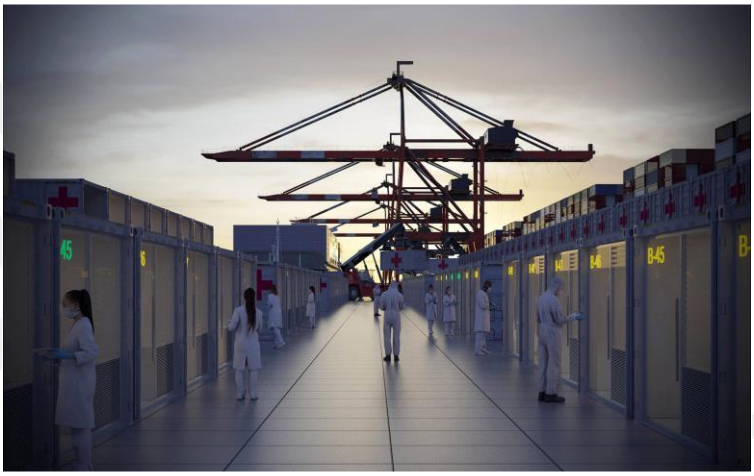


Figure 3.17. Covid-19 Hospital Ship Modules Placement Proposal (Iype, 2020)

Figure 3.16 and Figure 3.17 show the design proposal for hospital ship. It is thought 2000 beds per ship. The use of lift/elevator between floors, and the use of crane use for easy construction of container modules are suggested (Iype, 2020). It is seen that clean and dirty pathways for lift/elevator are not separated. If necessary precautions are not taken, spread of infection via these vertical elements can not be prevented.

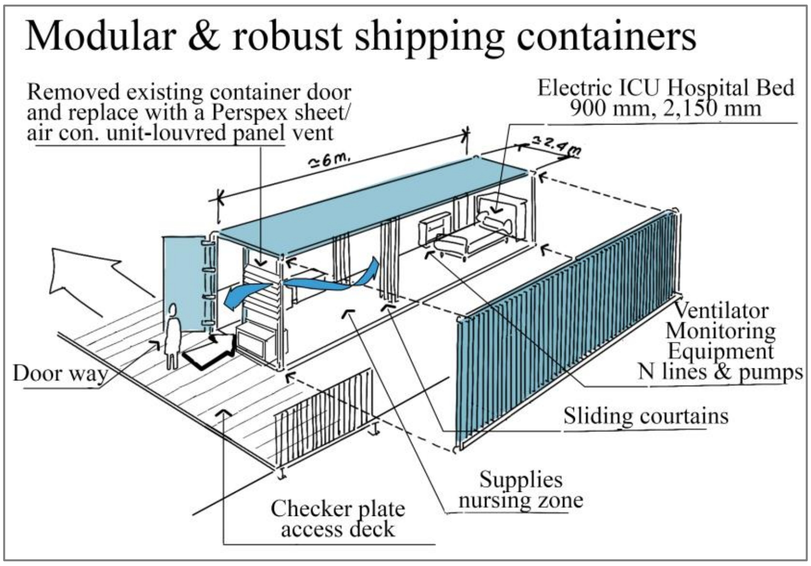


Figure 3.18. Covid-19 Hospital Ship Module Components (Iype, 2020) (Redrawn from info)

According to the Figure 3.18, existing container door will be replaced with a perspex sheet, and air conditioning unit and louvered panel will be located (Iype, 2020). Air conditioning is placed to the ground. It is a more preferable approach to prevent spread of infection. Both natural ventilation and mechanical ventilation are taken into consideration. However, there is no information about filter type that can be used for modules.

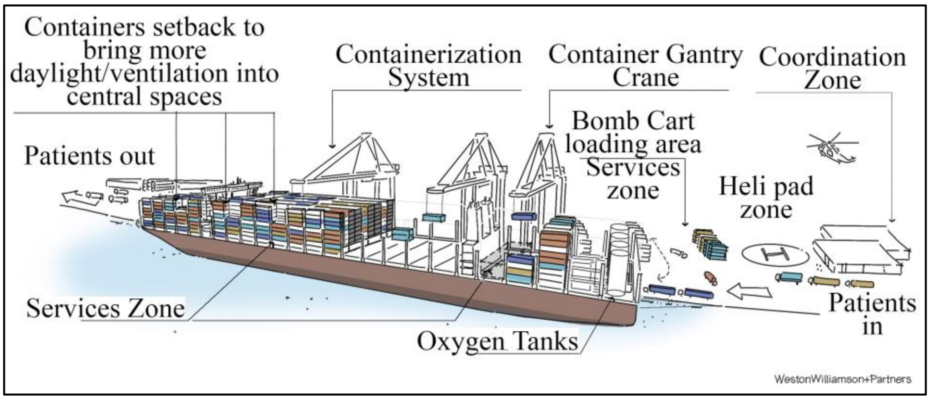


Figure 3.19. Covid-19 Hospital Ship Zoning Proposal (Iype, 2020) (Redrawn from info)

It is understood from Figure 3.19 that the hospital ship is separated into zones. Containers are also separated as services zone and supplies nursing zone. Sliding curtains are used to separate. However, the use of air tight door rather than sliding curtains can be more sufficient to prevent infection.

3.1.2. Layout Created by Combining Modules that Have Common Filtration

In this section, combined modules with common filtration system are analyzed. Layouts of the module combinations are also part of the analysis and believe to lead us for future design/ planning alternatives. In this context, module layout, pathways, entrances, air filtration, filter type, location of filter system, pressure direction, ventilation isolation are analyzed for each hospital. Emergency Modular Hospital, Field Rescue Center and Mobile Modular Hospital are examined in detail, respectively.

3.1.2.1. Emergency Modular Hospital

MMW Architects designed the Emergency Modular Hospital to ensure protection against covid-19 in USA. This proposal is not only developed against pandemic, but also to provide effective layout. By means of horseshoe-shaped plan, patient can be directly transported into isolation. It is claimed that for any future crisis, the current layout is open to adaptation and different scenarios. The construction is made of recycled shipping-containers (steel) and inflatable fabrics for circulation areas in between in order to prevent air contamination (Architizer, n.d.).

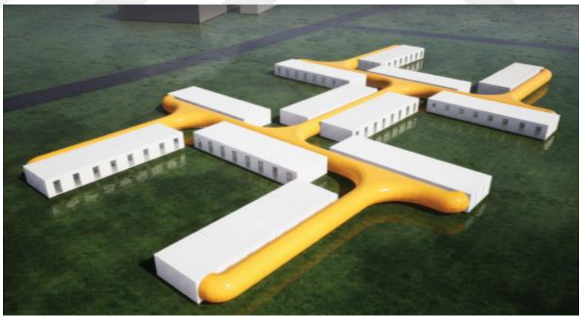


Figure 3.20. Emergency Modular Hospital Exterior View (Architizer, n.d.)

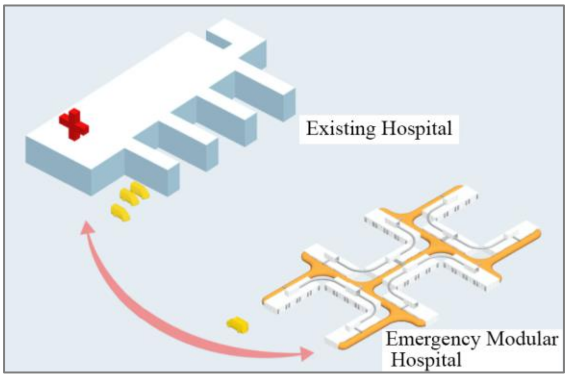


Figure 3.21. Relation of Emergency Modular Hospital with Existing Hospital (Architizer, n.d.)

Figure 3.20 and Figure 3.21 show the exterior view of the Emergency Modular Hospital. Emergency Modular Hospital is located to near of the existing hospital. Yellow areas defined in the figures are the inflated corridor spaces between rooms and modules.

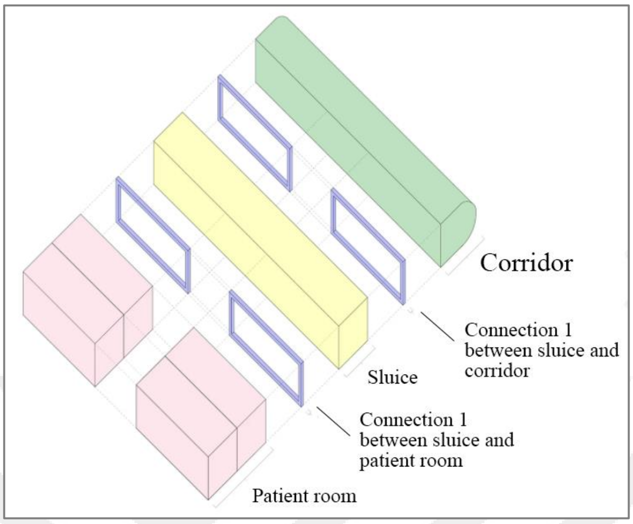


Figure 3.22. Schematic View of a Module (Architizer, n.d.) (Redrawn from info)

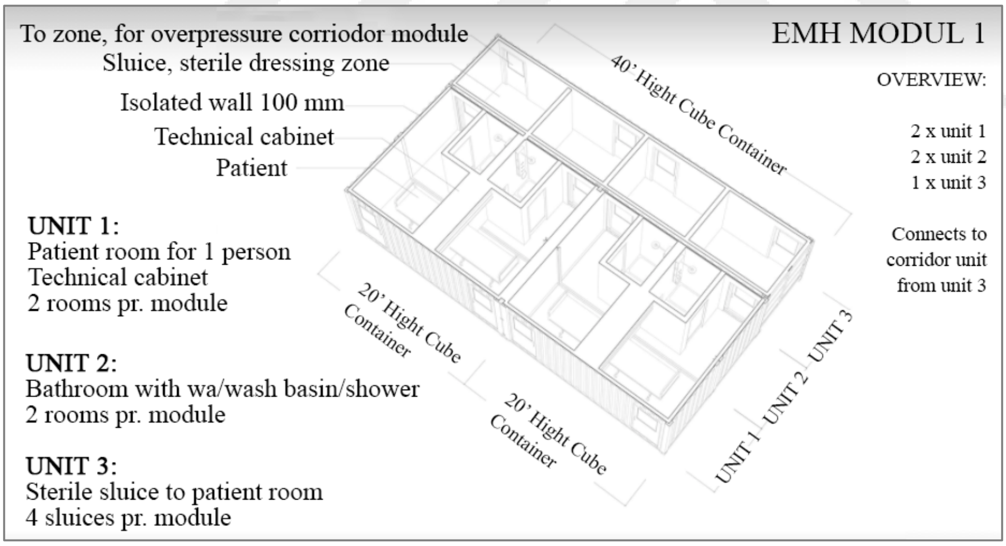


Figure 3.23. Axonometric View of Module (Architizer, n.d.) (Redrawn from info)

Figure 3.22 and Figure 3.23 give information about module interior and layout. There is no information about separation of corridors as clean and dirty pathways, but there is a sluice zone between each patient room and corridor. It provides disposal of human waste, so the placement of sluice zone in modular hospital layout is a positive approach to prevent infection and this area can be stated as dirty/buffer zone before entering the clean corridor zone.

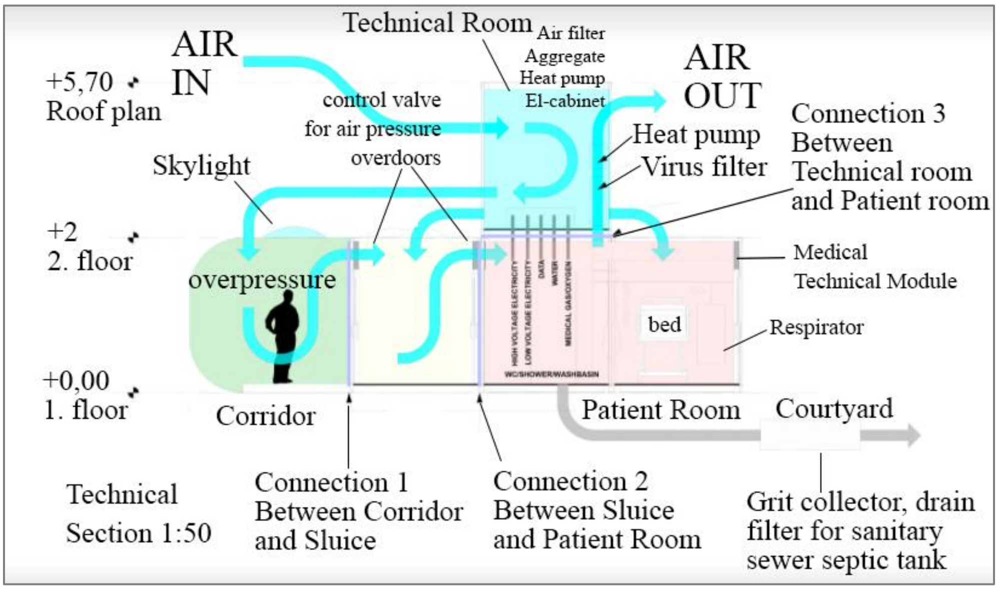


Figure 3.24. Technical Section of the Module (Architizer, n.d.) (Redrawn from info)

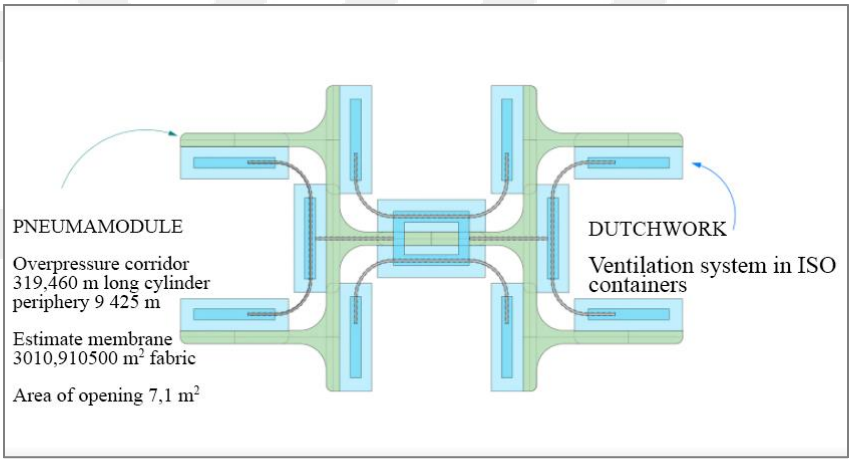


Figure 3.25. Ventilation System of Modules (Architizer, n.d.)

Figure 3.24 and Figure 3.25 show the filtration and ventilation system of modules. Because it is at the concept stage, there was no finding about the type of filtering. It is understood from Figure 3.24 that the filter is located on top of the module, and air inlet and outlet are placed at the ceiling level. However, it is stated that in order to prevent infection, the preference of low-level extraction is accepted better than ceiling level (Cheong & Phua, 2006). Unfortunately, this hospital proposes filtration that does not meet with suggestions.

According to the Figure 3.25, in this horseshoe layout, the ventilation of each 3-module is combined in a single center, and thus center consists of 4 groups. Air gets distributed throughout every module via dutchwork. Since dutchwork is a self-contained ventilation system, the ventilation entrances and exits must be controlled, otherwise it will be inevitable that the cause of the virus will spread.

3.1.2.2. Field Rescue Center

Field Rescue Center is a proposal of HAHA Architects Group from Poland. This modular hospital is designed to be used during crisis such as epidemic, pandemic, natural disaster, refugee crisis etc. Figure 3.26 and Figure 3.27 show the placement options of the Field Rescue Center. Thanks to the self- sustainability characteristic, modules can be built either next to the hospital, near or far from hospital. Besides, modules can be used as single or united (HAHA Architects Group, n.d.). It is built to provide operating rooms during emergency. Therefore, there is no defined quarantine zone for patients.

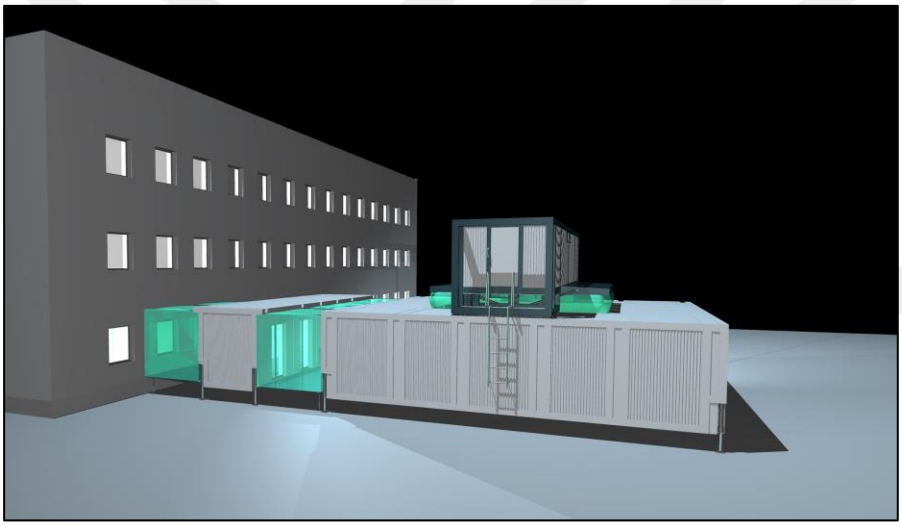


Figure 3.26. Field Rescue Center Adjacent Option (HAHA Architects Group, n.d.)

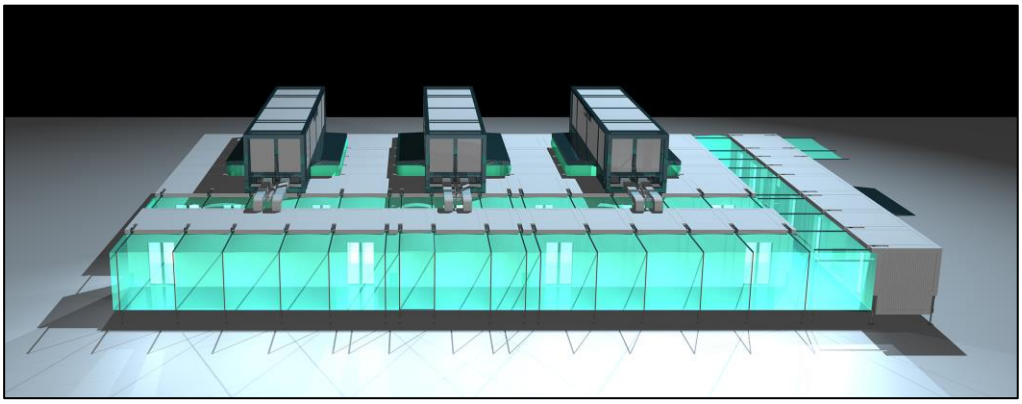


Figure 3.27. Field Rescue Center Self-sufficient Option (HAHA Architects Group, n.d.)

Green ones refer to EPDM (Ethylene Propylene Diene Monomer) membrane structure. TEU containers are compound with membranes, and membranes are used through corridors (HAHA Architects Group, n.d.). This area is believed to state as the clean operating zone and adjacent hospital is converted according to pandemic situation in this specific case.

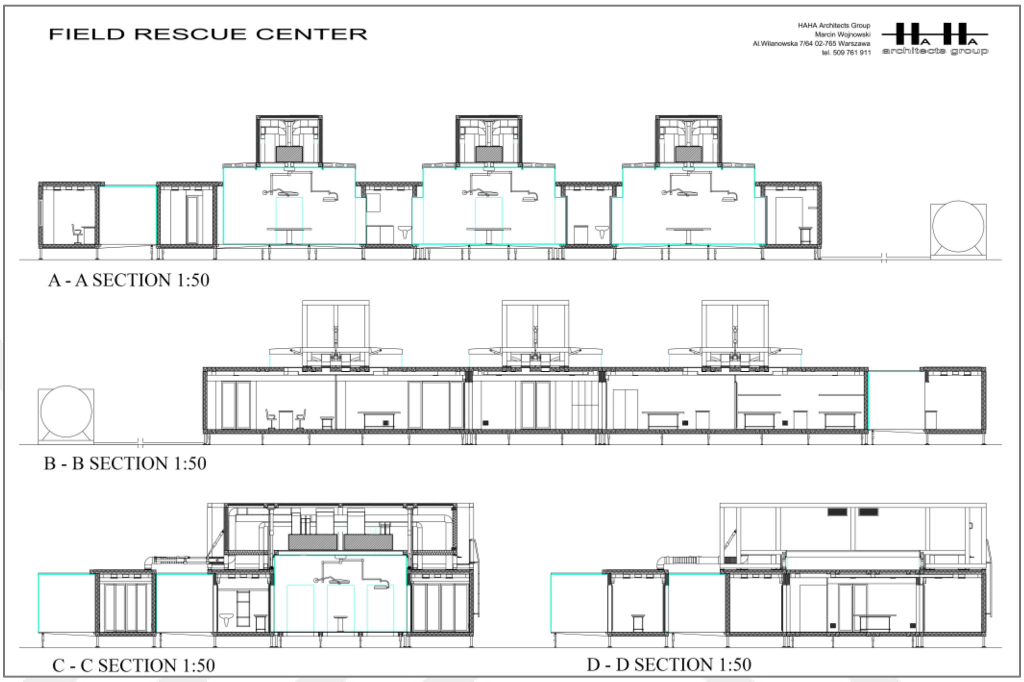


Figure 3.28. Field Rescue Center Section Drawings of Modules (HAHA Architects Group, n.d.) (Redrawn from info)

Figure 3.28 shows the sections of modules and air conditionings. There is no given information about filter type and pressure direction. It is understood that inlet and outlets of mechanical systems are placed on top of the modules. HVAC units of each operating room are separated. This is a correct approach to prevent different infections.

3.1.2.3. Mobile Modular Hospital

Golden Hour MMH is a firm of Esthonia origin that produces modular hospitals according to needs. Birth, dental, surgical, gynecological, dermatological, general treatment are some function configurations that have defined modules previously. HEPA filters and the use of negative pressure modules are preferred for the hospital adapted for Covid-19 (Golden Hour MMH, n.d.). In order to prevent infection, this is the correct approach. However, there is no given information about interior materials of modules.

Figure 3.29. Mobile Modular Hospital Exterior View (Golden Hour MMH, n.d.)

Figure 3.30. Mobile Modular Hospital Interior View (Golden Hour MMH, n.d.)

Figure 3.29 and Figure 3.30 show the view of Mobile Modular Hospital. It is located as self-sufficient on the land.

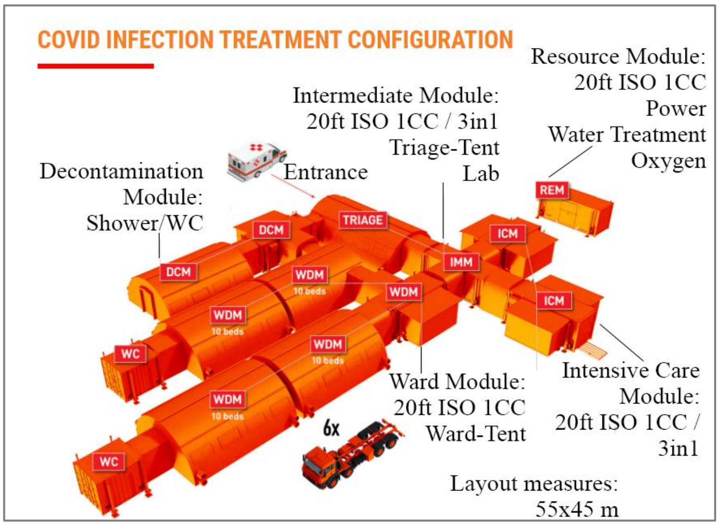


Figure 3.31. Covid infection treatment configuration (Golden Hour MMH, n.d.) (Redrawn from info)

Figure 3.31 shows the defined configuration for treatment of Covid-19 infection. According to the configurations, it is understood that there are two main differences between other configurations and Covid-19 infection treatment configuration. These are the increased bed numbers and the use of DCM (Decontamination module). DCM is only included in Covid-19 infection mobile modular hospital. As can be seen from Figure 3.29 and Figure 3.31, not all modules were given separate entrance. This can affect internal circulation and cause cross-infection. Intensive care modules have separate exit for patient loading. HEPA filter is included in operating room modules of the configurations (Golden Hour MMH, n.d.), however there is no given information about whether it is in the decontamination module.

3.1.3. Self-Standing Modules with Own Filtration

In this section, self-standing modules with own filtration system are analyzed. Layouts of the modules is part of the analysis and believe to lead us for future design / planning alternatives. In this context, module layout, pathways, entrances, air filtration, filter type, location of filter system, pressure direction, ventilation isolation are analyzed for each hospital. Modular Hospital Ward Prototype and QurE Circular Negative Pressure Quarantine Unit are examined in detail, respectively.

3.1.3.1. Modular Hospital Ward Prototype

In order to control infection and provide treatment during pandemic, a firm of Taiwan origin Miniwiz proposed the use of Modular Hospital Ward Prototype and built its first module at Taipei Hospital. Miniwiz is a firm that aims to show how post-consumer waste could be recycled into useful products, so recycled materials such as aluminum panels, aluminum cans and polyethylene terephthalate (PET) are used in this hospital. Walls are made of recycled anti-viral and bacterial panels. With the help of the anti-bacterial coating that provides ultraviolet self-cleaning system, 99.9 percent of bacteria can be reduced. In addition, wall panels are designed with curved corners for easy cleaning (Ravenscroft, 2020b).

Figure 3.32. Modular Hospital Ward Prototype Interior View (Ravenscroft, 2020b)

Figure 3.32 shows the interior of Hospital Ward Prototype. It is seen that two patient beds are located in the module, and beds are separated with the use of curtain.

Figure 3.33. Modular Hospital Ward Prototype Exterior View (Ravenscroft, 2020b)

According to the exterior view of the module as seen in Figure 3.33, mechanical area is placed next to the modules,. Each module has its own inlet mechanism placed at ceiling level and outlet mechanism placed at ground level. It is a correct approach to prevent infection among modules. However, there is no given information about preferred filter type. Besides, it is stated that negative pressure is preferred to prevent spread of virus (Ravenscroft, 2020b). All decisions given for this specific design example given about cleaning and ventilation are contemplated to prevent infection.

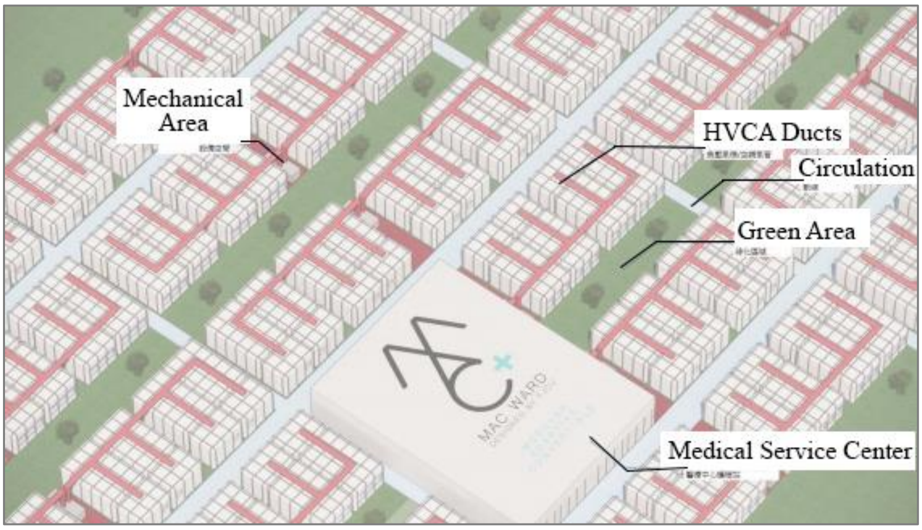


Figure 3.34. Location Option on Open Land for Modules (Frida, 2020) (Redrawn from info)

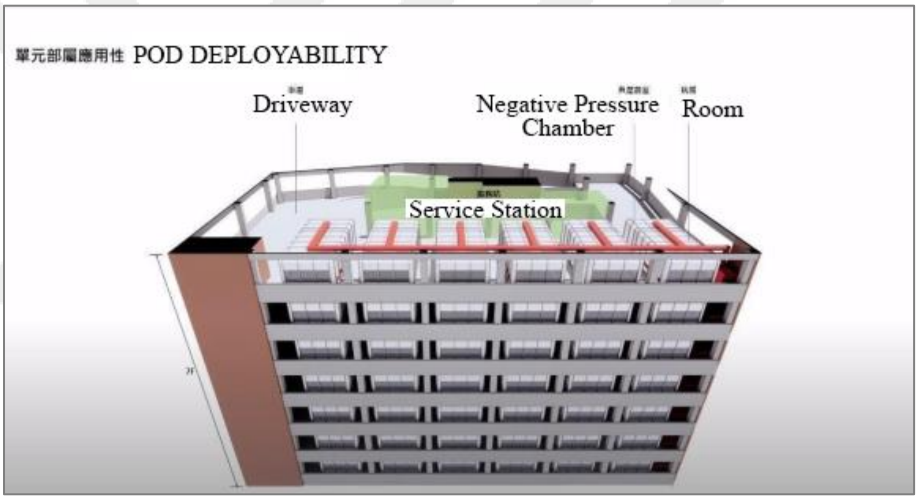


Figure 3.35. Location Option on Top of an Existing Building for Modules (Frida, 2020) (Redrawn from info)

Figure 3.34 and Figure 3.35 show the options for module placement. They can be built whether in an open land, or in part of an existing building as shown in Figure 3.35, at 7 stories parking tower. It is understood from the figures that red lines refer to ducts for HVAC. Ducts are placed on top of the modules. Besides, it is seen that there is no separation for clean and dirty pathways.

