BUILDINGS CONVERTED FOR COVID-19 PATIENTS: VENTILATION IN THE ISOLATION ROOMS MONASTERIES IN KESSERWAN CONVERTED FOR THE COVID-19 PATIENTS

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Buildings Converted for COVID-19 Patients:
Ventilation in the isolation rooms
Monasteries in Kesserwan converted for the Covid-19 patients.

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ABSTRACT

The emergence of respiratory diseases and pandemics through history such as the severe acute respiratory disease (SARS), the Spanish flu, and the current Covid-19 epidemic highlight the importance of ventilation in the transmission of airborne diseases. This research examines the buildings in Lebanon converted for hosting the cases of the Covid-19, focusing on the three pillars of sustainability which are the economic-social and environmental. This pandemic is affecting all the countries in the world, and concerns have risen about future epidemics that can cause the death of the population.

In the thesis, I will discuss and analyze if such buildings in Lebanon are sustainable; if the isolated blocks chosen have enough sunlight exposure and ventilation according to the orientation of the building and the location in relation with its surroundings, and these assessments will give guidelines for future implementation in case of similar pandemics which will help in the healing process of the patients. To note that Lebanon is not only facing a health crisis the Covid-19 outbreak, but also an economic crisis and a humanitarian crisis due to the large explosion on the 4th of August.

Due to the lack of management, the political and health crisis in Lebanon   the data collection is a difficult part because some information cannot be find easily or it needs time before getting access to it.

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1. INTRODUCTION

The healing environment has outlined that noise control, air quality, thermal comfort, lighting, communication, color, texture, privacy and view to nature are among the physical factors which have to be thoroughly considered in hospital design (Malkin, 1991; Gross et al., 1998; Schweitzer et al., 2004; Richard et al., 2005). The room size, the exposure to sunlight, windows, the ventilation system and the temperature in a room, are important aspects to create a healing environment for a patient in a room (Shajahan et al. 2019). The future of healthcare design will see an increased emphasis on the creation of healing environments (Aripin, 2007). Frank Lloyd Wright said that the patients in a hospital should not be imbued with the idea that they are sick and health should be constantly before their eyes, in a 1948 interview on hospital design (Hobday, 2013). Nevertheless, the rebuilding of wellbeing and health is not simply a matter of physical science (Day, 2007). The recovery of the patients and the environment they live in are connected, moreover the indoor environment controls infection rates and influences the overall patient outcome (Katz, 2017; Chaudhury, 2009; Choi, 2012).

The lack of ventilation or low ventilation rates are associated with increased infection rates or outbreaks of diseases (Atkinson, 2009 ; Qian, 2018). A higher ventilation rate is able to provide a higher dilution capability and reduce airborne infections (WHO, 2009).

The curative effects of fresh air were investigated at length by the physiologist Sir Leonard Hill (1866–1952) in the years following World War I and he reported on the importance of sun and air when judiciously applied (Hobday , 2009). One example is Hong Kong in 2003 after the outbreak of SARS (Severe Acute Respiratory Syndrome) where the focus in hospitals was to increase the ventilation either mechanical or natural, which helps in minimizing the spread of airborne infections in the building (Atkinson, 2009). The 1918 Spanish flu pandemic, measles outbreaks in schools and SARS all show that living conditions can play a critical role in the spread of a disease. But if buildings can make things worse, they can also make things better (Allen, 2020).

Currently in 2020, the World Health Organization (WHO) has declared Covid-19 as a pandemic based on the rate and pattern of spread and severity of the disease. This disease is transmitted by air (coughing or sneezing), and it can even stay in the air for around two hours.

Regarding the Lebanese context, 'the Lebanese government's failure to pay its bills to medical facilities seriously endangers the health of the population,' (Stork, 2019, p.2). Hospitals in Lebanon may not be able to provide urgent medical care to the patients even without the spread of the Covid-19, due to the financial crisis of the country (Lebanon: Hospital Crisis Endangering Health, 2019, p. 7).

In this chapter, I will go through history of the hospitals, the pandemic situations and the wellbeing of the patients. Moreover, I will state the context and the focus of my research following it with the objectives of the thesis that I am going to achieve.

1.1 Hospitals and epidemics

The health system during the modern era was formed by two factors during the past 150 years. The first factor was the improvement of the scientific part which allowed controlling the diseases and acknowledging them, whereas the second factor is the conscious of the public and their precaution when a virus appears (Chave et.al, 1984). ''In earlier centuries, when little was known about the causes of disease, society tended to regard illness with a degree of resignation, and few public actions were taken. As understanding of sources of contagion and means of controlling disease became more refined, more effective interventions against health threats were developed'', stated by the National Academy of Sciences (1988, p.2).

1.1.1 Health during urban areas

The nineteenth century had a significant increase of population, which resulted in having an environment full of viruses- bacteria especially in crowded areas as the classrooms and the work areas. ''In London, for example, smallpox, cholera, typhoid, and tuberculosis reached unprecedented levels. It was estimated that as many as 1 person in 10 died of smallpox. More than half the working class died before their fifth birthday'', stated the National Academy of Sciences. For example, "In the summers of 1858 and 1859 the Thames River stank so badly as to rise "to the height of an historic event … for months together the topic almost monopolized the public prints'." (Winslow, 1923)

"Lebanon is a middle-income country with a population estimated at 4 million, over 80% of whom live in urban areas. The population consists of Lebanese citizens (93%) and foreign and migrant workers from neighboring countries, as well as Palestinian refugees." stated by WHO (2006, p.2).

The coronavirus Covid-19 is affecting 209 countries and territories around the world (WHO, 2020). The American Institute of Architects is analyzing how to adapt buildings into healthcare facilities during the Covid-19 pandemic (Cogley, 2020). 'Hospitals and hotels have several common characteristics that make this a promising solution,' says Theodore (2020, p.3). Many states and municipalities are analyzing the chances to convert hotels into hospitals to free up the needed beds in hospitals for the patients who have extreme symptoms of Covid-19 (Caulfield, 2020). Whereas other countries such as New York, local governments considered dormitories, hotels, and office buildings to be converted to receive the Covid-19 patients (Krawetz, 2020).

1.2 A History of Pandemics

To understand the spread of Covid-19, an overview of the impact of pandemics historically is examined, including the spread of SARS which at a Hong Kong hospital, thought to be due to faulty ventilation, and transmission on aircrafts, which led to assuming that such a virus was spread through air and infected people in two separate flights. The outcome of the patients is dependent on the indoor environment of a building, and the infection rates are directly related to the IAQ (Indoor Air Quality) (Ulrich, 2008; Gesler, 2004; Hellgren, 2011).
Moreover, as the buildings in the current pandemic of Covid-19 are being converted to temporary healthcare facilities, architects should ensure that the buildings can be safely adapted for the doctors and nurses (Cogley, 2020).

1.3 The healthcare system in Lebanon

The Lebanese health system went through four phases that will be discussed through this section. In this section I will discuss how the hospitals and healthcare developed in Lebanon, especially in Beirut. In Lebanon they perceive the urban growth according to the politics preferences, they are economically oriented without taking into consideration the needs of the society.

To note that a study done by WHO (206, p.3) stated that “Lebanon has 26 beds per 1000 population making this one of the highest ratios in the Middle East. Only 12% of the hospitals and 10% of the beds are in the public sector.”

The data in this section are taken from a study done by El-Khoury? ref in collaboration with the Saint Joseph University in Beirut, the World Health Organization and the Ministry of Health in Lebanon.

1.3.1 The pre-independence phase which lasted from 1864 to 1943

Around the middle of the 19th century, there were a few qualified doctors which were mostly missionaries, and Ottoman members. The health care in this period was controlled by the charitable institutions which were religious. There was no big amount of public hospitals, and the existing buildings were small considered to offer a free care for the patients that were suffering from the transmissible diseases. In this time, the main concern of the government was to protect its citizens from the infectious diseases (El-khoury, 2012; WHO, 2012).
Under the French Mandate, after the World War I, the first Health Department was found with the Ministry of interior in Lebanon. In addition, few numbers of private hospitals existed in this era following the models of the French clinics (El-khoury, 2012; WHO, 2012).

