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NATURAL VENTILATION STRATEGIES FOR COVID-19 PREVENTATIVE ARCHITECTURE: CASE STUDY OF AN OFFICE ENVIRONMENT IN GAZIANTEP

Master's Thesis

BESTE ÖZKELEŞ ÇELEBİ

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Supervisor: ASSOC. PROF. DR. MEHMET BENGÜ ULUENGİN

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ABSTRACT

NATURAL VENTILATION STRATEGIES FOR COVID-19 PREVENTATIVE ARCHITECTURE: CASE STUDY OF AN OFFICE ENVIRONMENT IN GAZIANTEP

Beste Özkeleş Çelebi

Master of Architecture

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Throughout history, pandemics have not only been health problems, but also, they have had significant political, social, and economic consequences. Society and architecture are notions that need to be considered together because architecture exists for humans. As the architect, Frank Lloyd Wright said, “All fine architectural values are human values, else not valuable”. In fact, pandemics affect architecture, just as they affect people. Today, while many buildings are designed according to building codes and regulations. However, it seems that in the event of a pandemic, buildings are not sufficient to protect human health. Why building codes or regulations have not hitherto taken into considerations related to possible pandemics? Since these precautions are not taken and solutions are not produced, today the business life and education life in such public spaces are interrupted. As such businesses and educational institutions try to continue functioning from home. For a possible pandemic circumstance, designers should take precautions and it should reflect the precautions on architectural designs. In managing any epidemic circumstance, the most important thing is keeping human life as normal as possible for everyone else. Architects can think about appropriate design strategies for infection prevention and control. Covid-19 is an epidemic which transmitted by airway and contact. That is why enhancing the design of natural ventilation in building is an important topic for airborne pandemics.

In this thesis, firstly the needs that emerged during the epidemics in history were examined and the factors affected after the epidemic were investigated. The history of Covid-19 and Covid-19 has been researched. Since office buildings are one of the public areas most affected by the pandemic, an office building in Gaziantep was chosen. Studies and research were done for this office building. Open-ended questions were prepared in the light of specific health resources and asked to office workers. Thematic content analysis was conducted in the light of the keywords that emerged from the answers to the open-ended questions. A literature search was conducted on natural ventilation with keywords. In addition, in this thesis, the relationship between Covid-19 and other infectious diseases and architecture in the context of natural ventilation strategies was investigated and analyzes were made using softwares such as FormIt, Revit and Flow Design. The purpose of these analyzes is to analyze the path of the wind provided by natural ventilation in the space. This wind path will also mean the path through which the virus travels. With these analyzes, it has been observed how important the effects of architectural plans, the place of window and door, window and door sizes are in the spread of the virus.

As a result, the contribution of this thesis to the literature is how important ventilation strategies are for a possible pandemic situation, and what should be considered during the design of office buildings.

Keywords: Air-borne diseases, Pandemic, Preventative Architecture, Natural Ventilation Principles, Covid-19.

ÖZET

COVİD-19 ÖNLEYİCİ MİMARİ İÇİN DOĞAL HAVALANDIRMA STRATEJİLERİ: GAZİANTEP'TE BİR OFİS ORTAMINDA VAKA ÇALIŞMASI

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Pandemiler tarih boyunca sadece sağlık sorunu olmakla kalmamıştır, aynı zamanda önemli siyasi, sosyal ve ekonomik sonuçları da olmuştur. Toplum ve mimarlık birlikte düşünülmesi gereken kavramlardır çünkü mimarlık insanlar için vardır. Mimar Frank Lloyd Wright'ın dediği gibi, "Tüm güzel mimari değerler insani değerlerdir, aksi takdirde değerli değildir". Aslında salgınlar insanları etkilediği gibi mimariyi de etkiler. Günümüzde birçok bina yapı yönetmeliklerine ve yönetmeliklere göre tasarlanmaktadır. Ancak Covid-19 pandemisi ile birlikte bir pandemi durumunda binaların insan sağlığını korumak için yeterli olmadığı görülmüştür. Yapı yönetmelikleri veya yönetmelikler neden olası pandemiler için bir önlem almamıştır? Bu önlemler alınmadığı ve çözüm üretilmediği için günümüzde kamusal alanlarda iş hayatı ve eğitim hayatı sekteye uğramaktadır. İş hayatı ve eğitim hayatı eve sığdırılmaya çalışılıyordur. Olası bir pandemi durumu için tasarımcılar önlem almalı ve alınan önlemleri mimari tasarımlara yansıtmalıdır. Herhangi bir salgın durumu yönetilirken en önemli şey, günlük yaşamı herkes için mümkün olduğunca normal tutmaktır. Mimarlar, enfeksiyon kapma olasılıklarını önlemek ve kontrolü için uygun tasarım stratejileri hakkında düşünebilir. Covid-19 hava yolu ve temas yolu ile bulaşan bir salgındır. Bu nedenle, doğal havalandırma tasarımının geliştirilmesi, hava ile yayılan salgın hastalıklar için önemli bir konudur.

Bu tezde öncelikle tarihte salgınlar sırasında ortaya çıkan ihtiyaçlar incelenmiş ve salgın sonrasında etkilenen faktörler araştırılmıştır. Covid-19 ve Covid-19'un tarihçesi araştırılmıştır. Ofis binaları pandemiden en çok etkilenen kamusal alanlardan biri olduğu için Gaziantep'te bir ofis binası seçilmiştir. Bu ofis binası için analizler ve araştırmalar yapılmıştır. Belirli sağlık kaynakları ışığında açık uçlu sorular hazırlanarak ofis çalışanlarına sorulmuştur. Açık uçlu sorulara verilen cevaplardan ortaya çıkan anahtar kelimeler ışığında tematik içerik analizi yapılmıştır. Anahtar kelimelerle doğal havalandırma konusunda literatür araştırması yapılmıştır. Doğal havalandırma ve mimari tasarım ilişkisi incelenmiştir. Ayrıca bu tezde doğal havalandırma stratejileri bağlamında Covid-19 ile diğer bulaşıcı hastalıklar ve mimari arasındaki ilişki araştırılmış ve FormIt, Revit ve Flow Design gibi yazılımlar kullanılarak analizler yapılmıştır. Bu analizlerin amacı, doğal havalandırmanın sağladığı rüzgarın mekanda nasıl bir yol izlediğini analiz etmektir. Bu rüzgar yolu aynı zamanda virüsün dolaştığı yol anlamına da gelecektir. Bu analizler ile mimari planların, pencere boyutlarının ve benzeri yapısal bilgilerin etkilerinin virüs yayılımında ne kadar önemli olduğu gözlemlenmiştir.

Sonuç olarak bu tezin literatüre katkısı, ofis binalarının tasarımı esnasında havalandırma stratejilerinin olası bir pandemi durumu için ne kadar önemli olduğunu ve nelere dikkat edilmesi gerektiğidir.

Anahtar Kelimeler: Hava yoluyla bulaşan hastalıklar, Pandemi, Hastalık önleyici mimari, Doğal havalandırma ilkeleri, Covid-19.

CONTENTS

FIGURES

ABBREVIATIONS

ASHRAE	:	American Society of Heating, Refrigerating and Air-Conditioning Engineers
BIM	:	Building Information Modeling
ECDC	:	European Centre for Disease Prevention and Control
FDS	:	Fire Dynamic Simulator
REHVA	:	Federation of European Heating, Ventilation and Air Conditioning Associations
WHO	:	World Health Organization

SYMBOLS

Centimeter	:	cm
Degree	:	(°)
Fahrenheit	:	°F
Height	:	H
Hour	:	h
Kilometer	:	km
Meter	:	m
Meter(s) per Second (Velocity)	:	m/s
Micrometer	:	µm
Micron	:	µ
Mile per hour	:	mph
Millimeter	:	mm
Minute	:	min
Nanometer	:	nm
Parts per million	:	ppm
Percentage	:	%
Second	:	s
Time	:	t
The centimeter per second	:	cm

1. INTRODUCTION

Human history has faced many diseases since the world came into being. In this thesis, it was emphasized that natural ventilation criteria should not be ignored in the design process for human health because in buildings natural ventilation principles are important elements for maintaining a healthy environment. Air, with its components and quality, directs human health and can even cause death (WHO 2019). In the building design process, more attention should be paid to the provision of healthy air for the needs of people after the pandemic. The thesis includes studies on how natural ventilation principles affect human health when these principles are not included in the architectural design process. In this context, detailed natural ventilation research was carried out by taking as an example of the office quarters of a factory building in Gaziantep during the Coronavirus pandemic. In this building, examinations were made for 'principles of natural ventilation in the architectural design process' under the headings of building envelope and interior design elements.

1.1 THE RESEARCH QUESTIONS

Architects design many public spaces according to building codes and regulations. Why building codes or regulations have not hitherto taken into considerations related to possible pandemics?

Can user experience during the Coronavirus pandemic provide insight into the ways in which buildings can be made more resilients towards pandemic?

1.2 AIM OF THE STUDY

In this thesis, it is aimed to determine the principles and criteria of natural ventilation in office and areas where people congregate. People spent all day together and interact with their colleagues. So, it is thought that some standards regarding ventilation should be followed during the design phase.

The hypothesis is in case of a possible pandemic, buildings can be made more resilient towards pandemic in terms of natural ventilation principles.

Natural ventilation principles are important in design for human health. The study presents a method in terms of how to evaluate the principles and criteria of natural ventilation during design. These constitute the importance of the thesis.

1.3 SCOPE OF THE STUDY

Historical pandemics and examples of quarantine buildings in history were investigated. Covid-19 has been investigated in the literature. But a study was conducted on the covid-19 pandemic.
Ventilation definition and ventilation strategies were investigated. But focused on natural ventilation.

Measures were taken in the event of the Coronavirus pandemic in offices investigated. But studies were made specific to the selected building, and selected rooms.

Open-ended questions were prepared about Covid-19 precautions with information collected from certain health institutions. But these questions were customized for the selected building in Gaziantep.

FormIt, Revit, and Flow Design software were used for analysis. FormIt was used for finding the annual and monthly wind rose diagrams, finding temperature values. Revit was used for modeling the building. Flow Design was used for finding wind analysis with using these data.

The thesis includes outcomes about precautions for Covid-19 in terms of architecture. But the outcomes were made specific to the city and the building scale.

Wind analysis was made after the data of the region were obtained. Wind analysis was analyzed for each room separately because of to better observe the indoor air flow.

1.4 METHODOLOGY

Today, while many public spaces are designed according to building codes and regulations offered by municipalities. Therefore, why building codes or regulations have not been taken for buildings to a possible pandemic until nowadays? The purpose of the thesis is that seeking the answer to these questions and to determine the importance of natural ventilation principles and criteria during the pandemic.

Firstly, this thesis began by explaining the meaning of pandemic and examining its history. Then investigated precautions in pandemic periods and adaptations to architecture. Then, some examples of quarantine buildings are examined in this thesis. After, included a history study on Covid-19. Then, open-ended questions were asked to the employees in the determined case study. Sources that involve the measures for Covid-19 published by the world health organization, American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE), and the European Center for Disease Prevention and Control contributed to the creation of open-ended questions. These open-ended questions were asked to 10 people who were working in the determined case. The thematic content analysis method was applied to the answers. The quality of the data, and the researchers' experience and knowledge, qualitative content analysis can be performed various ways, resulting in categories and/or themes (Lindgren et al. 2020). In this case, the next step is to look for the underlying meanings running through these descriptive categories, interpret the latent content, and formulate sub-themes and/or themes (Graneheim, and Lundman 2004). The most frequently spoken words by the speakers were marked and identified by tabulating. These words were classified into main themes, sub-themes, and categories. The research was directed according to the repetition frequency and the categories of the words.

Then, ventilation strategies and the relationship between ventilation and the epidemic, were examined. With keywords derived from the questions, a comprehensive study has been conducted in the literature on natural ventilation methods.

Since office buildings are one of the public areas most affected by the pandemic, an office building in Gaziantep was chosen. Afterward, the office building plans were obtained. The office building was modeled by using Autodesks' Revit software. With the analysis in FormIt, the annual and monthly wind rose diagrams, temperature values will be obtained. The unique climatic data of the region were produced in this program. The climatic data of the region and the prevailing wind direction were also included in the study. The building was transferred to the Flow Design program and placed in the wind tunnel. Then, the Flow Design program was used for wind analysis. In this examination, in-circle wind movement diagrams were created by considering the locations, dimensions, direction of the wind, the structure, and the placement of the interior walls of the openings on the facades. As a result of these analyses, the direction of the wind towards the building, the direction of the building according to its form, and its cycle within the project can be observed. In this way, the Flow Design program created ventilation rate analyses for the building.

1.5 LITERATURE REVIEW

In the first chapter, the scope of the thesis study is defined.

Pandemics affect architecture, just as they affect people. The second chapter examined the pandemic notion's relationship with architecture. These sources have been studied to better understand the pandemic. The study of Yıldız (2014) titled “Epidemics in Anatolia at 19th century (The Plague, The Cholera, The Chicken Pox and The Malaria) and methods of struggles against epidemics” , the study of Sherman (2016) titled “Twelve Diseases that changed our world”, the study of Hays (2005) titled “Epidemics and Pandemics: Their Impacts on Human History”, the study of Watts (1997) titled “Epidemics and History Disease, Power and Imperialism”, the study of Marrin (2018) titled “Very, Very, Very Dreadful: The Influenza Panic of 1918”, the study of Barry (2004) titled “The Great Influenza: The Epic Story of The Deadliest Plague in History”, the study of Barnard (2005) titled “Outbreak: Plagues That Changed History”, the study of Denton (2019) titled “Pandemics: Deadly Disease Outbreaks”, the study of Johnson (2006) titled “The Ghost Map: The Story of London’s Most Terrifying Epidemic and How It Changed Science, Cities, and the Modern World”, the study of Tognotti (2013) “Lessons from the History of Quarantine, from Plague to Influenza A”, the study of Koley and Dhole (2020) titled “The COVID-19 Pandemic The Deadly Coronavirus

Outbreak”, the study of Saxena (2020) titled “Coronavirus Disease 2019 (COVID-19) Epidemiology, Pathogenesis, Diagnosis, and Therapeutics”.