3.1.3.2. QurE Circular Negative Pressure Quarantine Unit

Bio-architecture Formosana (BAF) is a firm of Taiwan origin proposed an emergency quarantine hospital for Covid-19 pandemic in cooperation with National Cheng Kung

University (NCKU). It is easy to install, and the unit is protective against cross-infection between patients (National Cheng Kung University (NCKU), 2020).

Figure 3.36. Covid-19 Prototype of Emergency Quarantine Hospital Building (National Cheng Kung University (NCKU), 2020)

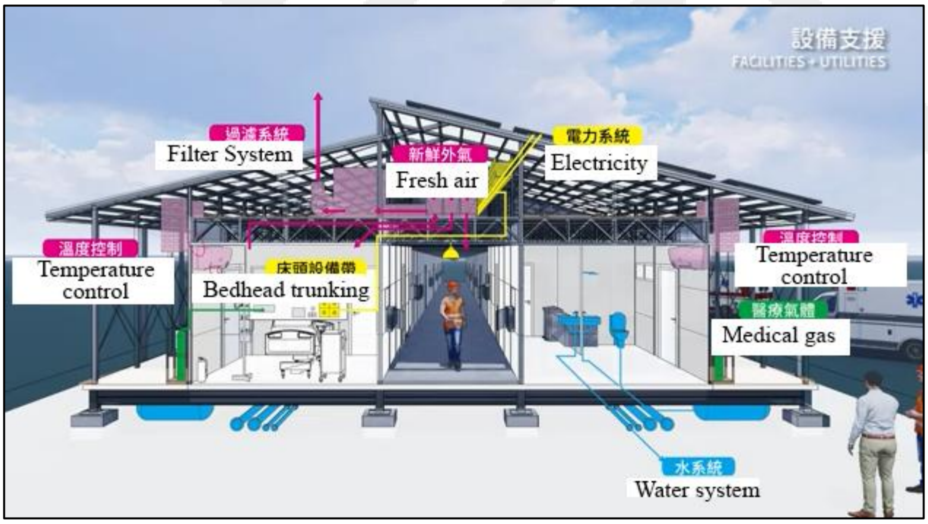


Figure 3.37. Systematical Features of the Covid-19 Prototype of Emergency Quarantine Hospital (National Cheng Kung University (NCKU), 2020) (Redrawn from info)

Figure 3.36 shows the built unit, and Figure 3.37 shows the mechanical system of the unit. It is seen that there is an open-sided corridor between wards. The corridor in the center is defined as a clean pathway and the two sides as a dirty pathway. It is a correct approach to prevent infection.

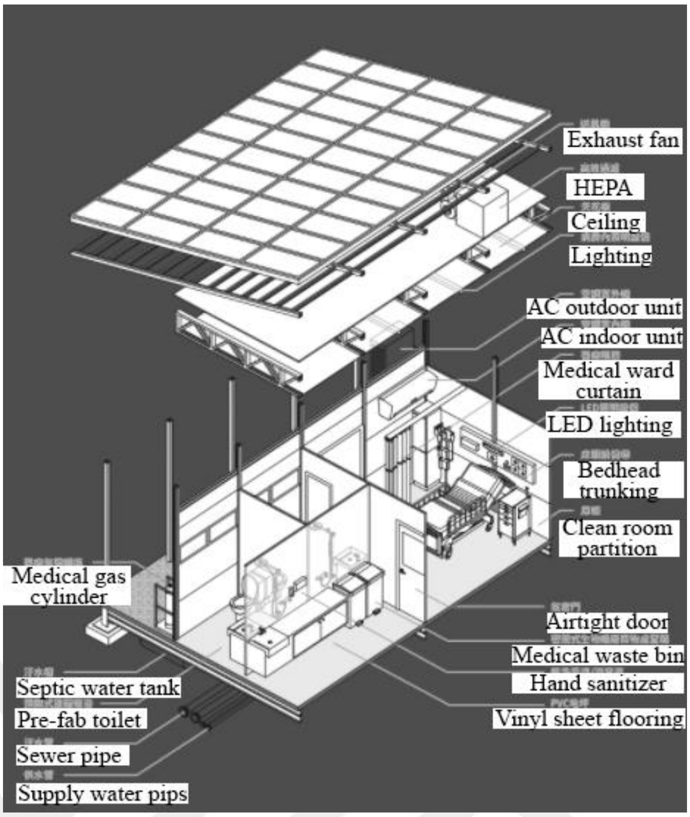


Figure 3.38. Structure of Circular Negative Pressure Quarantine Unit (National Cheng Kung University (NCKU), 2020) (Redrawn from info)

Figure 3.38 shows the exploded version of the unit's one side. Solar panel system is used to generate own energy for electricity. Vinyl sheet is preferred for flooring and steel for the structure (National Cheng Kung University (NCKU), 2020). There is no given more information about interior materials and their easy cleaning feature. As is understood from figure, airtight door is preferred, and HEPA filter is preferred for filtration and located on top of the module. These are important precautions to prevent infection.

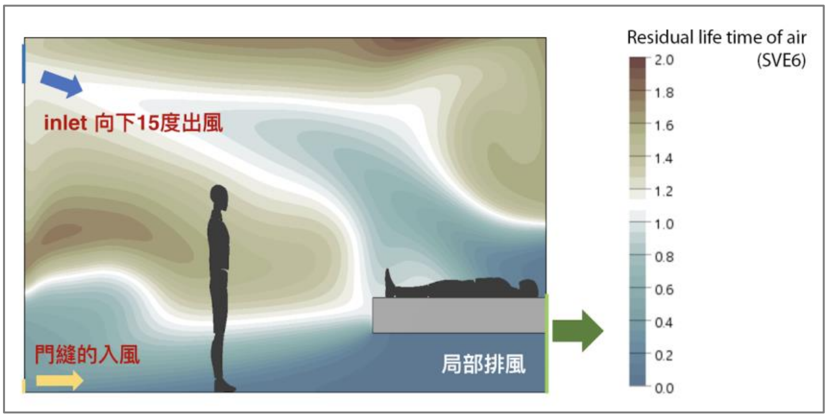


Figure 3.39. Air flow in the Module (QurE, 2020)

As the low-level extraction is strongly suggested to prevent infection (Cheong & Phua, 2006), Figure 3.39 shows that the module has its inlet mechanism at ceiling level and the outlet mechanism placed at ground level, and it is supported with laminar flow. However, there is an important issue that needs to be discussed is the use of the AC unit probably added for cooling purposes only in such indoor spaces, which are designed to prevent the spread of virus.

3.2. Eliminated Hospital Proposals

4 of 13 proposals were eliminated because no information can be found about their filtration types or mechanical ventilation strategies. These are listed in Table 3.2.1.

Table 3.2.1. Characterization of the Eliminated Modular Hospitals

Reference	Image	Project	Designer	Origin	Mechanical Ventilation	Filtration Type
(VHL Architecture & Danang Architecture University, 2020)		Mobile Hospital	VHL Architecture + Da Nang Architecture University	Vietnam	No information	No information
(!NFEKT, 2020)		CAMP-15	Infekt Architecture	Turkey	No information	No information
(AGX, 2020)		Kaksh	AGX Architecture	India	No information	No information
(Harrouk, 2020)		CNC-Medical Emergency Module	KOTKO	No information	No information	No information

3.2.1. Mobile Hospital

The mobile hospital is the proposal of VHL Architecture and Da Nang Architecture University in Vietnam. This model is designed to adapt respond to epidemics, natural disasters, and etc. The aim is to propose a cost-effectively solution to shortage of bed. The modules are designed to be easy to transport and install to rural areas (VHL Architecture & Danang Architecture University, 2020). Figure 3.40 shows the proposed placement of Mobile Hospital.

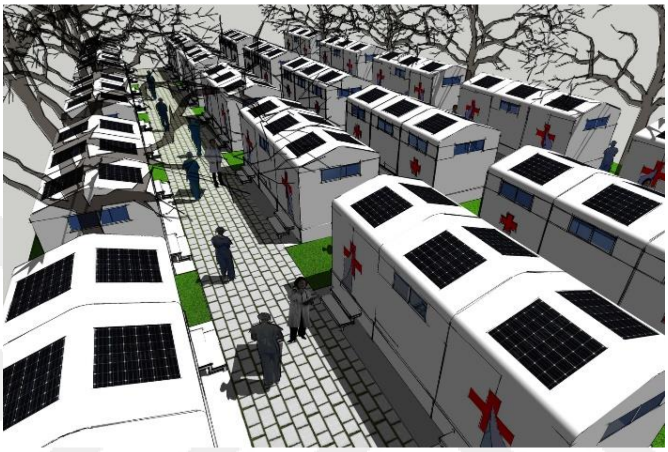


Figure 3.40. Mobile Hospital Proposal by VHL Architecture + Da Nang Architecture University (VHL Architecture & Danang Architecture University, 2020)

The use of iron tubes, lightweight cement panels and tarpaulin (cover canvas) are proposed to easy installation and affordability. Besides, it is recommended to install solar panels on top of modules for power generation (VHL Architecture & Danang Architecture University, 2020).

3.2.2. CAMP-15

Infekt Architecture is a firm of Turkey origin proposed the use of CAMP-15 during Covid-19 pandemic as a mass-quarantine zone. It was considered to be established in Kültürpark, Izmir. The aim is to invite infected patients for 15 days, and provide them social environment including open areas such as offices to work, sporting activities, restaurants and treatments, by taking care of isolation and social distancing. It is thought to separate patients and suppliers for patients by the use of buffer zones and checkpoints (!NFEKT, 2020). Figure 3.41 shows the CAMP-15 proposal built in an industrial building.

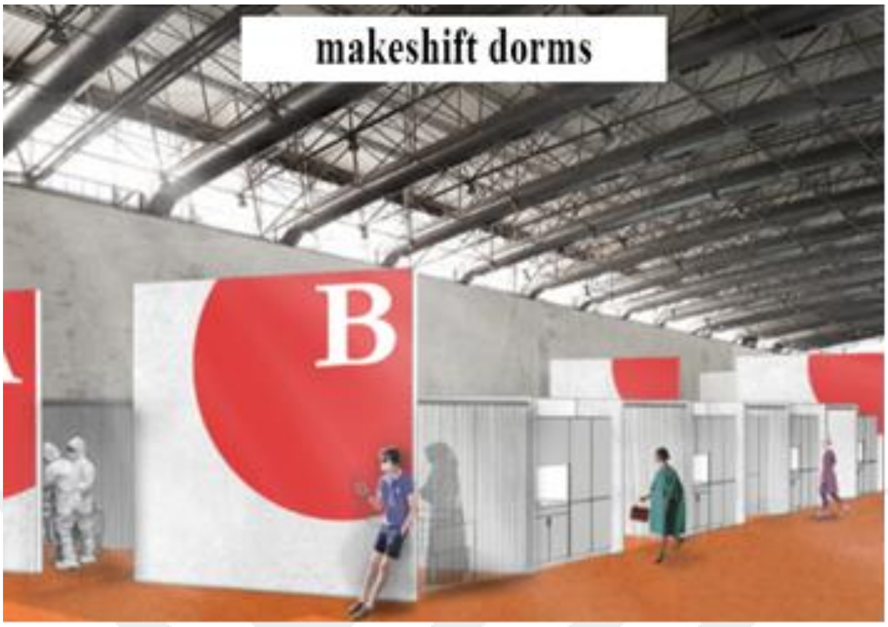


Figure 3.41. CAMP-15 (!NFEKT, 2020) (Redrawn from info)

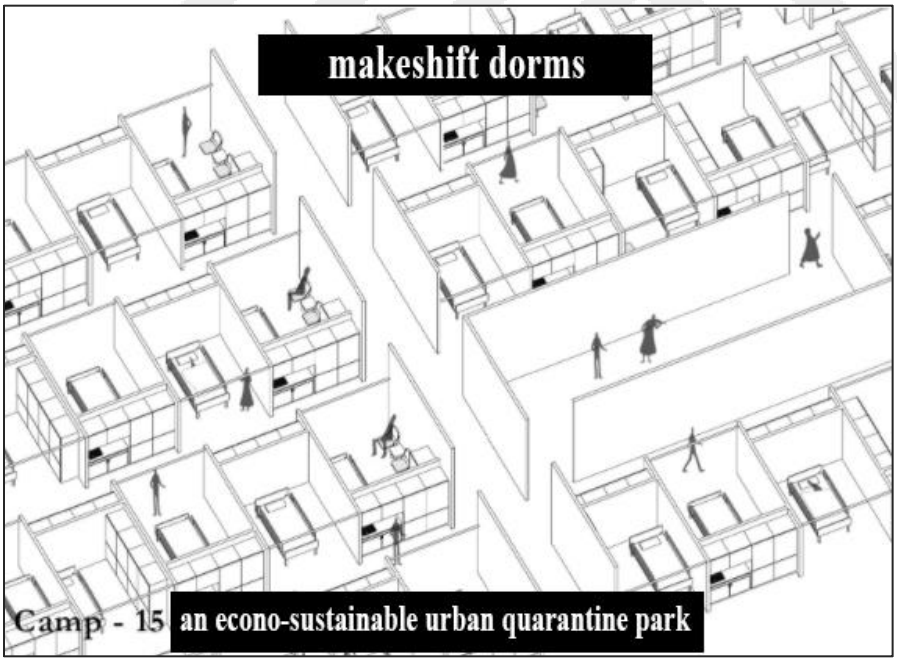


Figure 3.42. CAMP-15 Dorms Layouts (!NFEKT, 2020) (Redrawn from info)

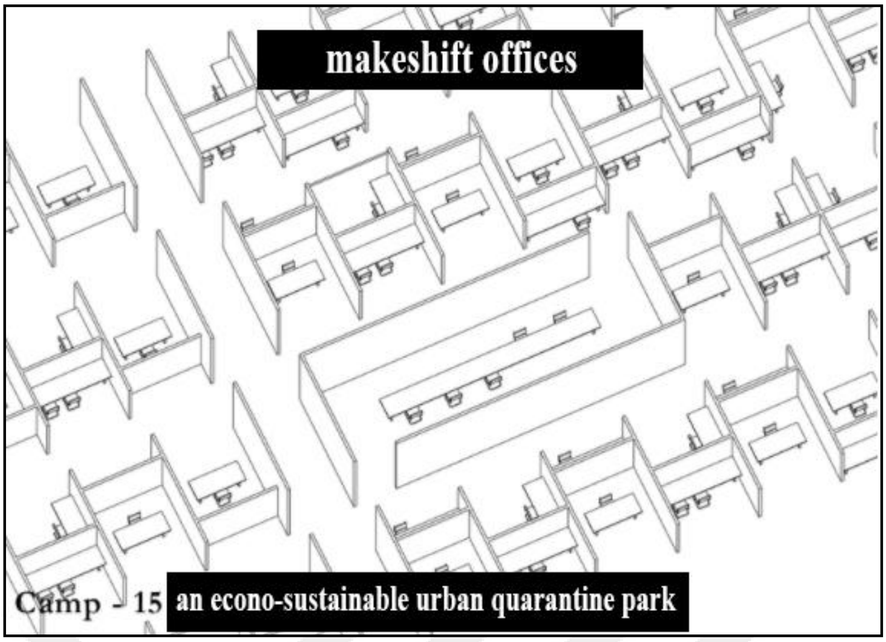


Figure 3.43. CAMP-15 Office Layouts (!NFEKT, 2020) (Redrawn from info)

Figure 3.42 and Figure 3.43 show the proposal for dorms and offices layout. There is no given information about material selection and filtration.

3.2.3. Kaksh

Kaksh is another quarantine zone proposal offers quarantine hospital/ testing lab/ shelter for Covid-19 pandemic. It is designed by AGX Architecture from India. It was intended to be placed in an open field. The aim is to provide less cost, less effort, easily found materials, easy transport and minimum installation time (AGX, 2020). Figure 3.44 shows the placement options for Kaksh.

Figure 3.44. Kaksh Quarantine Hospital/ Testing Lab/ Shelter (AGX, 2020)

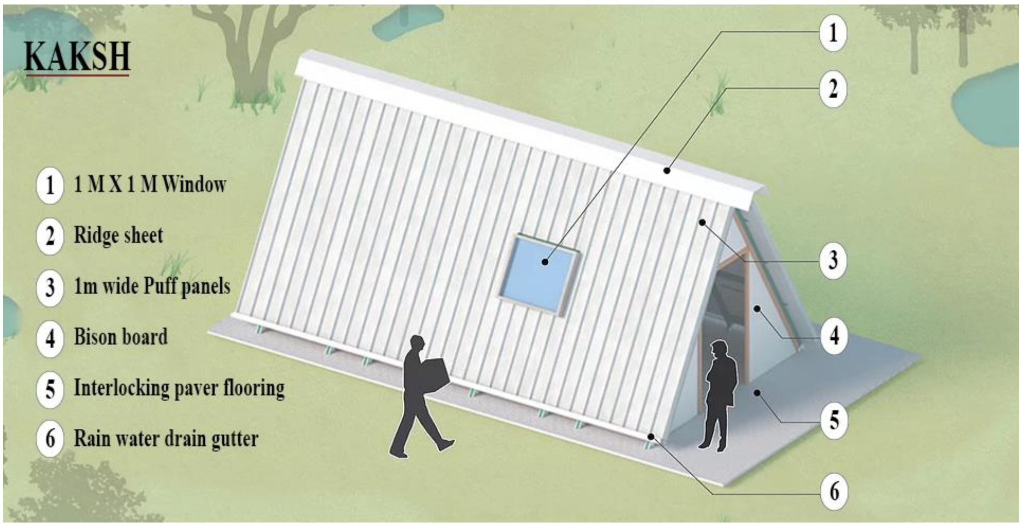


Figure 3.45. Kaksh Design Materials (AGX, 2020) (Redrawn from info)

Figure 3.45 shows the component materials of the Kaksh. The use of bison board, interlocking paver flooring, ridge sheet, puff panels are preferred (AGX, 2020).

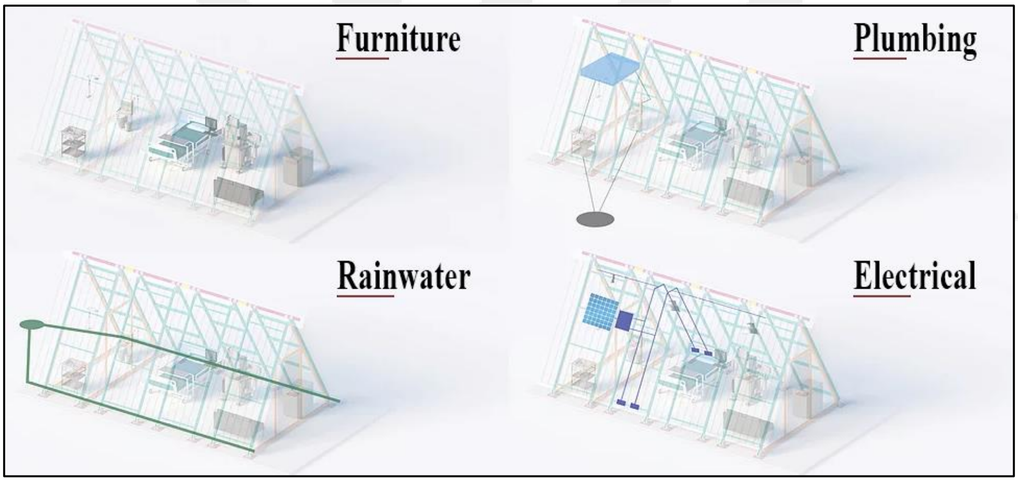


Figure 3.46. Structure of Kaksh (AGX, 2020) (Redrawn from info)

Figure 3.46 shows the structure of Kaksh. Furniture layout, plumbing, rainwater and electrical systems are illustrated. However, there is no given information about filtration.

3.2.4. CNC- Medical Emergency Module

CNC- Medical Emergency Module is the proposal of KOTKO, but there is no found information about designers and origin country. It is stated that the aim is to provide easy-to-install modules according to the availability of space (Harrouk, 2020). Figure 3.47 and Figure 3.48 show the different scenarios for construction of the module.

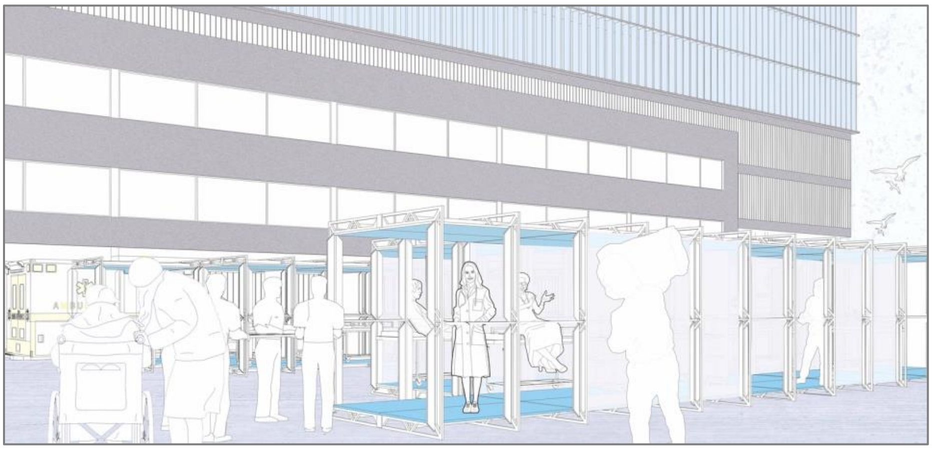


Figure 3.47. CNC- Medical Emergency Module Sketch View (Harrouk, 2020)

Figure 3.48. CNC- Medical Emergency Module Render View (Harrouk, 2020)

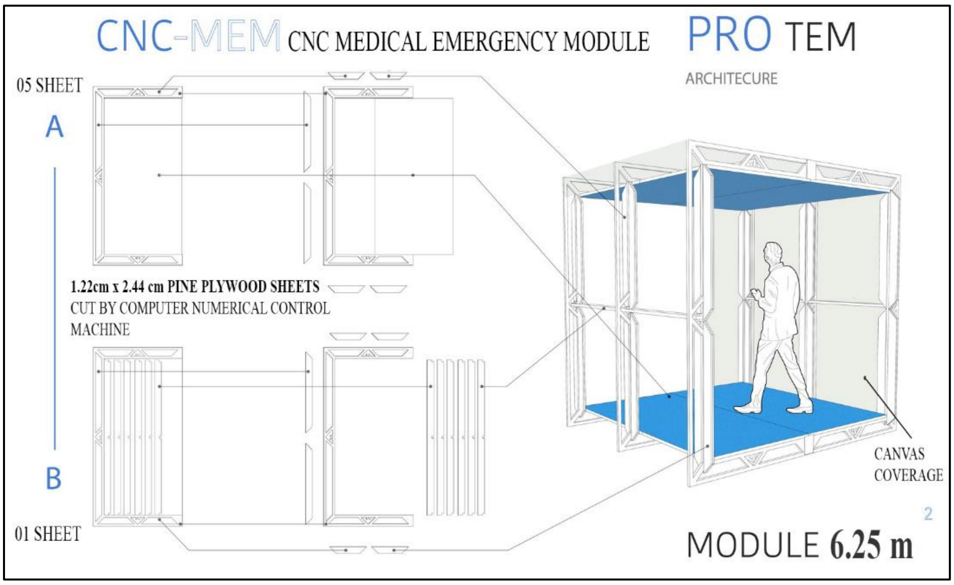


Figure 3.49. Structure of CNC-Medical Emergency Module (Harrouk, 2020)
(Redrawn from info)

Figure 3.49 shows the construction of module. The main idea is to create module by using CNC. There is no given information about filtration. 6 plywood sheets are used for each module, and it is understood from the figures that this module proposal has open sides.

3.3. Results

In this chapter, totally 13 modular hospitals proposals were examined in detail. Due to the lack of information about filtration or mechanical design of 4 hospital proposals, they were eliminated. Therefore, 9 of 13 hospitals became the focus point of this study, and their pros and cons intend to prevent of infection were determined. Since these hospitals were designed against Covid-19 pandemic, their features must meet the guidelines for infection. In this context, design of edges and corners, suitability of surfaces for easy cleaning, determination of dirty and clean pathways, safety patient flow, spatial layout in hospital interiors, the distance between patient room and nurse station, filter type, filtration system and pressure direction were evaluated.

According to the results, only 1 of 9 (Modular Hospital Ward Prototype) has curved edges and corners in module interior, and 1 of 9 (Emergency Modular Hospital) has curved corridors. Even though the use of curved surfaces is suggested for hospital environments in terms of easy cleaning (Spagnolo et al., 2013), this suggestion had not been considered for other proposals that have hard edges and corners. This may be related with use of previously defined modules or containers use in various cases for fast resolving taken actions to pandemic conditions.

Only 1 of 9 (Modular Hospital Ward Prototype) stated that anti-viral and bacterial materials, and self-cleaning system were preferred. It is a favorable approach against infection. However, there is no found information about the use of such materials in other hospital proposals.

Most of the hospitals, 6 of 9 were derived from containers, 1 of 9 (Modular Hospital Ward Prototype) is made of recycled aluminum panels, 1 of 9 is made of fabric, and there is no information about structural materials of STAAT Mod Units.

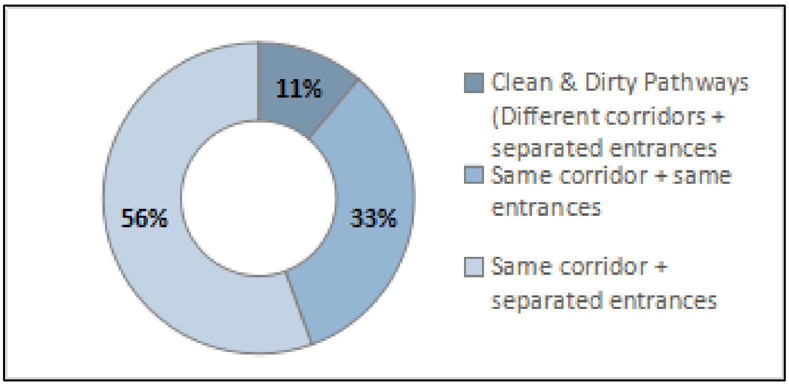


Figure 3.50. Layout Types of the Modular Hospitals

Figure 3.50 shows the layout types in terms of corridors and entrances of the modular hospitals. 2 of 9 (STAAT Mod Units, Emergency Modular Hospital) have horseshoe-shaped plan. The preference of this layout type can provide protection against infection thanks to the separated entrances. Including them totally 5 of 9 hospitals (56%) use same corridor and have separated entrances. While 3 of 9 use same corridor and entrance, only 1 of 9 (QurE Circular Negative Pressure Quarantine Unit) prefers dividing corridors as clean and dirty pathways. Others (STAAT Mod Units, Mobile Modular Hospital, CURA Pods, Losberger Emergency Modular Hospital System, Emergency Modular Hospital, Field Rescue Center, Modular Hospital Ward Prototype, and Covid-19 Hospital Ship) do not have separated clean and dirty pathways. This might cause spreading of infection and affect treatment process negatively. However, it must not be ignored that the STAAT Mod Units' corridors are used by only healthcare works, and both STAAT Mod Units and Emergency Modular Hospitals give entrance to patient rooms from outside for patients.