1.3.2 The independence phase that lasted from 1943 to 1960

In the 1950s, the Ministry of Public Health in Lebanon was committed to develop the health care system. It first began by developing the public hospitals and forming the infra structures of the hospitals and its network. But despite the progress done in this system, this service was still centralized and the majority of the population were not able to use it. Whereas, the private hospitals were increasing in numbers and in the quality of its services (El-khoury, 2012; WHO, 2012).

1.3.3 The fourth phase is from 1975 to 1992: Civil War Period

In this period, the Ministry of Public Health' work was decreasing due to the circumstances in the country. Its work continued to decline until it reached a certain point where it could not function properly anymore and crashed. This problem increased the dependence on the private hospitals in Lebanon.
This situation led the ministry to make contracts with the private hospitals, and led to the increase of the health expenses rapidly. At the end of the civil war, the sector of health had declined leaving the citizens to rely on the insurances and the private hospitals, to note that this type of luxury is applicable only on a specific socio-economic class, which left the poor people to an unknown end (El-khoury, 2012;WHO, 2012).

1.3.4 The current health system from 1993

''Lebanon's reforms: improving health system efficiency, increasing coverage and lowering out-of-pocket spending" stated by The World Health Organization (2012, p.11)
The amount of money spent on the health care system in 1998 was 12.4 % of the GDP of Lebanon. ''Out-of-pocket payments, at 60% of total health spending, were also among the highest in the region, constituting a significant obstacle for low-income people. Since then, a series of reforms has been implemented by the Ministry of Health to improve equity and efficiency'', declared El-Khoury (2012, p.30).
Lebanon is facing many difficulties, recently a huge explosion on the 4th of August was witnessed in Beirut the capital which is considered to be one of the biggest explosions in the world. This explosion added to the problems that are being faced in the country, along with the economic crisis. In addition, the pandemic of Covid-19 added more pressure on the economics of the country and the hospitals that were already having issues with their financial. The Lebanese healthcare system was collapsing (Khoury et.al, 2020).

The explosion destructed the hospitals in Beirut, and other hospitals were finding it difficult to continue in this pandemic when lacking the required equipment. To note that despite the aid of the NGO's and other countries, the ministry of health in Lebanon did not have any efficient plan to follow during the Covid-19 spread (Paules et.al, 2020).

1.4 History of pandemics in Lebanon

Lebanon has faced many pandemics through history, beginning from the 19th century and the healthcare system in Lebanon did not have any structure until the 1920s. Under the ruling of Ibrahim Pasha, Beirut was intended to be the main port for commercial trades between the east and the west, therefore it was compared for the Levant scale. During this time pandemics and diseases were affecting many foreign countries, so Beirut established a quarantine area for the ships and its occupants. Despite having two major ports in Tripoli and Sidon, they did not accept to have a quarantine base for the ships. Therefore, Beirut in 1834 accepted the construction of a lazaretto with the help of the European Union.

The lazaretto was made from three buildings, reception- store and for the travelers, in Beirut called the Karantina. These buildings can house approximately a hundred of people. The travelers are required to stay 12 to 40 days (De Clerck, 2020).

1.5 Aim of the Study

In order to reach the aim of this study, I am going to explore a sustainable conversion of buildings in the case of pandemics, especially related to airborne diseases. This would require studying the environmental, social, health and economic aspects related to these conversions while dealing with the buildings converted to receive patients of Covid-19 in Lebanon.

The conversion of the buildings to health-related facilities according to the sustainable architecture, which is the focus in this research, has three pillars which are social- economic and environmental. When dealing with hospitals, medical office buildings, clinics and other buildings where healthcare concerns are dominant, architects refer to the Green Guide for Health Care and the LEED for rating. Furthermore, Indoor Environmental Quality (IEQ) is important in health facilities because it can negatively impact the health of staff, patients and visitors according to the LEED standards.

1.5 Purpose and Scope

In the thesis, I will discuss and examine how the conversion of the buildings to receive the Covid-19 patients can be done in order to become sustainable. I will assess the already converted buildings regarding their sustainability to provide information for future conversions. The scope of this research will be the buildings potentially converted to receive the patients of Covid-19 themselves and analyzing them according to the sustainability criteria such as in LEED and the Green Guide for Health Care focusing on the ventilation through it. I will focus on the buildings assigned by the municipalities and the government and place them according to criteria which will be specified in the methodology. The outbreak of the Covid-19 has increased the pressure on the healthcare sector in Lebanon, and to note that I did not choose to discuss how we can build new hospitals/buildings that can be low cost with the use of materials considering that in Lebanon such luxury is impossible due to the economic crisis as stated in the background (Schellen, 2020; Stork, 2020). Lebanon is facing its worst economic crisis since its 1975-1990 civil war (Joles, 2020).

In contrast to other countries, which constructed temporary hospitals in ten days for the patients of Covid-19 (Hickman, 2020), Lebanon can only provide converted available buildings for isolation. For example, a declared building for quarantine is the Beit Anya-hotel in Harissa, and other hotels are being converted for isolation such as St. Antoine in Amchit, Rivoli hotel in Qartaba, Garda hotel in Zahle, and a hotel in Jbeil is ready to receive covid 19 patients, and moreover a residential building in Miziara- North Lebanon (data for now-from the media).

1.6 Research question and Objectives

Following the presentation of the problem under study and the approaches that will be followed to address it, the research question of this research is:

What are the requirements needed for buildings to be converted to receive the Covid-19 patients? How can these requirements meet sustainable standards for healthcare systems? On which aspect in sustainability the focus will be? What is the role of ventilation in the healthcare facilities?

To explore in this study, I will discuss how architecture can help in this pandemic situation. Based on the research question, the objectives are:

- To have an overview on the history of the healthcare facilities in pandemics, and focusing on the Lebanese hospitals through time.
  This objective helps in analyzing the work and the capability of the healthcare systems when faced with pandemic situations. It will be discussed in chapter two of the thesis.
- To identify the requirements of social, economic and environmental sustainability, while following standards such as the LEED and the Green Guide for Health Care.

  This objective will be discussed and analyzed in the literature review, chapter two of this thesis, where I will link the literature on hospitals and epidemic with the cases of the buildings for isolating the Covid-19 patients, while focusing on Lebanon.

- To research the conversion of the buildings done around the world.

  This objective helps in understanding the efficiency of the buildings chosen to be converted for the cases of Covid-19, and will be elaborated in chapter two.
- To research the relation of ventilation and the spread of diseases in the buildings.

  This objective will be tackled in the chapter two, and will help in the development of the methodology chapter of the thesis.

- To evaluate the buildings using software such as Computational Fluid Dynamics (CFD) for ventilation.
  The use of software as a method of analysis will be discussed in chapter three which is the methodology where I will gather data sets using programs and interpretations.
- To compare between the results of the existing buildings converted for the covid-19 patients and the standards will be done and analyzed. It is assessing these buildings in relation to the findings done in the previous objective.
  Reading the results to obtain a clear analysis of my research in chapter four which is the chapter of analysis. Then, I will obtain a synthesis from the results which will need validation.

1.7 Thesis Structure

Following the introduction, Chapter two is the literature review. In this part, I will read and analyze studies done in the world regarding the healthcare facilities in such pandemic situations and the ways we can in Lebanon implement sustainability methods to improve such buildings focusing on the ventilation.

Moreover, I will read articles about the plans that are being set to be followed by the World Health Organization (WHO)- ASHRAE- LEED, in order to have a healthier building/ environment for the patients in a building whether it is residential, commercial or religious one.

2. Literature Review

Therefore, this chapter is composed of four sections, each one dealing with a specific objective declared in the chapter one of the thesis. In order to have a comprehensive understanding regarding the ventilation and daylight exposure of the buildings converted for the patients of the Covid-19, references on the relation between the Covid- 19 or any airborne disease and the ventilation and sun exposure, while researching the ability to transform hotels, arenas and any other building into temporary hospitals will be reviewed in this chapter. The focus will be on health facilities, respiratory contagious diseases in relation to the economic, environmental and social related to the universal standards in health such as LEED- ASHRAE and the WHO to know and understand how to help the patients in the hospital/buildings for healthcare, and understand what kind of problems they face in their everyday activity that affect their physical health. In a hospital, the wellbeing of the patients is the main focus as well as their identity. The staff need to assist the patients to deal with their conditions as well as helping them to feel comfortable in their environment (Capolonga et al., 2009).