In the fourth section, ventilation strategies are examined with these sources. The study of Öztürk (1995) titled "The Architectural Design Process and Indoor Air Quality”, the study of Oral and Arısoy (2015) titled " Indoor Air Quality in Shopping Malls”, the study of Yang et al. (2008) "Inhaled nano particles – A current review”, the study of Bulut (2012) titled "Analysis of CO2 Amount in terms of Ventilation and Indoor Air Quality”, the study of Darçın and Balanlı (2012) titled "Principles for Providing Natural Ventilation in Buildings”. These sources also contain the questions about “How does the ventilation requirement arise?”.

“How does ventilation occur?” question has been investigated with these sources. The study of Lechner (1991) titled "Heating, cooling, lighting, sustainable design methods for architects”, the study of Demir (2013) titled "Numerical modelling of natural ventilation methods”, the study of Türksoy (2001) titled "Wind data measurement and analysis”, the study of Bulgurcu (2015) titled "Ventilation and Indoor Air Quality” and "Ventilation Methods”, the study of Lenin et al. (2019) titled "Optimization of Window type and vent parameters on single sided natural ventilation buildings”, the study of Avcı (2014) titled "Numerical analysis of natural ventilation in multi-unit building”, the study of Park and Rhee (2017) titled "Comparison of volume flow rate and volume-averaged local mean age of air for evaluating ventilation performance in natural ventilation”.

The relationship between ventilation and Covid-19 has been researched through the following sources.

The study of Li et al. (2020) titled “Aerosol transmission of SARS-CoV-2 Evidence for probable aerosol transmission of SARS-CoV-2 in a poorly ventilated restaurant”. In this article, they analyzed an outbreak involving three non-associated families in Restaurant X in Guangzhou, China. They evaluated the possibility of aerosol transmission of SARS-CoV-2 and characterize the associated environmental conditions in the restaurant. They collected the data. They experimented with spread of viruses. This experiment imitated the real environment. In experiment they used tracer gas for following the way of gas. Also, they did this experiment in computer simulation which is computational fluid dynamics (CFD) simulation. At the end, the simulation and experiment gave the same results. A sufficiently high ventilation flowrate reduces the contribution of aerosol transmission to a very low level, whereas a low ventilation flowrate leads to a relatively high contribution of aerosols to transmission. That is why, aerosol transmission of SARS-CoV-2 due to poor ventilation may explain the community spread of COVID-19.

The study of Liu et al. (2020) titled “Ultra-rapid delivery of specialty field hospitals to combat COVID-19: Lessons learned from the Leishenshan Hospital project in Wuhan”. Certain searches have been made before building the prefabricated hospital. Some methods have been used. One of them was a plan which is the fishbone-shaped layout to avoid infection risk. Another one is an analysis. In this analysis, data which are including the building shape, layout, location, and direction of air exhaust from Leishenshan Hospital, were extracted from the Building Information Modeling (BIM) model and imported into the Fire Dynamic Simulator (FDS). With the support of BIM, the simulation of contaminated air diffusion can be observed. Thus, some variables are located accordingly.

The publisher of European Centre for Disease Prevention and Control (2020) titled “Heating, ventilation, and air-conditioning systems in the context of COVID-19: first update. In this article, there were specific recommendations about natural ventilation through window and door openings. Some factors were characteristics of the room (volume, size, function of openings, occupancy rates), the activities taking place in the room, the climatic and weather conditions. Also, according to window types, they analyzed the air changes per hour. In addition, the measures about covid-19 were collected in a table accordingly for each country.

The publisher of Federation of European Heating, Ventilation and Air Conditioning Associations (REHVA) (2020) titled “COVID-19 Guidance Document.” In this document, REHVA summarized advice about the operation and use of building service systems during an epidemic in a coronavirus disease (COVID-19). Also, this document summarized the spreading of COVID-19 depending on HVAC (Heating, Ventilation, and Air Conditioning) or plumbing systems. There was information about the droplet size of coronavirus particles and their air transport. There were illustrations about how an infected person spreads its aerosols in the breathing zone of another person. There were illustrations about how aerosols spread in the air.

The study of Emmanuel et al. (2020) titled “Architectural design strategies for infection prevention and control (IPC) in health-care facilities: towards curbing the spread of Covid-19”. The article mentioned the hospital design strategies for any pandemic circumstance, and the article supported that these design strategies must involve the protection strategies of infectious diseases. The article mentioned the types of transmission of infectious diseases, and they were grouped such as airborne and droplet transmission, waterborne transmission, contact, or surface transmission. Then article advised appropriate design strategies for infection prevention and control. Strategies involved design for social distancing, design to enhance natural ventilation, design to enhance daylight or sunlight, design with adaptive finishing materials and construction methods, flexible design with sustainability features.

The study of Qian and Zheng (2020) titled “Ventilation control for airborne transmission of human exhaled bio-aerosols in buildings.”. In the article, 3 things affect airborne transmission. These are ventilation rate, flow direction, and airflow pattern. These elements also affect the transmission of infection. Ventilation rate is important for airborne transmitted disease. Also, Wells-Riley Equation supported this idea in the thesis. The Wells-Riley equation successfully predicted a measles outbreak in a suburban school in the USA. This article explains these topics.

The study of Jalayerian et al. (2020) “Post-Pandemic HVAC Systems Strategies for High-Rise Office Buildings.”. This article mentions that Covid-19 and potential future pandemics. Also mentions potential future pandemic results for building design and high-rise office buildings. Therefore, mechanical ventilation precautions propose for high-rise buildings during a possible pandemic. Studies conduct on how pathogens follow the air with UFAD and Overhead systems.

In qualitative content analysis, these sources were used in the research. The study of Elo and Kyngäs (2008) titled “The qualitative content analysis process. Journal of advanced nursing”. The study of Lindgren et al. (2020) titled “Abstraction and interpretation during the qualitative content analysis process". The study of Flick et al. (2004) titled "A Companion to Qualitative Research".

In the fifth section, the contribution of Revit energy analysis and flow design programs to the natural ventilation for the design process was analyzed. These sources were used in the research. The study of Yuyucu (2016) titled "Analysis of natural ventilation in buildings with computer simulation in examples. In this thesis, four projects were selected in Beylikdüzü, Esenyurt, and Avcılar. These projects were selected for studying their relationship with the wind. Revit program from BIM (Building Information Modeling) systems was used to determine the unique climatic data of the regions. Later, the projects were mass-modeled in the SketchUp program. The flow Design program was used for transferring to the wind tunnel. It was concluded that the correct orientation and positioning, as well as the correct formation and surface decisions, are also important to provide effective natural ventilation.

The study of Küçüker (2019) titled "Natural ventilation principles during the process of architectural design". This thesis aimed to search natural ventilation principles and criteria. In this study, the concept of building biology was investigated in the context of the relationship between building, environment, and occupant health. The definitions of natural and mechanical ventilation have been researched, their methods and systems have been examined. Natural ventilation criteria in residences have been investigated at settlement and building scales. The flow Design program was used in the analysis. This program analyzed how the wind reaches the building at the settlement scale and the effects of the surrounding buildings on the wind. Certain fixed formulas are used for building scale analyzes. In this way, an approach has been developed to evaluate the fulfillment of the requirements for ventilation methods for air pollution. Then a residence which was chosen in Üsküdar was examined in terms of location, prevailing wind, topographic location, building characteristics, and building design.

The study of Yavaş (2019) titled "Investigation of natural ventilation performance in buildings by building information modeling.". In this study, the natural ventilation performance of examples was examined. Examples located 3 different urban patterns in Elazig province. The examples were modeled with the Revit program and the climatic data of the region, and the prevailing wind direction were also considered. A flow design program was used for wind analysis. The results of the simulations were presented as a Flow Design screenshot. Results were analyzed with a Likert scale.

The study of Ofluoğlu (2016) titled "Conceptual energy analysis with Revit/Green Building Studio.". Energy analysis is used to estimate how much energy the building consumes as a heating and cooling load. The Revit program is used to find these concepts. In this way, the desired analyzes are obtained.

2. PANDEMICS IN HISTORY, PRECAUTIONS IN PANDEMIC PERIODS AND ADAPTATIONS TO ARCHITECTURE

2.1 THE MEANING OF THE PANDEMIC

The world has witnessed many pandemics throughout history since its existence. Pandemics usually occur in cases of the epidemic. The epidemic is the term for a disease. It occurs in certain geographical regions. If this disease occurs more than expected, it will become a pandemic. It spreads to other geographic areas. It affects continents; it affects the entire world (Koçak 2020).

2.2 TRANSMISSION METHODS OF INFECTIOUS DISEASES

Epidemics can spread in many ways such as airborne transmission and droplet transmission, direct contact and indirect contact, waterborne transmission, transmission with blood and blood products, transmission with insect vectors and animals.

2.2.1 Airborne Transmission and Droplet Transmission

Microbial particles stay in the air for a long time. Airflow causes the travel to particles. If a person inhales these particles, a person can be infected. This situation is called airborne transmission (Lateef 2009).
Viruses are small (20–400 nm). Viruses need a living cell to survive. Viruses can transmit easily in crowded places, poorly ventilated environments. Therefore, a generally indoor environment is the best place to get an infection (La Rosa et al. 2013; Barker et al. 2001).

Droplet transmission occurs with large respiratory droplets (> 10 μm). These droplets occur with sneeze, cough, or exhale when talking or breathing. Giuseppina et al. added that a single cough or sneeze in a corridor, lobby, or passage can discharge thousands of droplets, (up to 40,000) at speed of up to 50–200 miles per hour, each droplet comprising millions of viral particles (La Rosa et al. 2013). Droplet transmission is different from the airborne transmission. Aerosol droplets cannot suspend in the air. These droplets travel only 1 or 2 meters (Van Doremalen et al. 2020).

2.2.2 Direct Contact and Indirect Contact Transmission

Infectious diseases are transmitted from person to person. It can direct or indirect. Direct contact means physical contact which involves the infected individuals' mucus fluid (Lateef 2009). Indirect contact means a person's contact with an infected surface. Some organisms can live in the material. For example, coronavirus (Covid-19) can live for 72 h on a plastic surface, 24 h on a cardboard surface, and the Copper surface for 4 h (Van Doremalen et al. 2020). These contacts can cause infection.

2.2.3 Waterborne Transmission

Water borne transmission occurs in water-borne, water-washed, water-based, and water-related ways (Gleick 2002). For this reason, it is possible to get the disease by water.

2.2.4 Transmission with Blood and Blood Products

Some viruses can enter and infect the human body through the bloodstream or other body fluids. Therefore, blood is a factor in the transmission of infectious diseases.

2.2.5 Transmission with Vectors and Animals

Infected microorganism passes to another living organism via vectors or animals. This transmission occurs through an inter carrier (vector) such as fleas, ticks, mosquitoes, or animals. This situation is a vector transmission.

2.3 EPIDEMICS IN HISTORY

Plague is a well-known disease since ancient times. There are different types of plague such as bubonic plague, pneumonic plague and, black death. It has been seen many times in history with various names. These are B.C. Atina Plague, Antonine Plague, Justinian Plague, 1346-1350 Black Death. In 541, Justinian Plague was seen in İstanbul. The plague spread in 2 ways. One of them is spreading due to the bites of rodents, another one is spreading with the airway (Yıldız 2014). Today, plague can be treated with antibiotics.

Cholera can spread in a variety of ways, such as vomiting, feces, and contaminated water. Therefore, the poor infrastructure in the city leads to the growth of the epidemic. It is known that this disease occurred in India in 1768. The rate of spread is higher in hot weather (Yıldız 2014). Especially dirty water resources are the most important causes of cholera infection. Cholera is not common in our country, but it is still a serious problem for other countries.

Typhus is a bacterial infection. Generally, it is transmitted by contaminated food and drinking water. Some people carry the bacteria without any symptoms but can infect other people. Early diagnosis can be successful if treated with antibiotics.

Smallpox is transmitted by the cough of a sick person. It is transmitted by the saliva droplets of a sick person. For this reason, viruses can be transmitted by contact with the surface. The first vaccine in history is the vaccine for smallpox. It is a treatable disease.

Measles, a contagious epidemic disease, can be transmitted by direct contact or breathing. These viruses can stay in room air for more than an hour and can be transmitted by breathing this air.

Tuberculosis is a contagious lung disease. It spreads by air. The tuberculosis vaccine helps to prevent the disease. It is a curable disease.

With mosquito bites, malaria transmits from person to person. Africans destroyed the rainforest to grow potatoes and starch. As a consequence of these situations, swamps occurred, and malaria occurred (Yıldız 2014). Malaria, except mosquito bites; can also be transmitted to humans through blood transfusion, organ transplantation, or joint use of needles. It is a disease that can be treated with medication.

Yellow fever is an acute, viral bleeding disease transmitted by the bite of mosquitoes that are infected with the yellow fever virus. There is no specific treatment. Supportive treatment is provided according to the symptoms.