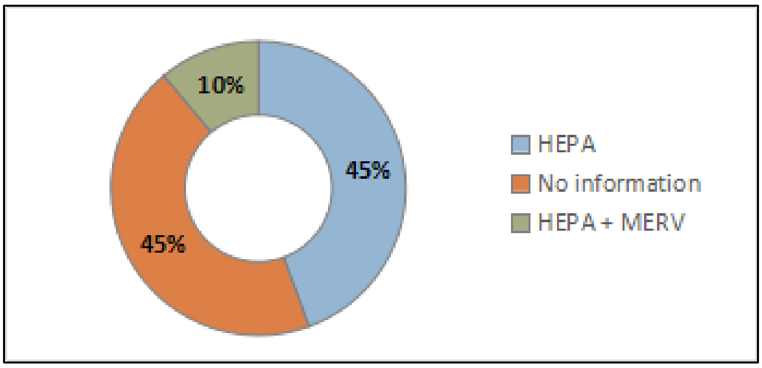


Figure 3.51. Percentage of Preferred Filter Types

Figure 3.51 shows the percentage of filter types preferred for the modular hospitals. 4 of 9 proposals (Mobile Modular Hospital, CURA Pods, QurE Circular Negative

Pressure Quarantine Unit, Losberger Emergency Modular Hospital System) stated that they prefer HEPA filter, 1 of 9 (STAAT Mod Units) stated that they prefer doubled filtered system (HEPA and MERV). 4 of 9 (Modular hospital ward prototype, Emergency Modular Hospital, Covid-19 Hospital Ship, Field Rescue Center) have not given any information about filter type. As is mentioned in literature review, HEPA filters and MERV 8, MERV 14 and MERV 17 are recommended filters by ASHRAE (Salonen et al., 2013). It can be inferred that 55% of proposals are complied with this criteria and they consider ASHRAE Standards. In addition, while all proposals have mechanical ventilation system, only 1 of 9 considers both mechanical and natural ventilation. The reason might be that natural ventilation does not allow negative pressure, as WHO stated (Salonen et al., 2013).

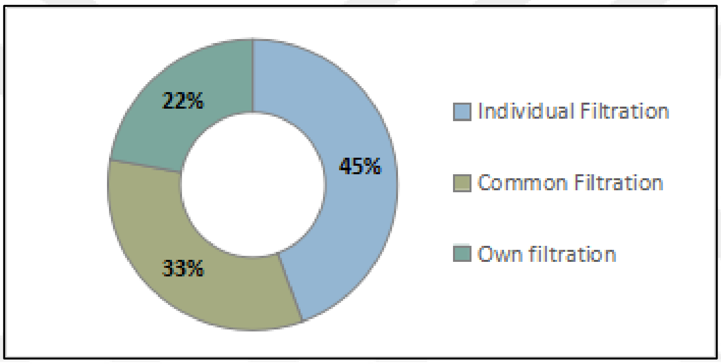


Figure 3.52. Filtration Type of Modular Hospitals

Figure 3.52 shows the preferred filtration types of modules. The most preferred type (45%) is individual filtration. While 4 of 9 hospitals use individual filtration in layout created by combining modules, 3 of 9 use common filtration. Besides, 2 of 9 which are defined as self-standing modules use their own filtration. The use of common filtration may cause spread of virus if it is not well controlled with filters and not provided right pressurization of patient rooms and other infectious risk spaces. Therefore, preferring separated filtration for both layout created by combining modules and self-standing modules has importance to prevent infection.

It is not recommended to use a common HEPA filter for more than one area. However, it should be noted that if 100% fresh air is provided to the areas connected to the same air handling unit, isolation can also be achieved without the use of HEPA filters (Evren, 2021). No information has been found about whether the use of 100% fresh air or not for these examined hospitals.

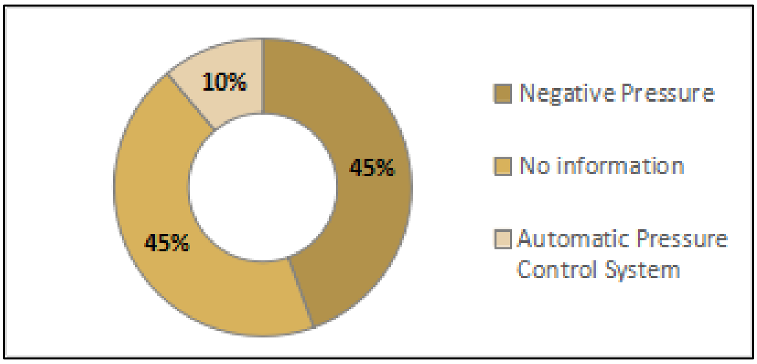


Figure 3.53. Pressure Directions

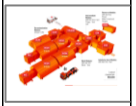
Figure 3.53 shows the preferred pressure types. WHO strongly suggests the use of negative pressure in isolation areas (Salonen et al., 2013). 4 of 9 hospitals prefer the use of negative pressure, 1 of 9 prefer automatic pressure control system, while 4 of 9 do not give any information about pressure direction.

Preferring low-level extraction is suggested rather than ceiling level (Cheong & Phua, 2006), and it is clearly understood that only 3 of 9 proposals (QurE Circular Negative Pressure Quarantine Unit designed by Bio-architecture Formosana (BAF) in cooperation with National Cheng Kung University (NCKU), Staat Mod Units designed by HGA, and Modular Hospital Ward Prototype designed by Miniwiz) take into consideration the low-level extraction.

Table 3.3.1 shows the examined 9 modular hospital proposals and the features of their filtration system. Some modules have been built and used during Covid-19 pandemic (STAAT Mod Units, Mobile Modular Hospital, CURA Pods, Modular hospital ward prototype, QurE Circular Negative Pressure Quarantine, Losberger Emergency Modular Hospital System) while others have remained just proposals (Emergency Modular Hospital, Covid-19 Hospital Ship, Field Rescue Center). Implemented proposals enable to have more information and concrete evidence about the systems integration.

As a result of a detailed examination, it is inferred that some proposals believed to show deficiencies to prevent infection while some of them conform to guidelines. Layout arrangements, filtration preferences and surfaces applications made for these modular hospitals which considers recommendations to prevent infection can be accepted as recommendatory for future designs.

Table 3.3.1. Characterization of the Modules

Reference	Hospital Type	Image	Project	Designer	Built	Origin	Module Location	Module Material	Filter Type	Filter Location	Pressure Direction	Extraction Level	Ventilation Type	Ventilation Isolation
(HGA, n.d.)	Layout Created by Combining Modules That Have Individual Filtration		STAAT Mod Units	HGA	✓	USA	Near or far from hospital	No information	MERV and HEPA	No information	Negative pressure	Low-level	MV	Individual Filtration
(Golden Hour MMH, n.d.)	Layout Created by Combining Modules That Have Common Filtration		Mobile Modular Hospital	Golden Hour MMH	✓	Esthonia	Open field	Containers	HEPA	In a separated module	Negative pressure	No information	MV	Common filtration
(Alter, 2020; CURApods, n.d.)	Layout Created by Combining Modules That Have Individual Filtration		CURA Pods	Carlo Ratti and Italo Rota	✓	Italy	Near or far from hospital	Shipping containers	HEPA	Embedded to the pod's wall	Negative pressure	Ceiling Level	MV	Individual Filtration

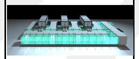
(MV: Mechanical Ventilation, NV:Natural Ventilation)

Table 3.3.2. Characterization of the Modules (continued)

Reference	Hospital Type	Image	Project	Designer	Built	Origin	Module Location	Module Material	Filter Type	Filter Location	Pressure Direction	Extraction Level	Ventilation Type	Ventilation Isolation
(Evolve Technologies Corporation, n.d.; Losberger de Boer, 2020)	Layout Created by Combining Modules That Have Individual Filtration		Losberger Emergency Modular Hospital System	Evolve Emergency & Losberger de Boer	✓	USA	Open field	PVC coated fabric	HEPA	Next to the module	Automatic pressure control system	No information	MV	Individual Filtration
(Architizer, n.d.)	Layout Created by Combining Modules That Have Common Filtration		Emergency Modular Hospital	Mmw Architect	X	USA	Near the hospital, on the same field	Recycled shipping-containers (steel), inflatable fabric	No information	On top of the module	No information	Ceiling level	MV	Common filtration
(Ravenscroft, 2020a)	Layout Created by Combining Modules That Have Individual Filtration		Covid-19 Hospital Ship	Weston Williamson + Partners	X	UK	Ship	Shipping containers, Perspex	No information	Next to the module	No information	No information	MV & NV	Individual Filtration

(MV: Mechanical Ventilation, NV:Natural Ventilation)

Table 3.3.3. Characterization of the Modules (continued)

Reference	Hospital Type	Image	Project	Designer	Built	Origin	Module Location	Module Material	Filter Type	Filter Location	Pressure Direction	Extraction Level	Ventilation Type	Ventilation Isolation
(HAHA Architects Group, n.d.)	Layout Created by Combining Modules That Have Common Filtration		Field Rescue Center	HAHA Architects Group	X	Poland	Next to the hospital, near or far from hospital	TEU containers, Epdm membrane	No information	Top of the module	No information	Ceiling Level	MV	Common filtration
(Frida, 2020; Ravenscroft, 2020b)	Self-standing Modules with Own Filtration		Modular hospital ward prototype	Miniwiz	✓	Taiwan	Inside existing buildings or on land adjacent to hospitals	PET wallpanels, nano coated with recycled aluminum panels	No information	Next to the module	Negative pressure	Low-level	MV	Own Filtration
(National Cheng Kung University (NCKU), 2020; QurE, 2020)	Self-standing Modules with Own Filtration		QurE Circular Negative Pressure Quarantine Unit	Bio-architecture Formosana (BaF)	✓	Taiwan	Open field	Container, Vinyl sheet flooring, steel	HEPA	Top of the module	No information	Low-level	MV	Own Filtration

(MV: Mechanical Ventilation, NV:Natural Ventilation)

CHAPTER 4
CASE STUDY: EXAMINATION OF TWO HOSPITAL LAYOUTS WITH THEIR MECHANICAL SYSTEM PROPERTIES

This chapter presents the case study containing two surveys conducted with hospital management and hospital personnel, two interviews conducted with an architect and mechanical engineer professionalized in healthcare design, and transformation proposals for two private case study hospitals.

First, in order to determine the needs and conditions of a regular hospital through Covid-19 pandemic process (before transformation), two different surveys were conducted through both face-to-face and online surveying methods. One of the surveys was prepared for the hospital management (face-to-face) and 4 people were participated to this survey. The other survey was prepared for the hospital personnel (online) and 35 people were participated this survey.

Second, two interviews were conducted with a specialized mechanical engineer and an architect to get information about hospital layout and ventilation strategies, and how to transform areas in reserve to isolated conditions.

Third, with the all obtained data from literature review, surveys and interviews, it is aimed to make constructive suggestions for possible future in-hospital transformations.

In order for the transformation proposals to be consistent with the existing ventilation design, during the examinations, the mechanical as-built drawings of the hospitals gathered and examined. We worked with mechanical engineering professionals (TTM Engineering and Evren, 2021) through examination and transformation of mechanical systems design.

Both hospitals are located in Turkey, and for this study they are named as Hospital A and Hospital B due to non-disclosure agreement protocols done with hospital administrations and design teams. Surveys were conducted only with Hospital A management and personnel, since the Hospital B was under reconstruction at the time of this study.

4.1. Surveys

Two different surveys were conducted between 8th and 15th of March 2021 with hospital workers and hospital management of Hospital A. The research question that the study focuses on is mainly related with the adequacy of hospital practices in managing the pandemic processes.

In order to evaluate the adequacy, physiological and psychological effects of the practices carried out within the hospital in the management of the pandemic process on hospital workers and hospital management is questioned. This process was analyzed with 30 questions through two main headings.

The main headings are; hospital environment and pandemic process management. Subheadings are; working and resting environment of hospital personnel, ventilation, isolation, separation of in-hospital areas.

The surveyed are hospital personnel and the management team of Hospital A. Age and gender of participants were ignored. Two different surveys were conducted with the hospital workers (Appendix-3) and hospital management (Appendix-4). Hospital workers are nurses, doctors, cleaners, secretaries, accounting staff and, the hospital management team includes the chief physician, the chairman of the Covid Commission and other team members.

The survey with hospital workers was conducted online via the google surveys link shared with the participants through the hospital management. The participants' credentials were kept confidential, they were only asked about their duties within the hospital. The survey questions for hospital workers are as stated in Appendix-3.

The survey with hospital management team was conducted both face-to-face and online. The survey was conducted online with one person from the management team because he was busy, and the survey was conducted with three other people from hospital management as face-to-face in the hospital environment. The survey questions for hospital management are as stated in Appendix-4.

4.1.1. Answers of Hospital Management

According to the answers given, during the pandemic, the people in hospital management are working from 8 to 16 hours on the days when they are in the hospital, and working days at the hospital are a minimum of 6 days per week.

The hospital administration said that isolation has been successfully achieved during the pandemic. They noted that they has no problems, especially from an architectural point of view, because the hospital had just opened, they had enough free spaces. However, one of the participants said they had a difficulty because there was a constant change of guidance. In terms of the difficulty of the process of ensuring isolation, the answers to the question are ‘‘no’’ and ‘‘slightly ensured’’.

4.1.1.1. Isolation Steps

According to information obtained from the hospital administration, Hospital A followed the Science Committee guidelines to ensure isolation. A new service was opened on the ground floor for Covid-19, and patients were treated on that floor. The first room on the ground floor was designated as an outpatient clinic, while the last rooms were used as single isolation rooms. The corridor was cleared and patient passage was provided. A private elevator was reserved for the Covid service. Étagères were removed from the patient rooms to corridors. Supplies in the ICU were taken out into the corridor so that they could remain sterile. A storage was emptied in intensive care unit, and this storage was made a dressing room for personnel. Health workers wore protective equipment. Disposable containers were also used.

4.1.1.2. Patient beds

It was said that beds were converted due to the pandemic, and after the second wave of the pandemic, the number of intensive care beds were increased due to the request of the Turkish Ministry of Health. Extra beds were brought to the hospital.

4.1.1.3. Ventilation

Hospital management states that the mechanical ventilation in the hospital is quite adequate, the windows in the patient rooms are definitely not operable, and only mechanical ventilation is used throughout this hospital.

4.1.1.4. Sampling for Covid-19

According to the information obtained by the survey conducted with the hospital administration, sampling from people who came for the Covid-19 test was initially carried out in the area defined as the Covid outpatient clinic within the hospital. Tests were then carried out outside the hospital in a cabin. Now the tests are only done in this cabin. There's a separator between the person who came in for the test and the hospital worker. Tests are conducted according to social distancing principles set by the Turkish Ministry of Health.

4.1.1.5. Hospitalization

Hospital admissions were made at the request of patients whose Covid-19 test result is positive. Patients suspected with Covid-19 were taken to the outpatient clinic. Patients in serious condition were admitted to intensive care. In addition, patients came to the hospital also with referrals.

4.1.1.6. Disinfectants

Hospital management believes that disinfectants within the hospital are positioned so that they are accessible to everyone. As can be seen from Figure 4.1, there is automatic disinfectant at the entrance of the hospital, and there are manual disinfectants on all tables, especially on the ground floor more than one on each desk.

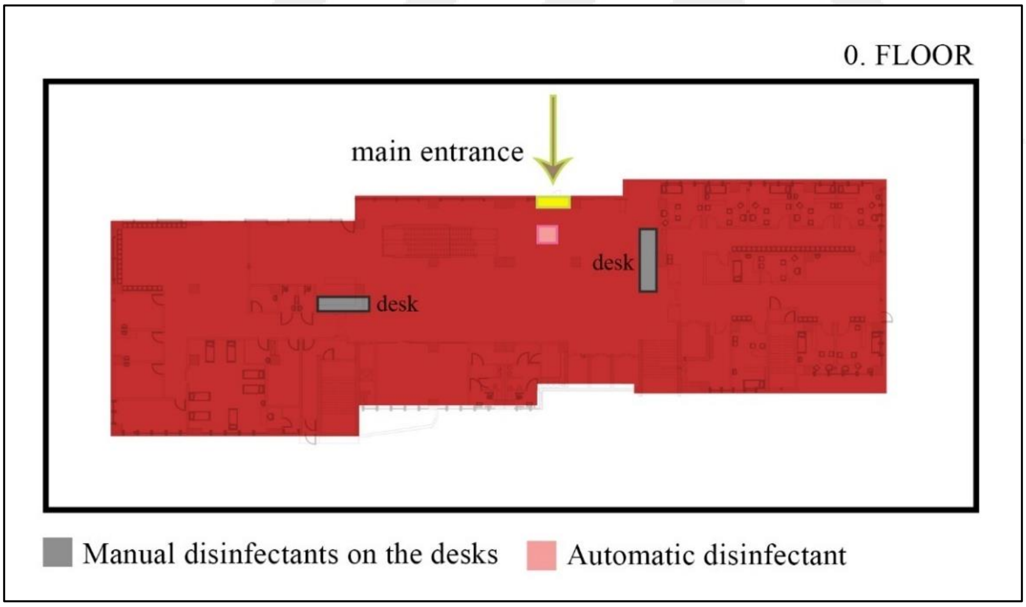


Figure 4.1. Actual Placement of Disinfectants

4.1.1.7. Overall Results

According to the responses of the survey participants in the management, all the actions asked were well applied. These are; separation of infectious areas, application of social distancing rules, supply of special clothing equipment, the use of disinfectants, planning the use of elevators and stairs, regulations in the dining hall and cafeteria, staff working hours regulations, and more controlled hospital entrances and exits.

In general, the answer of the participants to the question of what other measures would you like to take in order to feel more secure in the hospital environment was 'the measures taken were sufficient'. One of the participants said that smoking areas and staff rest areas could be removed because staff come together in these areas and do not pay attention to social distancing rules and increase the risk of transmission.

4.1.2. Answers Of Hospital Personnel

A total of 35 hospital personnel volunteered to participate in the 15-question survey conducted on Google Forms. Out of the 35 people surveyed, 4 are doctors, 20 are cleaning personnel, 6 are accounting personnel and 5 are secretaries.

According to the answers obtained from the question asked about how many days the surveyed personnel worked per week, 3 out of 35 personnel worked 7 days, 19 personnel worked 6 days, 9 personnel worked 5 days, 2 personnel worked 4 days, 1 personnel worked 3 days, and 1 personnel did not work. It is seen that most of the personnel (80%) worked 5 or 6 days during pandemic.

According to the answers, during pandemic, 8 personnel worked in the 0-8 hour range, 26 personnel worked in the 8-16 hour range, and 1 personnel worked in the 16-24 hour range. It is seen that the vast majority of personnel spend two-thirds of their days in the hospital.

When it was asked whether the Covid-19 pandemic process affected their weekly working schedule, 11 people answered as ‘‘Slightly affected’’, 9 people ‘‘Yes, affected’’ and 2 people ‘‘yes, affected too much’’. When examined as a percentage, it is understood that 62.8% of personnel were affected by the pandemic process in terms of working time.

4.1.2.1. Resting Areas

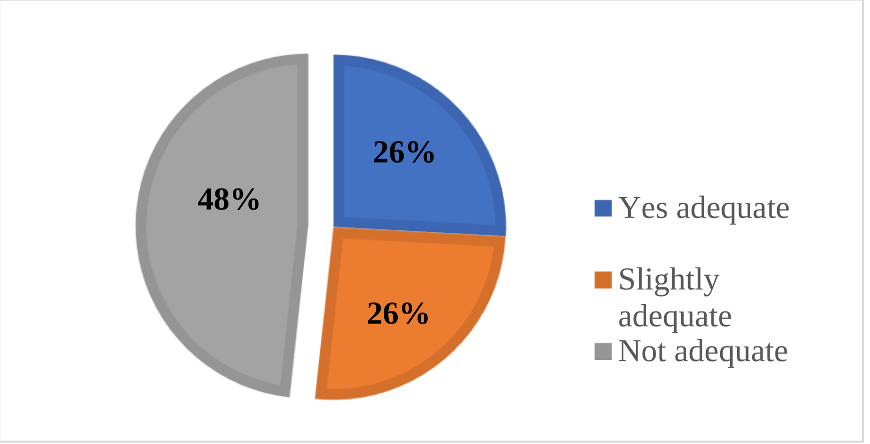


Figure 4.2. Adequacy of the Resting Areas for Personnel

Figure 4.2 shows the adequacy of the resting areas for personnel. When asked if personnel resting areas were adequate to participants, 9 people answered "Yes adequate", 9 people answered "Slightly adequate" and 17 people answered "Not adequate". The answer no is almost half of all given answers. This result shows that the personnel area is not considered sufficient by a large majority.

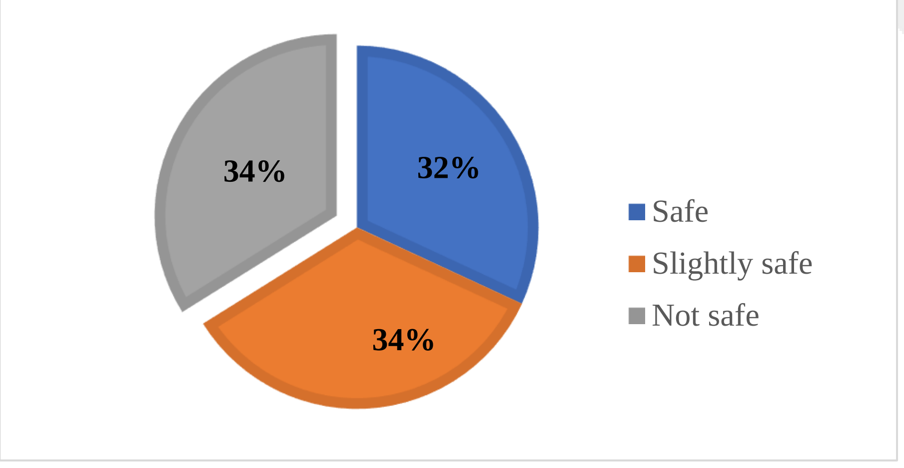


Figure 4.3. Safety of Ventilation and Mechanical Conditions of the Resting Areas

Figure 4.3 shows the safety of ventilation and mechanical conditions of the resting areas. When asked if personnel resting areas were safe in terms of ventilation and pandemic conditions, 11 people answered "Safe," 12 people answered "Slightly safe", and 12 people answered "Not safe".

4.1.2.2. Working Areas

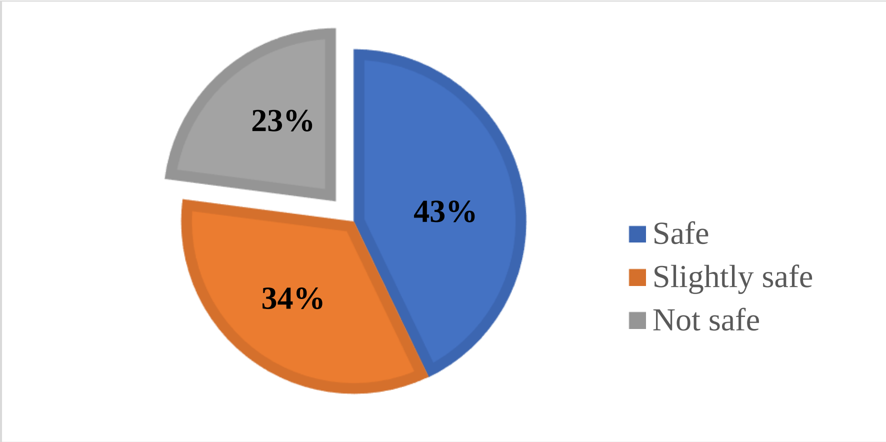


Figure 4.4. Safety of Ventilation and Mechanical Conditions of the Working Areas

Figure 4.4 shows the safety of ventilation and mechanical conditions of the working areas. When asked if personnel working areas were safe in terms of ventilation and pandemic conditions, 15 people answered "Safe", 12 people answered "Slightly safe", and 8 people answered "Not safe". According to the answers obtained from personnel, ventilation and pandemic conditions in the working environment (77%) are more appropriate than in the personnel rooms (66%). In this case, it should also be recommended to improve the conditions of the personnel rooms.

4.1.2.3. Infection Risk

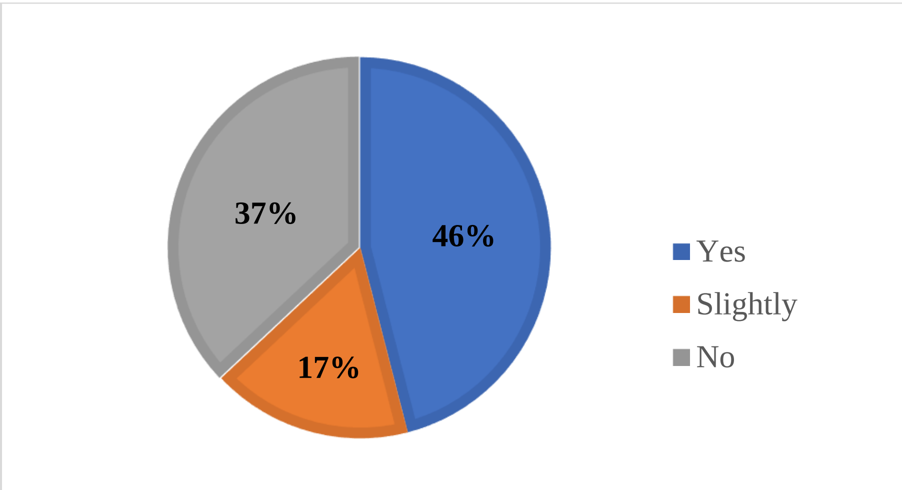


Figure 4.5. The Risk of Increase of Infection due to Personnel Duties

Figure 4.5 shows the increase of infection exposure rates due to personnel duties. When asked if their duties in hospital were caused to increase the risk of infection transmission, 16 people answered "Yes, there is a risk of increase of infection transmission", 6 people answered "There is a slightly risk of increase of infection transmission", and 13 people answered "There is no risk of increase of infection transmission". This indicates that most personnel (83%) are at risk of infection transmitted in the hospital. Because of their duties, direct contact with the patient or reasons for being in the environment where the patient is in can be the basis of this risk.

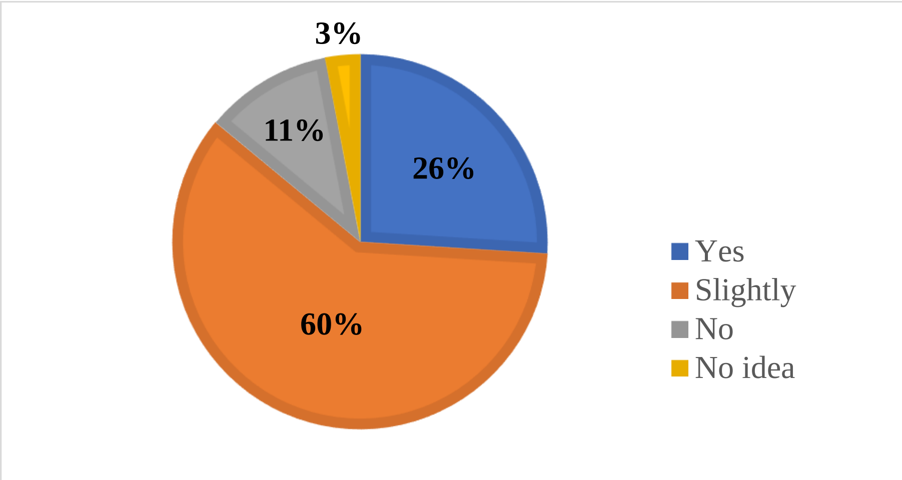


Figure 4.6. Cautiousness of Patients about Infection Control

Figure 4.6 shows the patients ' cautiousness for infection control. When asked about if patients coming to the hospital are cautious about the risk of infection, 9 people answered "Yes", 21 people answered "Slightly", 4 people answered as "No", and 1 one the participants answered "No idea".