2.1 The history of the hospitals through pandemic situations

The term "quarantine" is used nowadays on daily basis, after the pandemic of The Covid-19, to indicate the separation of sick people that have a virus that can be transferred to the healthy unaffected people through different ways. The quarantine is not a modern word, it dates back from the 14th century (Bassareo et.al, 2020) (Rackford, 1950)

Quarantine means a number of 40 days; ''quarantena'' in Italy. In the 14th century, the quarantine was an obligation for any ship that was coming from a foreign country who is suspected to have a transmissible diseases/virus, therefore its passengers were required to stay 40 days abroad before entering the destined land. An example of Venice in the 1300s, in the pandemic of the virus black death (Rackford, 1950) (Kilwein et.al, 1995) (Bassareo et.al, 2020)

A. Timeline of the pandemics in the human history

In 430 B.C., a pandemic hit Athens during the Peloponnesian War

In 165 A.C., during the Barabrian invasions smallpox were transmitted through people causing the Antonine Plague that lasted till 180 A.C.

In 250 A.C., during the honoring of St. Cyprian the Christina, a bishop has witnessed a severe plague that reached Africa and the territories of the Roman, it was known as the plague of Cyprian and which last three additional centuries.

In 541 A.C., a plague was caused by the bubonic plague- the Justinian plague, it started first in Egypt spreading through the Byzantine Empire and the Mediterranean area. This pandemic was severe, it killed a quarter of the world population.

During the 11th century, a virus called Leprosy, has invaded numerous hospitals, it was considered a punishment sent by God to the sinners, and therefore they should be isolated. This virus still appears nowadays under the name of Hansen's disease but it is cured with antibiotic.

In 1334, China faced a pandemic that killed two thirds of its population.

In 1492, the Columbian exchange. During the discovery of the new world, diseases were spreading among people such as the smallpox- measles- tuberculosis and bubonic plague. These diseases were transmitted by the Spanish people.

In 1665, London faced a pandemic that killed fifth of its population, the Great Plague of London.

In 1817, many countries such as Russia- Europe- British Empire- Africa and Japan were faced by the first Cholera pandemic out of seven, and killed many people in each. The seven other cholera pandemics were spread over the next 150 years.

In 1885, a third worldwide pandemic hit China- India and Hong Kong, and it killed about 15 million persons.

In 1889, a Russian flu which was the first significant pandemic that started from Siberia through Moscow.

In 1918, the Spanish killed up to 100 million people around the world, and it vanished in the summer of 1919 when people built an immunity against this influenza.

In 1957, an Asian influenza started from China and then it was spread worldwide; it caused the death of 1 to 4 million persons.

In 2003, the emergence of SARS

In 2009, the H1N1 influenza pandemic.

B. Buildings converted for quarantine through history

The first buildings that people went to when they had any diseases were the temples, healing gods. In this period of time people prayed in order to heal. Then, through time each country was creating its own facilities to keep its population healthy and to be able to overcome any future pandemics. Therefore, healthcare systems were established only in the most developed countries, only about 40 countries in the world, whereas the poor ones were not able to provide such facility to the people.

The first healthcare facility was called the Bismarck Model, located in Germany and dates back to 1883. This system had an insurance for the people; sickness funds. It was mainly used by the employers and their employees.

The second system is in the UK; the Beveridge Model. It was created in 1948 and had a centralized system.

Sustainable design strategies are being introduced in healthcare facilities supporting the idea that green buildings improve and increase the recovery of the patients, and even the staff in such buildings (Beauchemin, 1996).Though the design for good indoor air quality (IAQ) is a complicated endeavor, the implementation of four basic design principles can go a long way to providing healthier indoor environments (Bernheim, 2008). Source Control which is the reduction of the indoor air chemical's concentrations and the pollutant of the outdoor air that enters inside the room, then it decreases the exposure of the patient to different harmful chemicals. Then, the ventilation design which consists of adequate filtration, ventilation rates, humidification and mechanical systems, all should be considered in the design for a healthy ventilation flow in the rooms (Heymann, 2007; Bernheim, 2008).

Moreover,' the Building Maintenance is important and requires maintaining mechanical systems (filter changes) and cleaning with environmentally friendly cleaning agents protects the building asset and can significantly improve the air quality and occupant health over the long term', stated Bernheim (2008, p.37).

During the spread of the SARS in Hong Kong in 2003, a study was done in a hospital ward in the region (Qian, 2010). The main focus of the research was the ventilation in the hospital. Results showed that the ventilation design and the distribution of air in the ward were not balanced. The research was done by using the Computational Fluid Dynamics (CFD) program. The CFD simulations and trials showed that there is a relation between the room of the patient infected by SARS and the spatial SARS infection pattern. The possibility of airborne transmission of SARS in the ward studied suggest a development of the ventilation and the air conditioning system in the spaces. 'One question often asked by ventilation engineers was why effective displacement ventilation could not be used in general hospital wards'(Fiberg et al., 1996).

The emergence of respiratory diseases, i.e., severe acute respiratory syndrome (SARS) epidemic in 2003, H1N1 influenza epidemic in 2011 and Middle East respiratory syndrome (MERS) outbreak, analyzed the significance of ventilation in buildings (Qian, 2018). Ventilation is recognized as an important factor influencing the transmission of airborne diseases. The significance of ventilation was also reemphasized by the 2003 worldwide SARS outbreak in 2003 worldwide and in particular a super spreading event in a hospital in Hong Kong.

An environment is considered healthy for its occupants if the quality of indoor air is according to certain standards. Poor indoor environmental qualities are responsible for many health problems including allergies, eye irritations, and respiratory problems (Yau et al., 2011). However, the performance and condition of ventilation in hospitals have great impact on the perceived indoor air quality (Hellagren et al., 2011).

2.1.1 Building designed for quarantine through history by Architects

The physiologist Sir Leonard Hill was having an investigation regarding the positive effects of fresh air to cure illness; this investigation was done between the years of 1866 and 1952 following the World War 1. Sir Leonard Hill focused on the importance of the sun and the ventilation to cure the tuberculosis, if applied correctly. In 1919, Hill wrote in the *British Medical Journal* that "the best way to combat influenza infection was deep breathing of cool air and sleeping in the open. Whether the patients at Camp Brooks or other temporary hospitals were spared the worst of the influenza pandemic because they slept in the open is uncertain." (Hobday et.al, 2009).

A. The first tuberculosis sanatorium in the United States was founded by a doctor named Edward Livingston Trudeau

The buildings in Trudeau's center had special features to ensure a healthy indoor air quality for the patients of the Tuberculosis. The center of the buildings was a glass-enclosed deck known as a cure porch. These porches will be the place where the patients spend most of their resting time, and it can be even used during winter season while sleeping under many blankets. (Yuko, 2018). The building was design with the first emergence of Modernism. The elements that show the Modernism era are the flat roofs, the terraces and the balconies, the rooms that are white or painted with a light color. In 1925, the Swiss architect Le Corbusier dreamed of a city where every citizen's house was whitewashed and hygienic. "There are no more dirty, dark corners. Everything is shown as it is. Then comes inner cleanliness."