HIV/AIDS is a virus that is transmitted through blood and sexual contact. It can settle in various tissues of the body but shows its main effects on the immune system. Medicines developed for HIV prevent the virus from reproducing in the body. The effect of medicines by immunosuppressive, allow HIV-positive people to live a long and healthy life.

In history, there were lots of influenza pandemics such as Spanish Influenza, Asian Influenza, Hong Kong Influenza (A H3N2, In 1968), H5N1(In 1997, and 2003-2004), H7N7 (In 2007), Influenza A H1N1 pdm09.

Spanish Influenza (Influenza A H1N1) began in 1918. This virus is the H1N1 virus which containing genes of bird origin. In this period there were no vaccines or medicine for this disease. That is why the population applied some rules such as, isolation, quarantine, personal hygiene, and avoiding communities to come together.

In west Asia, there were began an epidemic. It turned pandemic in 1957. Its name was Asian Influenza (Influenza A H2N2).

Influenza A H1N1 pdm09 seen in 2009, in America. It did not seem like other influenza viruses. There was no vaccine. When the vaccine was developed, the disease was already had reached its peak.

2.4 EXAMPLES OF QUARANTINE BUILDINGS AND ISLANDS IN HISTORY

Earlier times, water provided a barrier for protection the disease and isolation. At that time, generally, transportation was provided by the sea. For this reason, there were many quarantine buildings or quarantine stations on the islands. These buildings prevented to spread of the epidemic.

These epidemics have defined new concepts and functions for architecture. Such as the importance of ventilation, sunlight, surface materials, isolation, and distance rules.

The architecture organization of the quarantine station plays a crucial role in the process of quarantine. In quarantine buildings, ventilation, fumigation, disinfection, and decontamination are specific algorithms for avoiding infection.

Buildings of Quarantine Stations (Lazzaretto) are using for quarantine in history. These buildings are designed to be self-contained. In this period, “It was the decree of 1179 which triggered the birth of specifically designed buildings and urban spaces aiming to contain and segregate the infected (Garcia 2020).

2.4.1 Quarantine at Grosse Ile

Grosse Ile was a quarantine station for the Port of Quebec, which was Canada's main gate from 1832 to 1937. Also, in 1847, The Island witnessed a typhus epidemic. (Quarantine at Grosse Ile) The Island was divided into central, sick, and healthy divisions. The sick division part had hospitals and hospital staff. Hospital made with brick and two-story. It included separate wards for sick people’s isolation. The hospital had sterilization rooms for beds, clothes, etc. In healthy division, there were houses for suspected passengers. This division had a washhouse, six furnaces, boilers, a bacteriological laboratory, hot air disinfection, and fumigation rooms. There was also a steam disinfecting house with boilers. The emptied hospitals of the ship were disinfected with mercuric chloride solution and treated with superheated steam on this island (Montizambert 1893).

Figure 2.1: Quarantine at Grosse Ile.

Source: (Forster 1995)

Figure 2.2: New hospital constructed at the quarantine station in 1881.

Source: (Forster 1995)

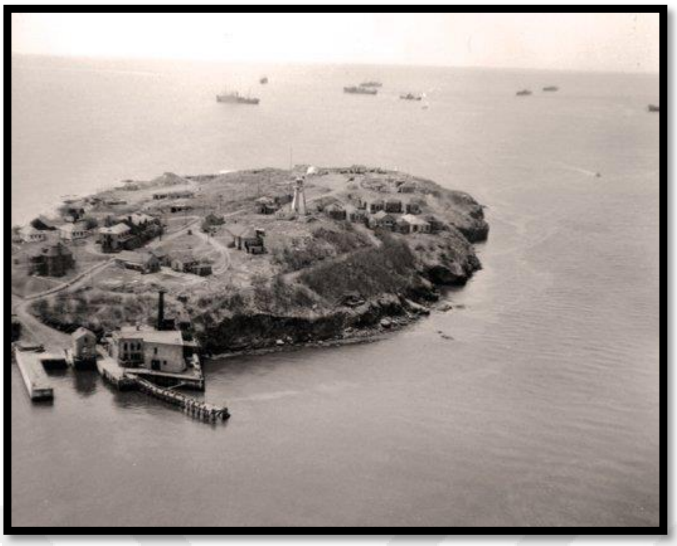
Figure 2.3: Disinfection building in 1892 where immigrants and their belongings were disinfected here.

Source: (Forster 1995)

2.4.2 Partridge Island

Partridge Island located in the coast of Saint John, New Brunswick. This place is used as a quarantine station. Here the buildings were repaired for quarantine and supplied steam disinfectors such as a dioxide sulfur blast and mercuric drench. An isolation environment was provided as a healthy area and an infected area on the island (Montizambert 1893).

Figure 2.4: Partridge Island.

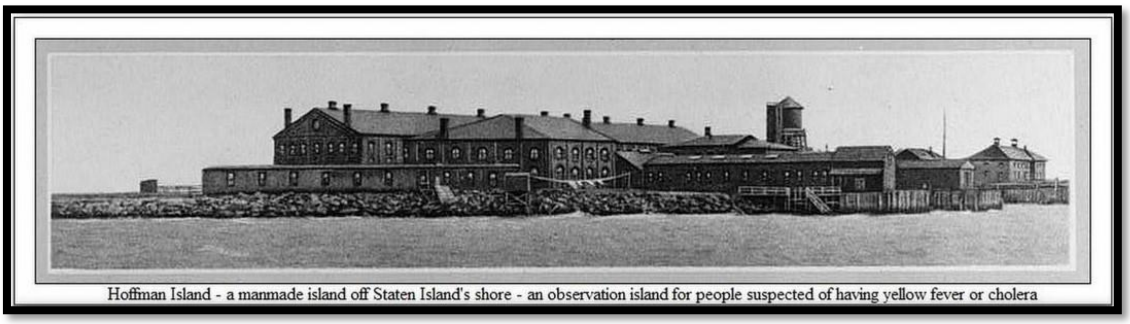


Source: https://mynewbrunswick.ca/partridge-island/, [Accessed 5 January 2021].

2.4.3 Hoffman Island

This island had four buildings which were dormitories, an administration building, and a building. A building contained boilers, steam heating, pump, drying rooms, laundry, and dining room on the first floor. In this building, the boilers supply the steam for disinfection and drying rooms on the second floor. In these island dormitories, they used galvanized iron for separate rooms. Also, they used arrangements to prevent the infection. These were covering the surface which are non-absorbent and impermeable materials, disinfecting the sewage, isolating several groups, and providing fresh air to them (Smith 1189).

Figure 2.5: Hoffman Island.



Source: https://www.nytimes.com/2020/05/22/realestate/quarantine-hoffman-island-swinburne.html, [Accessed 5 January 2021].

2.4.4 Ellis Island

Ellis Island was a result of an architectural competition. The Island had isolation wing. This isolation wing's surfaces and materials are designed with glazed tiles and copper fixtures. They used these materials for antibacterial properties. This wing is structured with a single corridor, and isolation wind is structured around this corridor (Garcia 2020).

Figure 2.6: Ellis Island

Source: Sueddeutsche Zeitung Photo / Alamy https://www.architectural-review.com/buildings/health/distant-space-the-architecture-of-quarantine, [Accessed 5 January 2021].

2.4.5 Urla Quarantine Island

In the 1800s, when epidemics spread to the world from Asia, quarantine zones were created in places where there were intercontinental transitions. One of these names is the Urla Quarantine Island, located in the Urla district of Izmir. In January 1840, the quarantine island Urla-Izmir (Smyrna) emerged from the ancient settlement of Klazomenai, and it was established as an example of the "Ottoman quarantine system (Tunçbilek 2020).

On this island, passengers were taken to changing rooms after disembarking from ships. The clothes of the passengers were put in nets. Passengers wore loincloth and sabot. After then, the clothes were placed in the rail system for carrying to the building. This system provides avoiding the infection risk from clothes. The rail system started from the port and it extended to the sterilizing machines. Clothes were placed in cabinets that rotate 360 degrees when they arrived at the building. The officers who were on the back wall of the changing rooms took the clothes from the rotating cabinets and started the disinfection process. The clothes were sterilized with 120 degrees of steam. Clothes did not get wet, and passengers could wear their clothes after bathing.

The main purpose of this quarantine station was to prevent the spread of infection and creating impermeable areas for infection. This quarantined area was defined by walls, ceilings, and floors. This structure was designed to follow every movement of the passengers with visual transparency concept (Zdebik 2012, p. 5).

In the event of a possible infection on this island, contaminated areas were isolated from all communities. Therefore, the quarantine building was designed to have two floors with high walls and multiple entrances. Thus, the building provides control of contagion and contamination (Tunçbilek 2020).

Figure 2.7: Urla Quarantine Island in Turkey.

Source: Urla Municipality http://www.urla.bel.tr/urla/2/urla-karantina-adasi, [Accessed 5 January 2021].

Figure 2.8: The main entrance of the station with the railway. Urla-İzmir Quarantine Island.

Source: Urla Municipality http://www.urla.bel.tr/urla/2/urla-karantina-adasi, [Accessed 5 January 2021].

Figure 2.9: The space organization of sterilizer machine.

Source: Urla Municipality http://www.urla.bel.tr/urla/2/urla-karantina-adasi, [Accessed 5 January 2021].

2.4.6 Malta Lazaretto Building

Malta had a complex of buildings, Lazzaretto buildings, and a quarantine organization. Lascaris building (Lazzaretto) consisted of eight halls with a central courtyard. Lascaris building's ground floor had two courtyards and a warehouse for ventilation and purification. The first floor and second floor consisted of a lot of small room for passengers to provide quarantine. Also, part of the building was used to fumigate the letters. This island had cattle sheds for the quarantining of animals. Six cemeteries were located in the area. Lazzaretto was also used as a hospital (Cassar 1987).

Figure 2.10: Malta Lazaretto Building.

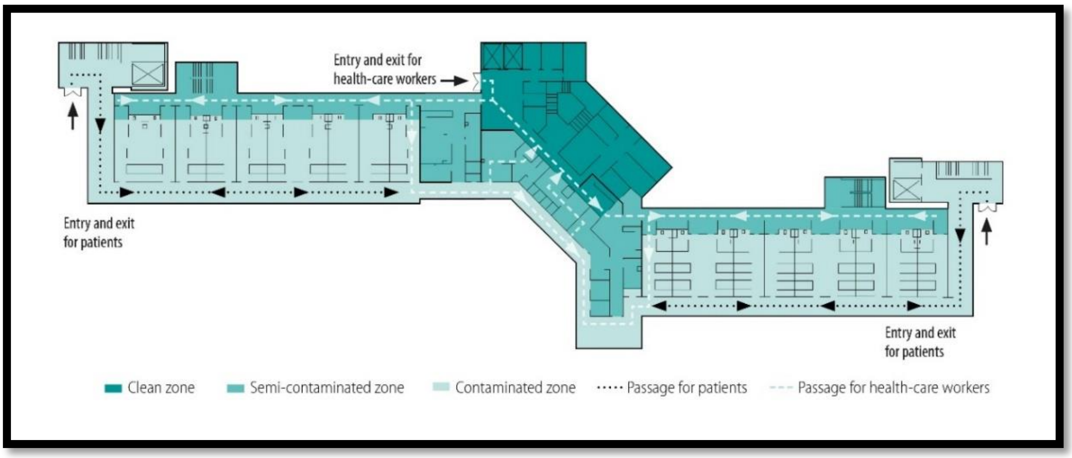
Source: https://timesofmalta.com/articles/view/when-breaching-quarantine-was-a-matter-of-life-and-death.794096, [Accessed 5 January 2021].

2.5 EXAMPLES OF HOSPİTALS FROM EPIDEMIC PERIODS

2.5.1 Beijing's Xiaotangshan Hospital

This hospital was established in 2003 for the SARS virus in China in Beijing. The purpose of the establishment of this hospital was to check the passengers from foreign countries in terms of illness. With Covid-19, the borders of this hospital have been expanded. This hospital consisted of two separate areas. Some of them were the places where the patients stayed to determine the diseases, the other part was the place where they were treated. It consisted of 3 regions in both areas. One of these is the contaminated area where the patients stay, the other is the semi-contaminated area where the healthcare professionals take off their clothes, and the other is the clean area where the healthcare professionals rest (Luo et al. 2021). With these decisions taken in the architectural design, the risk of contamination is reduced.

Figure 2.11: Beijing's Xiaotangshan Hospital.



Source: (Luo et al. 2021).

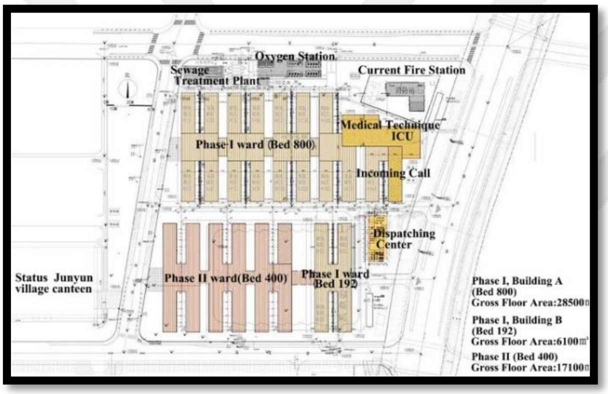
2.5.2 Leishenshan Hospital

There was no place left in hospitals due to the increasing number of infected patients with the coronavirus epidemic in China. Faced with this situation, the Chinese government started the construction of two field hospitals which are Huoshenshan Hospital and Leishenshan Hospital. The concept of the field hospital was a hospital in case of the battlefield, an emergency such as natural disasters, and rapidly evolving disease outbreaks. The constructions took 9 and 12 days respectively. Leishenshan Hospital consisted of three areas. These were the logistics area, ambulance decontamination area, and the medical treatment area. In the logistic area, there were a supply warehouse, wastewater treatment station, and trash incineration station. In medical treatment, they used a fishbone layout which included three zones and two passages. Three zones included a clean zone, a semi-contaminated zone, and a contaminated zone. The two passages included a passage for medical personnel and a passage for the patient. They separated these two passages to avoid the infection.