The total of answers "Slightly" and "No" (71%) seem quite a lot. In this case, hospital employees may need to encourage those who come to the hospital to be more careful in terms of precautions or set more controlled regulated spaces for both infected patients and personnel related.

4.1.2.4. Disinfectants

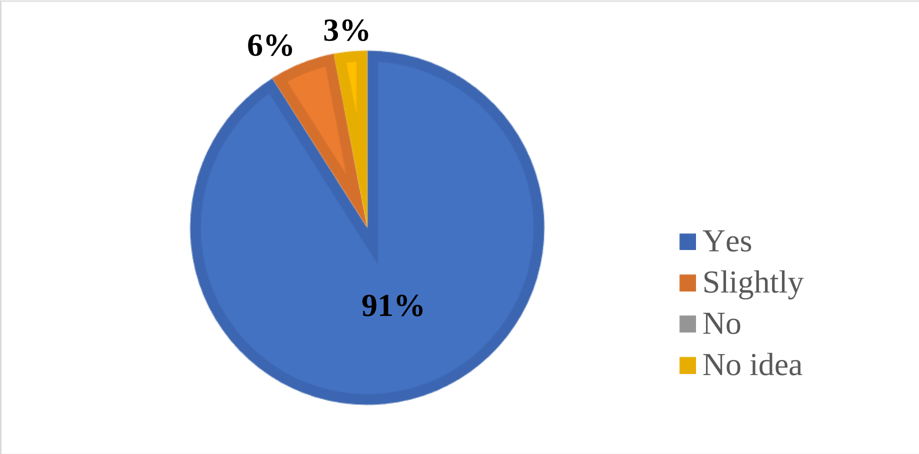


Figure 4.7. Easy Access to Disinfectants

Figure 4.7 shows the answers for the access to disinfectants inside the hospital. When asked if disinfectant placements were accessible to everyone inside the hospital, 32 people answered "Yes", 2 people answered "Slightly", and 1 of the participants answered "No idea". No one answered as "No".

4.1.2.5. Isolation and Safety

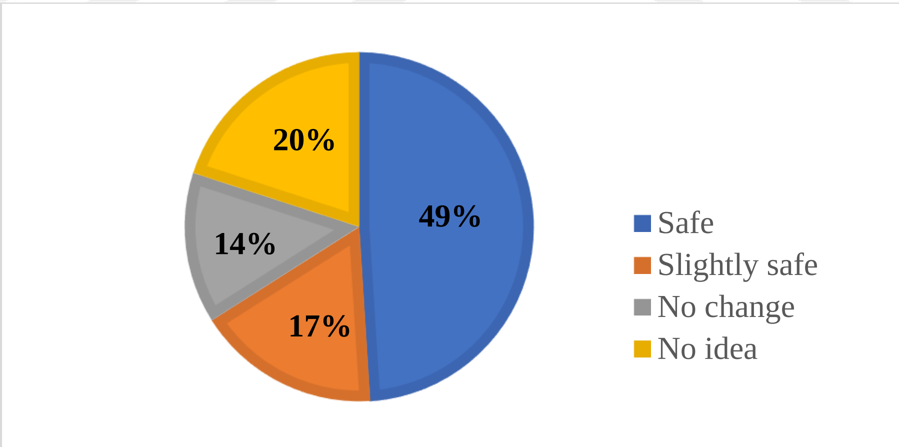


Figure 4.8. Evaluation of the Effect of Providing an Isolated Environment on the Sense of Safety

Figure 4.8 shows how providing isolation areas change the feeling of hospital personnel in terms of safety. When staff were asked how providing an isolated environment inside the hospital during the pandemic would change your sense of safety, 17 people answered "Safe", 6 people answered "Slightly safe", 5 people answered "No change", and 7 people answered "No idea". It is understood that 63% of personnel considers isolation areas necessary.

4.1.2.6. Precautions Inside the Hospital

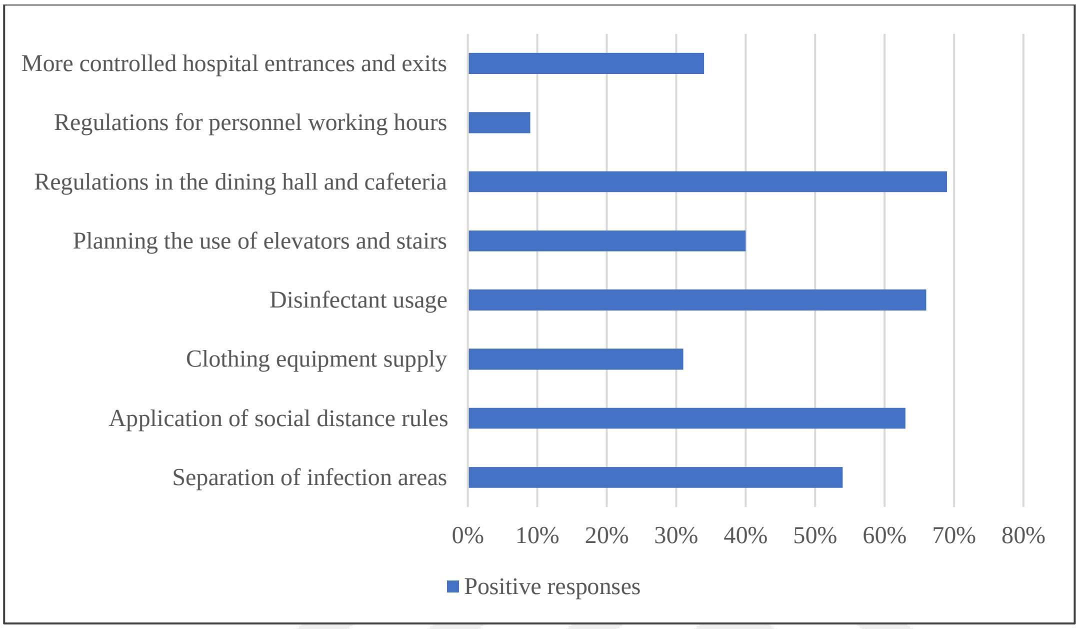


Figure 4.9. Assessment of Precautions Taken Inside the Hospital

Figure 4.9 shows the assessment of the adequacy of the precautions taken against infection within the hospital by the personnel. Personnel were asked about the hospital's precautions for the Covid-19 pandemic. The responses of the personnel to this question, which were multi-responsive, were as follows: 19 people responded positively to the decomposition of infection areas, and 22 people responded positively to the implementation of social distancing rules. 11 people responded positively about the supply of clothing equipment. 23 people responded positively to the use of disinfectants. 14 people responded positively about planning the use of elevators and stairs. 24 people responded positively to the regulations in the dining halls and cafeterias. 3 people responded positively to the regulation of staff working hours. 12 people responded positively to the fact that hospital entrances and exits were more controlled.

4.1.3. Survey Results

It is understood that personnel are least satisfied with working hours and the supply of clothing equipment. This problem is present in many hospitals in general, and it is common in pandemic processes. However, by designing a separate space for personnel to dress, a more protective environment against infection can be provided for them. This also helps them to feel psychologically more relaxed.

According to the answers given by the hospital personnel, the precautions to control hospital entrance and exist are not sufficient. Therefore providing separated entrance for Covid-19 service can be effective to solve this problem.

Considering all the answers given from an architectural/interior architectural point of view, it is concluded that more care should be given for more controlled hospital entrance and exit designs under pandemic conditions. Also, to plan the use of elevators and stairs close to designated infection control entrances will help to separate the infection areas.

4.2. Interviews

In order to understand ways of new zoning/planning alternatives for transformation of hospitals for pandemic conditions, original zoning of hospitals according to mechanical and physical needs must be discovered. For this purpose, tape-recorded interviews were conducted as face-to-face with hospital designing architects and interior architects and mechanical engineering professional. Explanations and recommendations of architects and mechanical engineers specializing in the field on the architectural and mechanical designs of hospitals and the criteria to be considered in making hospitals suitable for transformation in pandemic processes were transferred to the study both as references and schematic format.

4.2.1. Interview With Ekrem Evren

An interview was conducted on 22^{nd} February with a specialist in the mechanical engineering field Ekrem Evren in order to better understand the key points in hospital ventilation, filtration, zoning interiors in accordance with ventilation and filtration, and the steps necessary for the transformation of hospitals in pandemic processes. Interview questions are given in Appendix-1.

According to the information obtained from the interview, the criteria to be taken into account when making in-hospital arrangements are listed below.

1) Especially in hygienic areas, air flow must necessarily be provided according to differential pressures. It is important to adjust airflow direction from sterile areas to dirty areas. Airflow must to come from the operating room to the fully sterile corridor in front of it, from there to the stretcher transfer or doctor asepsis, from the doctor asepsis to the dirty area, or stretcher transfer to the dirty corridor (Evren, 2021), as is shown in Figure 4.10.

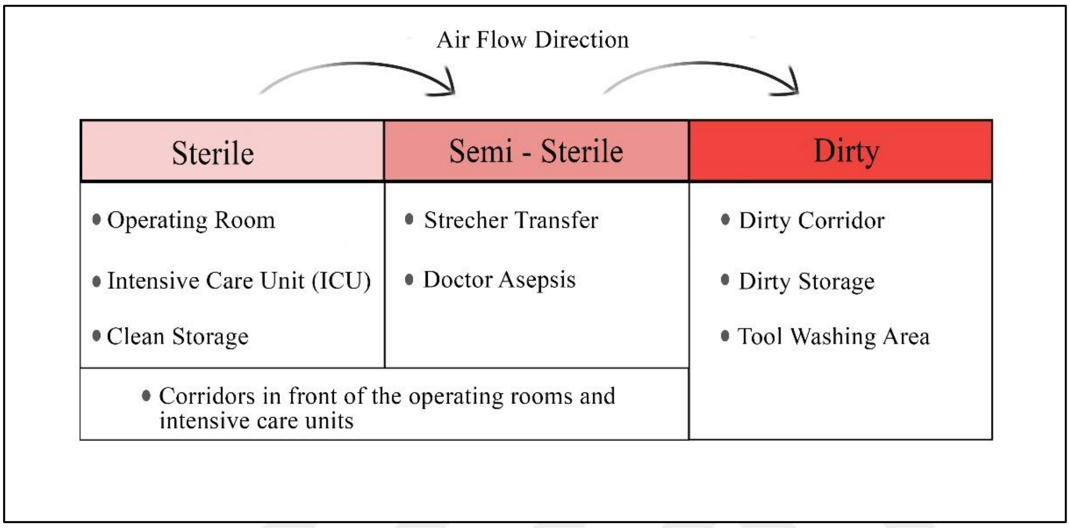


Figure 4.10. Required Air Flow Direction among Spaces in Hospitals

2) Patient rooms, sterilization, mortuary, laboratories, operating rooms, intensive care all have different ventilation, and according to the characteristics of the place, therefore placement of air inlet and outlet changes (Evren, 2021). The recommendation for isolation rooms is visualized as is shown in Figure 4.11.

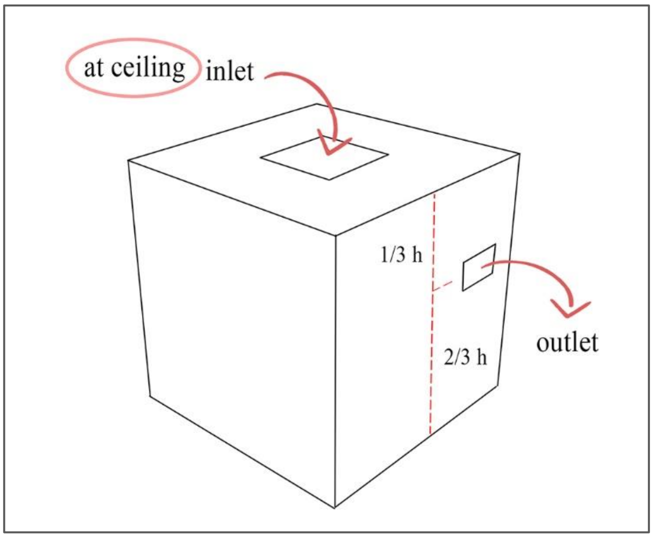


Figure 4.11. Air Inlet and Outlet Placements for Isolation Rooms

Fresh air is usually given from the ceiling, as it is necessary to spread to the environment. If possible, suction is given from below, if not, fresh air is given so that it does not come on the patient, and suction is provided over the patient. In isolation rooms, air is given from above and suction is provided from the lower level near the head side of the patient's bed (Evren, 2021).

3) Not all hospital interiors can be transformed in accordance with the pandemic, a specific group can be planned in accordance with the transformation. It is necessary to determine a separate air handling unit in the area where isolation is required. A heat recovery unit can be placed in order to provide fresh air to areas where the air handling unit cannot be placed. Thus, if 12 air exchange can be provided, an isolation area for pandemic process will be provided without the need for transformation (Evren, 2021).

4) When adjusting the pressures of the areas, the pressure is adjusted to decrease from the cleanest area to the dirtiest area. The consistency of differential pressures is controlled from building automation or central control. If the difference is reset, there can be a problem. Leaving the door open and opening the window cause a change in pressure. Hospitals are controlled areas where air flow is in balance, so natural ventilation can be a problem due to cause of pressure changes (Evren, 2021).

The consistency of differential pressures, Pascal (Pa) and Celsius (°C) values of the areas are controlled from building automation or central control. As an example, pressures in Hospital A are controlled through automation, as is shown in Figure 4.12.

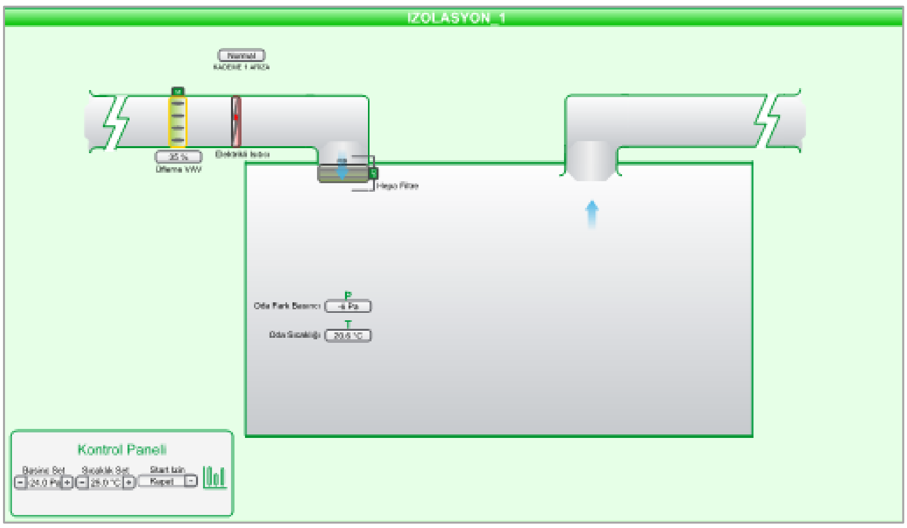


Figure 4.12. The Control of Pressure through Automation in a Isolation Room of Hospital A

5) If there is an air handling unit for an isolation room and air circulation can be made, it does both give fresh air and recirculate the rest of the air. For instance, if it is sent 2400 m^3/h air to air handling unit, it will be fifty-fifty fresh air and recirculated air. Therefore, the use of HEPA filter will be needed to clean recirculated air. But if an air handling unit is used for more than one isolation room, it is needed to give 100% fresh air as the standard. Recirculated air cannot be used in this case. It is inferred that in such situations, if it is aimed to make an isolated room, and if 1 air handling unit is used for more than 1 room, it is required to give 100% fresh air. However, if each room has its own air handling unit, recirculated air can be used and HEPA filter is needed to clean recirculated air (Evren, 2021), as is explained in Figure 4.13.

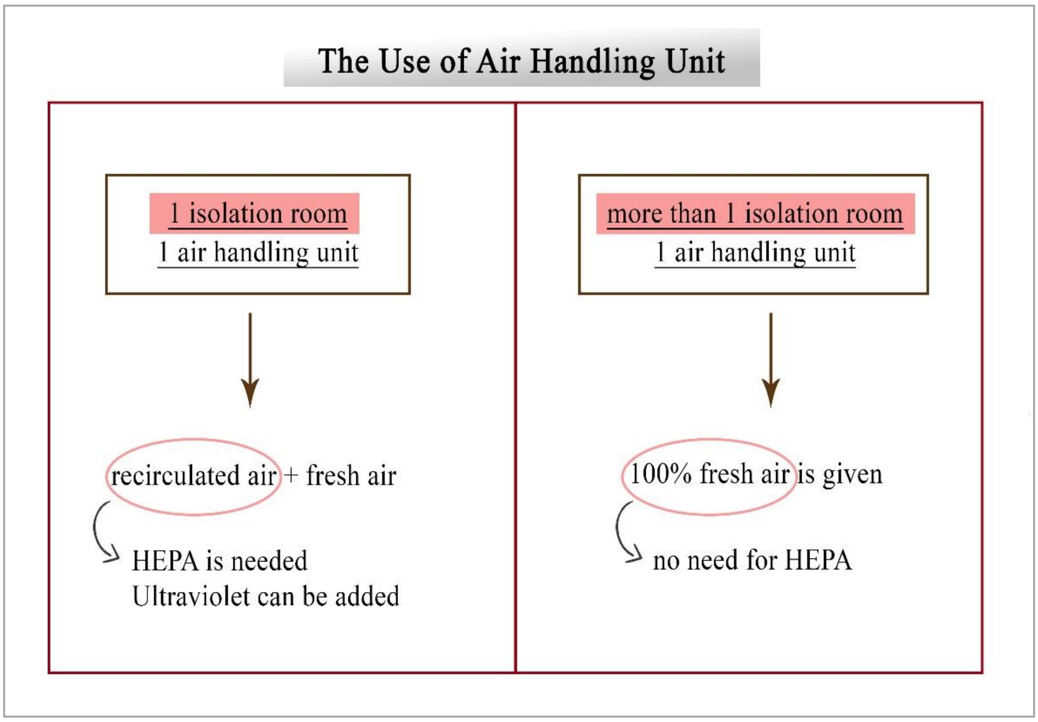


Figure 4.13. Need of HEPA in accordance with the Number of Isolation Room

6) HEPA filters should be replaced by a trained technical service. The dirty filter needs to be delivered to the medical waste storage in a controlled procedure (Evren, 2021).

7) Not only the measures taken inside the hospital, but also the measures taken around the hospital are important to prevent the spread of infections. If there are other air handling units beside the air handling unit that contains dirty air, the air coming out from that should be thrown up at least 15 m using Jetcap so that other air handling units do not absorb the dirty air and release it into the hospital (Evren, 2021), as is shown in Figure 4.14.

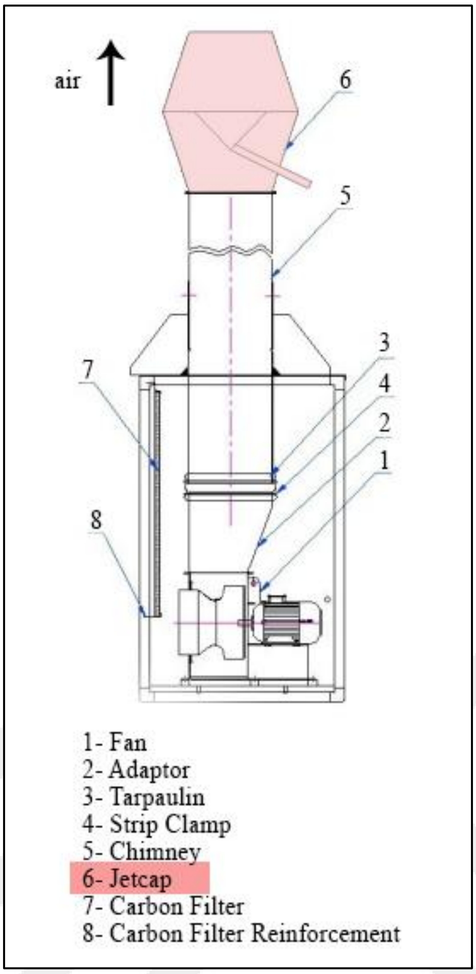


Figure 4.14. Removing air via Jetcap (HEMAK, n.d.) (Redrawn from info)

4.2.2. Interview With Gonca Ateş Öztürk

An interview was conducted on 15th February with a hospital specialist in the architecture field Gonca Ateş Öztürk in order to better understand the key points in hospital interior design, ensuring hygiene, and the steps necessary for the transformation of hospitals in pandemic processes. Interview questions are given in Appendix-2.

According to the information obtained from the interview, the criteria to be taken into account when making in-hospital arrangements are listed below.

1) Filtering varies depending on how many people there is in and purpose of use of the area. For this reason, mechanical engineers get a plan of furnishing from architects / interior architects. Architects and engineers work together in ventilation and architectural plan drawings (Ateş Öztürk, 2021).

2) Avoiding unnecessary angles in hospital design is very important for ensuring hygiene. Attention should be paid to the round line of the skirting board at sharp corners, chamfering should be done in necessary situations in design (Ateş Öztürk, 2021).

3) Beside minimizing edges and corners, the use of easy-clean materials is also important to provide hygiene. For this purpose, granular ceramics, vinyl materials, joint near zero and larger size ceramics, sterile area PVC are generally preferred (Ateş Öztürk, 2021).

4) Doors designed according to the needs of the space are used in transitions to different pressurized areas. Sectional doors must be used, and this kind of doors are determined according to the guidelines. From the point of view of hygiene, it is preferred as doors that open with a card, open when it sees movement, or open with an elbow (Ateş Öztürk, 2021).

4.3. Hospital Transformations

4.3.1. Examination of Hospital A

Hospital A is a hospital with a total of 10 floors, including 3 basement floors (from -3 floor to 6 floor). Most of the Air Handling Units are located on the 6. floor of hospital A., as is shown in the Figure 4.15. In order to examine which floors the Air Handling Units (AHUs) located on the 6. floor were related, 6. floor was examined in two stages: the right and left parts. Figure 4.1 shows the floors related with the AHUs on the left side of the 6. floor: 4. and 2. floor. However, Intensive Care Unit AHUs are located on both sides of the 6. floor.

According to this figure, operating room, operating room suites and intensive care units are located on the 4 floor, while delivery room and neonatal ICU (Intensive Care Units) are located on the 2. floor. In addition, it is seen that the AHU of the patient rooms located on the 2. floor is located on the same floor. It is understood from the mechanical plans that the patient rooms are not HEPA filtered, but it is given primer fresh air.

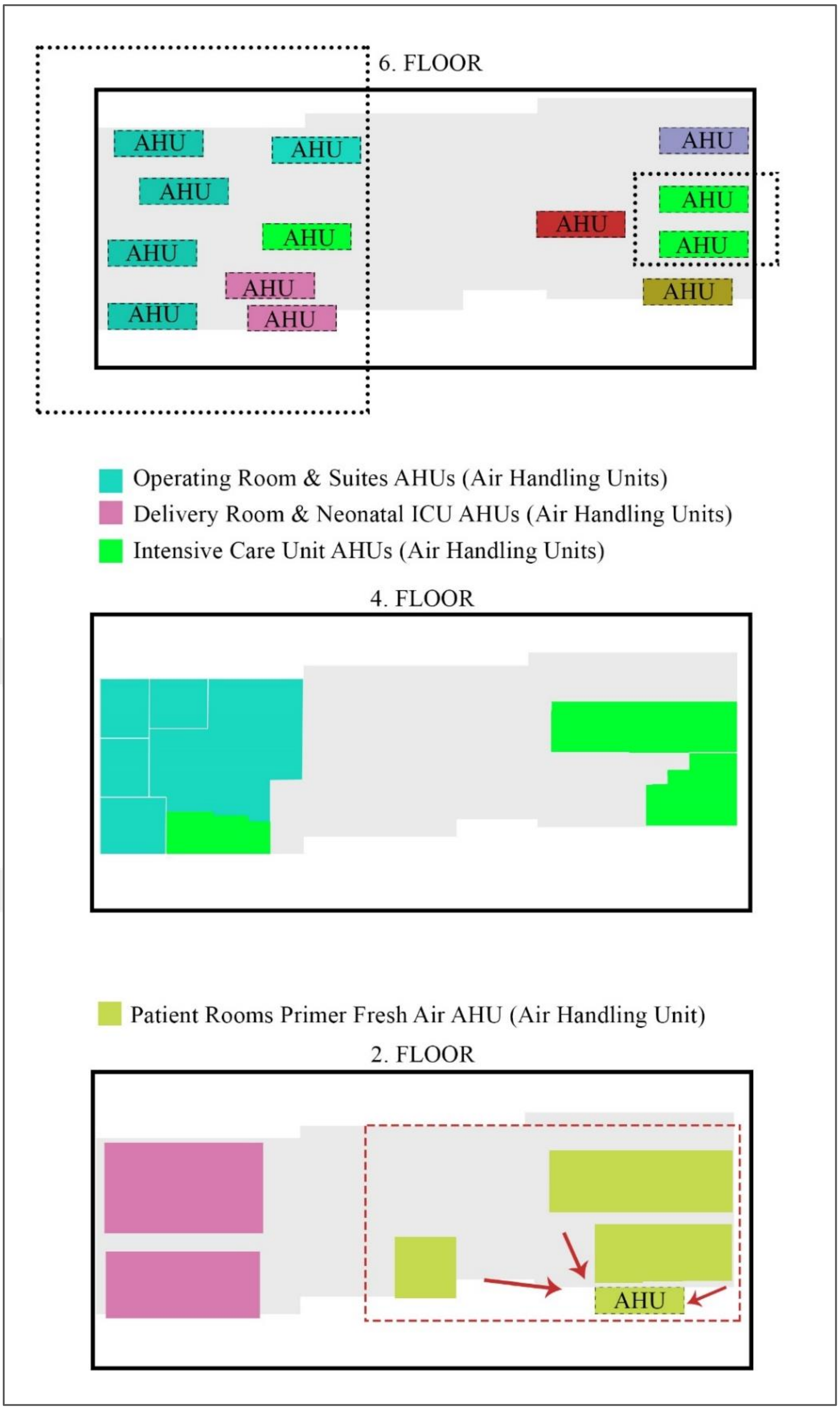


Figure 4.15. Left Side of the 6. Floor and AHUs' Locations

The floors related with the AHUs on the right side of the 6. floor are shown in Figure 4.16. According the plans, the AHUs on the right side are related with 5, 0 and -2. floor matched with colors.