On a porch at the Trudeau Sanatorium, patients were wheeled out in their beds for fresh air and companionship. One patient is wearing goggles against snow glare.
Alfred Eisenstaedt/ The LIFE Picture Collection/Getty Images

Figure 1: The Sanatorium in the mid-19th century

In the mid-nineteenth century, the sanatorium movement began in Europe, with resorts in Silesia (now Poland), Germany, and Switzerland. (Davos was once known as Europe's "tuberculosis capital.") Sanatoria grew from a cluster of huts in hilly areas to purpose-built structures intended to minimize the transmission of germs while offering crucial elements for recovery: dry, fresh air. The problem of mass graves had not gone away by the time of the Spanish influenza epidemic (1918–20). At the height of the pandemic, Philadelphia, one of the worst-affected US cities, had approximately 1,000 deaths per day, necessitating the employment of steam shovels to dig mass graves and the utilization of six cold-storage factories as supplemental morgues. This reuse of old buildings, infrastructure, and urban spaces is only ephemeral. Former Royal Navy ships were requisitioned, de-masted, connected together, refitted as smallpox hulks, and moored at barren Long Reach, 27 kilometers downstream from London Bridge, in 1882, amid a significant smallpox outbreak in Great Britain. The Castalia, a failing twin-hulled paddle-steamer with five ward blocks placed on its deck, was one of these floating hospitals. To prevent the spread of the Spanish flu, the Drill Hall at the Naval Training Station in San Francisco was transformed into a massive sleeping area divided by person-high cloth sneeze screens. In Australia, the Royal Hall of Industries at the Royal Agricultural Society Show grounds in Sydney was converted into a mortuary, as did the Great Hall of the Royal Exhibition Building in

Melbourne. Also converted to hospitals were dozens of schools like Nowra State School in country New South Wales and Armadale State School in suburban Melbourne.

Figure 2: Hospital beds in Melbourne Exhibition Centre's Great Hall during the Spanish influenza pandemic, c. 1919.

B. Paimio Sanatorium / Alvar Aalto

The Piamio Sanatorium was built in 1933 by the architect Alvar Aalto, he designed this building due to the tuberculosis- a disease transmitted through a person to another attacking the lungs and had no cure at that time. The tuberculosis sanatorium was recognized as a masterpiece in architecture. To note that in 1960, this building was transformed to a hospital. The building is located in Piamio- Finland.

''Building art is a synthesis of life in materialised form. We should try to bring in under the same hat not a splintered way of thinking, but all in harmony together.'' Alvar Aalto

‘’The patient bedrooms generally held two patients, each with his or her own cupboard and washbasin. Aalto designed special non-splash basins so that the patient would not disturb the other while washing.’’ Alvar Aalto

During this time, tuberculosis had no treatment. Thus, the only treatment that was required is the sun exposure and the fresh air. In his design, Alvar Aalto created terraces that has direct sun exposure and can be accessed on each floor.

The patients stayed in one specific wing of this hospital that was oriented to the south so that all the rooms received sunlight. The south east orientation enabled the rooms to receive a maximum amount of sun in the morning.

“The room design is determined by the depleted strength of the patient, reclining in his bed,” Aalto was quoted as saying in Göran Schildt’s *Alvar Aalto: The Complete Catalog of Architecture, Design and Art* (Wiley, 1994).

Alvar Aato designed this specific building focusing on the patient, on his comfort to heal. He considered that the hospitals were not designed to be comfortable. So, in his design he wanted to create a healthy atmosphere especially for each patient.

Source: By Fabrice Fouillet

Figure 3: Alvar Aalto building

Fabrice Fouillet

Figure 4: The interior of the building of Alvar Aalto

Figure 5: The interior of the building of Alvar Aalto

The building was surrounded by green are, and each room has an opening with two beds. The quiet surrounding with the greenery and the openings created a healthy environment for the patient.

2.2 The healthcare systems and sustainability

WHO defines health as a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity (World Health Organization, n.d.). Moreover, the Alliance for Natural Health (ANH) first defined sustainable healthcare as:

> 'A complex system of interacting approaches to the restoration, management and optimization of human health that has an ecological base, that is environmentally, economically and socially viable indefinitely, that functions harmoniously both with the human body and the non-human environment, and which does not result in unfair or disproportionate impacts on any significant contributory element of the healthcare system' (2008, p.5).

The concept of sustainable development has been a common concept to adapt in the public health since the 1990s (Weiz et al., 2011).

Sustainable design must prioritize the health of the people, the focus should be on the humans and their experience. Designing for health is designing sustainable approaches to therapeutic architecture (McDonough, 2015).Strategies are being done to manage health organizations and hospitals because of the new integration of sustainability (Altpeter et al., 2014). The sustainability concept is related to the environment, society and especially the economic regarding the health systems (McVanel-Viney, 2009). Thus, the reduction of consumption of the natural resources, and the decrease of the pollution is the main focus of the environmental sustainability (Mattioda et al., 2013).

2.2.1 The relation between hospitals and the sustainability standards set for healthcare facilities

The sustainable concept especially in the health sector is increasing in different ways which are socially, environmentally and economical. Many sustainability certifications such as BREEAM, LEED, and GREEN GUIDE. During the current pandemic situation the ASHRAE has created an epidemic task force related to healthcare regarding the Covid-19. In this research, the focus is on the healthcare facilities and any other building being converted to receive the patients affected by the Covid-19, and also the patients infected by contagious respiratory disease in the future. Furthermore, it gives the standards to be available in such buildings such as the ventilation systems, the facilities, the maintenance and the approaches.

In 2008, a sustainable approach was applied which was the Building Establishment Environmental Assessment Method Healthcare (BREEAM Healthcare, 2019). The main objectives of this implementation are to improve the health of the patients, the buildings of the healthcare regarding the sustainability concept and to help the staff working in such buildings to have better conditions (Guenther, 2008).

Another example of a universal standard is the Leadership in Energy & Environmental Design (LEED), which is specialized in HealthCare and was released in 2009.

2.2.2 The three pillars regarding the sustainability in healthcare

The implementation of a new concept which is the sustainability in the healthcare systems is a current debate for most of the countries (Borgonovi, 2013). The best known definition of sustainability is meeting the needs of the present generation without affecting the ability of future generations to meet their needs (Mattioda et al., 2013).

Companies and governments became concerned about damaging the environment, due to the activities that are using a great amount of natural resources and it can contribute to the integration of the environmental management in the work routine. The concern about the environmental impacts should be of everyone. The reuse of materials, especially with the quality of life of a society, is no longer just a matter of time. Actions to environmental improvements gained strength in the business context (Buys et al., 2014).The social sustainability focuses on benefitting the society as a whole with no exception. It is a process of the development that can lead to a stability in the growth while maintaining an equal distribution of income. It aims to improve the living conditions of the citizens in a society (Cavanagh and Hickey, 2012).
The economic pillar of sustainability, the third pillar of sustainability, combines the social and the environmental aspects to create a more wealthy future for the society and its population (Cavanagh and Hickey, 2012). Organization of Economic Co-operation and Development (OECD) countries have seen healthcare costs consistently outgrow the economy for decades. To become financially sustainable the healthcare systems should therefore create models to help in the management of the demand in an efficient way and eliminate any waste if possible (McKinsey, 2012).

2.3 Covid-19: Converting existing hospitals, hotels, convention centers, and other alternate care sites for coronavirus patients

The Covid-19 pandemic is increasing, it is outpacing the response of national governments and the health systems are being overwhelmed around the world (Grabowski et al., 2020).

The healthcare system around the world has no longer the capacity to receive the patients of coronavirus due to the growing number of the infected people. Countries are looking for additional beds to help people[1]. Hotels and arenas have the most feasible functions to help in creating temporary healthcare facilities, due to their individual rooms with private restrooms, which help in minimizing and controlling the contamination (Chrisman et al., 2020.). Moreover a hotel, high school or public assembly space can decrease the pressure on the hospitals by being converted to temporary healthcare buildings, to note that no alternative space is perfect but such buildings are more practical in this epidemic situation than constructing new healthcare facilities in a short time (Schroer, 2020).

2.3.1 The pandemic in different Countries

In countries where there is political instability, economic crises, millions of refugees and the incapacity of healthcare systems, are unable to contain the increase of pandemics and protect the large numbers of the patients in such situations (Al Nsour et al., 2020; Malik et al., 2020).

In the Eastern Mediterranean Region (EMR), there is no specific approach taken by the governments to approach the current pandemic of Covid-19 (Fadi El-Jardali et al., 2020). Whereas, in countries like the USA, the United Kingdom, and Spain, all of which are bracing for surges of Covid-19 patients, local governments have been working with hotels and arenas to potentially transform the buildings into makeshift care facilities or quarantine centers. ASHRAE has formed an epidemic task force. Its first meeting was on March 29.

‘Our immediate focus will be on supporting health care facility capacity needs in the face of the current surge in admissions, but we will also be providing guidance on short-term measures applicable to other types of buildings,’ (Bahnfleth ,2020, p. 5).