Figure 2.12: Leishenshan hospital under construction. Photo provided by Huang Lei.

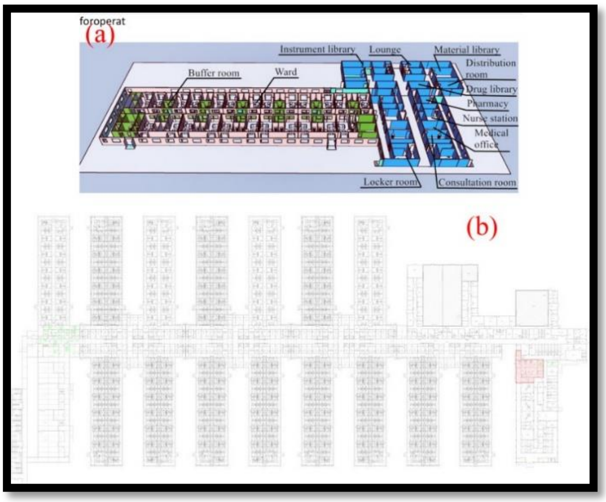
Source: (Chen et al. 2021)

Figure 2.13: Introduction of Leishenshan Hospital Project.



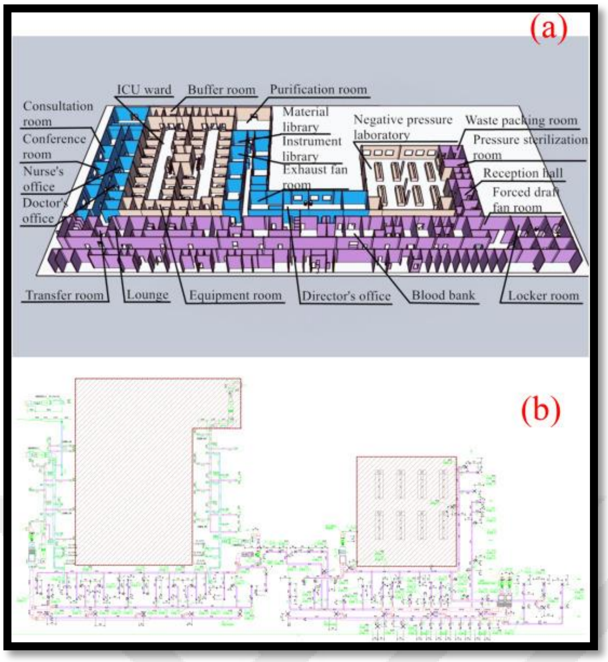
Source: (Chen et al. 2021)

Figure 2.14: The nursing unit module of the isolated medical area. (a) schematic diagram, and (b) unit plan.



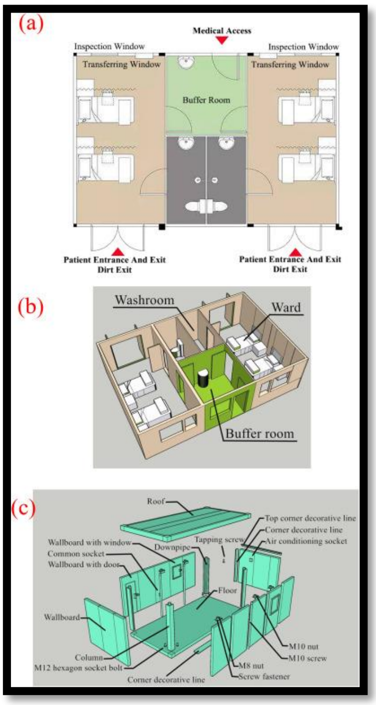
Source: (Chen et al. 2021)

Figure 2.15: Medical technology unit module of isolated therapeutic area. (a) schematic diagram, and (b) unit plan.



Source: (Chen et al. 2021)

Figure 2.16: Nursing unit of the isolated therapeutic area. (a) unit plan, and (b) schematic diagram of box room module components.



Source: (Chen et al. 2021)

When looked at the quarantine station in history it can be seen the importance of architectural spatial organization, separation of spaces, material selection, ventilation. In any epidemic circumstances, these issues are important for preventing the infection. Therefore, the places where patients stay are very important.

2.6 COVID-19 AND COVID-19 HISTORY

On 31 December 2019, Cases of pneumonia thought to be due to a different virus have been reported from Wuhan, China. In 2020 January 20, It was stated that there is human-to-human transmission in China. The World Health Organization (WHO) declared the COVID-19 outbreak as a pandemic on March 11, 2020. It can be transmitted to another person by the infected persons' coughing, sneezing, talking, or breathing. Viruses can be transmitted to other people, especially by inhalation and by close contact within 2 meters. Studies have shown that the virus has a longer-range transmission potential in closed and poorly ventilated areas (Az 2021; Lu et al. 2020). At the same time, it has been stated that who contact with the contaminated surface, if a person touches the mucosal areas such as eyes, nose, or mouth, contamination can occur (Fu et al. 2020). In experimental studies, the SARS-CoV-2 virus, except the respiratory tract; has also been detected in samples such as feces, blood, ocular secretions, and semen. However, the role of these regions in contagion has not been proven yet (Az 2021; Cheung et al. 2020; Wang et al. 2020). In 2021, the pandemic still continues. Necessary precautions are taken, and vaccination has started.

3. THEMATIC CONTENT ANALYSIS OF THE CASE STUDY

First of all, open-ended questions were prepared for thematic content analysis. Resources including the Covid-19 measures published by the World Health Organization ASHRAE and the European Center for Disease Prevention and Control contributed to the formation of open-ended questions. Questions are available in the appendices. Then the questions were asked verbally to the users in the room. The answers of the people whose permissions were taken were audio recorded. After the answers to the questions were completed, the answers to the questions were written down. Words that were read and repeated many times were underlined in the answers. These words were grouped into categories. These categories formed the themes and sub-themes. The obtained keywords were searched in the literature.

Questions:

i. What is your age?
ii. What is your gender?
iii. What precautions were taken with Covid-19 in your working environment?
iv. What precautions do you take for Covid-19 in your working environment?
v. How is the air-conditioning provided in your working environment?
vi. Have the systems related to mechanical ventilation been disabled with Covid-19? Or have any precautions been taken in mechanical ventilation?
vii. What time does the air conditioning system start and end in your working environment?
viii. How is the room ventilated? What do you think about the ventilation in the room?
ix. Do you think that the number of window and ventilation in the room is sufficient?
x. How often do you open the windows during the day?
xi. Are the windows of the room you work in double opening or single opening?
xii. Do you think windows are suitable for frequent opening and closing?
xiii. What do you think about the size of the room? Do you think the number and size of windows are sufficient compared to the size of the room?

xiv. How many people do you work with in the office? How many desks are there in your office?

xv. Is your workspace in the form of an open office?

xvi. If your workspace is in the form of an open office, are there partition walls or panels between the desks?

xvii. How is the distance between the desks in your office?

xviii. How many people do you work with in your room? What do you think is the relationship between the number of people you work with compared to the size of the room?

xix. What is the distance of your desk from the window?

xx. How do you find the ceiling height of the room? Does it spacious or frowsty?

xxi. Is there a ventilator in your working environment?

xxii. Are curtains available for windows? If available, does the curtain prevent the window from being opened?

xxiii. Do you need to use artificial light in your working environment? Or is sunlight enough?

xxiv. What are the materials of the surfaces you touch frequently during the day? Give an example.

xxv. How are the corridors ventilated?

xxvi. How often are the windows in the hallways opened? Is it suitable for continuous on and off? Are the windows in the corridor double opening or single opening?

xxvii. Are there seating groups in the corridors? If yes, what is the distance to windows and ventilation?

xxviii. Does the toilet ventilation work 24/7?

xxix. Is natural ventilation provided in the toilets?

xxx. How do doors open in your working environment? How does the light on and off work?

In the light of the questions asked, the most repeated themes were determined, and categories were created such as hygiene, location, personal hygiene, distance, precaution to avoid being ill, ventilation, room design, distance, touched materials/surfaces as shown in appendix A3. Then the categories were examined, and frequently repeated words were determined such as ventilation, distance, architectural design, ceiling height, room size, window size, number of windows, window distribution and materials. These words have been searched in the literature.

4. VENTILATION DEFINITIONS AND TITLE DEFINITIONS FROM THE THEMATIC CONTENT ANALYSIS

4.1 VENTILATION DEFINITION

Ventilation occurs by regenerating the air directly or indirectly. There are two types of ventilation systems: mechanical and natural ventilation. Natural ventilation is a situation that occurs due to wind or temperature difference in the outside and inside without using a mechanical system. The ventilation requirements of the buildings arise primarily from the breathing requirement of the users inside.
However, Covid-19 disease, which is a health problem that deeply shakes the world today, has brought up the importance of ventilation.

4.1.1 Evaluation of Building Location

The urban texture directs and affects the wind with its design features. Thus, the location of the building is important. Features depend on urban texture and location. All buildings affect the wind with their presence, texture, and size in urban texture. The wind cannot be stopped but can be directed. This orientation creates a positive or negative result with the design decisions of the building.

4.2 BUILDING GROUPS AND WIND EFFECTS FOR NATURAL VENTILATION

The wind cannot be stopped. However, they can be guided by effective designs. Therefore, the urban texture structure affects the wind by directing it. The shape, texture and size of buildings also affect the wind. The urban context can affect the urban wind environment for good or bad depending on the situation. The effect of the winds varies from region to region. The prevailing winds, as the winds that have effects on the region, are the subjects that should be examined in this regard. For a location near the coast, breeze winds should be examined. In terms of urban context, the effects of urban wind are examined in the appendices in appendix A4 with tabular form.

4.3 VENTILATION REQUIREMENT FOR COVID-19 AND INFECTIOUS DISEASE TRANSMISSION WITH AIRBORNE

Transmission of SARS-CoV-2 generally occurs in closed space. Thus, the ventilation system is the most important thing in this situation because this virus is transmitted with mostly the airway.
REHVA published a guidance document for Covid-19. This guide document contained information on preventing the spread of this virus.

The coronavirus spreads through the air. The size of a coronavirus particle is 80-160 nanometer. These particles can live many hours on a surface depending on the surfaces' material. Indoor, these particles can remain active for up to 3 hours and live the surface 2-3 days. Virus travel with respiratory fluid droplets. Large droplets fall but small droplets can travel with the airway in indoor spaces. Also, the ventilation system is help to travel these droplets. Expelled respiratory droplets that are suspended in air (which means airborne) range from less than 1 micrometer (micrometer = micron) to more than 100 micrometers in diameter, which is the largest particle size that can be inhaled.[1]

Airborne transmission occurs by close contact and long-range regions. These contacts depend on the coronavirus particle size.

Coronavirus droplets travel 2meter and then fall into surfaces. This traveling depends on the coronavirus particle size. At an initial droplet velocity of 10 m/s larger droplets fall within 1,5 m 4 1 nanometer = 0.001-micron Page | 4 Respiratory activities correspond to a droplet velocity of 1 m/s for normal breathing, 5 m/s for talking, 10 m/s for coughing, and 20-50 m/s for sneezing.[2] Expelled droplets evaporate. Then these droplets dry in the

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[1] REHVA, 2020, COVID-19 Guidance Document, 2020, https://www.rehva.eu/fileadmin/user_upload/REHVA_COVID-19_guidance_document_V3_03082020.pdf, [date of access January 25, 2021].
[2] REHVA, 2020, COVID-19 Guidance Document, 2020, https://www.rehva.eu/fileadmin/user_upload/REHVA_COVID-19_guidance_document_V3_03082020.pdf, [date of access January 25, 2021].

air and the final droplet size smaller than the first droplet size. In these situations' droplets can go further than 1.5 meters with the airway.

Long-range airborne transmission defines by further than 1.5 meters. Droplet desiccation is a fast process; for instance, 50 μm droplets desiccate in about two seconds and 10 m droplets in 0.1 s to droplet nuclei with roughly a half of the initial diameter.[3] Droplet nuclei <10 μm may be carried by airflows for long distances since the settling speeds for 10 μm, and 5 μm particles (equilibrium diameter of droplet nuclei) are only 0.3 cm/s and 0.08 cm/s, so it takes about 8.3 and 33 minutes respectively to fall 1.5 m.[4]The virus needs a liquid to survive, which is why they are called virus droplets. Droplets from aerosols in the air. Transport of these aerosols is 1-1.5 meters in well-ventilated spaces. However, this transport distance increases in poorly ventilated spaces.

Many health organizations such as the world health organization have issued statements on taking preventive measures for this virus. These specific recommendations are relevant to characteristics of the rooms such as volume, size and openings, the occupancy rate of the room. In places where the ventilation rate cannot be measured, the carbon dioxide ratio will give a clue about ventilation. Technical guidelines recommend that the carbon dioxide concentration is kept below 800 to 1 000 ppm to ensure sufficient ventilation.[5]

4.4 NATURAL VENTILATION DEFINITION AND METHODS

Natural Ventilation is the way outside air reaches the interior of the building through the gaps (windows, doors, joint gaps, etc.) in the building shell without the need for mechanical systems. In this way, indoor air is thrown out (Öztürk et al. 2005).