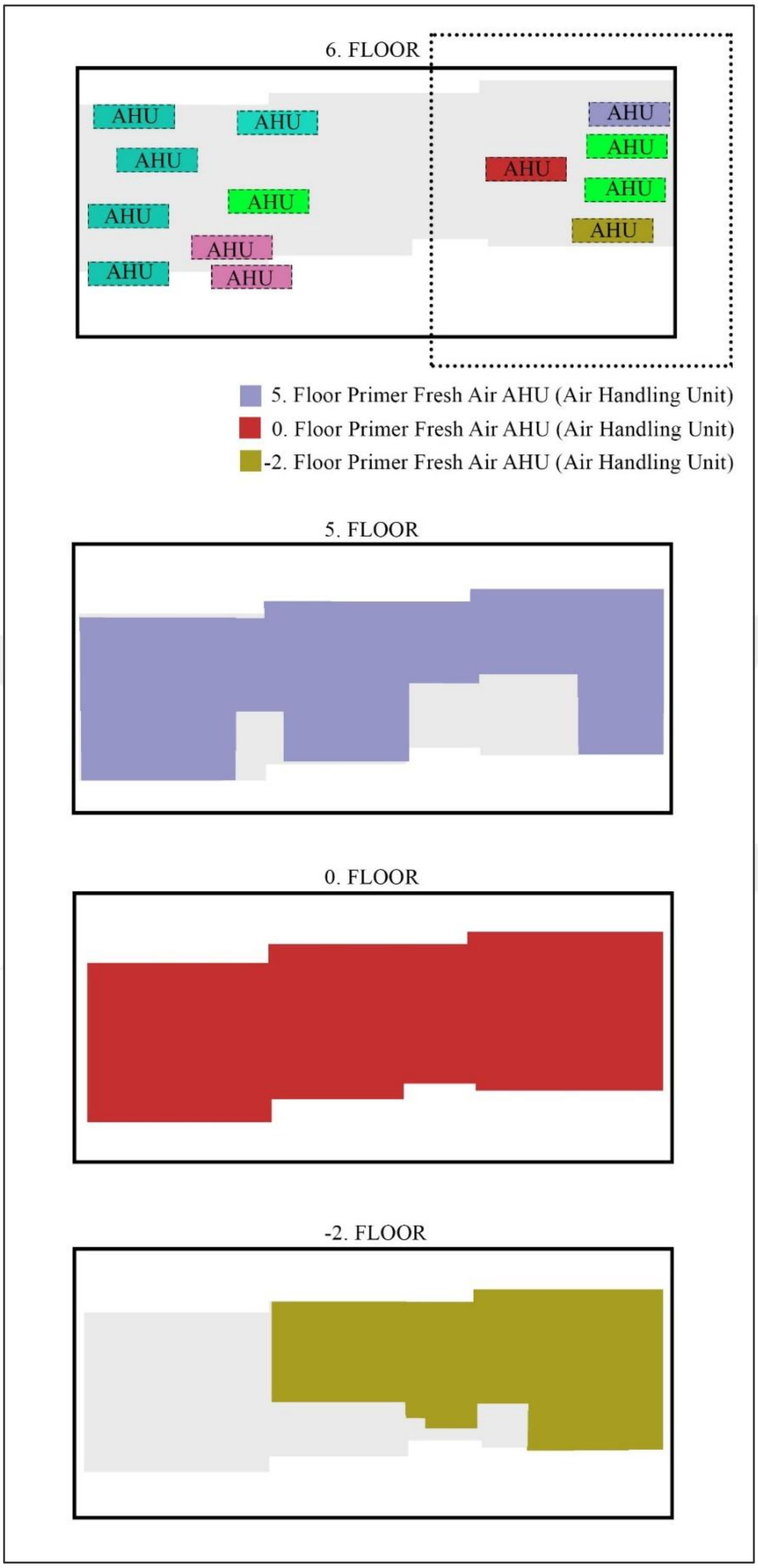


Figure 4.16. Right Side of the 6. Floor and AHUs' Locations

In addition to patient rooms located on the 2. floor, recreation are and polyclinics in 1. floor, and patient rooms and 2. recreation area located on the 3. floor has their own AHUs on these floor as is shown in Figure 4.17.

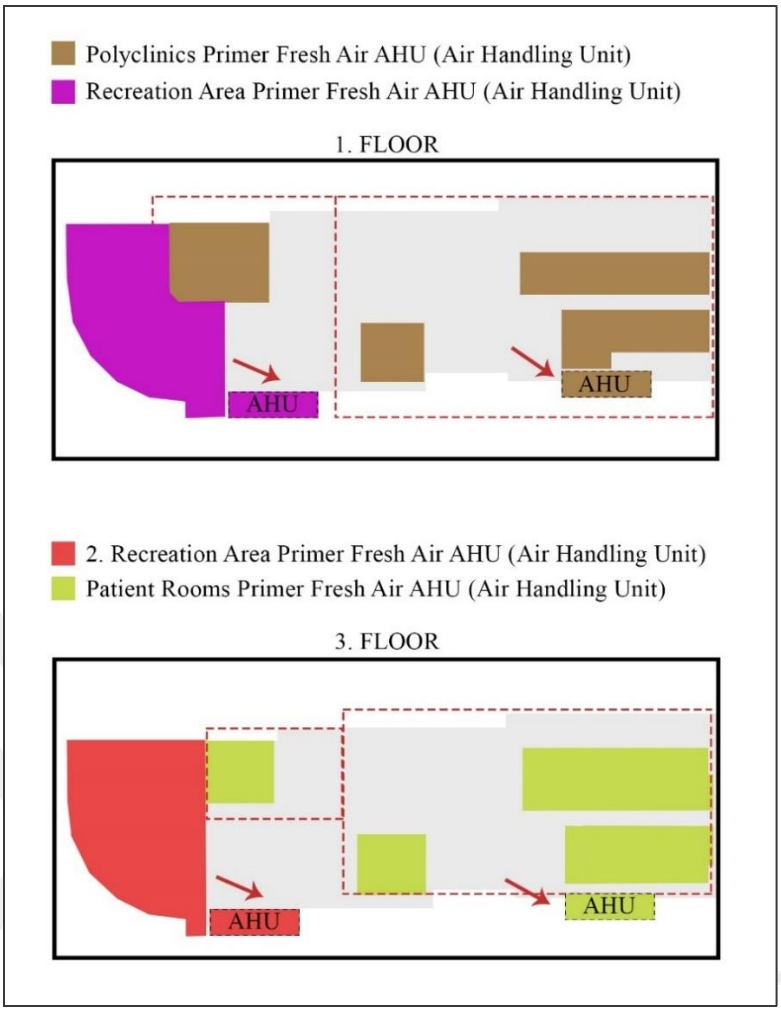


Figure 4.17. AHUs Located on 1. and 3. Floors

It is seen that only the AHUs of the 4th floor, the AHUs associated with the operating room, intensive care and the AHUs of the delivery room located on the 2nd floor, are HEPA filtered, and other AHUs in the hospital are primary AHU that provides fresh air.

4.3.2. Transformation of Hospital A

In Hospital A, there are 3 different floors transformed into isolation areas. Some patient rooms in Hospital A are located on the 2. and 3. floor. In addition to patient rooms, fifth floor was transformed as it found to be suitable to convert. Since the Air Handling Units used on the right and left parts of the floors were separated on the 2. and 3. Floors (on the same floor located in terraces attached to right zone), it was enough to transform only the right parts / zones. 5. floor was connected to a single AHU, and the

AHUs used in isolation areas should not be connected to other areas to avoid spreading infection. Therefore, the entire of 5. floor can be transformed.

In order to provide access to these transformation areas in isolation conditions, it is recommended that the entrance to be made from the storage door at the back, which is different from the main entrance of the building, as is shown in Figure 4.18. In order to make an isolated area in Hospital A from the newly defined entrance, it was decided to use the elevator located in the right part of the Hospital A for only transformed area. The door of the storage leading to the ground floor was removed and direct access to the isolation area was provided. By adding a separation wall around the sterilization area, the sterilization area was separated from the ground floor. White lines refer the added walls. Negative pressure is recommended for this area, since the mechanical ventilation cannot be separated from the rest of the ground floor.

In addition, currently, the Covid-19 swab test is performed outside the hospital, as shown in the figure. It is also recommended that this test area to be positioned close to the service entrance, as a different entrance recommended for the Covid-19 isolated service.

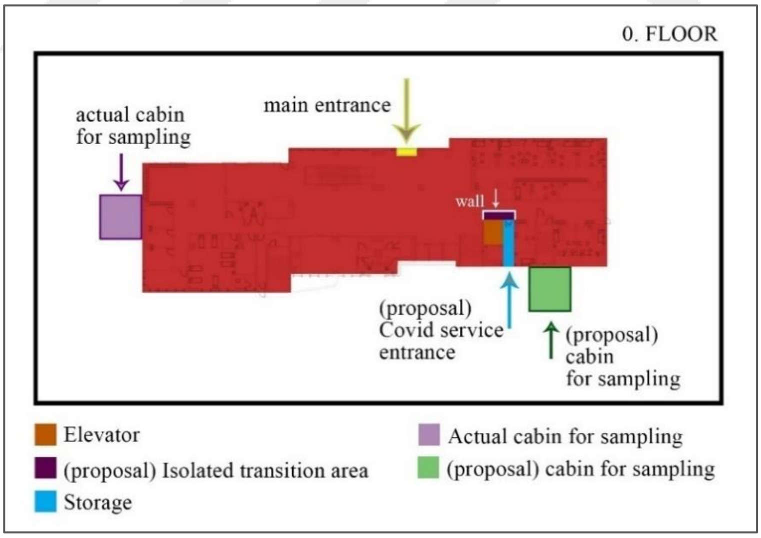


Figure 4.18. Defined New Entrance to the Isolated Areas in Hospital A

When designing transformation scenarios for patient rooms on floors 2 and 3, only the right parts of these floors were transformed and right side mechanical zones were separated from left parts by adding a buffer sterilization area, as is shown in Figure 4.19. The sterilization area was continued until the area indicated by the red line, and airlock mechanical system transition is designed as shown by the red line, to prevent infection from passing to the left side of the same floor.

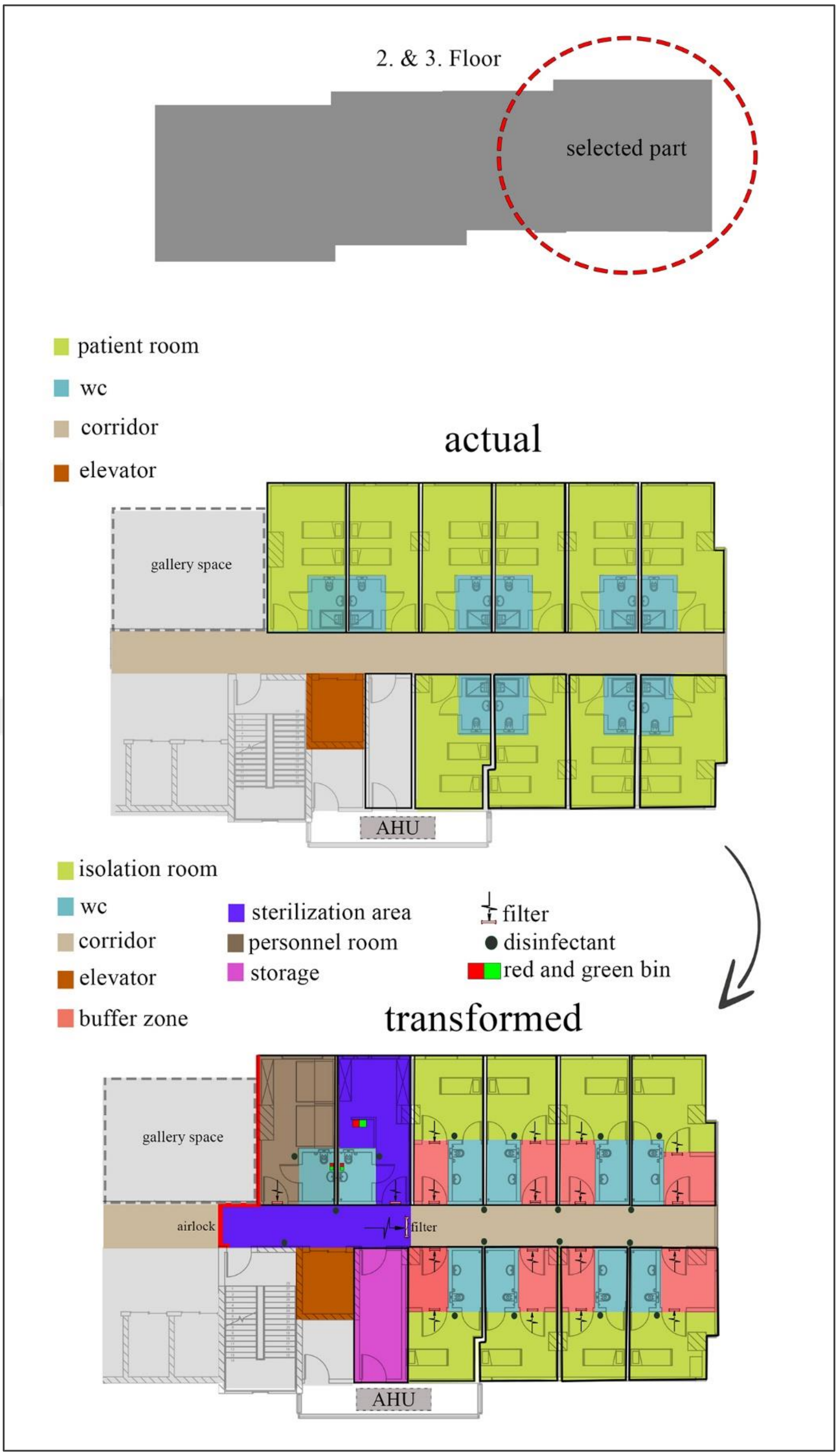


Figure 4.19. Transformation of 2. and 3. Floor

As is seen in Figure 4.19, first, the actual layout of patient rooms were visualized, then the layout transformed in accordance with isolation room needs. In order to make an isolated room, buffer zone is required to prevent spread of infection. Therefore, buffer zones were added to the entrance of the rooms. Disinfectants placed at the entrance of each room. Red and green bins, which were decomposed as dirty and clean recycling bins, were placed in both personnel rooms and sterilization areas. Also, HEPA filters added to control contaminated air transferred from room to buffer zone and buffer zone to main channel heading to dedicated AHU.

For such in-hospital transformations, in order to prevent spread of infection, a filter on the ventilation line must be placed at each room exit and at each buffer zone exit. This criteria was considered for all transformations in this study, and applied to plans as is shown in Figure 4.20.

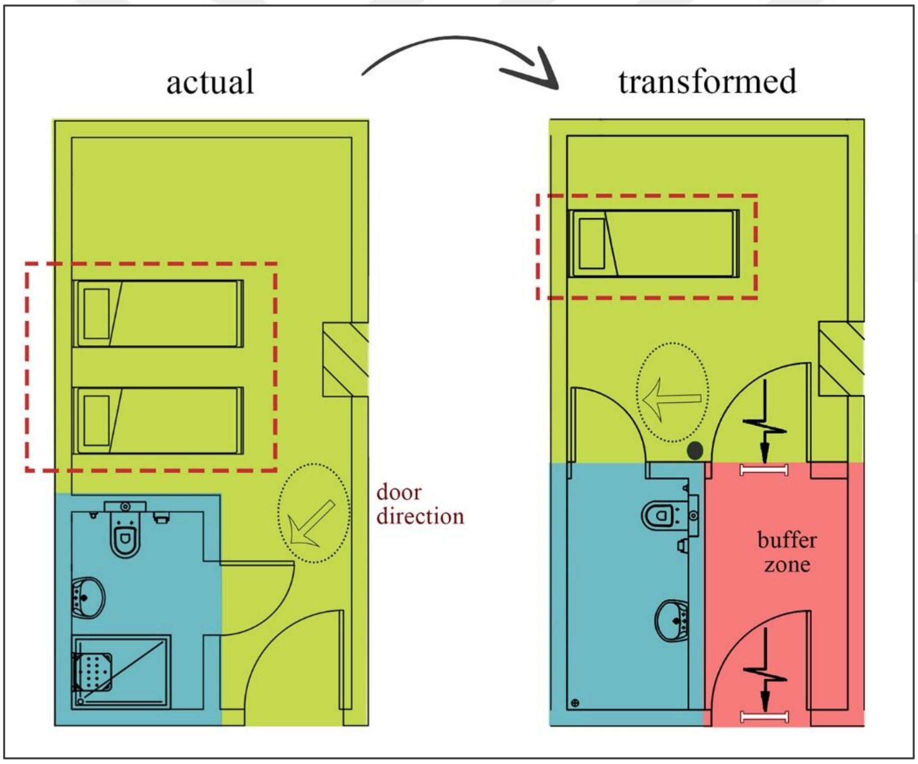


Figure 4.20. Transformation of Rooms Located on 2. and 3. Floor

Since the patient rooms on the 2. and 3. floors have the same typology, only one transformation proposal was made for these rooms. In these rooms, when a buffer zone was placed at the entrance, the direction of the toilet doors had to be changed. Due to changing the direction of the door, the interior of the toilets were refurbished. In addition, the number of beds was reduced from 2 to 1 so that the patient room could be transformed into an isolation room for one, as is recommended by Turkish Ministry of Health to control infection (The Ministry of Health of Turkey, 2010).

It is thought that one of the rooms should be allocated to the personnel due to the fact that the personnel working in the Covid-19 service also need rest area. Figure 4.21 show the transformation of a patient room into the personnel room. In order to transform, first the patient bed was removed. Then, sofa beds and wardrobes were added to the room. It was aimed that the sofa bed did not cause congestion in the interior when it was open. Therefore, 2 sofa beds were placed. In the toilet, two bins in red and green were placed to separate recyclable and medical waste items that would be thrown. Since the personnel room was not an isolated room, the buffer zone was not needed, but a filter was placed in the mechanical ventilation way out as shown in the figure.

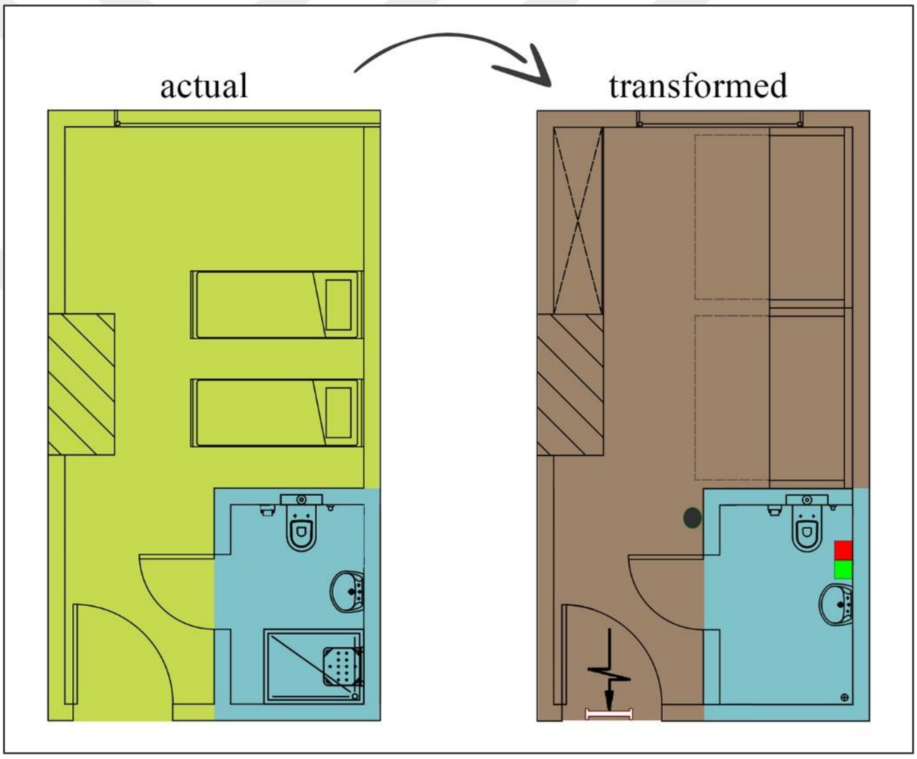


Figure 4.21. Transformation of a Patient Room into the Personnel Room

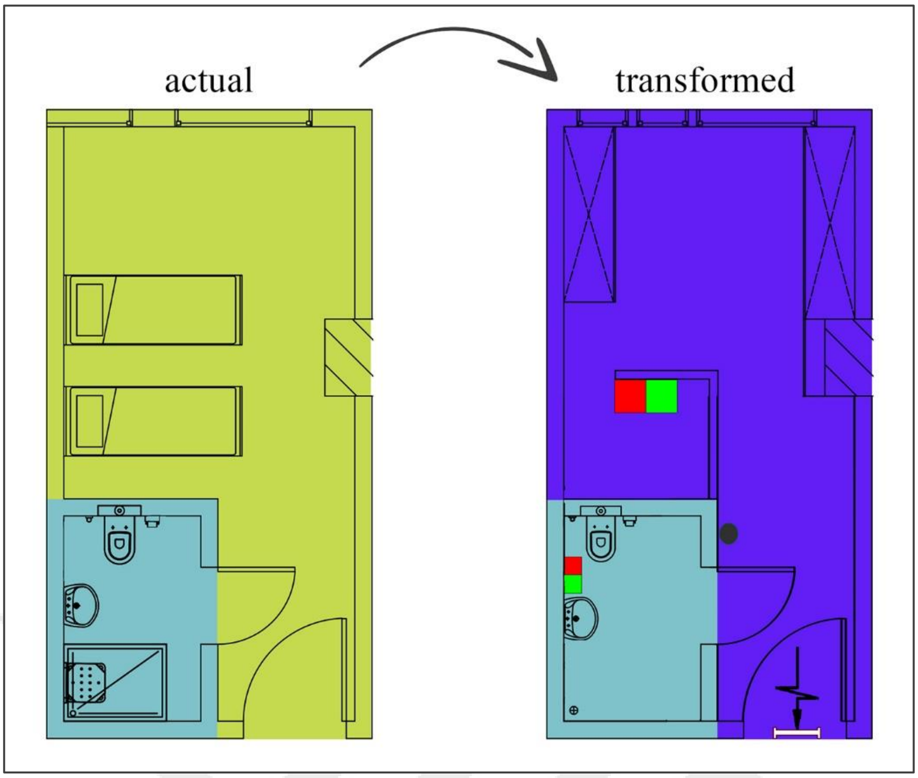


Figure 4.22. Transformation of a Patient Room into the Sterilization Area

Figure 4.22 shows the transformation of a patient room into the sterilization area. As health workers were required to change their clothes in a separate area from the personnel room to prevent infection, this area was reserved for the need of a dressing room for personnel. Wardrobes were placed. Besides, a separated cabin was placed to provide an area for personnel where they could dress comfortably. Two bins in red and green were placed within the cabin to separate items that would be thrown or disinfected for reuse. Last, a HEPA filter was placed in the return ventilation channel where it coincides with the exit of the room.

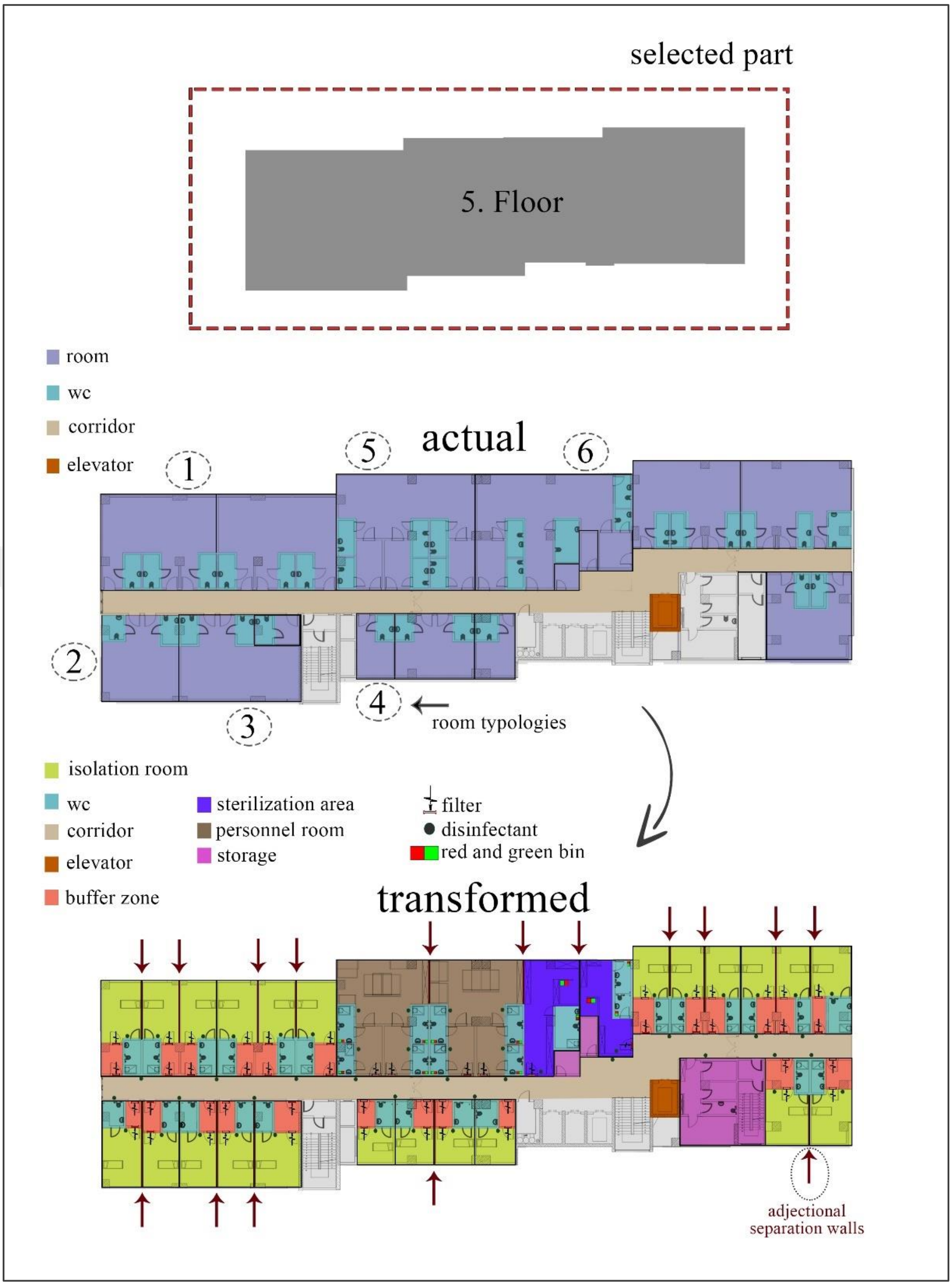


Figure 4.23. Transformation of 5. Floor

Figure 4.23 shows the transformation of 5. Floor. There are several reasons why this floor is considered suitable for conversion. Room layouts on this floor are suitable for conversion into isolated patient rooms. The mechanical ventilation of the entire floor is connected to a single AHU, and it is separated from other floors. One of the elevators can be dedicated to only 5. floor, as previously done for 2. and 3. floors. Besides, there is no need for a buffer sterilization area because the fifth floor is completely transformed and has its own mechanical equipment (AHU).

According to the typologies of the rooms as is seen in Figure 4.23, six different room typologies were examined and transformed in detail. The remaining rooms have similar typology except for differences in their sizes. Figure 4.24 shows the actual and transformed version of the Room-1. In fifth floor, totally there are 4 rooms that have this typology.

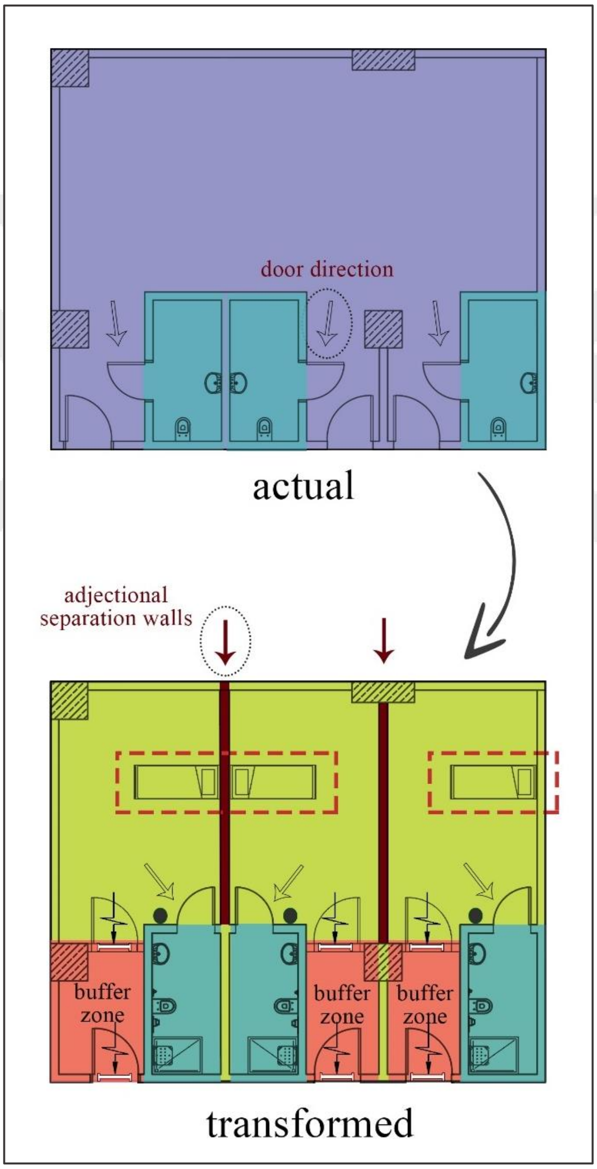


Figure 4.24. Transformation of Room-1 on the 5. floor

In order to transform Room-1 to an isolated room, the first thing was made is to add separation walls, since the room is quite large for one isolation room and it has 3 toilets. By adding walls, 3 different rooms were created. In order to be able to add buffer zones to the entrances of the rooms, the door directions of the toilets were changed and the interior of the toilets were refurbished. Showers were added to the toilets. Disinfectants were placed at the entrance of each room. In actual plan, 5. Floor has rehabilitation areas and management room. These rooms originally do not have any patient bed. Therefore, one patient bed was placed in each room, room sizes are available for two patients as well if needed.