[1] (https://www.nytimes.com/2020/04/15/world/coronavirus-cases-world.html, 2020)

Patients with high risk factors based on age and pre-existing health conditions would be best suited for the hospital. The hotel solution is intended to preserve hospital resources for the sickest patients (Schroer, 2020).

Figure 6: Map showing the pandemic Covid-19naround the world, 2020

The map below, shows the different buildings and places that are being converted to temporary healthcare facilities and accommodate large numbers of coronavirus patients around the world. Such as in America, Italy, France, Germany, Spain and the United States.

This map is taken from a Spanish research.

Coronavirus is spreading in a fast way worldwide forcing the governments to take measurements that decreases the number of dead people and ensure a healthy place for quarantine for the patients. Therefore, new strategies are being followed; hotels- parks and religious buildings are designed to receive patients with low risk of the Covid-19 virus.
For example, O'Higgins hotel in Viña del Mar is a hotel that dates from the 1900s is now during the Covid-19 epidemics a quarantine center that can receive patients with low risk. It contains 500 beds each having a private bathroom and a storage for the required equipment. Moreover, it can be used by a person that needs a space for quarantine without risking the health of his parents and surrounding. This building is a public building owned by the Municipality and accessed for

free by the patients. During the Covid-19 crisis, unnecessary internal furniture and decorations were removed from the rooms to create a comfortable environment for the patients. Hotels-hospitals, is a strategy followed by in many countries where the tourists are replaced by the patients (Latorre, 2020) (Jara, 2020).

An event center in Huechuraba, the Espacio Riesco, is being transformed to a temporary hospital following the crisis of the Covid-19 and the increase of number of the patients. This center was

Riesco space. Photo: Mario Tellez / La Tercera.

Figure 7: Riesco space, Image by Mario Tellez/ La Terrcera

chosen because of its large scale and its capacity to accommodate a large number of infected people. To note that the patients that will stay in require a minimum amount of medications and expert's supervision. Therefore, it is a place designed for the patients with low risk of infection.

The President of the country Sebastian Pinera named this place the Ciudad Hospitalaria de Huechuraba which the persons aged 18 years and above can benefit from this facility (Latorre, 2020). In this center 200 beds were installed with the required medical equipment and the doctors to help the persons in need. In the future, if the number of the cases affected by the Covid-19 increases, this center can house 3000 persons while respecting the health conditions required by the World Health Organization.

Spain was not the only country that converted an unused space into a hospital or a quarantine center. For example, in Germany the Messe- Berlin which used to be a traditional industry, was converted to adapt thousands of beds for the patients of the Coivd-19. Moreover, the United States had a large number of people infected by the coronavirus and also a high rate of death. So, six centers in different states such as Miami- Chicago and Boston were converted to receive the patients for quarantine; acting as temporary hospitals. And, in Brazil- Argentina – Colombia-Latin America, the government is trying also to convert centers and large areas to accommodate the patients (Latorre, 2020)(Jara, 2020).

Slums and poor neighborhoods throughout the world are especially inclined to disease. The United States has seen COVID-19 ravage bad neighborhoods in New York City and Detroit, preying on human beings with pre-existing stipulations like diabetes and high blood pressure.89 Studies exhibit that these conditions are more popular in bad neighborhoods.
The disease has additionally attacked people with allergies who are at increased threat for respiratory infections. Asthma is often generic in low-income communities where disease grows in apartments. Tragically, facts collected by means of the Centers for Disease Control and Prevention (CDC) exhibit that African Americans dwelling in poor neighborhoods had been greater probably than other agencies to be hospitalized and to succumb to Covid-19.

2.3.2 Future residential buildings_ Post Covid-19 virus

During the Covid-19 pandemic, the residential buildings have shown that they lack in the design area. More than 90% of infected cases happened in cities, as they have a significant amount of dense and concentrated places (Committee for the Coordination of Statistical Activities, 2020).

‘’Since multi-story housing is standard in most cities, they need special attention. ‘’ stated by Tokazhanov et.al (2020, p.5).

‘’Safety is the prior requirement of a building design. Through the prism of pandemics, it is essential to provide the necessary means of protection from infections inside housing, owing to the fact that most places mandate that people coming from abroad usually undergo a two-week home quarantine’’ , said Chinazzi et.al (2020, p.395).

The main point to tackle, in a residential unit, especially during quarantine is the comfort.

The personal comfort is a mix of natural proper day lighting- ventilation and adequate acoustics level.

For example, people in Central Asian countries have large families, meaning that more than 3000 families in Kazakhestan can have more than six and seven children in each family. Furthermore, this result in having less personal space; each person has less than a room that can be considered provate for him (Sputniknews, 2020). Moreover, for example in Uzabekistani 10% of the families have more than five children each.

WHO (2020) recommends ‘’having separate sanitation facilities in households to eliminate the risk of viruses’ propagation. Lack of access to private sanitation facilities complicates the isolation of infected occupants. Crowded housing negates social distancing measures and also worsens comfort during lockdowns due to inadequate privacy. Due to the coronavirus outbreak, the usage of information technologies has been significantly boosted for a better minimization of human-to-human interaction such as food and medicine deliveries, booking slots to visit a doctor, and public services for householders.

For a sustainable building, the spaces should be developed to have a good air quality that helps people to overcome their health problems, especially when tackling the sustainability aspects during a pandemic such as the Covid-1. ‘’A healthy indoor quality is required where a person spend most of his time. Air extractors could be equipped in the rooms without windows (e.g., bathrooms, toilets, closets) with constant cleaning to avoid their contamination with the virus’’, stated by Settimo (2020).

Furthermore, the humidity in a room should be appropriate when dealing with the ventilation, and the current technologies can help in creating systems that could benefit the human (Signorelli et.al, 2016).

An indoor healthy environment is crucial for a person, especially if the person is affected by a virus that is directly linked with his respiratory system.

2.3.3 The buildings chosen for conversion in the pandemic of the Covid-19

Healthcare buildings are incapable alone to protect the citizens if they were diagnosed with the Covid-19 due to the short number of beds (Nacoti et al. 2020). In such contexts, community-centered responses providing for outreach services, community surveillance, triage and initial treatment, non-ambulatory care overflow, and/or isolation have proven vital for containing previous outbreaks and shifting the epidemic curve (WHO, 2020; Rugarabamu et al., 2020; Abramowitz et al., 2015; Kutalek et al., 2015; WHO, 2014; Hick et al., 2004).

In such pandemics governments should apply an approach to cover different types of facilities which are out of hospital care as existing non-hospital facilities that can be used for patient's isolation and care, and alternate care facilities that can receive the patients while meeting the standards of the health care during a pandemic (Gostin et al., 2012). The patients being exposed to Covid-19 and do not have symptoms or only have mild ones, can be provided with temporary housing for quarantine. These patients in such buildings for isolation would require minimal care. They would rely on themselves. In such a situation, the medical staff is not required so a hotel or dormitory can house the patients infected by the Covid-19 virus (Gostin et al., 2012). Moreover, studies done on different hotels show that the used rooms for the patients should handle the heating, ventilation and air-conditioning (HVAC) systems appropriately (WHO, 2010) And that in converted buildings/ spaces air should not circulate to other parts in the hotel from a room to another while maintaining the indoor air quality (Jeanne Anderson et al., 2008).

2.3.4 The rating systems and healthcare facilities around the world

The latest national standard of China for green building assessment is Assessment Standard for Green Building (ASGB). The ASGB certification is helping in the current pandemic of Covid-19 for prevention and control. The green buildings/sustainable have a positive effect in such pandemic such as the current Covid-19 by relying on five principles (Green Buildings, 2020).

The first pillar is providing the basic functions for epidemic prevention and control, which consists of monitoring the air quality in a room, monitoring the quality of the water, and having specific equipment regarding the pandemic. The second pillar is providing facilities and accessibility, by having an easy accessibility for the patients to medical equipment and help, and to the vehicles. The third pillar consists of the decrease of the cross ventilation by controlling the mechanical systems, the decrease of the polluted air in a room, and the increase of natural ventilation (Green Buildings, 2020). The fourth and the fifth pillar rely on protecting the health of the occupants, which should be the main concern of the architects.