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[3] REHVA, 2020, COVID-19 Guidance Document, 2020, https://www.rehva.eu/fileadmin/user_upload/REHVA_COVID-19_guidance_document_V3_03082020.pdf, [date of access January 25, 2021].

[4] REHVA, 2020, COVID-19 Guidance Document, 2020, https://www.rehva.eu/fileadmin/user_upload/REHVA_COVID-19_guidance_document_V3_03082020.pdf, [date of access January 25, 2021].

[5] REHVA, 2020, COVID-19 Guidance Document, 2020, https://www.rehva.eu/fileadmin/user_upload/REHVA_COVID-19_guidance_document_V3_03082020.pdf, [date of access January 25, 2021].

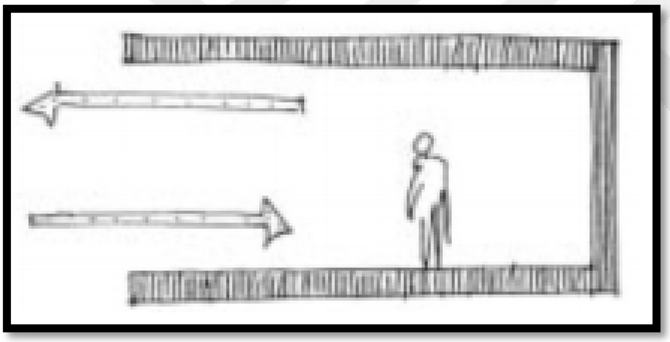
Natural ventilation is a movement that occurs as a result of density differences caused by temperature differences and wind pressure (Lechner 2014).

There are three different methods of natural ventilation. Ventilation occurs depending on the temperature differences, density differences, and wind pressure differences of the indoor and outdoor air. However, if the route of the air is as clear as possible in the space, it will make the ventilation more effective. In other words, it depends on the quality of the floor plans, openings, and similar features in the design process.

4.4.1 Single-Sided Ventilation

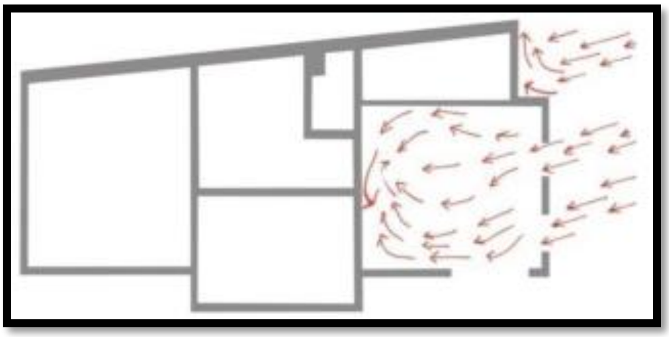
For the single-sided ventilation method to be successful, the depth of the room should not exceed 2-2.5 times the interior height of the room.

Figure 4.1: Single-sided ventilation section



Source: (Kleiven 2003)

Figure 4.2: Single-sided ventilation plan.

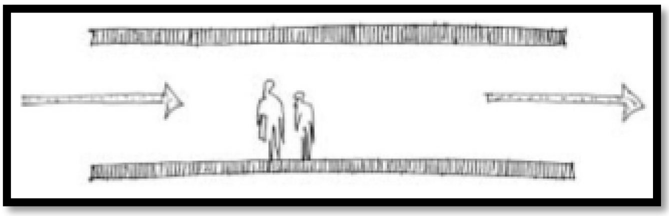


Source: (Darçın 2010)

4.4.2 Cross Ventilation

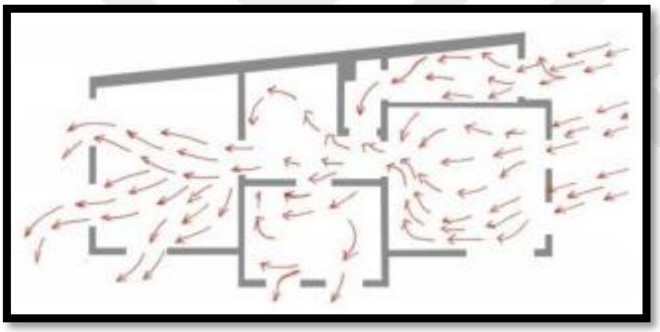
Successful cross ventilation is valid for an area as deep as 5 times the interior height. It is the ventilation of indoor and outdoor spaces with pressure difference with windows located on two opposite facades.

Figure 4.3: Cross ventilation section.



Source: (Kleiven 2003)

Figure 4.4: Cross Ventilation plan.

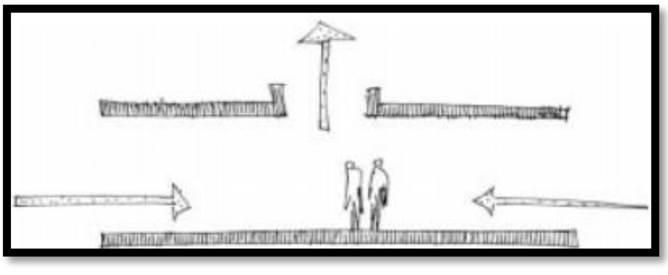


Source: (Darçın 2010)

4.4.3 Stack Ventilation (Ventilation with Chimney Effect)

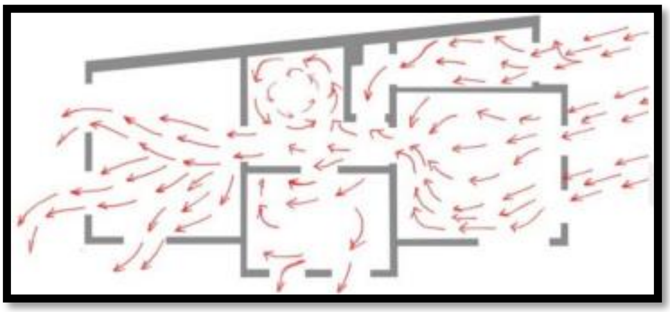
Fresh air is taken into the building from space at a low elevation and goes out of the building through space at a higher elevation. Stack ventilation is valid for a deep area that is more than 5 times the internal height.

Figure 4.5: Stack ventilation (ventilation with chimney effect) section.



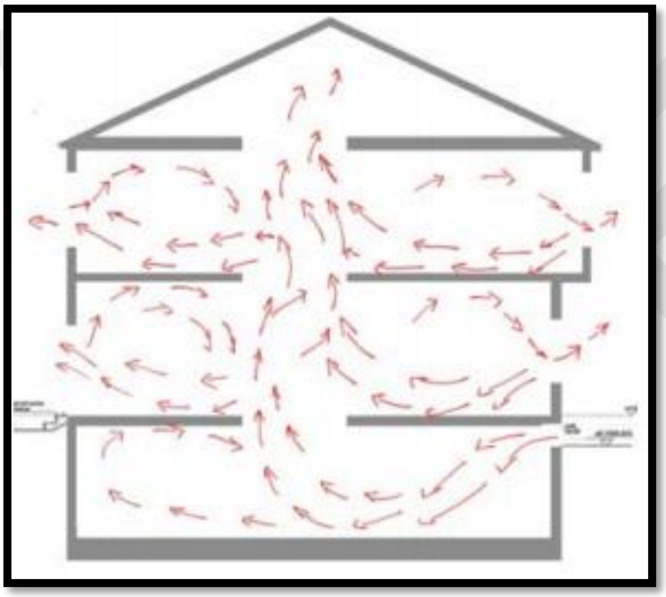
Source: (Kleiven 2003)

Figure 4.6: Stack ventilation (ventilation with chimney effect) plan.



Source: (Darçın 2010)

Figure 4.7: Stack ventilation (ventilation with chimney effect) section 2.

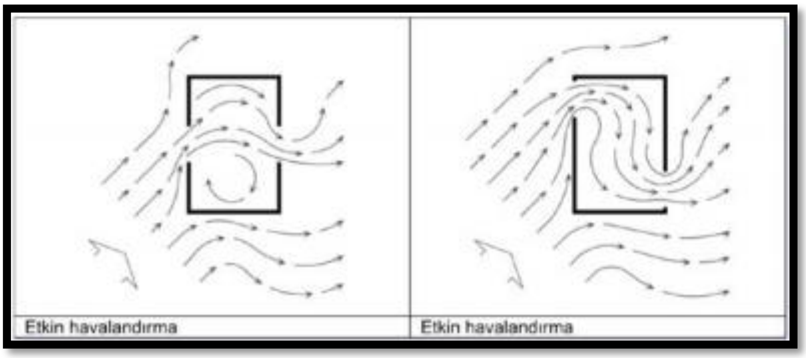


Source: (Darçın 2010)

4.4.4 Evaluation of Architectural Plan for Natural Ventilation

When designing a building, the location, depth, and interior height of the spaces are important to provide natural ventilation.

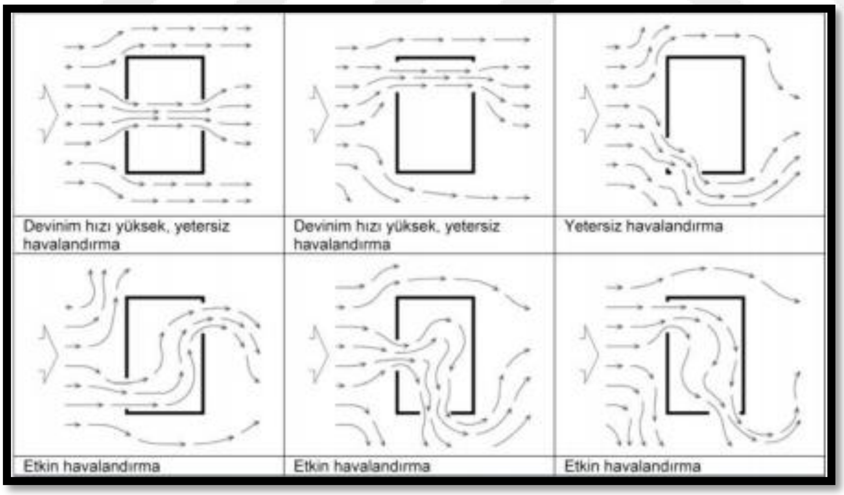
Figure 4.8: Wind direction and speed of movement according to the opening sizes and locations of the openings.



Source: (Watson, and Labs 1993).

The shapes of the volumes through which the air passes are important because they affect the flow rate. If the shape of the cavity is smaller than the previous space, the air will compress as it passes and move more slowly. Corridors act as passageways and corridors that affect the direction of the wind.

Figure 4.9: Wind speed and direction based on opening sizes and locations in the room.



Source: (Watson, and Labs 1993).

Floor height is important in single-sided and double-sided ventilation. For good ventilation, the floor height should be greater than the room depth. Also, room depth is important in one-sided ventilation (Kleiven 2003; Ahmed 2012; Darçın 2010; Schulze 2015; Yuyucu 2016; Bahadur 2018).

At the same time, the location, size of the window, size of the door, and openings are important factors for efficient ventilation. It is important for effective ventilation that the positions of doors and windows are designed as staggered.

4.5 DEFINITION OF MECHANICAL VENTILATION

Mechanical ventilation allows the movement and exchange of air to take place with fans.

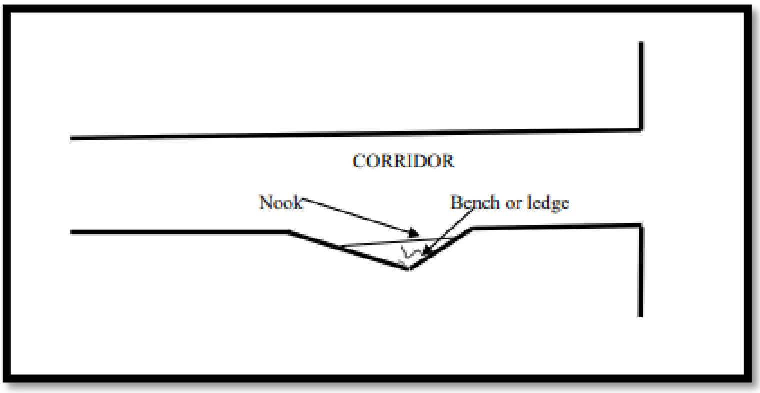
Natural air intake and mechanical air suction are provided. Mechanical air supply and natural air outlet are provided. Mechanical air supply and mechanical air suction are provided. This situation is defined as balanced ventilation (Küçüker 2019).

Although mixed systems and mechanical ventilation are preferred among the public today, natural ventilation is favorably received to protect the health of the user, to provide thermal comfort, to provide structural cooling and to increase the indoor air quality.

4.6 DISTANCE

The virus can travel long or close distances. For this reason, design for social distancing is an important factor for designing a building. When design a common space especially waiting areas, corridors, hallways, stairs, and entrance lobby should supply the social distance for protection from infection. This social distance has been revealed as a length as a result of certain studies. Because factors such as the size of the aerosol droplets and the way the virus spreads have affected the result of this study. To illustrate, the ledge corridor design was earlier introduced to hospital design by Carthey to encourage interactions among team members. Creating spaces to communicate in such secluded corners should be avoided in figure.

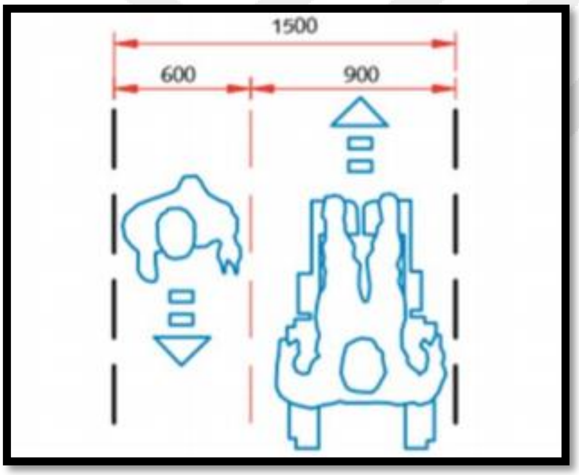
Figure 4.10: Example of corridor nook which was used for some hospitals.