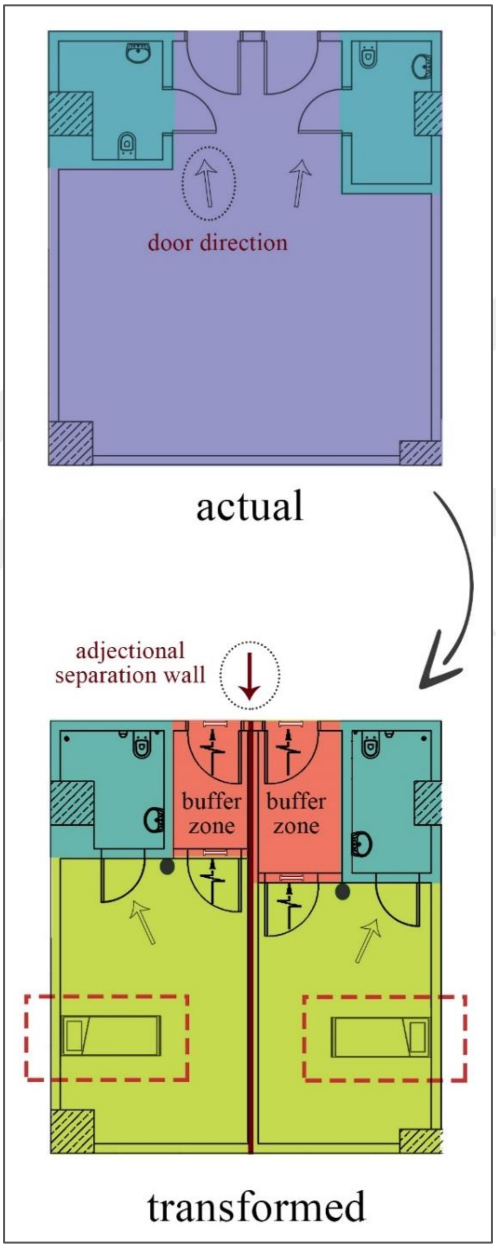


Figure 4.25. Transformation of Room-2 on the 5. floor

Figure 4.25 shows the Room-2 transformation. In order to transform Room-2, a separation wall was added to divide room into two rooms. Buffer zone was placed for both rooms, and toilet doors' directions were changed to separate toilet entrances and buffer zones. For each room, one shower and one patient bed were placed. For adding a shower and changing the direction of the door, it is required to refurbish interiors of toilets.

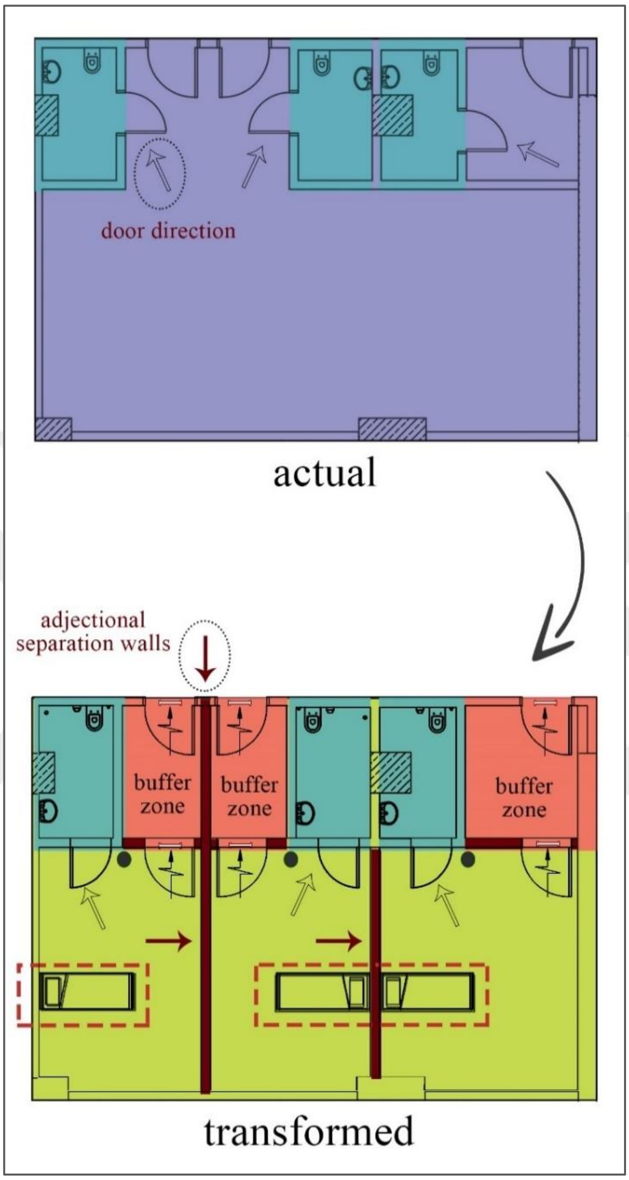


Figure 4.26. Transformation of Room-3 on the 5. floor

Figure 4.26 shows the transformation of Room-3. The same interventions were made also for this room. After adding separation walls, buffer zones were added, the door directions of the toilets were changed, patient beds and showers were added. What makes this room different from Room-1 is that the toilet on the right side is not included in the room. After the transformation, this room has a similar typology as Room-1. Since a buffer zone is added to the rooms in isolation room transformations, it is enough to make only a door opening on the wall of the right side of the Room-3 in order for providing a buffer zone.

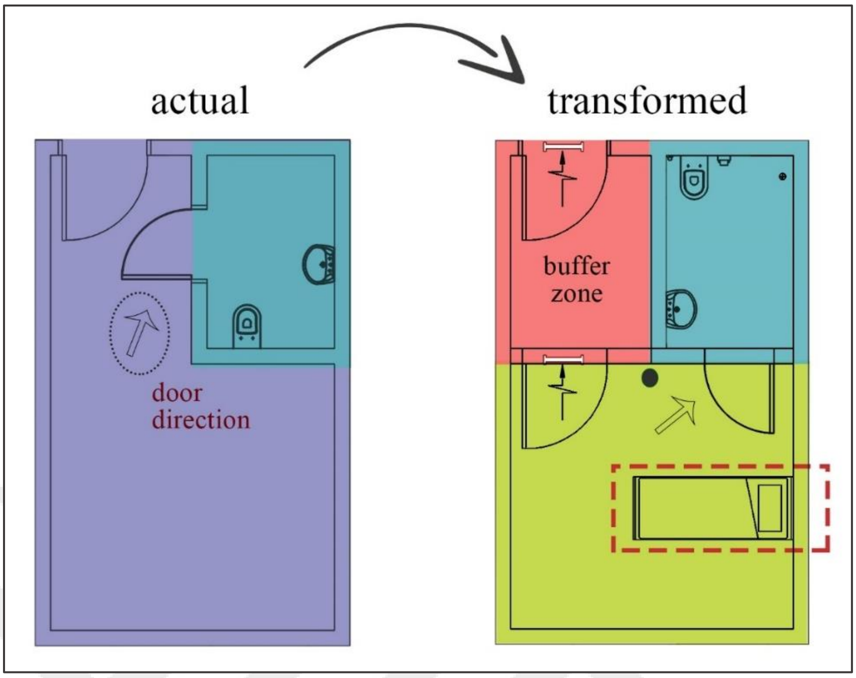


Figure 4.27. Transformation of Room-4 on the 5. floor

Transformation of Room-4 was visualized in Figure 4.27. There are two rooms that have this typology on 5. floor, while all the patient rooms on the 2. and 3. floors have this typology. Therefore, the same interventions were made for Room-4, too. A buffer zone was placed at the entrance, the direction of the toilet door was changed. One patient bed was placed in the room. The interior of the toilets were refurbished and a shower was added within the toilet.

As can be seen, all transformation proposals have the same criteria. A buffer zone should be provided, the number of patient beds should be limited to 1, if necessary, separation walls should be used in the rooms. Since patients might stay in these isolated rooms for a long time, if there is no shower in the toilets of the converted rooms, it should be added. If the opening direction of the toilet doors faces the buffer zone, the placement and direction of the door should be changed. As changing the door will also affect the layout of the toilets, the necessary arrangements should be made in the most appropriate way to ensure comfort within toilets.

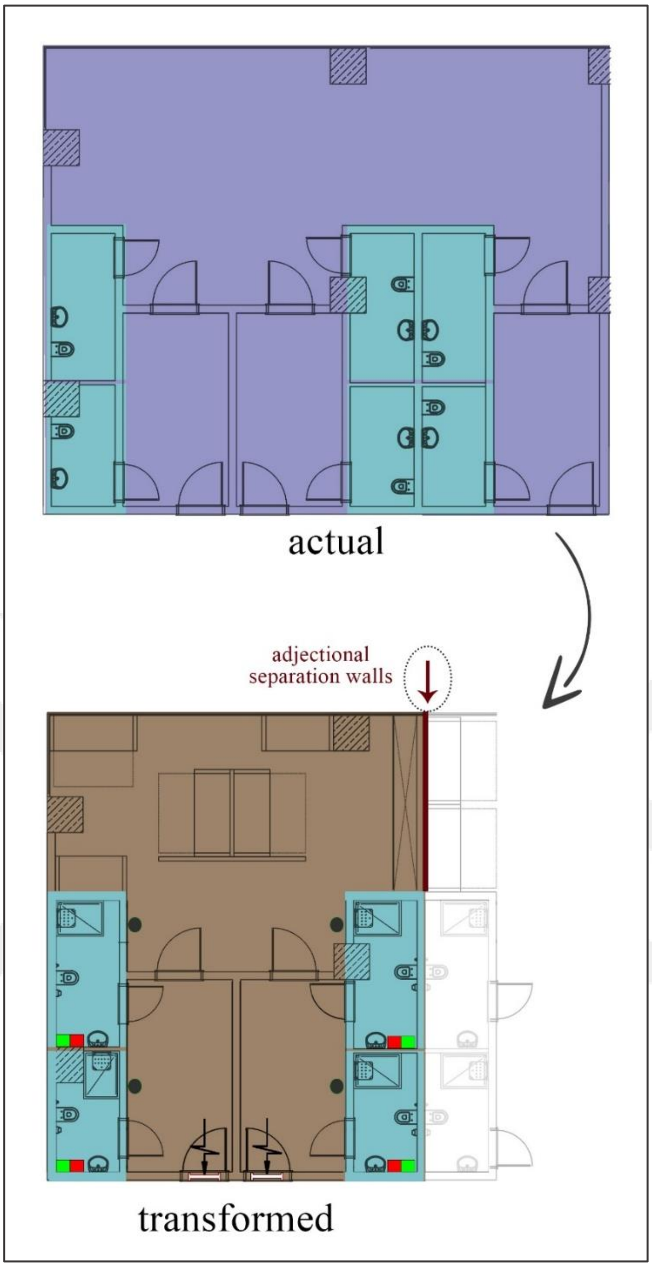


Figure 4.28. Transformation of Room-5 into the Personnel Room

Since the rooms of 5. floor are used for rehabilitation and management, these rooms have more than 1 toilet, as is seen in Figure 4.28. It is thought that these rooms should be allocated to the personnel. Room-5 and the other room next to it, which has the similar typology as this room, are available to Covid-19 service workers. Thus, the staff room can be located on the center of the 5. floor. When converting Room-5 into a personnel room, sofa beds can be placed in this room to provide a rest area for the personnel. In addition, cabinets or wardrobes can be placed in the appropriate spaces in front of the wall. The room next to this room also has similar room typology. Therefore, by shifting the wall between these rooms slightly, two equal areas were formed, and these two areas were planned as resting areas for the personnel, as is shown in general transformation plan in Figure 4.28.

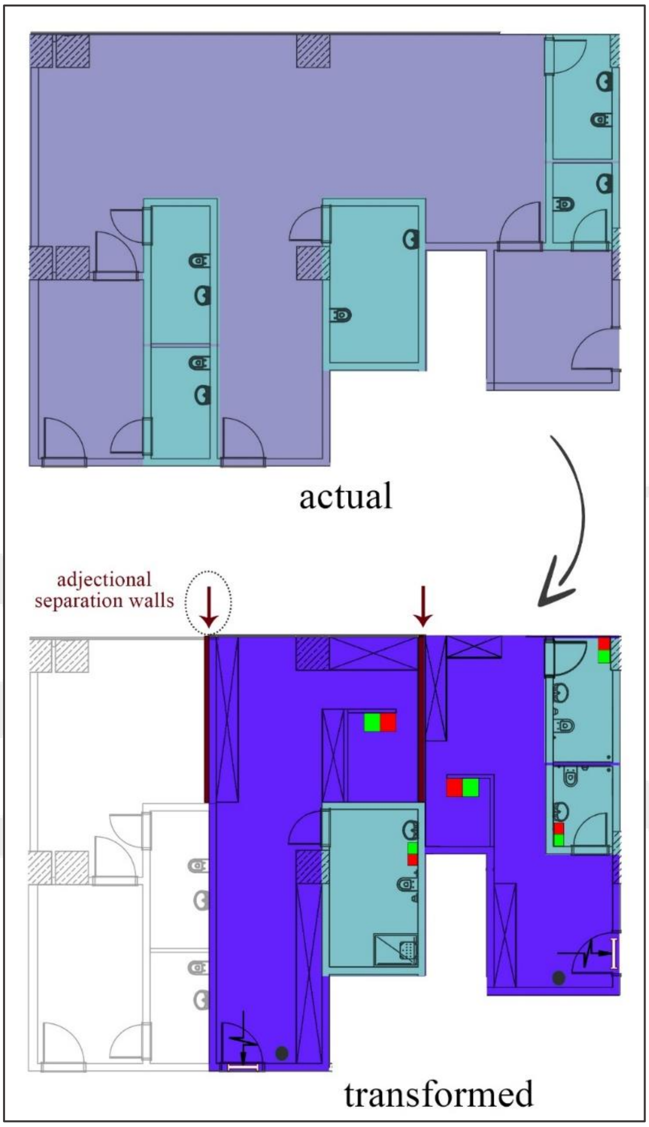


Figure 4.29. Transformation of Room-6 into the Sterilization Areas

The left part of Room-6 was used for personnel room. The remaining part of the room was divided into two by adding separation wall, and then transformed to the sterilization areas that can be used as a dressing room for the staff, as is shown in Figure 4.29. Because during the pandemic, health workers regularly change their clothes many times during the day, they need a dressing room outside the staff room. Wardrobes were added to the room and a space reserved for dressing was considered inside the room.

4.3.3. Examination of Hospital B

Hospital B is a hospital with a total of 5 floors, including 1 basement floors (from -1 floor to 3 floor). Air Handling Units are located on the rooftop of the Hospital B, as is shown in the Figure 4.30.

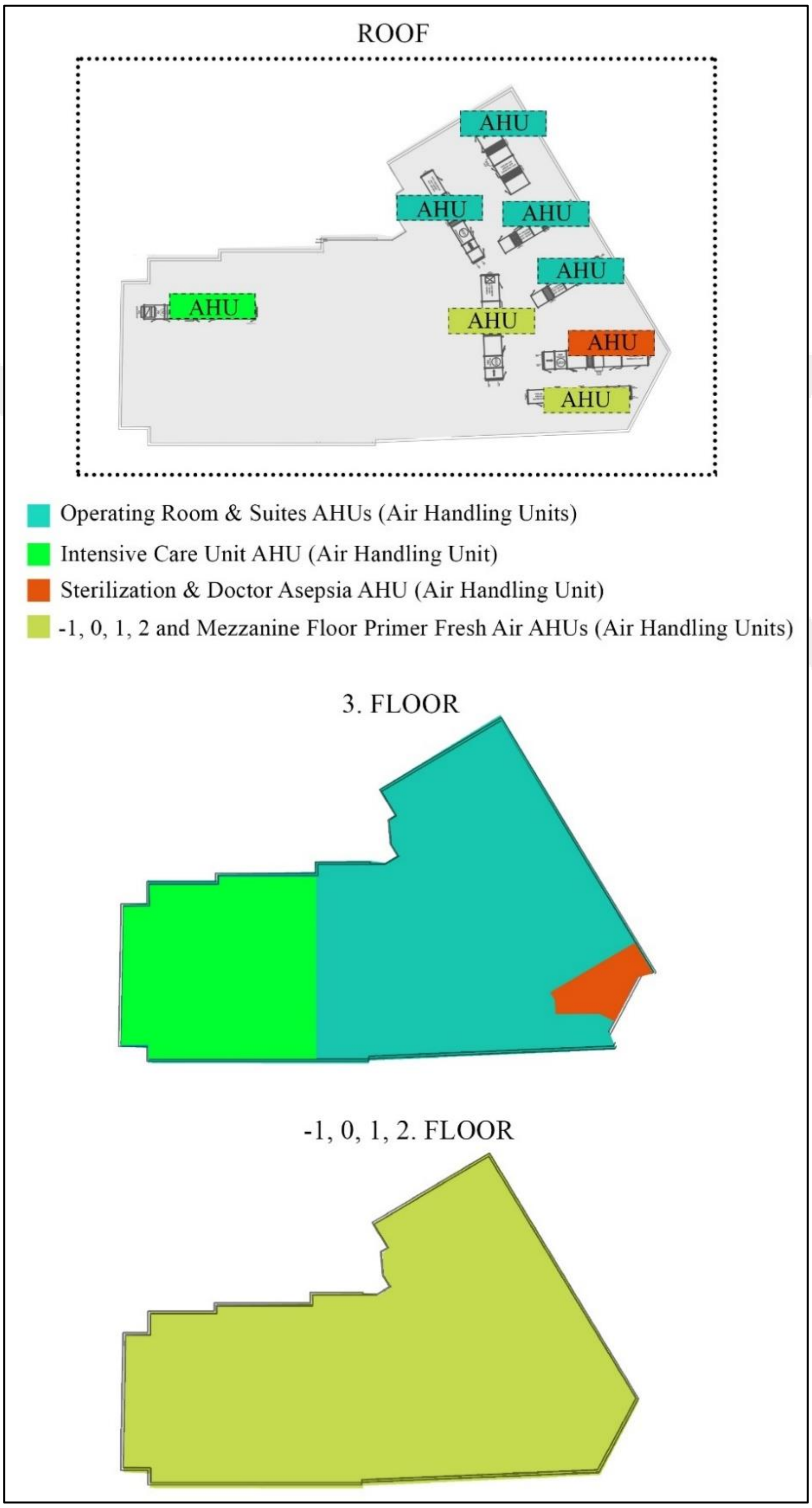


Figure 4.30. Air Handling Units of Hospital B

On the third floor of the hospital, there are operating rooms, operating room suites, intensive care units, sterilization and doctor's asepsis area. For these areas, HEPA filtered AHUs are used. For the floors from -1 to 2, Primer Fresh Air AHUs are used. In order to transform the 2. Floor into an isolated area, one of these two Primer Fresh Air AHUs should be dedicated to only 2. Floor.

4.3.4. Transformation of Hospital B

In Hospital B, only 2. floor that has patient rooms was transformed, because other floors are not proper for transforming to isolated patient rooms.

In order to provide access to 2. floor in isolation conditions, it is recommended that the entrance to be made from the fire exit at the back of ground floor, which is different from the main entrance of the building, as is shown in Figure 4.31. By adding a separation wall around the sterilization area, the sterilization area was separated from the ground floor. White lines refer the added walls. Negative pressure is recommended for this area.

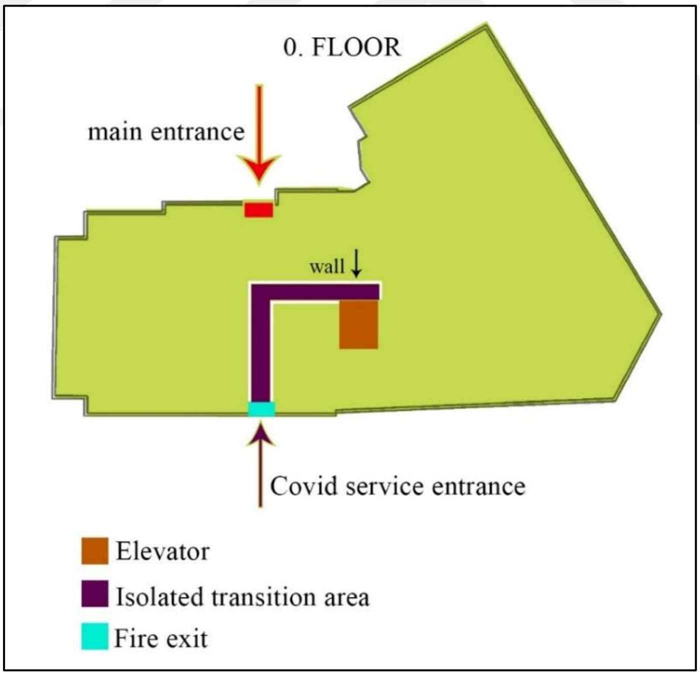


Figure 4.31. Defined New Entrance to the Isolated Area in Hospital B

In Hospital B, there are 7 different room typologies that were transformed into isolation rooms, as shown in Figure 4.32. In addition to the room transformations, 1 room was transformed into the personnel room, and 1 room was transformed into the sterilization area. There is no change for storage area for Covid-19 service workers.

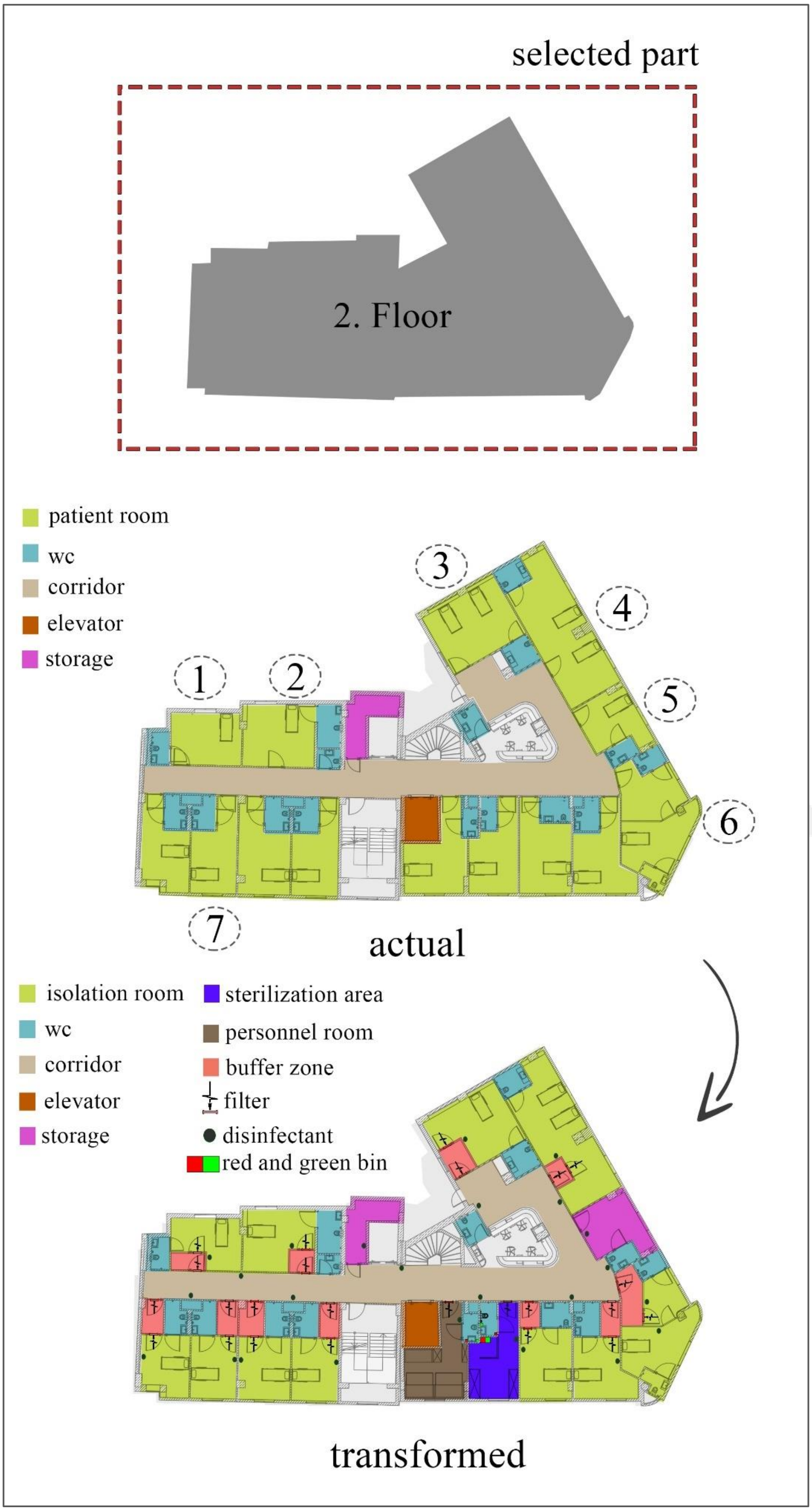


Figure 4.32. Transformation of 2. Floor

As one of the measures that can be taken to prevent the spread of infection, it is recommended to place a filter on the ventilation return channel at each room exit and at each buffer zone exit.

Figure 4.33 shows the transformation of Room-1. In order to transform this room and to be able to add buffer zone to entrance, the direction of toilet door was changed. This change also required refurbishing in the toilet. Disinfectants were placed at the entrance of each room. In addition, the bed was shifted slightly to the left to provide enough space next to the bed.

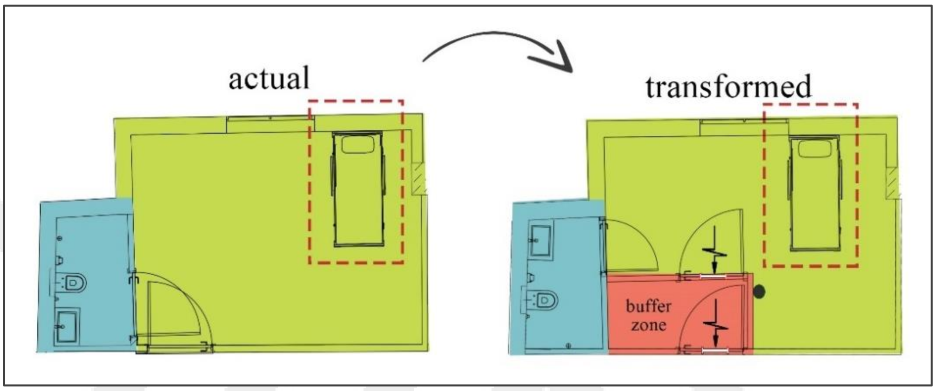


Figure 4.33. Transformation of Room-1 on the 2. Floor

Figure 4.34 shows the transformation of Room-2. Adding a buffer zone to the entrance was enough to transform this room, because the placement of the toilet in the room does not affect the addition of a buffer zone. In addition, the position of the bed was changed so that it could create the necessary space around the bed.