Furthermore, LEED certification requires natural ventilation that can dilute the airborne particles found in the inner air of the room. Additionally, the windows play a big role in such pandemics with their heights, and locations to allow the entrance and flow of the air (Dunne, 2020).

2.4 Ventilation in the healthcare systems

Adequate ventilation in the healthcare facilities is an important and necessary aspect, the natural ventilation alone cannot maintain a safe quality of the indoor air, therefore alternative ventilation systems should be considered which are the hybrid ventilation and the mechanical ventilation (Atkinson et al., 2009). More than 90 percent of the hospitals around the worls use the mixed ventilation systems which push the air into the upper part of the designated room and decrease the polltants that exist in the indoor air of the room (Jafari et al., 2015; Villafruela et al., 2019).

2.4.1 Sick buildings

Sick Building Syndrome (SBS) is a number of factors that affect the physical health of the human in several ways. It affects the health and the performance of the people living in a specific building (Alwaer, 2018) . SBS is a situation where the occupants of the buildings feel uncomfortable and cannot stay several hours in such buildings, this feeling can be caused in a specific room in the building or throughout all the space of such structure (Joshi, 2008; Janz, 2011).

The buildings have codes that should be met while designing the heating, cooling, and the air-conditioning systems, these systems should have a proper performance to ensure a healthy environment for the occupants. Moreover, the ASHRAE recommends such codes to remove the pollutants that can accumulate in a certain area in the building (Burge, 2004).

2.4.2 Studies on the importance of ventilation in epidemics such as the Covid-19

Lack of ventilation or low ventilation rates are factors that increase the infection rates in a room or a building especially when dealing with airflow pattern is a major aspect to remove the cross contamination between different rooms (Bhagat et al., 2020; Cheong et al., 2018). The health of the patients in a room is affected by the indoor environment air quality, therefore adequate building heat ventialtion and HVAC system are to be considered in a hospital or a building converted to healthcare (Azimi et al., 2013; Katz et al., 2017; Nimlyat et al., 2015; Huisman et al., 2012).

Studying the ventilation results in removing the pollutants in the room of a specific building, it can be done by using two methods which are mixing ventilation and displacement ventilation. To have better results analysis should be done by using the CFD program for testing the ventiation in a building (Escombe et al., 2019; Zhou et al., 2020; Doremalen et al., 2020). So, as Bhagat(2020, p.10) stated, 'Adequate ventilation is essential to maintain a healthy indoor environment in hospitals and other public buildings'.

The ventilation has two main methods, either it was a natural ventilation or a mechanical one. In a building with air conditioning the ventilation is mixed to let a flow of inlets and outlets to create a well-ventilated space where the temperature is moderate and the flu/ viruses or any contaminants can disappear (Stelzer-Braid et al. 2009; Yan et al. 2018). Coughing, speaking, singing, sneezing and even laughing are ways to transmit diseases and increase the number of the infected persons in the room. To note that according to Bake et al. (2019), when a human exhales it has droplets that vary between 0.01 and 1000 μm. The droplets are split into two categories according to the researchers, there are droplets that are larger than 5 μm regarding the diameter (respiratory droplets) and there are droplets smaller than 5 μm which are aerosols according to WHO (2014) and Milton (2020). Air naturally dilute the small particles that are released by a sneeze or a cough, so ventilation is necessary in room and a building. Health administrations have admitted that when we improve the ventilation in a certain building, it will hence help in the reduction of the danger of spreading the viruses especially the Covid-19 virus between the persons (AIHA, 2020; ASHRAE, 2020; WHO, 2020).

The natural ventilation costs lower than the mechanical ventilation, it is more efficient and has a low cost of energy. (ASHRAE, 2019)

Crowded spaces can be a source of Covid-19 transmission between people. Besides the droplets of one person, the infection can occur when there is no proper ventilation in a room. (Chen et al. 2006; Kumar and Morawska, 2019; Liu et al, 2020; Van Doremalen et al., 2020). Therefore, a study on the indoor ventilation is required especially during the current pandemic Covid-19. The poor air quality in a room is caused by a lack of ventilation. The current pandemic has forced people to stay indoor in their residential apartments. Therefore, the indoor air quality is a factor that should be tackled to determine the pollutants that exist in the room. (Chan and Liu, 2018; Naethe et al., 2020; Rowan and Laffey, 2020; WHO, 2010; Yuan et al., 2019). Mechanical ventilation is adapted in some polluted areas to dilute the airborne contamination, thus it creates a healthy and comfortable environment for the residents. The mechanical ventilation when mixed with the natural ventilation increase the quality of the indoor (Chan and Liu, 2018; Gao et al., 2009; Hoffman, 2019; Rackes and Waring, 2014; Yu and Kim, 2011; Zhao et al., 2020). Architects can use the digital simulation to analyze the indoor air quality of the buildings in this pandemic. Computer-Aided Design (CAD) helps in analyzing the indoor ventilation, the Building Information Modeling (BIM) and the Computational Fluid Dynamics (CFD). (Brittain et al., 2020).

Covid-19 has highlighted the importance of the quality of the indoor environment, whether in a residential room- and an office or a healthcare unit. The World Green Building Council (World GBC) has a global project to create better places for people especially after the spread of the contagious virus the Covid-19 in a sustainable way (Jacobs, 2020). A study done by the Harvard University found that when a person is exposed for a long period to a polluted air, he has an 8% more chance to die due to the Covid-19, than a person that lives in a healthy environment. The World GBC is a council specialized of the sustainability of the buildings. It takes into consideration the climate- health and the well-being of a person to create a healthy environment worldwide for the people.

The World GBC is working in association with the Plant a Sensor to measure the efficiency of the indoor air quality. When facing an epidemic related to airborne diseases, experts should be analyzing measures in order to solve a problem.

The ventilation is the solution to decrease the airborne diseases in a room, but the designers should avoid adding energy use while creating a good ventilated room.

The main issue that the World GBC is dealing with is ''So, how do we balance the elevated need for buildings that help control the transmission of infectious disease indoors—whilst minimizing environmental impacts and working towards our climate goals?'' stated by Jacobs (2020, p.1). ''How does the built environment balance ventilation requirements to improve indoor air quality, whilst working towards ambitious net zero carbon building targets by 2030?''. The main question in this study is how a building can be healthy for the residents to stay in without the fear of contamination. The Covid-19 pandemic has made the architects and engineers to rethink the design of the buildings that should be more than a space with some openings and lighting. A study was done on 200 buildings that were not occupied during the last months that enabled the designers to determine the problems and find way to solve it by creating a healthy environment. First of all, the water systems should be taken into consideration, then a maintenance for the HVAC system is required to ensure a healthy indoor environment.

Considerations to create healthy indoor environment: Indoor Air Quality

Jean-Marie Thouvenin, Director Building Physics, stated that:

''Through its Multi Comfort Sustainable Buildings program, Saint-Gobain has been exploring many different aspects of building design to understand how comfort works in real built environments. There are a few concepts Saint-Gobain could bring into the equation applying multi comfort principles to office spaces in the post-COVID period''(2020, p.2).

Energy efficiency of the envelop of the building- thermal comfort

The location of the buildings can play a role in determining the envelope of the building, by studying its orientation-the sun angles, which enables the architect to create the windows in a specific location to have a good air flow in the room. This procedure reduce the energy use of the building and create a healthy indoor air quality.