Source: (Emmanuel et al. 2020).

When designing a building, the UK Department of Health recommends a corridor width of 1500 mm.

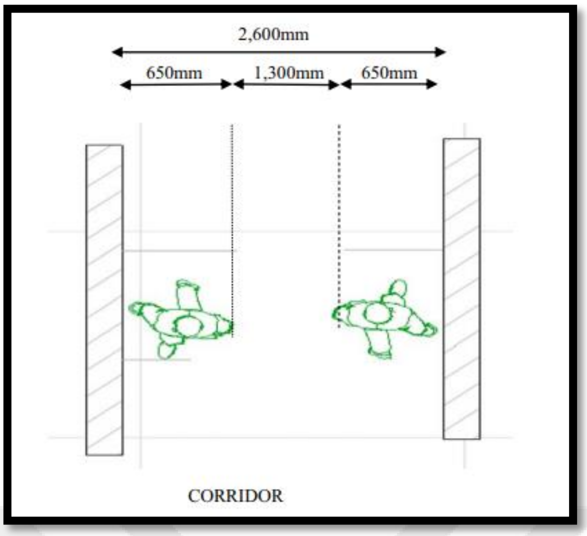
Figure 4.11: Corridor width as recommended by UKDH.



Source: (Emmanuel et al. 2020).

Emmanuel, Osondu, and Kalu suggest have suggested a minimum of 2600mm for corridor width. This is to allow for 1000 mm minimum interval in social distancing and 300 mm as bilateral freeboards since human movement is not exactly in a straight line (Emmanuel, Osondu, and Kalu 2020).

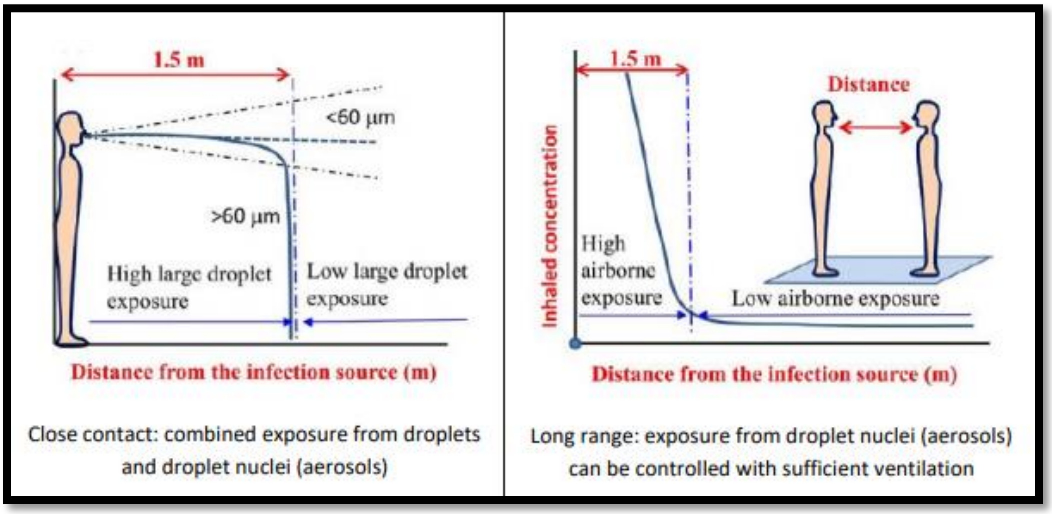
Figure 4.12: Suggested minimum corridor width (author).



Source: (Emmanuel et al. 2020).

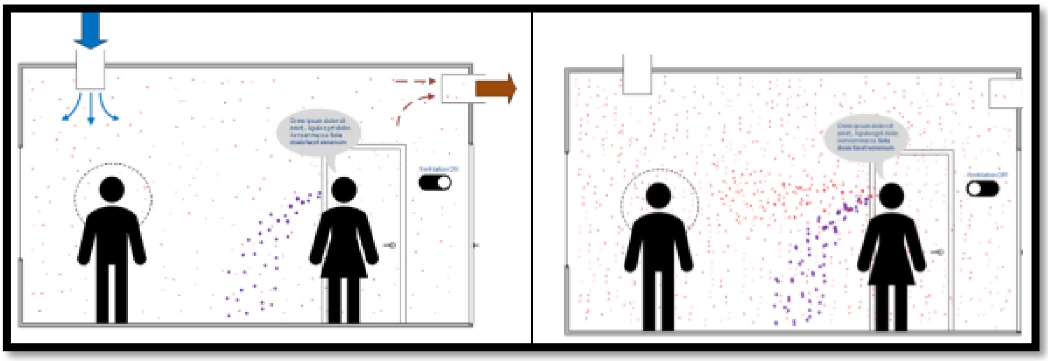
The distinction between close contact combined droplet and aerosol transmission (left) and long-range aerosol transmission (right) can be controlled with ventilation diluting the virus concentration to a low level.

Figure 4.13: Close range droplet delivery illustrator (left), illustrator of long range transmission of droplet when droplet density decreases with aeration (right).



Source: (REHVA 2020)

Figure 4.14: Illustration of how an infected person leads to aerosol exposure in the breathing zone of another person (left) (red spikes are droplets, purple spikes are large droplets), illustrator of the spread of droplets in the room when there is no ventilation (right).



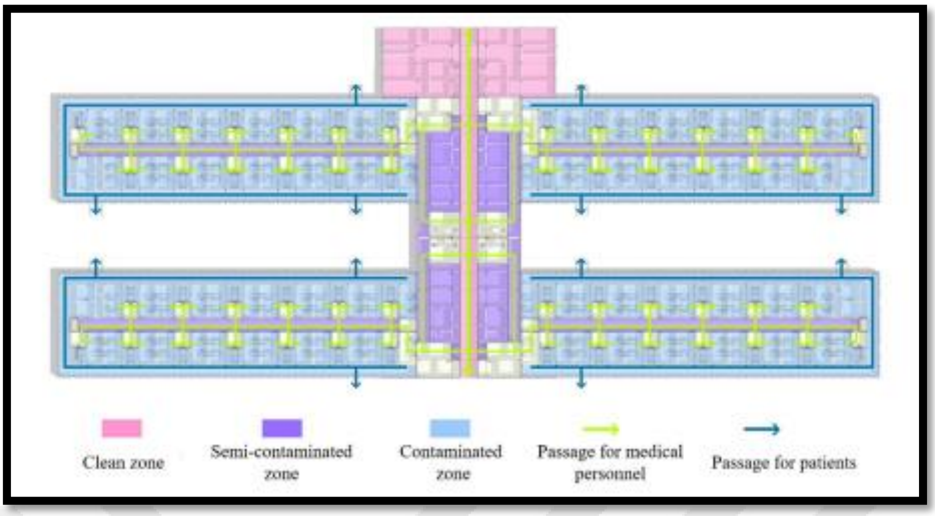
Source: (REHVA 2020)

4.7 ARCHITECTURAL DESIGN

Lariboisiere hospital was constructed in 1854 in Paris. They used a pavilion plan for protection from infection. These pavilions provide isolation for patients (Emmanuel et al. 2020).

Leishenshan is a hospital in Wuhan. Leishenshan Hospital consists of three main areas which are the medical staff living area, logistic area, and ambulance decontamination area. In this hospital, they use fish-bone layout protection from infection. Three main zones and two passages create a fish-bone layout. These three zones include contaminated, semi-contaminated, and clean zone. They did two passages for medical staff and patients. Also, in this plan, there are lots of buffer zone for transmission points by using a one-sided door (Luo et al. 2020).

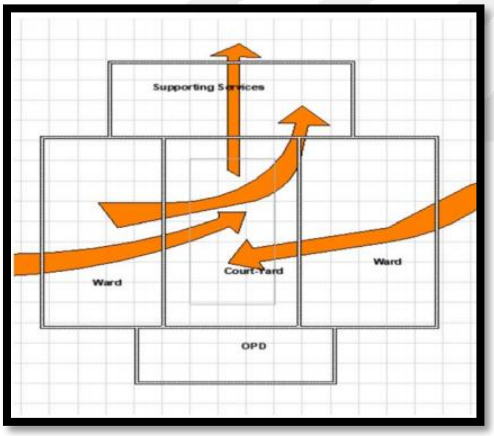
Figure 4.15: Plan of Leishenshan Hospital.



Source: (Luo et al. 2020)

Buildings can be designed as inner courtyards to provide a ventilation passage.

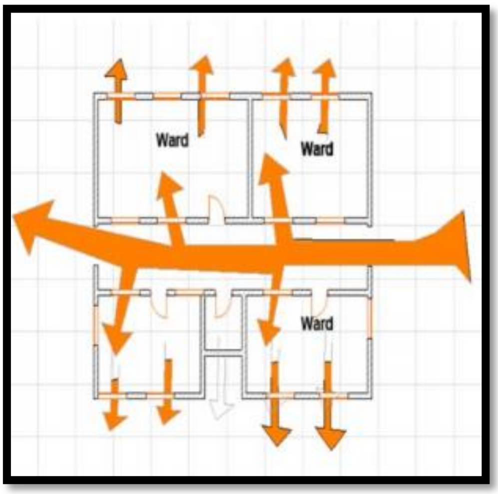
Figure 4.16: Example of courtyard approach for healthy ventilation.



Source: (Emmanuel et al. 2020).

To better ventilate the corridors, it can be ensured that both ends are open. To reduce the circulation of hot air, upper ventilation windows can be provided on the corridor walls or ventilation shutters on the door sill (Emmanuel et al. 2020).

Figure 4.17: Example of open-end corridor for healthy ventilation.



Source: (Emmanuel et al. 2020).

4.8 CEILING HEIGHT

Ceiling height is important for the one-sided ventilation method to be successful. As a rule of thumb, single-sided ventilation is effective to a depth of about 2 – 2,5 times the floor to ceiling heigh (Kleiven, 2003). As the depth of the room increases, the ceiling height should also increase or more windows should be positioned. Also, in stack ventilation ceiling height is an important factor for ventilation.

4.9 ROOM SIZE

In the post-pandemic era, it is predicted that there will be wide corridors and enlarged entrances compared to the past (Emmanuel et al. 2020). It is possible to increase the divisions between the work areas to prevent infection. It can be constructed as more individual spaces instead of collectively being together in common areas. The demand for socializing areas can be solved by overflowing the socializing spaces to the outdoors. Thus, open spaces dominated by natural ventilation can be added to the design, instead of unhealthy spaces with artificial ventilation. In addition, improvements and changes in indoor ventilation systems are among the measures that can be taken to prevent the spread of the virus.[6]

With the rise of concepts such as modular design, flexible partitions, and prefabricated add-ons, architects will start to produce new solutions with social distancing measures in mind. With the pandemic, Space sizes that can change according to the increasing number of people in indoor spaces and social distance seating combinations will also be among the issues to be considered.[7]

4.10 WINDOW SIZE AND NUMBER OF WINDOWS

Ventilation rate is among the factors affecting the spread of the virus. If the ventilation rate cannot be measured, measuring the carbon dioxide air levels in the room can be an indicator of the adequacy of the air. Technical guidelines recommend that the carbon dioxide concentration is kept below 800 to 1 000 ppm to ensure sufficient ventilation.[8]

To minimize the spread of the virus, it should be ensured that the ventilation conditions are better than before the pandemic. Uncontrolled air circulation should not be allowed in the room.

Countries have taken a lot of measures for the pandemic. To illustrate, in Belgium, according to the recommendations, windows should be kept open for at least 15 minutes at least three times a day. They prepared a table for ventilation requirements.

[6] Naturadergi, 2020, http://www.naturadergi.com/anasayfa/post-pandemik-mimarlik/?lang=en, [accessed 11 December 2020].

[7] Naturadergi, 2020, http://www.naturadergi.com/anasayfa/post-pandemik-mimarlik/?lang=en, [accessed 11 December 2020].

[8] REHVA, 2020, COVID-19 Guidance Document, 2020, https://www.rehva.eu/fileadmin/user_upload/REHVA_COVID-19_guidance_document_V3_03082020.pdf, [date of access January 25, 2021].

Figure 4.18: Measures of Belgium for Coronavirus

Setting	Air changes per hour (ACH)*	Time to decrease contamination by 90%
Closed windows without mechanical ventilation	0.1-0.5	5-25 hrs
Window tilted (one side)	1-2	1 h15 min-2hrs
Windowless room with mechanical ventilation	4	37 min
Windowless room with increased mechanical ventilation	8	20 min
Windows wide open	± 10	15 min
Windows wide open, in opposite walls	± 40	5 min

* At least 2.5 ACH are needed to change at least 90% of the air in a room

Source: (ECDC 2020).

In Italys' coronavirus guide, doors can be closed to prevent air diffusion between adjacent rooms. Increasing the air velocity in the room will prevent virus spread (ECDC 2020).

4.11 WINDOW DISTRIBUTION

The sources stated for Cyprus are that the fresh air should cross the room. Windows should open for 15 minutes frequently (ECDC 2020). In cross ventilation, window sizes, positions, and ceiling height are important.