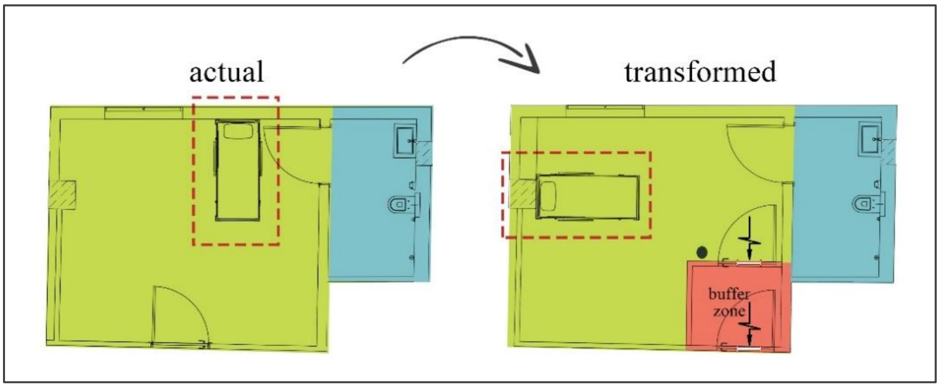


Figure 4.34. Transformation of Room-2 on the 2. Floor

Both Room-1 and Room 2 have only 1 patient bed, while Room-3 and Room-4 have 2 patient beds. In order to make an isolated room, the number of patient beds of Room-3 was decreased to 1, as is seen in Figure 4.35.

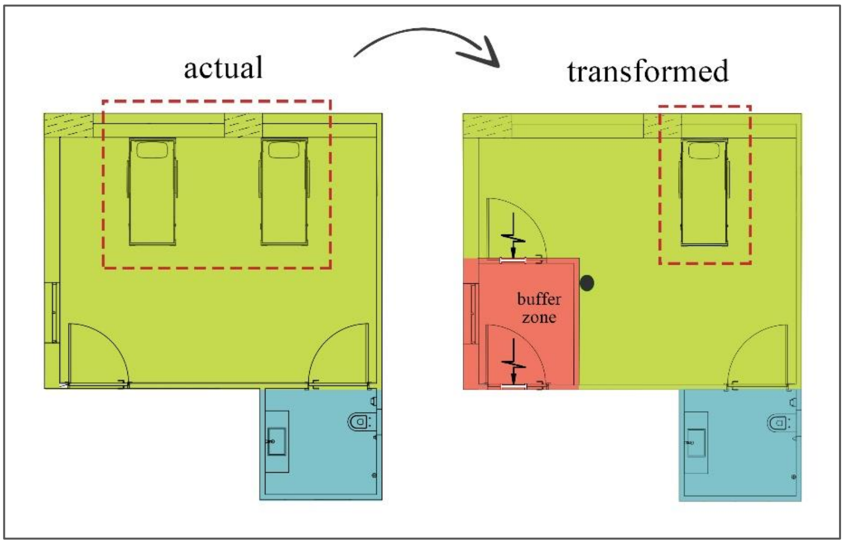


Figure 4.35. Transformation of Room-3 on the 2. Floor

Adding a buffer zone is quite simple for Room-3 and Room-4, since the entrance doors and the toilets are located far away from each other.

The number of patient beds of Room-4 was not changed due to the possibility of using oxygen tents for the beds as is shown in Figure 4.36. However, the position of the beds was changed to allow sufficient space around.

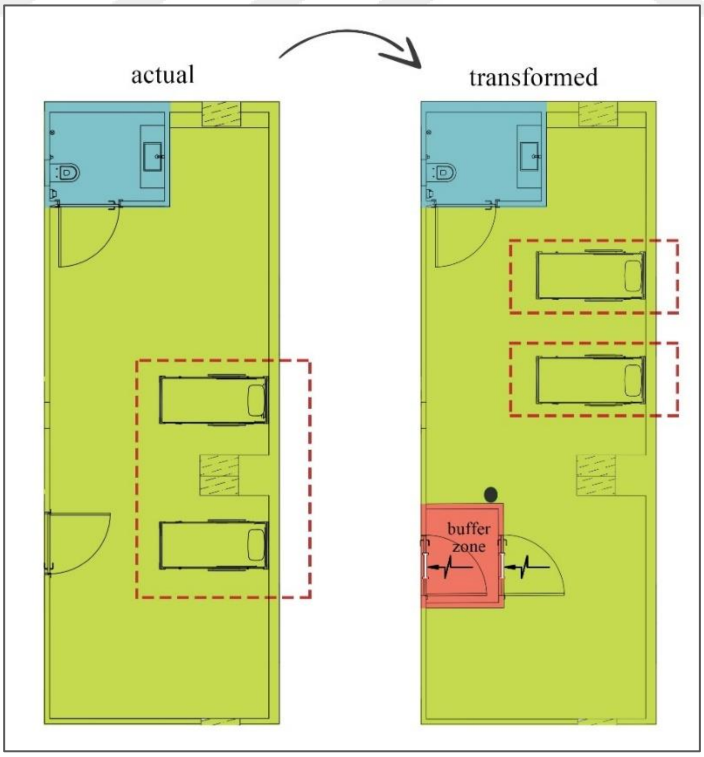


Figure 4.36. Transformation of Room-4 on the 2. Floor

Figure 4.37 shows the transformation of Room-6. Adding a buffer zone also for this room is quite simple because toilets' doors do not open to the entrances of the rooms. In addition, the bed number of this room is also suitable for making an isolated room. The only thing should be done is to place a buffer zone at the entrance. However, Room-5 next to Room-6 was transformed into the storage because it was not suitable to have a buffer zone.

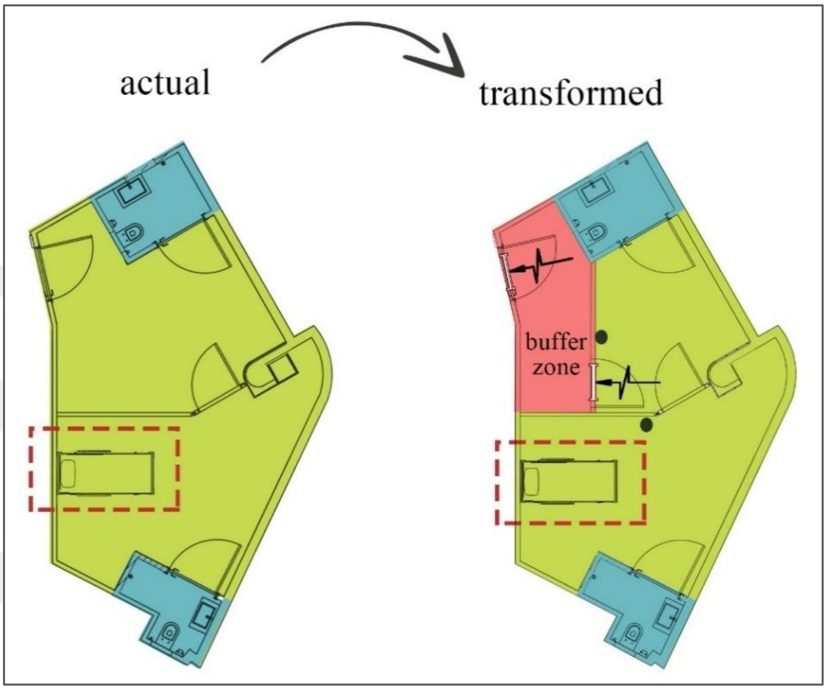


Figure 4.37 Transformation of Room-6 on the 2. Floor

Additional furniture can be placed in large rooms such as Room-4 and Room-6, except for the bed. In this study, other furniture included in existing plans for hospital rooms was ignored since it is taken into account only the number of beds in room transformations.

Figure 4.38 shows the transformation of Room-7. In order to transform Room-7, first a buffer zone was placed at the entrance, and then the placement of toilet door was changed. The change in the placement of the door did not cause changes in the interior of the toilet in 6 of the 7 rooms, while the location of the sink was changed in one of the rooms.

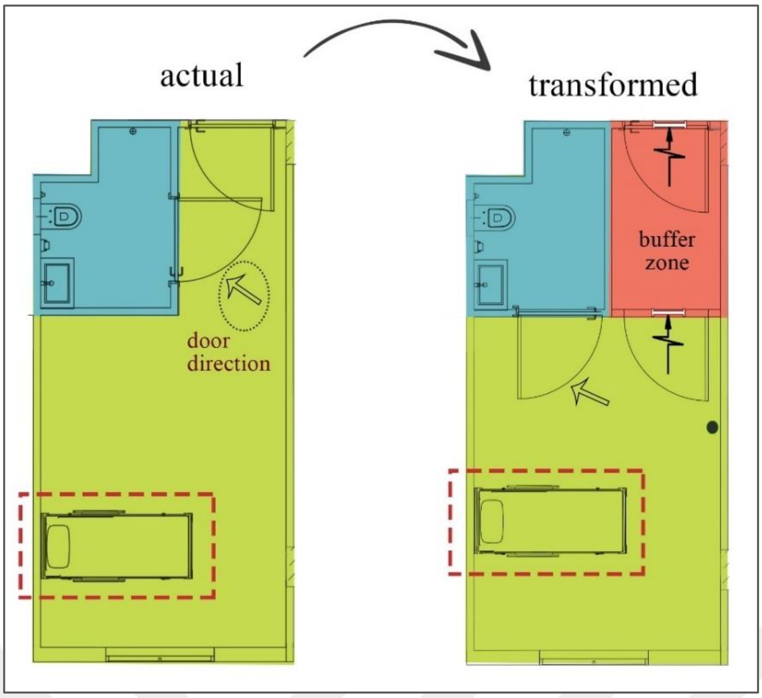


Figure 4.38. Transformation of Room-7 on the 2. Floor

There are 8 patient rooms that have this typology. However, one of them cannot be transformed due to the fact that the location of toilet and the direction of toilet door cannot be changed. Therefore that patient room was transformed into the personnel room, as is seen in Figure 4.39. Besides, one of the rooms was transformed into a sterilization area as is shown in Figure 4.40, because personnel needs a space to be separate from the restroom for changing clothes.

In the transformed version of the personnel room, the patient bed was removed and sofa beds were placed to create a rest area for the personnel. Due to the typology of the room, 2 of the sofa beds can be opened, while 1 of them is fixed. Also, wardrobes were added.

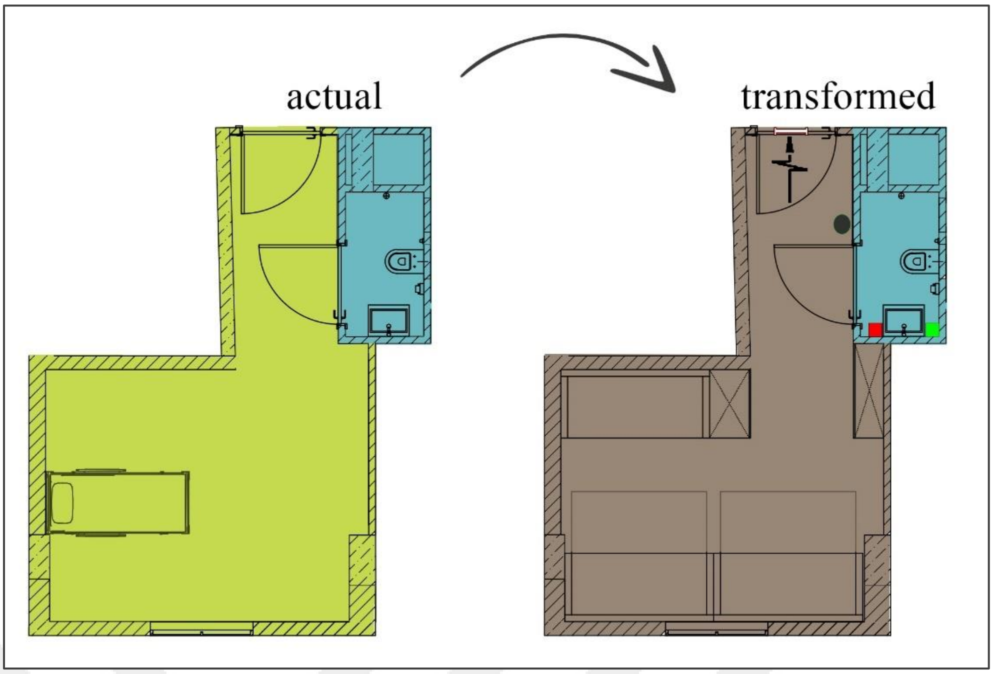


Figure 4.39. Transformation of a Patient Room into the Personnel Room

In the transformed version of the sterilization room, the patient bed was removed and wardrobes were added to create an area where personnel can put their clothes. A separator was added to the left of the room to create a space for personnel to get dressed.

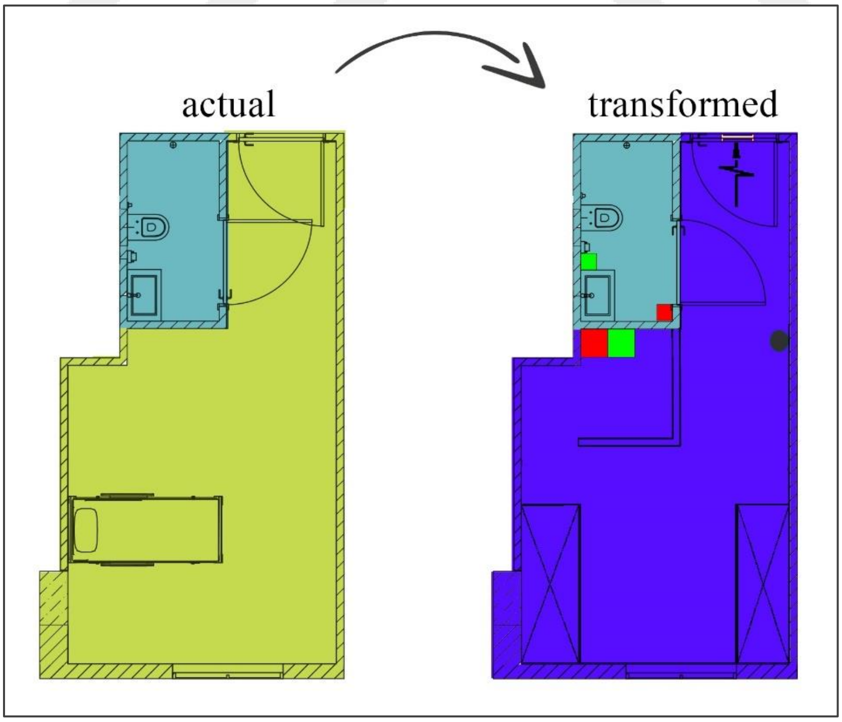


Figure 4.40. Transformation of a Patient Room into the Sterilization Room

4.3.5. General Interpretation about Transformation Proposals of Hospital A and Hospital B

In this study, in order to transform the areas according to pandemic conditions, the ventilation systems of the hospitals were first examined and the zoning of the areas that could be transformed with the air handling units were understood by drawn diagrams in Figures 4.15, 4.16, 4.17, 4.30. Because, when creating an isolation area, the air handling unit of the isolated area should not be connected to other areas preferably. Hospital rooms in this study were not HEPA-filtered. But since there is no requirement that air handling units that give 100% fresh air to the rooms should be HEPA filtered, it was considered appropriate to transform hospital rooms and HEPA filter added by us.

While the rooms were transformed, the isolated floor in Hospital A and B, and isolated semi-floors in Hospital A were separated from other areas, and a separate entrance for the Covid-19 service was defined at the entrances to the hospitals. Buffer zones were placed at the entrance to the isolation rooms to prevent direct access to the room from the corridor. Attention was paid to the position of buffer zones and toilets in the rooms. If the areas are intertwined, arrangements have been made for the replacement of toilet doors and refurbishing toilet interiors. Recommendations were made for the placement of disinfectant boxes in each room. Care was taken to keep disinfectants close to the room entrances and on Covld-19 reserved corridor areas.

Since it is recommended to treat a single patient in an isolated room, the number of patient beds in the rooms was limited to one. As the health workers working in the Covid-19 service needed a special rest area and sterile changing area, extra care taken to determine a special area for the staff while the rooms were transformed. One of the elevators for patients and healthcare workers, who would go from the new hospital entrance to the isolation floor was reserved for the Covid-19 service, and the front of the elevator was defined as a sterilization area.

Although the two hospitals examined have different typologies, isolation areas were provided by doing the same practices.

- To define the area to be transformed according to the separation of the Air Handling Unit (AHU)
- To define a separate entrance for isolation area

- To define the location of the swab test area in accordance with defined separated entrance
- To define a buffer zone to the entrance of isolation rooms
- To define a private elevator for isolation area
- To add HEPA filters to control contaminated air transferred/returned from room to buffer zone and buffer zone to main channel heading to dedicated AHU.
- To add disinfectant to rooms and corridors
- To limit the number of beds to one
- To determine resting and sterilization area for personnel
- To place bins in the toilets of personnel room for waste and recycling bins in the cabins of the sterilization area

It can be concluded that these steps are generizable and they can be followed for other hospitals to provide similar isolated areas for pandemic conditions control.

CHAPTER 5
CONCLUSIONS AND FUTURE STUDIES

This study has investigated the retrofit options for transforming hospital interiors in order to enhance indoor comfort, ensure better treatment and prevent spread of infection. In this respect, this study incorporates several qualitative and quantitative methods. As this study was intended to be based on solid foundations, the evaluation criteria of the study were formed by a detailed literature review, examination of set standards, sample hospital reviews, surveys and interviews made with mechanical and architectural and planning specialists.

The first question of this study was asked about retrofit options for transforming interior space. This study indicates that when transforming the interior, ventilation and layout plan must be in compliance. In this case, if there is a ventilation system that is not suitable for making an isolated area, ventilation system should be improved by considering interior zoning. Areas that are not suitable for transformation should be refurbished.

The second question of this study was asked about transformable proposals for hospital interiors in order to enhance indoor comfort and ensure better treatment. In light with the obtained data from literature review, surveys and interviews, this study presents proposals for transformation of hospitals. When starting to plan the transformation of hospitals, first, the suitability of the ventilation system was examined, and then the hospital floors to be studied were determined. After determining floors, a private entrance and elevator were dedicated to the isolated areas. Then, the necessary bed, wc, corridor arrangements were made for the transformation of these rooms, buffer zones were added in the plan layout, finally HEPA filters were installed on the mechanical ventilation outlets of these isolated rooms. If only half of a floor is used as isolated area, airlock barrier was placed to separate the area from rest of the floors.

The third question of this study was asked about whether these transformation proposals are suitable for all types of hospitals. The steps defined for transformation could be applied to both two examined case study hospitals. In addition, as hospital designs have a certain standard (room typologies, personnel access etc.), it is believed that the steps of the case study defined in Chapter 4 are also applicable for other hospitals.

By considering recommendations and standards, in this study, safe patient flow (Spagnolo et al., 2013) was provided by separating Covid-19 service entrance, elevators and floors dedicated, and latter isolated areas were also divided into zones as clean, buffer and dirty (Chandrashekhar et al., 2005; Zhang et al., 2020).

5.1. Generic Transformation of Typical Standard Hospital Rooms

Since the patient room transformed in the case study is a typical Turkish hospital room, it is believed that other hospital rooms also can be transformed by applying the same conversion criteria. In order to confirm this assumption, conversion scenarios were carried out as shown in Figure 5.1, 5.2 and 5.3 on a single patient room plan (determined as 475 cm to 660 cm) taken from the guideline of Turkish Ministry of Health (The Ministry of Health of Turkey, 2020).

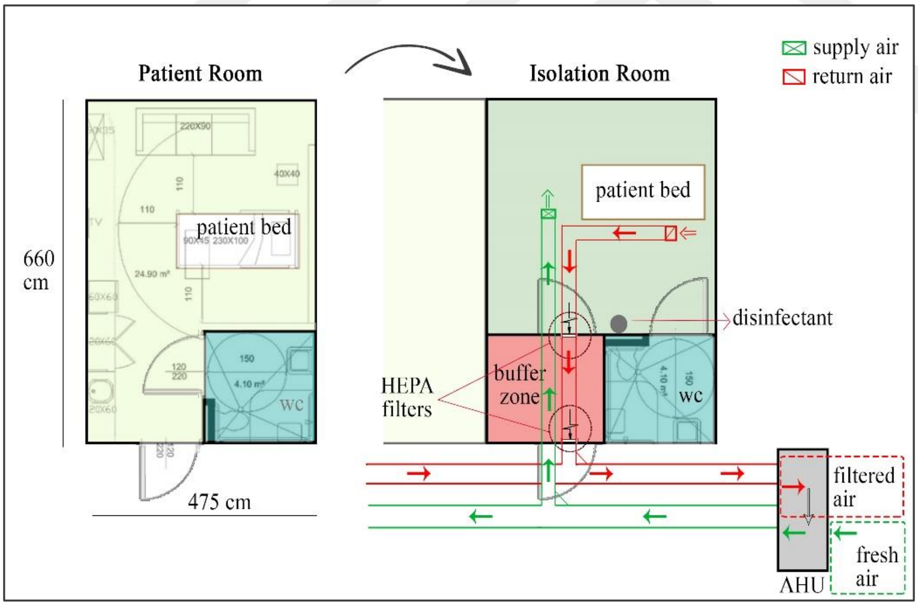


Figure 5.1. Transforming a Patient Room Defined in Turkish Standards to an Isolation Room

Figure 5.1 shows both architectural and mechanical intervention in the transformation of a typical patient room into an isolation room. For transformation, a buffer zone was placed at the entrance to the room as is recommended by the Turkish Ministry of Health (The Ministry of Health of Turkey, 2010), and the direction of the toilet door was changed to remain outside the buffer zone. For this reason, changes have also been made in the direction of toilet furnishing. In order to provide the necessary space around the patient's bed, the bed was removed away from the toilet door. HEPA filter has been added to the buffer zone exit and the parts of the ventilation line that correspond to the room exit to prevent infection in case dirty air leaving the room is recirculated, as is recommended in DIN 1946-4:2008 standard (İşbilen, 2013). Last, disinfectant was placed in the room.

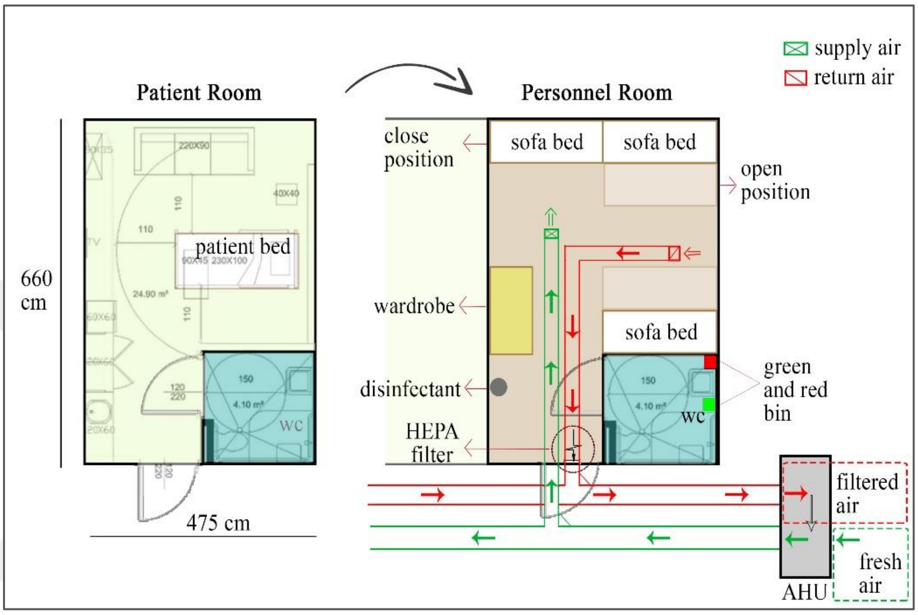


Figure 5.2. Transforming a Patient Room Defined in Turkish Standards to a Personnel Room

Figure 5.2 shows both architectural and mechanical intervention in the transformation of a patient room into a personnel room. No buffer zone was needed when transforming the room, and a HEPA filter was placed on the ventilation line corresponding to the exit of the room. In order to create a resting area for personnel, sofa beds were placed by removing the patient bed, and a wardrobe that personnel can be used was placed. Into the toilet, a red and green bin were placed so that personnel can dispose their garbage as medical and other. Last, a disinfectant was placed at the entrance of the room.

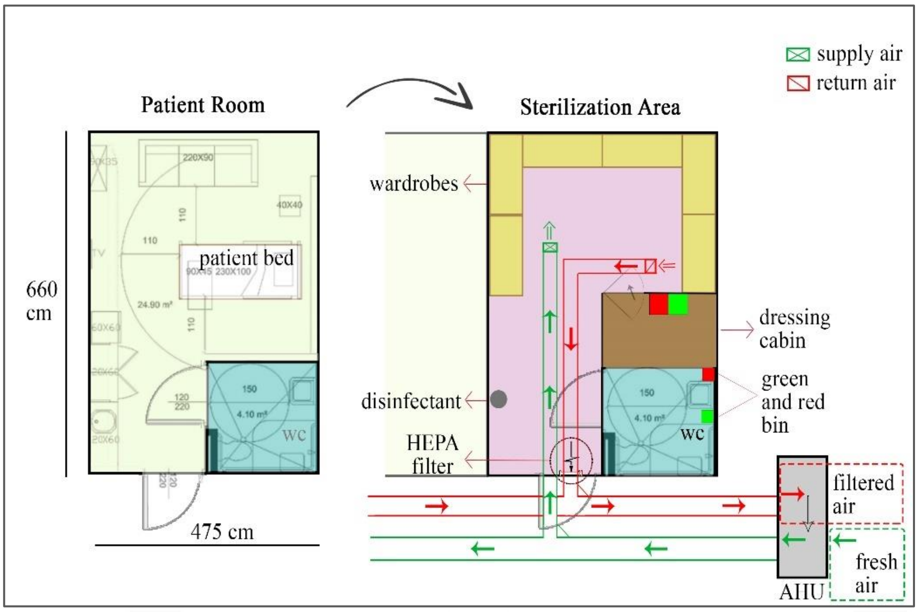


Figure 5.3. Transforming a Patient Room Defined in Turkish Standards to a Sterilization area

Figure 5.3 shows both architectural and mechanical intervention in the transformation of a patient room into a sterilization room. As in the personnel room, the buffer zone was not required for this transformation, and the HEPA filter was placed on the ventilation line corresponding to the exit of the room. It is aimed to provide that healthcare worker can change their protective clothes after leaving from isolation room and before entering to the personnel room. For that, the patient bed in the room was removed and wardrobes and a dressing cabin was placed so that the personnel could leave their belongings and get dressed. Large bins were placed inside the cabin so that personnel can dispose dirty clothes, and a red and green bin were placed inside the toilet, so that personnel can dispose their garbage as medical and other. Last, disinfectant was placed at the entrance of the room. The same transformation steps are applied also for two-person patient rooms, as is shown in Figure 5.4, 5.5 and 5.6.

Figure 5.4 shows the transformation of a two-person patient room defined in Turkish standards to an isolation room. In order to transform, the only thing was made different than Figure 5.1 is to reduce the number of beds from 2 to 1.

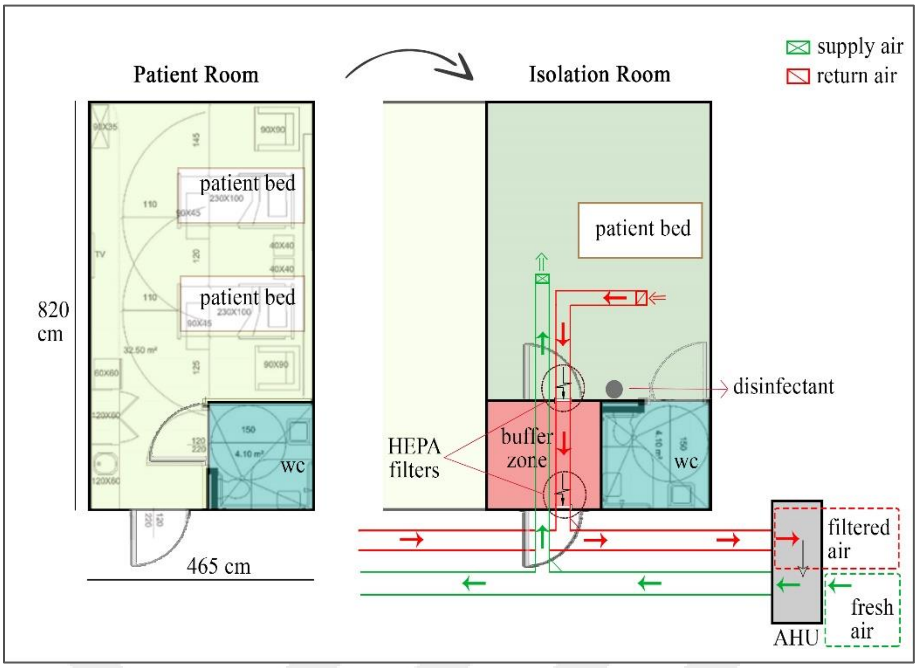


Figure 5.4. Transforming a Two-person Patient Room Defined in Turkish Standards to an Isolation Room

Figure 5.5 shows the transformation of a two-person patient room defined in Turkish standards to a personnel room. Because the size of the two-person room is larger than the single room, more wardrobes and sofa beds could be placed within.