Air flow control

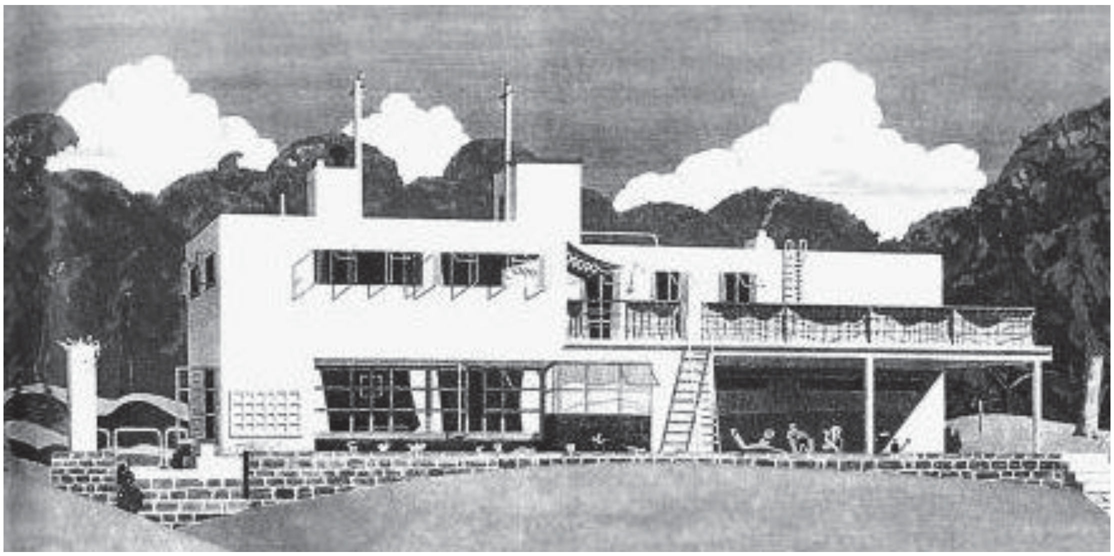
/(

A good design of the building with a proper ventilation; mechanical- natural, increases the penetration of the fresh air in the room therefore, it reduces the airborne diseases and the contamination between the occupants.

The Tuberculosis disease influenced the architects to create healthy environment _ Modernism

A. In 1963, a house Pen Pits was designed in Surrey by the English architect P Harland. The house was characterized by having balconies and terraces, built following the healthy environment that recommended the benefits of the sun exposure and the natural ventilation to decrease the diseases (Bliss, 1981).

Figure 8: A house by the architect P Harland



B. Between the 1928 and 1931 a Dutch tuberculosis sanatorium was built in Hilversum called the Zonnestraal meaning the sunbeam, focusing on the importance of the sun light in a room. The architects in the modern are were following a slogan ‘’ Always sleep with the window open’’, associated with the importance of light and air in a sanitary building to create a healthy environment for the users.
   This approach was demonstrated in architecture by creating open- well lit interiors with large areas that had glazing and an exterior space for the patient. ‘’ Symbolic associations of healing light, air or sun might be thought of as passing medical fashions, similar to the superstitious use of gold that was also prevalent at this time, but light and air, and specifically sunlight, were influential in the interpretation of modernist hygienic ideas for the design of flat roofs, balconies, terraces and recliner chairs’’, stated Campbell (2005, p. 3).

In the process of healing, the patients can use the balconies- terraces and the flat roofs. This process can happen in some chalets or in a social housing in the urban. The middle class society implemented the modernist design for a healthy living, where hygiene is the essential for a healthy life.

2.4.2.1 Ventilation in a room/ building

Through history, the buildings relied in their designs on the natural ventilation (Olgyay, 1963) and now with the increased awareness regarding the impact of a building on the environment (energy use and pollution) and the cost of the mechanical ventilation; architects are finding solutions to design the buildings while focusing on the natural ventilation. Moreover, they are trying to create a healthy indoor air quality for the occupant (Walker, 2016).

‘’ In favorable climates and buildings types, natural ventilation can be used as an alternative to air-conditioning plants, saving 10%–30% of total energy consumption.’’ Stated Walker in her article (p.1, 2016).

The natural ventilation is the difference in pressure that allows the movement of the fresh air through the building.

The pressure is the result of the difference in humidity- temperature and the effect of the buoyancy. Moreover, the openings play an important role in a building; the location of the opening and its size help in allowing the entrance of the natural ventilation in the room.

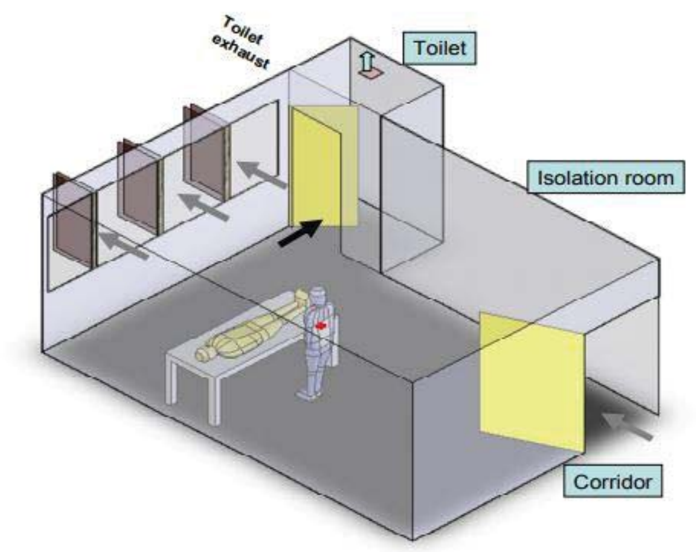
Moreover, Walker stated that ‘’Openings between rooms such as transom windows, louvers, grills, or open plans are techniques to complete the airflow circuit through a building. Code requirements regarding smoke and fire transfer present challenges to the designer of a natural ventilation system. For example, historic buildings used the stairway as the exhaust stack, a technique now prevented by code requirements in many case.’’ (2016, p.3).

When designing a building natural ventilation will depend on the location, the local climate and the type of the building. First of all, an increase of ventilation can be induced when the building is facing in perpendicular to the summer winds. Then, a naturally ventilated building is often narrow, in such way it allows the penetration of the wind in all the building.

Illustration of the desired direction of air flow in a properly designed naturally ventilated isolation room (achieved by opening the windows, and the door between the isolation room and the corridor)

‘’Two forces drive natural ventilation; wind pressure and stack pressure’’, stated by WHO (2007, p.40).

Figure 9: Room for the Covid-19 patients



A building has a negative pressure and a positive pressure. When the wind penetrates a building; it penetrates from the positive pressure through the negative pressure. It is driven by the openings (Allard et.al, 1998).

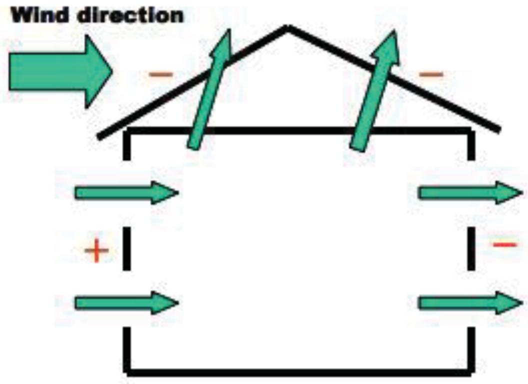


Figure 10: The wind direction and the flow in a building

‘’The choice of isolation areas and placement of patients within the facility need to be carefully planned and designed to further reduce the risk of infection for people in the surroundings’’ stated Jiang (2003, p.27). In a health care facility the isolation room are away from the other part of the hospital, and placed in a well-ventilated area. This room should be placed next to an opening (on the exterior wall), which allows a cross ventilation in the room to decrease the airborne diseases. (Allard et.al, 1998) (Liddament et.al, 1996)

2.4.3 Ventilation Guidelines for future buildings.

To reduce the spread of a virus, focusing on the Covid-19 pandemic, researches and studies suggest that building should have an increased ventilation- filtration and moderate humidity. According to ASHRAE, during one year of pandemic, a crowded area (room- restaurant- church, etc.) with ineffective ventilation increase the risk of spreading the virus among the persons in the room especially within a short distance.

ASHRAE, CDC (Centers for Diseases Control and Prevention) and WHO have set some guidelines they consider effective to minimize the transmission of Covid-19. The guidelines are named Roadmap set to improve the quality of air in the space. This study includes three types of buildings: healthcare – nonresidential and residential, with mechanical and natural ventilation.

2.4.3.1 Ventilation

Ventilation is important in a room to remove the impurity existing. Three basic elements define the ventilation in a building which are: the rate of the ventilation, the airflow direction and the pattern of the air. In addition a ventilation in a building can be natural- mechanical or mixed.

The current pandemic of Covid-19 is imposing changes on the societies all over the world, and some of these changes are permanent. This virus will force architects and engineer to create houses that are safer and can prevent a future possible pandemic. The LEED, WELL and Fitwell are putting points to be taken into consideration while designing a building.