4.12 MATERIALS

Studies on Covid-19 are investigating that the virus has different life spans on different surfaces. Studies show that the coronavirus can last up to 3 days on plastic and steel, less than 24 hours on spongy fabrics such as cotton leather and cardboard, and 4 hours on copper surfaces. For this reason, material selection has become more important especially for architects (Doremalen et al. 2020). In one study, plaster material used in construction was evaluated as a suitable area for the spread of pathogenic elements (Nightingale 1868).

To illustrate, Ellis Island which was a quarantine island used copper fixtures to avoid infection.

Aerosols/droplets produced during dental procedures may remain in the air for 3 hours (Meselson 2020). Metals containing copper have antiviral properties, and their alloys, like brass and bronze, are considered antimicrobial. It takes 40 min on a brass surface and 2 hours on a copper (70%) nickel surface to inactivate the SARS-CoV-2 (Ren et al. 2020).

Copper-containing interior materials, copper-alloy air vents, air conditioning ducts can also help remove the virus while cooling or heating the circulating air (Isha et al. 2020).

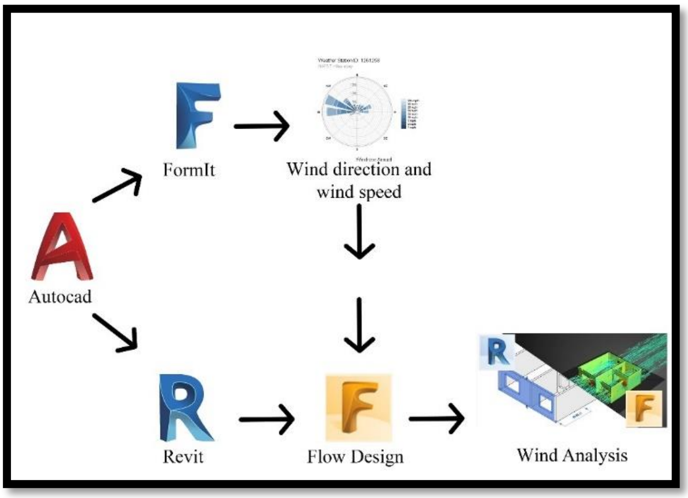
5. BIM FOR BUILDING PERFORMANCE ANALYSIS AND CASE STUDY

There are communication difficulties between different disciplines in the building sector. Building Information Modeling (BIM) prevents mistakes and helps prevent the possibility of mistakes causing material damage. It also provides system control and management. Additionally, it covers the architectural design process that provides information on building performance issues (Watson, and Labs 1993).
BIM is a set of systems that enable the common use of a three-dimensional model created from graphic data such as geometric and form related to the building and numerical data such as material, cost, physical environment control by participants from different disciplines.

The relationship between columns, walls, doors, and windows, which are the building elements, allows them to take place on the model with their real duties and behaviors.

A factory in Gaziantep was selected for wind analysis. The name and location of this factory are kept anonymous in this thesis. The office rooms where the employees are in the factory are determined and the rooms are modeled including window openings and door openings for wind analysis. This factory was chosen because the different numbers of people working in the rooms and the different sizes of the rooms will provide diversity in the wind analysis. In this study, wind data of the region were obtained with the FormIt program. Revit programs were used for modeling and Flow Design programs used for wind simulation.

Figure 5.1: Interdisciplinary study process.

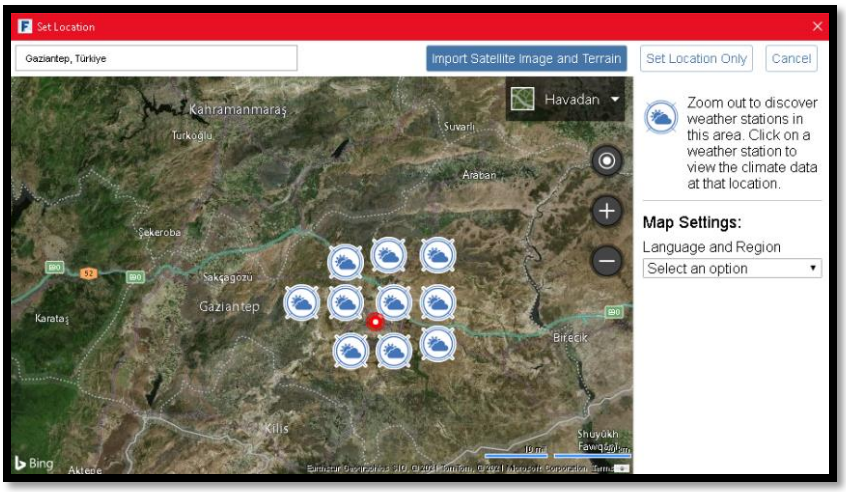


5.1 MODELING AND ANALYSIS PROCESS

5.1.1 FormIt

With the FormIt program, information about wind and temperature can be obtained from the closest weather station to the region that needs to be analyzed. Fahrenheit is used as the unit of temperature degree.

Figure 5.2: Set location menu 1.



From this menu, the closest weather station to the area to be analyzed is found and the data of the region is obtained.

Figure 5.3: Monthly temperature.

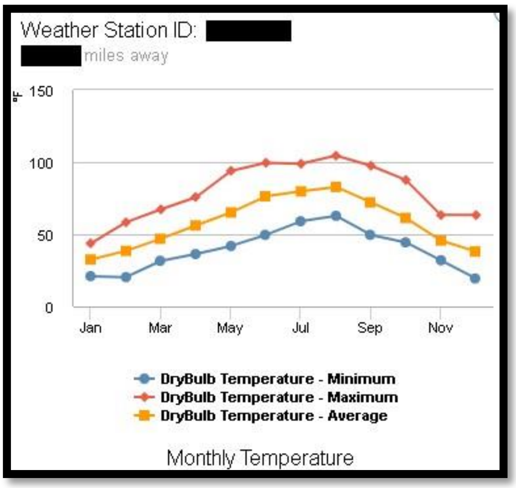


Figure 5.4: Monthly temperature average.

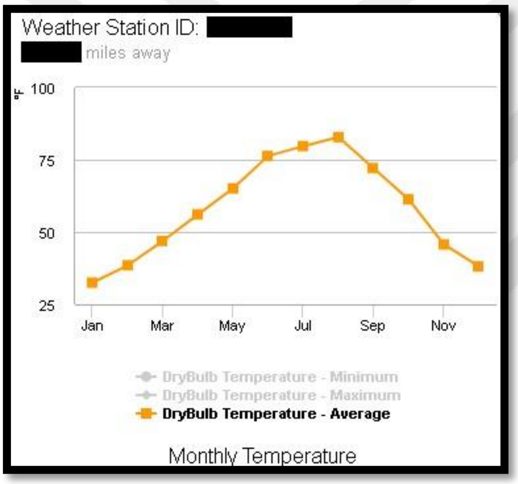


Figure 5.5: Dry bulb temperature - maximum.

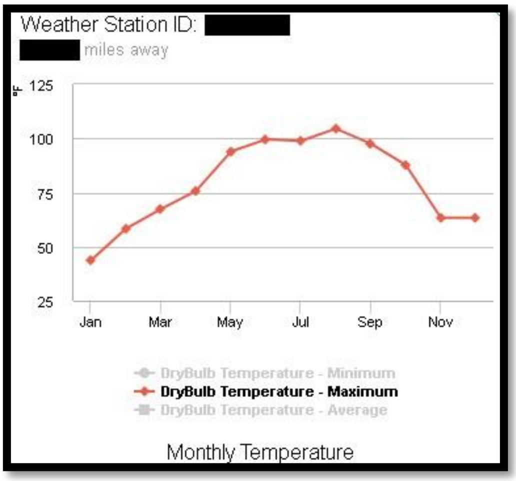


Figure 5.6: Dry bulb temperature – minimum.

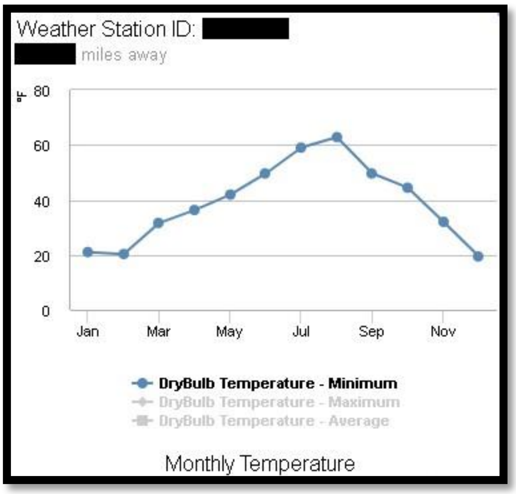


Figure 5.7: Windrose annual.

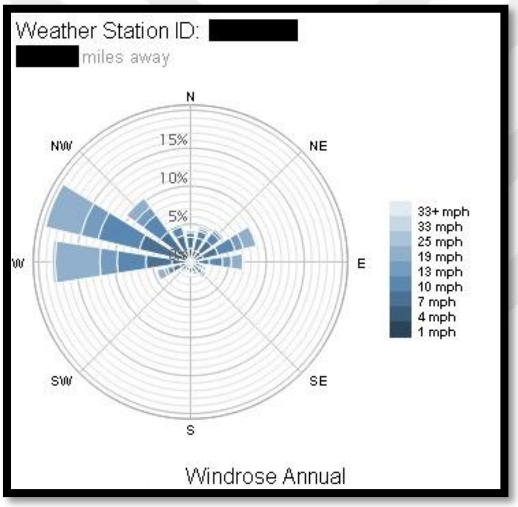


Figure 5.8: Windrose speed dec-feb.

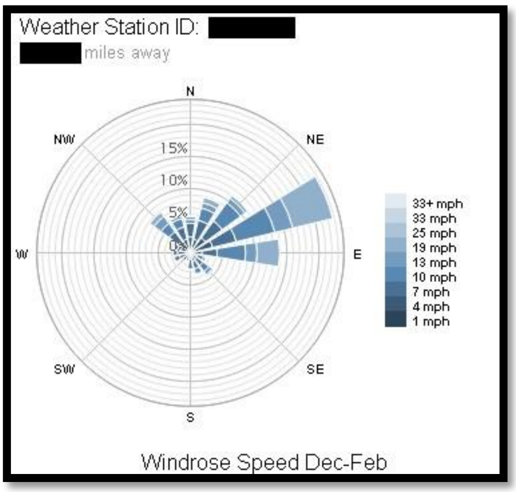


Figure 5.9: Windrose speed jun-aug.

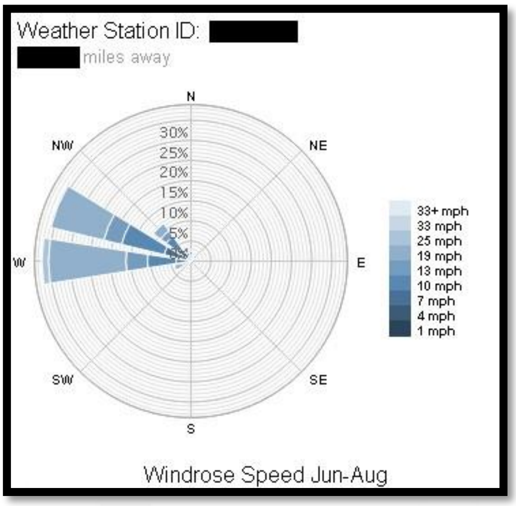


Figure 5.10: Windrose speed mar – may.

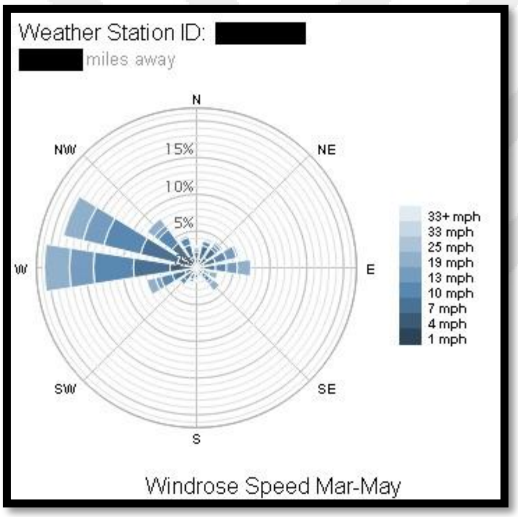
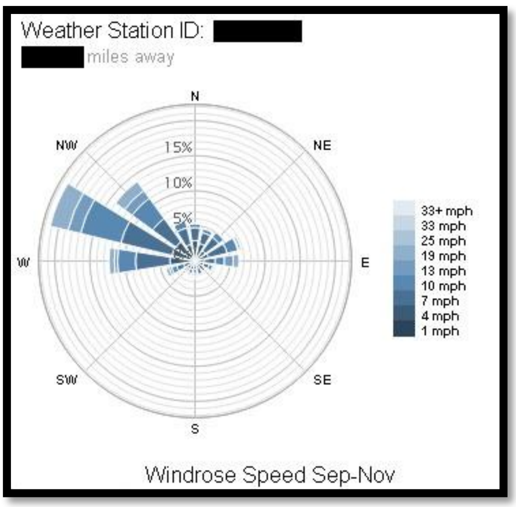


Figure 5.11: Windrose speed sep – nov.



5.1.2 Revit

It is a widely used program in building information modeling systems that allows users to design with parametric modeling and drawing elements. It is an effective program for architectural design, MEP (mechanical, electrical, and plumbing), structural engineering and provides interdisciplinary coordination and collaboration (Yavaş 2019). It can provide the necessary data for the analysis of some factors such as daylight, lighting, wind, direction, and form. In this thesis, the factory is orientated according to its current location. The windows of the rooms to be analyzed were facing west. The rooms to be analyzed was marked in red and their room numbers was given.

Figure 5.12: First floor of the factory.