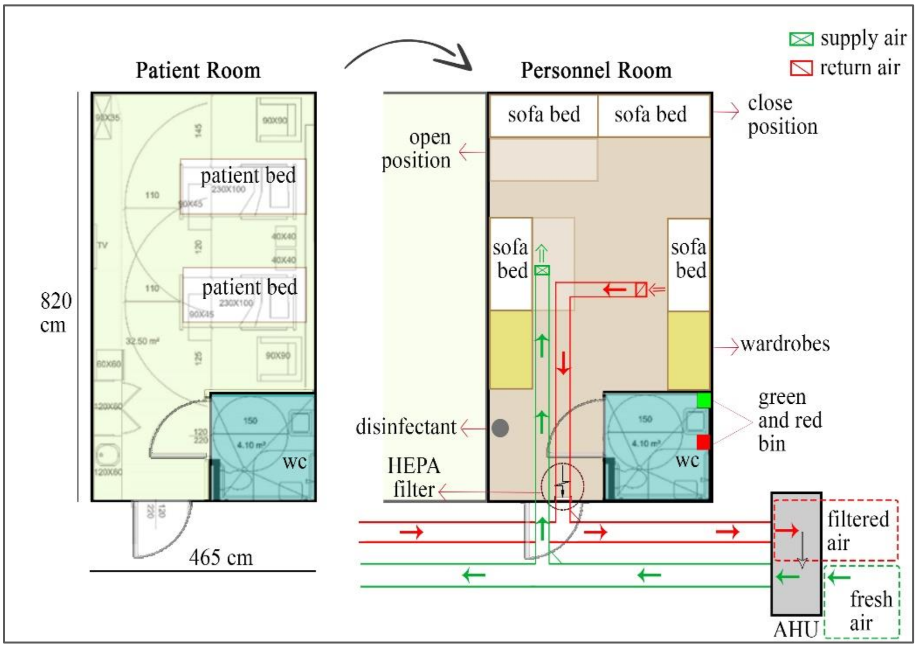


Figure 5.5. Transforming a Two-person Patient Room Defined in Turkish Standards to a Personnel Room

Figure 5.6 shows the transformation of a two-person patient room defined in Turkish standards to a sterilization area. Because the size of the two-person room is larger than the single room, more wardrobes could be placed within.

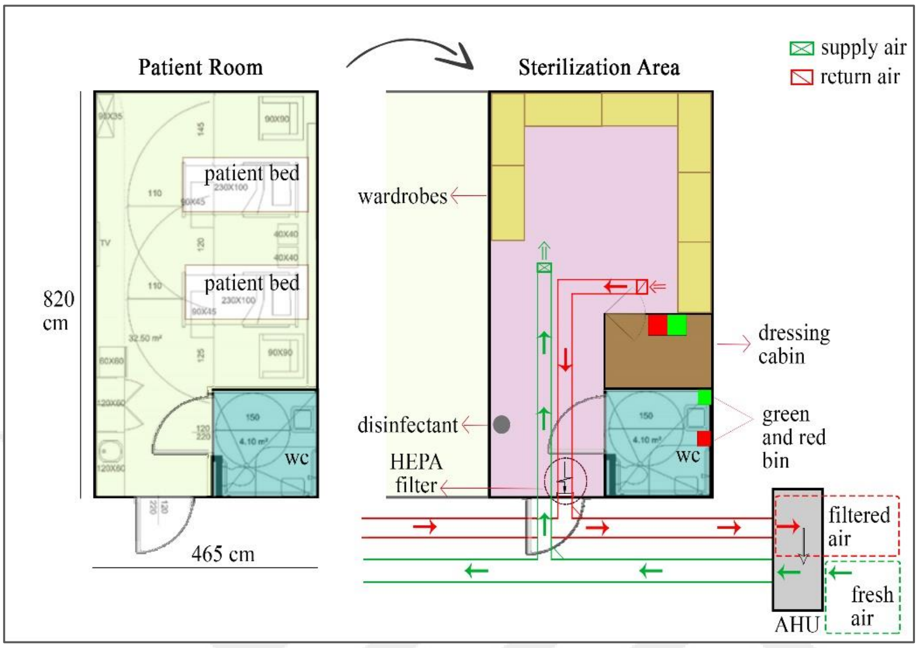


Figure 5.6. Transforming a Two-person Patient Room Defined in Turkish Standards to a Sterilization Room

5.2. Generic Transformation Overall Results and Future Study Opportunities

A study has been completed that can play a role in ensuring the consistency of mechanical and architectural planning in order to achieve successful results of hospital transformation practices to prevent the spread of infections in pandemic processes. It is thought that as a result of in-hospital transformations, hospital rooms can become suitable for the use of pandemic processes, taking into account the mentioned suggestions. In the conclusion section, it is seen that the T.C. Ministry’s hospital room typology can be diversified and will allow transformation in different infection conditions only by changing the direction of the wc furnishing. In applications other than branch hospitals, that are intended to be designed in accordance with transformation, different entrances, transportation (elevators, etc.) can be planned by collecting epidemic rooms that can be rapidly transformed into an isolated room on the same wing, and defining a special mechanical ventilation system for these areas are presented as critical planning requirements of rapid transformation. In such epidemics, it is important to correctly associate the Intensive Care Unit (ICU) that will serve the epidemic wing with isolated areas.

The resilience of hospital designs to pandemic conditions can be maintained by adaptable design ideas as introduced in this study. For future studies, these transformation scenarios can be created for City / State Hospitals, which can accept more patients in order to cope with unforeseen disasters. The use of intensive care units for Covid-19 and similar services can be included in the transformation scenario, mechanical systems can be integrated with isolation rooms or mechanical AHU can be solved area-specific, completely decoupled from the system. In addition, glass-derived transparent materials can be applied to certain parts of the patient room and intensive care unit walls in order to better observe the isolation rooms and intensive care by personnel. Therefore, a more effective and integrated transformation can be achieved throughout the isolated floor.

5.3. Modular Hospital Planning Scenarios for Hospital Extensions

When hospitals are inadequate, modular hospitals can be banded to the existing building so that they can be used to treat patients during pandemic by taking advantage of the hospitals' facilities. If modular hospitals are preferred to be used during pandemic process, both separation and controlled connection can be done. The hospitals can be built as self-standing on any land or adjacent to the existing hospital with buffer zone as is illustrated in Figure 5.7 and Figure 5.8.

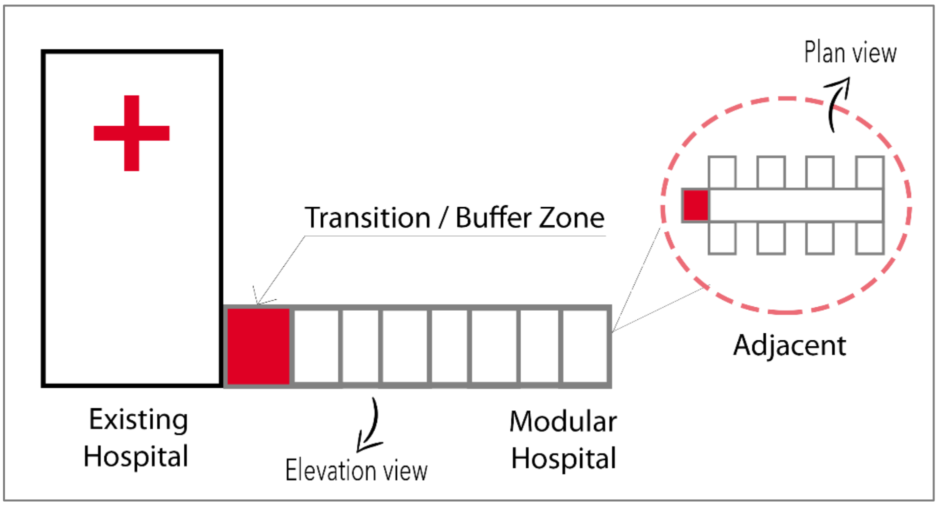


Figure 5.7. The Proposal to Use Modular Hospitals as Adjacent Building

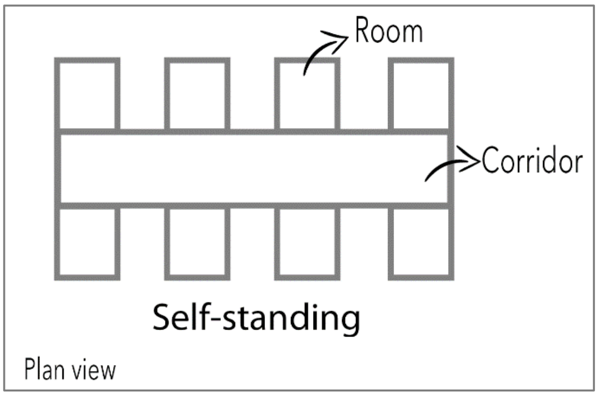


Figure 5.8. Self-standing Layout for Modular Hospitals

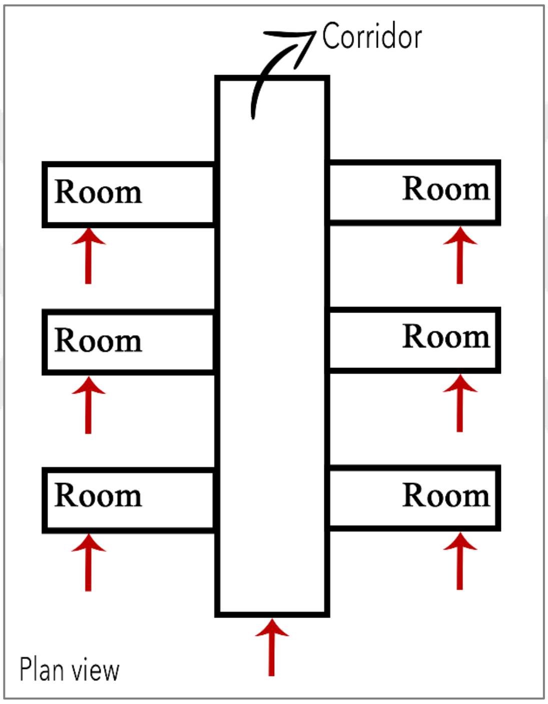


Figure 5.9. Own Entrance for Each Module

As the entrance for Covid-19 service was separated from the main entrance, a different entrance can be given for each module of modular hospitals to reduce infection risk for health professionals, and provide safety patient flow (Spagnolo et al., 2013) as is shown in Figure 5.9.

If all entrances for patients are to be given from outside, the corridors can be used by only health professionals, and a buffer zone can be added to each room entrances, as is shown in Figure 5.10. In order to prevent virus transmission, this layout can be implemented. The mid circulation area / corridor can be kept patient and infection free under these conditions.

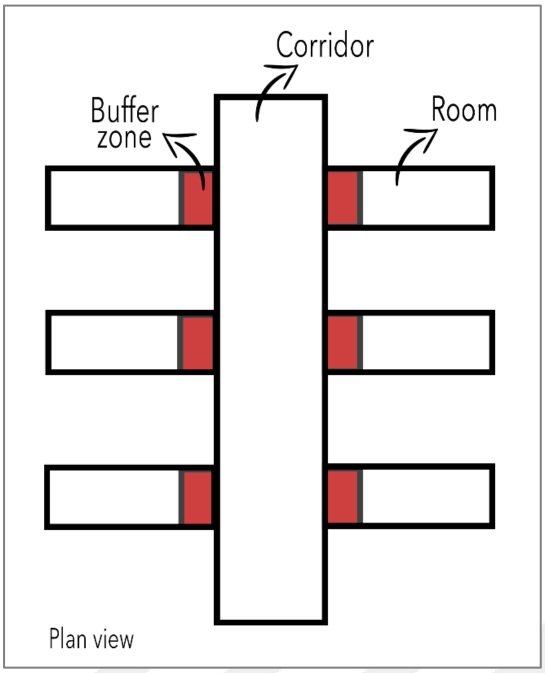


Figure 5.10. Buffer Zone (Sluice) for Each Module

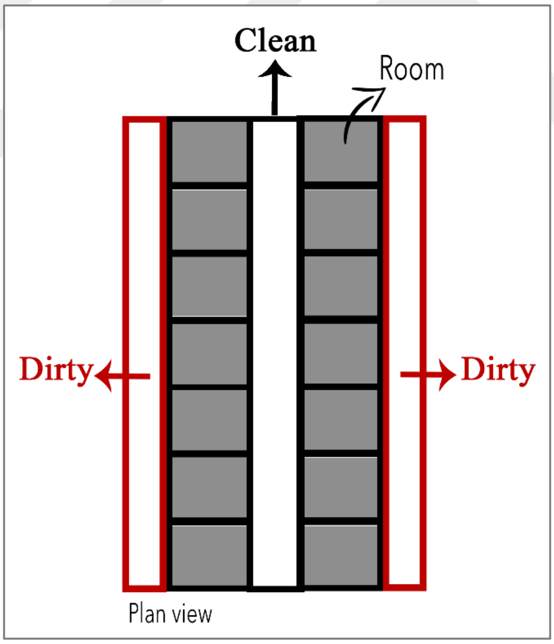


Figure 5.11. Clean and Dirty Pathways for Modular Hospital

As entrances can be separated, dirty and clean pathways of modular hospital can also be separated in order to prevent virus transmission in cases, where patients use the circulation areas for reaching various parts of the hospital for treatment as is recommended (Spagnolo et al., 2013), and shown in Figure 5.11. To each patient room, two different entrances can be given, one opening to a clean and the other to a dirty pathway so that prevent infection among healthcare workers.

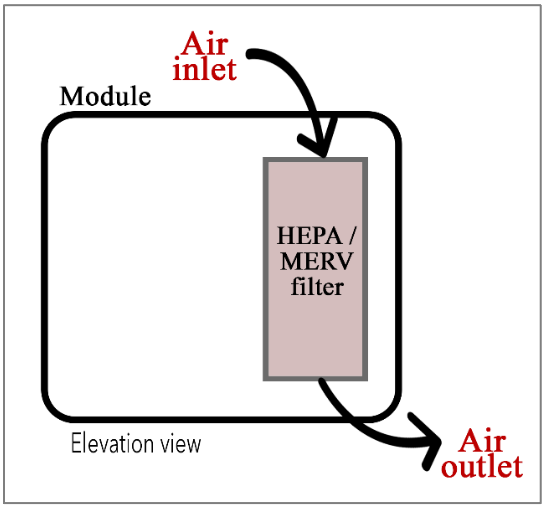


Figure 5.12. Air Inlet and Outlet Placement

As a result of the study, it is clearly understood that filtration system has great importance to protect people from infection. Preferring HEPA / MERV filters for hospital environments (Salonen et al., 2013), the providing low- level extraction / air outlet (Nielsen et al., 2010) which is better than ceiling level (Cheong & Phua, 2006) is overemphasized. Extraction of air must better be set at the ground level as is illustrated in Figure 5.12. Air outlet must not be located at the ceiling level for effective removal of pollutant in the rooms of a hospital, which can be hard to arrange within hospital rooms of Turkey.

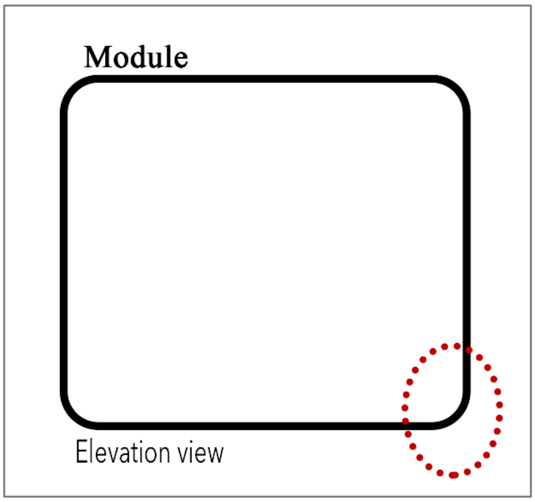


Figure 5.13. Curved Edges and Corners for Module Interiors

As is illustrated in Figure 5.13, it is suggested to minimize edges and corners to provide easily cleanable surfaces and areas (Spagnolo et al., 2013). Curved inner coating may be recommended for the spaces that have sharp corners.

5.4. Concluding Remarks

In this thesis, the steps that can be applied in the transformation of hospitals were presented in accordance with the research conducted and supported by the case studies. Inferences have been made in the light of research that hospital buildings and modular hospital structures can also be subjected to the same steps for effective mechanical ventilation systems and proper interior layout, and then these inferences are visualized and presented. The main aim in the transformations is quite clearly stated: ensuring a hygienic hospital environment, ensuring effective air circulation to avoid infection and removing polluted air. Even though hospital capacities and building sizes might be different in general, this study shows that the same steps of design integration (mechanical & architectural) could be effective for all hospital buildings under pandemic conditions. This opinion was addressed through the following ways,

- Transforming standard hospital rooms (given by Ministry of Health, Turkey) by changing room configurations and number of patients if needed
- Transforming 2 different hospitals which have different typologies
- Examination of the proposed modular hospitals around the world and making general transformation proposals for typical modules.

As a result, a study has been completed that can play a role in ensuring the consistency of mechanical and architectural planning in order to successfully complete hospital transformation practices to prevent the spread of infections in pandemic processes.

As the problems experienced in the pandemic process affect psychology, economy and human health, it is aimed to get over this process with minimal damage. By giving needed consideration to given recommendations, in-hospital transformations can be made suitable to use for pandemic process.

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APPENDIX 1 – INTERVIEW

Name	Ekrem EVREN
Profession	Mechanical Engineering
Date	22.02.2021

This interview questions has been prepared as a part of the method for the master thesis in order to learn important criteria in designing mechanical ventilation systems in hospitals.

1)Are you zoning when you draw the hospital mechanical plan? How do you do the zoning? For example, according to pressure differences?

2)How do you determine the ventilation inputs and outputs? (Floor or ceiling level)

3)What guidelines do you use when planning mechanics for the hospital?

4)How do you work with interior designers and architects for the consistency of mechanical planning and architectural planning?

6)About how many square meters does a filtering placement need?

7)How do you choose HEPA or MERV filter? Are there any differences in choice within the hospital?

8)What do you pay attention to when applying mechanical ventilation and natural ventilation together?

9)How to clean filters? How soon do they have to be cleaned up? Does it vary from place to place? Do filters have a lifetime? If it does, how long before they have to be replaced?

10) Can you suggest a filter-free solution for the isolation room in the pandemic process, like a normal patient room in a separate wing, if we are going to turn the patient room into a pandemic room?

11) Not if we turn the entire hospital into a covid hospital, but if there is a pandemic wing, should we separate the ventilation?

12) How do you determine the pressure direction of the filters? In what circumstances does it change? (Negative pressure, positive pressure). How do you ensure pressure control in areas requiring different pressure or separate ventilation and transitions to areas with a difference in pressure.

APPENDIX 2 – INTERVIEW

Name	Gonca ATEŞ ÖZTÜRK
Profession	Architecture
Date	15.02.2021

This interview questions has been prepared as a part of the method for the master thesis in order to learn important criteria in designing of hospital interiors.

1)Do you think about zoning when drawing a hospital plan? Do you consider mechanical constraints i.e.?

2)Which ways do you follow in determining sterile areas? What kind of materials do you use for these areas?

3)Which ways do you follow in the process of designing the function units? Where do you start planning?

4)How do you determine the ventilation inputs and outputs? (Floor or ceiling level)

5)Which guidelines do you refer when planning a hospital?

6)How a way do you follow with mechanical engineers for the consistency of mechanical planning and architectural planning?

7)Which filter do you use for ventilation? How do you determine filters placement and their intervals?

8)How do you make planning in areas that require different pressure or separate ventilation?

9)Do you pay attention to reducing sharp corners on surface areas in terms of hygiene?

10) Do you believe that you have provided enough space for hospital staff to rest and meet their necessary needs?

11) What do you pay attention when determining the position and number of stairs and elevators in circulation?

12) What are the criteria that you particularly consider when providing in-hospital circulation?

APPENDIX 3 – SURVEY

These survey questions were prepared as part of the Master's Thesis method in order to learn the adequacy of hospital practices in managing the pandemic process and their physiological and psychological effects on hospital personnel.

The Process of Covid-19 Pandemic and Its Impact on Hospital Personnel

Adequacy of Hospital Practices in Managing the Pandemic Process and Its Physiological and Psychological Effects on Hospital Personnel

* Required

1. The purpose of this form is to inform you about the research you have been asked to participate in and to obtain permission from you to participate. In this context, the research entitled "Adequacy of Hospital Practices in Managing the Pandemic Process and Its Physiological and Psychological Effects on Hospital Personnel" is carried out by Yaşar University graduate student Nurefşan Sönmez with volunteer participants. Information collected from you during research will be kept confidential and used only for research purposes. You have the right not to participate in this research. At the same time, you can exit the study after participating in the study. Approving this form will mean that you have given your consent to participate in the research.

   Check all that apply.

   ☐ I read and confirmed

2. What is your profession? *

   Mark only one oval.

   ◯ Nurse
   ◯ Doctor
   ◯ Cleaning Personnel
   ◯ Other: ____________________

3. How many days a week did you work in the hospital during the Covid-19 pandemic? *

   Mark only one oval.

   ◯ 0
   ◯ 1
   ◯ 2
   ◯ 3
   ◯ 4
   ◯ 5
   ◯ 6
   ◯ 7

4. How many hours did you usually work on the days you were in the hospital during the Covid-19 pandemic process? *

Mark only one oval.

- 0-8 hours
- 8-16 hours
- 16-24 hours

5. Did the Covid-19 process affect your weekly uptime? *

Mark only one oval.

- Yes, too much
- Yes
- Slightly affect
- No

6. Do you think the rest area reserved for personnel is adequate? *

Mark only one oval.

- Yes adequate
- Slightly adequate
- Not adequate

7. Do you think the rest area reserved for personnel is safe in terms of ventilation and pandemic conditions? *

Mark only one oval.

- Safe
- Slightly safe
- Not safe
- No idea

8. Do you think your work environment is safe in terms of ventilation and pandemic conditions? *

Mark only one oval.

- Safe
- Slightly safe
- Not safe
- No idea

9. What did you feel when the outbreak of the pandemic occur and negatively affect health workers? *

Check all that apply.

- [ ] Fear
- [ ] Worry
- [ ] Desperation
- [ ] Loneliness
- [ ] Stress
- [ ] Nervous
- [ ] Unhappiness
- [ ] Confusion
- [ ] Sadness
- [ ] Angry
- [ ] Nothing

10. How did the in-hospital restrictions on the pandemic process make you feel? *

Check all that apply.

- [ ] Safety
- [ ] Hope
- [ ] Gladness
- [ ] Happy
- [ ] Worry
- [ ] Desperation
- [ ] Loneliness
- [ ] Stress
- [ ] Nervous
- [ ] Unhappiness
- [ ] Confusion
- [ ] Sadness
- [ ] Angry
- [ ] Uneasiness
- [ ] Nothing

11. Did your role in the hospital increase the risk of transmission for you during the Covid-19 pandemic? *

Mark only one oval.

- Yes
- Slightly increased
- No

12. Do you think disinfectants are placed inside the hospital as everyone can access them? *

Mark only one oval.

- Yes
- Slightly
- No
- No idea

13. Do you think that patients who come to the hospital are cautious about the risk of infection? *

Mark only one oval.

- Yes
- Slightly
- No
- No idea

14. What actions have been taken to reduce the risk of infection in your environment? *

Check all that apply.

- Separation of infection areas
- Application of social distance rules
- Clothing equipment supply
- Disinfectant usage
- Planning the use of elevators and stairs
- Regulations for the dining hall and cafeteria
- Regulations for personnel working hours
- More controlled hospital entrances and exits

15. How would providing an isolated environment in the hospital during the pandemic change your sense of safety? *

Mark only one oval.

- Safe
- Slightly safe
- No change
- No idea

16. What other measures would you like the hospital management to take to make you feel safer in the hospital environment?

APPENDIX 4 – SURVEY

These survey questions were prepared as part of the Master's Thesis method in order to learn the adequacy of hospital practices in managing the pandemic process and their physiological and psychological effects on hospital management.

The Process of Covid-19 Pandemic and Its Impact on Hospital Management

Adequacy of Hospital Practices in Managing the Pandemic Process and Its Physiological and Psychological Effects on Hospital Management

* Required

1. The purpose of this form is to inform you about the research you have been asked to participate in and to obtain permission from you to participate. In this context, the research entitled "Adequacy of Hospital Practices in Managing the Pandemic Process and Its Physiological and Psychological Effects on Hospital Management" is carried out by Yaşar University graduate student Nurefşan Sönmez with volunteer participants. Information collected from you during research will be kept confidential and used only for research purposes. You have the right not to participate in this research. At the same time, you can exit the study after participating in the study. Approving this form will mean that you have given your consent to participate in the research.

   Check all that apply.

   ☐ I read and confirmed

2. How many days a week did you work in the hospital during the Covid-19 pandemic? *

   Mark only one oval.

   ◯ 0
   ◯ 1
   ◯ 2
   ◯ 3
   ◯ 4
   ◯ 5
   ◯ 6
   ◯ 7

3. How many hours did you usually work on the days you were in the hospital during the Covid-19 pandemic process? *

   Mark only one oval.

   ◯ 0-8 hours
   ◯ 8-16 hours
   ◯ 16-24 hours

4. Did you provide in-hospital isolation when the pandemic first occured? *

Mark only one oval.

- Yes
- Slightly
- No
- No idea

5. How did you provide in-hospital isolation when the pandemic first occured? *

____

6. Did you have a hard time providing in-hospital isolation when the pandemic first occured? *

Mark only one oval.

- Yes
- Slightly
- No
- No idea

7. What did you feel when the outbreak of the pandemic occur and negatively affect health workers and hospital management? *

Mark only one oval.

- Fear
- Worry
- Stress
- Desperation
- Loneliness
- Nervous
- Unhappiness
- Confusion
- Sadness
- Angry
- Uneasiness
- Nothing

8. How did inpatient bed usage change due to the pandemic? *

Check all that apply.

- [ ] Increased
- [ ] Decreased
- [ ] Transformed
- [ ] No idea

9. Do you think that the mechanical ventilation facilities that your hospital has are sufficient to prevent infection? *

Check all that apply.

- [ ] Yes
- [ ] No
- [ ] No idea

10. Do you think disinfectants are placed inside the hospital as everyone can access them? *

Mark only one oval.

- ◯ Yes
- ◯ Slightly
- ◯ No
- ◯ No idea

11. Do you think that you managed well in ensuring isolation conditions when conducting Covid-19 swab tests? *

Mark only one oval.

- ◯ Yes
- ◯ Slightly
- ◯ No
- ◯ No idea

12. Where do you buy swab samples from patients when for Covid-19 tests? *

____

13. Where do you treat patients who get a positive result after Covid-19 test? *

____

14. Did you separate in-hospital areas as clean, buffer zones and dirty zones to prevent the spread of Covid-19? *

Mark only one oval.

- ◯ Yes
- ◯ No
- ◯ No idea

15. Do you think the rest area reserved for personnel is safe in terms of ventilation and pandemic conditions? *

Mark only one oval.

- Safe
- Slightly safe
- Not safe
- No idea

16. What actions have you taken to reduce the risk of infection in the hospital environment? *

Check all that apply.

- [ ] Separation of infection areas
- [ ] Application of social distance rules
- [ ] Clothing equipment supply
- [ ] Disinfectant usage
- [ ] Planning the use of elevators and stairs
- [ ] Regulations in the dining hall and cafeteria
- [ ] Regulations for personnel working hours
- [ ] More controlled hospital entrances and exits

17. What other measures would you like to take to make you feel safer in the hospital environment?

____