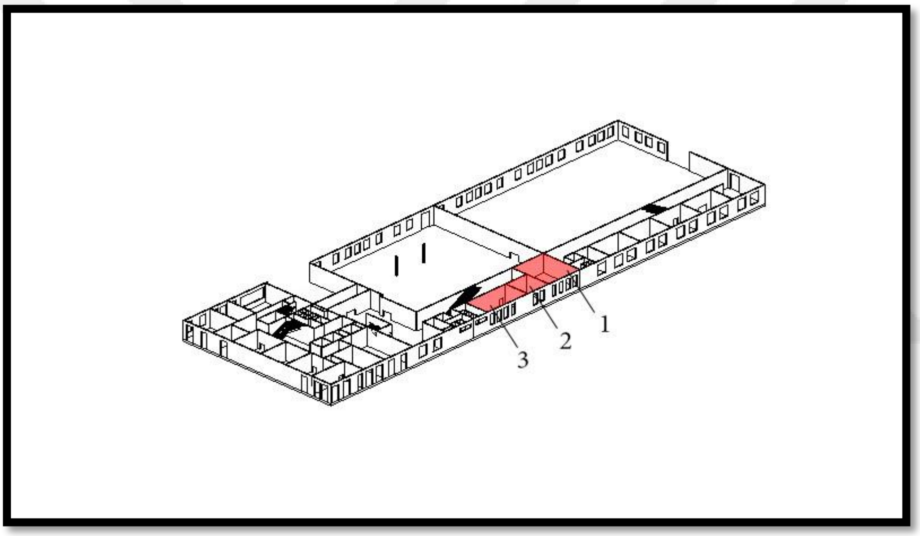
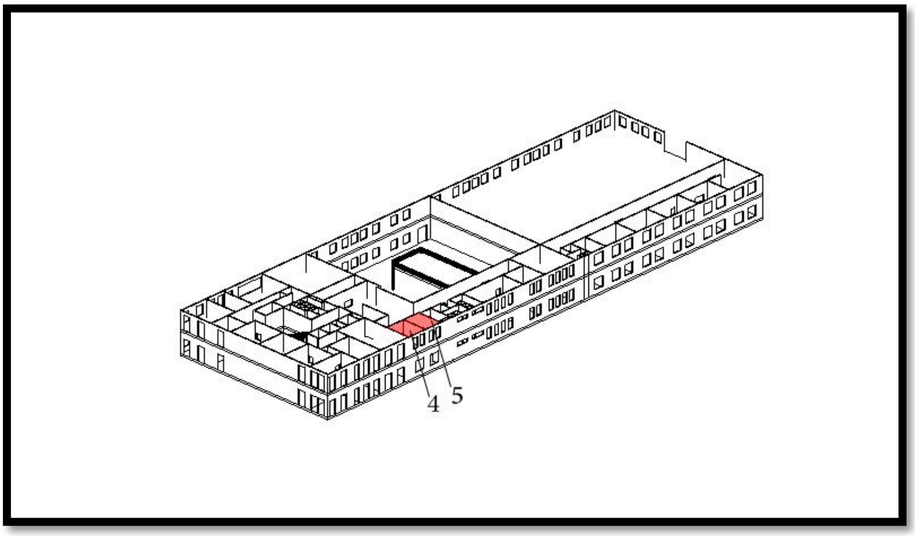


Figure 5.13: Second floor of the factory.



5.1.3 Flow Design

Flow Design is a computational fluid dynamics (CFD) software that allows designers and engineers to simulate airflow around any object in a virtual wind tunnel. It allows users to see the flow, pressure, and velocity behavior of the air around the model a few seconds after the application starts. Automobile designers can use it to understand the aerodynamic impact of design changes, and an architect can use it to see how the building he builds affects wind levels and pressure zones (Yavaş 2019).

When the 3D model designed in the Revit program is transferred to the Flow Design program, the flow on the geometry is automatically performed. The user can adjust the direction and speed of the wind tunnel as desired. In the simulation performed here in wind-related characteristics were entered from the information obtained from the FormIt program. The annual wind speed and direction are taken as a basis for wind analysis. The wind speed was determined according to the analysis result in the program. Wind speed was analyzed as 25 mph. By making the necessary transformations, the wind speed was obtained as 11 m/s. This information was entered into the FormIt program, and the wind tunnel was created. To better observe the wind movement, the wind analysis of the rooms was done separately. Since it is an office building, the office rooms are examined separately because the wind enters the room first through the windows and comes out of the room through the door. As a result of the surveys, it was found out that no divider panels were used in the rooms. Therefore, the first movement of the wind is from the window to the door, and this movement of the wind is examined within the scope of the study. Ventilation rate can be interpreted from the colors formed in the analysis and the scale created by the flow design.

Figure 5.14: First Floor Wind Analysis

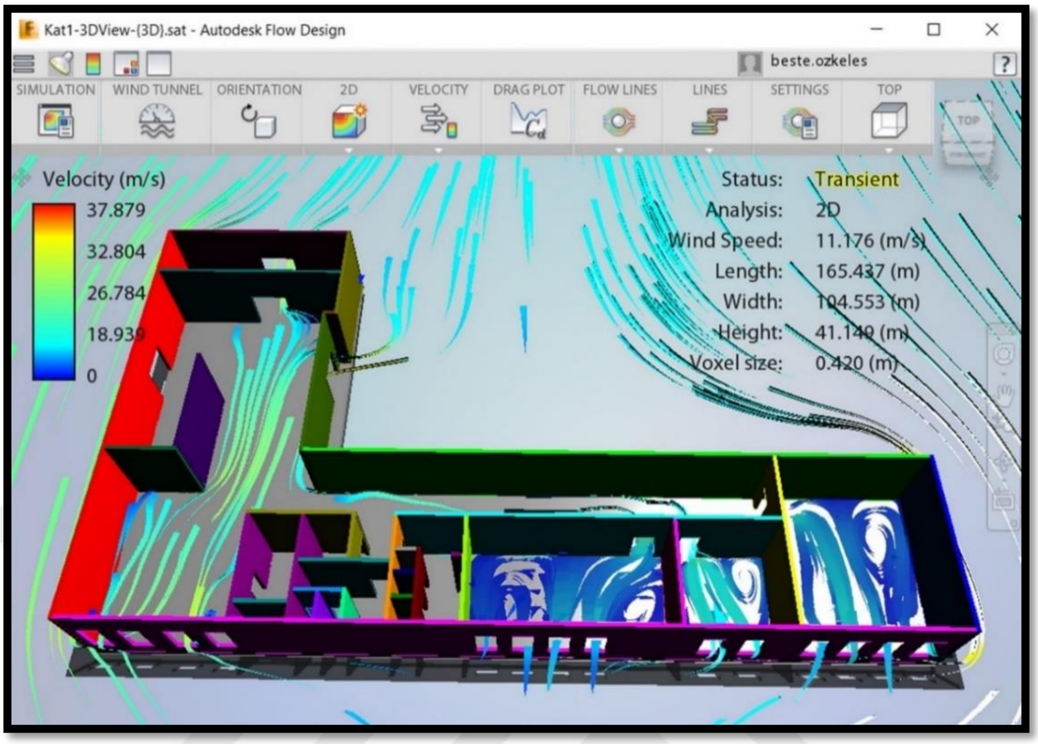


Figure 5.15: Second Floor Wind Analysis

5.1.3.1 Room 1

The first room is the largest analyzed room. It is 64.50 square meters in total. It has 4 windows. The dimensions of these windows are 100 cm wide and 210 cm high. The doors are 100 cm wide and 240 cm high. Since the space can directly benefit from the prevailing wind, natural ventilation can be provided with maximum efficiency. According to Figure 5.14, the air velocity decreases in a part of the room, forming a vortex. This indicates that effective ventilation has slowed down in this section. It can be said that cross ventilation is provided with the door opening. The region where the air swirls can be a risky area for airborne diseases. The depth of the chamber is 6 meters. The depth of the room is considered deep to provide one-sided ventilation. The number of windows is not sufficient compared to the room size and depth, as the analysis shows. The speed slows down considerably at corner points. The first room is used as the room where all participants are trained.

5.1.3.2 Room 2

The second room is a total of 25.65 square meters. It has 2 windows. The dimensions of these windows are 100 cm wide and 210 cm high. The door is 100 cm wide and 240 cm high. The corners of the room are usually the parts where there is insufficient ventilation if there is no opening. According to Figure 5.14, at the points where natural ventilation and wind flow are provided. The color of the vortex formed at the corners appears to be dark blue. According to the speed determined by Flow Design, the wind speed is almost zero. The 6th and 3rd participants are working in room 2.

5.1.3.3 Room 3

The third room is 48.50 square meters in total. It has 4 windows. The dimensions of these windows are 100 cm wide and 210 cm high. The door is 100 cm wide and 240 cm high. Although the wind speed entering through the window is 11,334, the wind speed is quite slow at some points due to the size of the room and the location and number of windows. The door side, which is opposite the wall with the windows, provides effective ventilation, but in the corner where the door is not located, the wind speed decreased, and vortex formation was observed. In Room 3, the 7th, 8th, 9th and 10th participants are working. According to the thematic content analysis, employees in room 3 are neither good nor bad for the number of people working in the room. 3rd room workers say that the size and number of windows are important for ventilation. When we look at the ventilation performance analysis of the room, it cannot be said that natural ventilation is provided effectively in the room. It is thought that social distance will be sufficient if masks are worn by the employees, but adequate ventilation is provided in certain parts of the room according to the results of the wind analysis.

5.1.3.4 Room 4

The total area in the fourth room is 19.25. It has 2 windows. The dimensions of these windows are 100 cm wide and 210 cm high. The door is 100 cm wide and 240 cm high. Due to the small size of the room, natural ventilation is provided. Spirals are not formed. In room 4, the 4th participant is working.

5.1.3.5 Room 5

The total area in the fourth room is 19.25. It has 2 windows. The dimensions of these windows are 100 cm wide and 210 cm high. The door is 100 cm wide and 240 cm high. Due to the small size of the room, natural ventilation is provided. Spirals are not formed. 1st, 2nd, 5th participant is working in room 5. The number and size of windows are considered by the workers in the 5th room to be sufficient for the room. According to the analysis, these thoughts are confirmed. The first participant working in the fifth room mentioned that the room was very frowsty. However, according to the analysis, the fifth room is one of the rooms with the best natural ventilation.

6. CONCLUSION

In general, it can be said that the rooms examined in the project get the maximum efficiency from the wind because the windows are on the front where the prevailing wind is. In room 1, room 2, and room 3, the corner areas can be interpreted as the regions where the wind speed decreases, and the vortex area is formed compared to the other parts of the room. According to the results of the thematic content analysis, the employees in the 3rd room think that the number and size of the windows in the room are sufficient and say that they provide natural ventilation, but according to the analyzes made, it was observed that the cross ventilation could not be provided enough due to the width of the room and the wind speed decreased in some parts of the room. Since rooms 1, 2, and 3 are larger than rooms 4 and 5, it is possible to see that the wind speed decreases and swirls form in the corners. The number and size of the windows are considered sufficient for the room by the employees in the 5th room. According to the analysis, these thoughts were confirmed. Although ventilation seems to be good in terms of ventilation quality, more effective natural ventilation can be achieved if the number or size of windows in rooms 1, 2, and 3 are increased. For good ventilation, the floor height should be greater than the room depth. Also, room depth is important in one-sided ventilation (Bahadur 2018; Yuyucu 2016; Schulze 2015; Ahmed 2012; Darçın 2010; Kleiven 2003). All of these analyzed rooms provide this situation.

While making the first design decisions, the structure should be modeled and inserted into the wind tunnel, and the obtained data should be interpreted correctly, and future problems and problems should be prevented by forming and surface decisions. The location of the building and its surface decisions, as well as the indoor positioning, are important for human health in terms of the pandemic.

Along with the findings in previous chapters, Flow Design analyses show that inadequate natural ventilation may adversely affect human health if it is not planned well. The air is directed according to the number of windows, size, and location of the openings. For this reason, when designing an office, natural ventilation should be designed by considering these parameters, the number of people and the size of the room. Buildings can be made more resilient towards pandemics. The examined rooms have different sizes, different size and number of windows, and openings. Therefore, the air circulation in each room was observed differently. This shows how important these parameters are in air circulation. This and previous studies demonstrate that three factors affect airborne transmission of diseases. These are ventilation rate, flow direction, and airflow pattern (Qian et al. 2020). For this reason, these parameters should be designed in such a way that the air circulation is the most efficient. To prevent airborne diseases, this airway should be considered more, and the design should be made accordingly. If correct formation, positioning, and solutions cannot be provided for natural ventilation, an extra mechanical system will be needed to provide clean air, which will be detrimental to the environment and will increase operating costs. These systems will also cause extra problems in case of a possible pandemic, and as such, should be discouraged.

For airborne epidemics such as Covid-19, parameters such as natural ventilation, wind speed, window size, and location are associated with the spread of the disease. This study confirms the natural ventilation can reduce the spread of the virus.

At the same time, to protect from infection, material selection is important in the interior at the design stage, along with natural ventilation. Because the survival time of the virus on every surface varies according to the surface characteristics. Like the islands of quarantine buildings, buildings must take precautions for pandemics and not disrupt daily life. Therefore, these design criteria should be given importance. Maybe, in the case of a possible pandemic, just like in the quarantine islands, people who feel bad can be taken to a room with high ventilation and spend this process there. In this way, dirty, clean, and semi-clean areas can be created like in hospitals. Necessary natural ventilation systems can be used in areas considered to be polluted and interior materials can be selected accordingly.

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