The main point stated in these requirements is improving the HVAC ventilation systems; air should penetrate the room in order to dilute any airborne particles, required by LEED IEQc1.3- WELL A03 and WELL A05. Windows are important in the airflow in a room; WELL A07.

However, in cold and hot climate the penetration of outdoor air is sometimes impossible so filtrations and purifiers can be a substitution to create a healthy indoor environment. As mentioned by the LEEDc1.4 and WELL A12: the filtrations can ensure a healthy IAQ (Dunne, 2020) (Stanley, 2020). Moreover, the humidity in a room plays an important role in transmitting or eliminating the diseases. A low humidity can enable the growth of bacteria such as the current Covid-19. "Therefore, maintaining relative humidity levels between 40-60% is important to prevent the growth of these microbes within a building. WELL W07: Moisture Management and WELL T09: Humidity Control are credits focused on managing humidity levels indoors." Stated by Dunne (2020, p.2).

2.4.3.2 The Roadmap designed by the World Health Organization (WHO)

''SARS-CoV-2 transmission is particularly effective in crowded, confined indoor spaces where there is poor or no ventilation.'' Stated by ECDC (2020)

'' Therefore, ensuring adequate ventilation may reduce the risk of COVID-19 infection.''DAI et.al (2020, p.13).

The ventilation in a building has three basic elements (WHO, 2020): the rate of the ventilation which is the volume of the air that penetrated into the room or the building, the direction of the air which should always be directed from the clean zones of the building to the infected/ dirty areas or rooms, and the last element is the airflow pattern which requires an efficient distribution of the air in all the building.

A. Non-residential buildings: offices- religious buildings and schools

A Minimum ventilation rate is recommended which is 10 L/s/person (EN 16798-1) (42, 43).

> Minimum ventilation rate – natural ventilation system. How to estimate it?
>
> As a rule of thumb, wind-driven natural ventilation rate through a room can be calculated as follows (20):
>
> Ventilation rate [L/s] = k x wind speed [m/s] x smallest opening area [m2] x 1000 [L/m3]
>
> k = 0.05 in the case of single-sided ventilation
>
> k = 0.65 in the case of cross ventilation in the case of mosquito net presence = ventilation rate x 0.5
> wind speed: the wind speed refers to the value at the building height at a site sufficiently away from the building without any obstructions (e.g. at an airport)
>
> (Atkinson et.al, 2009)

A. Natural Ventilation

If the rate does not meet the minimum requirement, certain changes should be done:

- The dimensions of the openings (windows and doors) with its locations should be studied taking into consideration a possible change of the dimensions or the addition of new windows.
- Use of air purifiers and fans to improve the indoor air quality.

If the facility (room or building) has always occupants living in:

- "Open the windows to allow proper ventilation before and after occupied times. Windows should be opened for approximately 15 minutes when entering the room (especially when the room was occupied by others beforehand)" stated by WHO (2021, p. 23) (REHVA, 2020)

B. Mechanical Ventilation

- If the ventilation does not meet the standards in a room, the occupants should first reduce the number of users in a room, then they can use fans/ or split systems to increase the ventilation.
- If the HVAC system work with recirculation mode; "Increase the percentage of outdoor air as air supply, using economizer modes of HVAC operations, potentially up to 100%. Before increasing outdoor air percentage, verify compatibility with HVAC system capabilities" stated by Centers for Disease Prevention and Control (2021) in the Roadmap to improve and ensure good indoor ventilation in the context of COVID-19 (p.24, 2021).
- If the HVAC system is designed with heat recovery; the virus is not transmitted in the room; there is a separation in the HVAC system between the return and the supply side.
- The HVAC system should always be maintained and regularly cleaned; the filter should be cleaned and in some cases replaced according to the maintenance guidelines.
- "If the system does not allow air filter installation, consider fencing the area nearby the exhausted outlet, keeping people or animals at a distance at least of 4 m. The air intake should be at least at 2 m if air outlet is above and 4 m if air outlet is below (EN 16798) from the exhaust." stated by WHO, (2021, p. 25).

B. Residential buildings and self – quarantine in the house

A. Natural ventilation

Minimum recommended ventilation rate: 10 L/s/person (42) (EN 16798- 1) within the isolation area.

- If the ventilation rate does not meet the requirements; they should consider adding windows- modifying the dimensions of the doors/ openings.
- The fans in the bathrooms and the kitchens should operate in a continuous way (Technical resources for commercial settings. American Society of Heating, Refrigerating and Air-Conditioning Engineers, 2020).

The isolation room;

- If possible the room should be separated from the other ones with a private bathroom.
- "In collaboration with a HVAC professional, if the device is equipped with filters, consider replacing existing air filters with MERV 14 / ISO ePM1 70- 80% filter or the highest compatible with the filter rack. Make sure the units can overcome the additional pressure drop of the new filters. Note: Consider that non-ducted recirculating units do not replace ventilation in any circumstance" stated by WHO (2021, p. 27)
- A negative pressure should be created in relation with the corridor.

B. Mechanical ventilation

- If the ventilation rate does not meet the requirements; forced ventilation should be applied by using fans and splits.
- There should not be a mix between the air in the isolated room and the household, therefore return grilles should be added to decrease the spread of the virus.
- "The use of fans and/or fan coil or split system units for cooling and heating increases the air mixing within the room or space. This strategy should be implemented only if the minimum ventilation rate has been met. Note: Air mixing should be enhanced within areas but considering the isolation area and the rest of the house separately." Stated by WHO (2021, p.28).

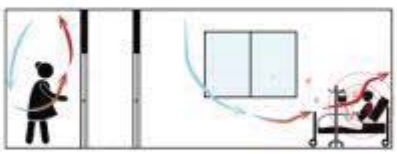
C. Health care – hospitals and quarantine areas

Ventilation rate minimum requirements (32): • 160 L/s/patient or 12 ACH where AGP are performed • 60 L/s/patient or 6 ACH other.

A. Natural Ventilation

- If the airflow does not move from the clean area to the contaminated area;

Figure 11: Wind flow



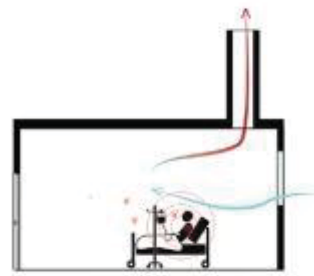


Figure 12: Ante-room

Figure 13: Stack effect

Adding an anti-room which helps in controlling the direction of the air in the room. The anti-rooms have double doors that do not open in the same time; in this way it creates a separation between the corridor and the room of the patient; creating a clear air.

"A cost-effective solution is the use of a plastic door zipper as a partition to create an ante-room", stated by WHO 2021, p.18).

Moreover, architects should create a cross ventilation in a room that is single sided ventilation. But the cross ventilation method should not be done when the room contains patients with Covid-19 and does not have a proper air circulation.

B. Mechanical Ventilation

Ventilation rate minimum requirements (32): • 160 L/s/patient or 12 ACH where AGP are performed • 60 L/s/patient or 6 ACH other.

HVAC professionals suggest that when the ventilation does not meet the bare requirements in the room; the demand control should be based on the number of occupants and CO2 concentration. And moreover, air cleaners should be disposed in order to clean the room from viruses (short term strategy). If the air does not flow from a clean to a less clean area: the professionals in HVAC systems require that the placement of the systems/splits should be reconsidered. The air must be directed to the outside of the room through the vents without penetrating in a room with a human being living in. (Centers for Disease Control and Prevention; 1990). A negative pressure should be applied in relation with the corridor; when the units of HVAC system in the room have a poor filtration. A negative pressure therefore is created by using extractor fans. (Y Shen, Li C, Dong H, Wang Z, Martinez L, Sun Z, et al., 2020).

“When implementing the roadmap, building owners and managers should consider, amongst other factors, weather conditions and outdoor air pollution” (WHO, 2021, p.17)

The Roadmap notes that “The risk of getting COVID-19 is higher in crowded and inadequately ventilated spaces where infected people spend long periods of time together in close proximity. These environments are where the virus appears to spread by respiratory droplets or aerosols more efficiently, so taking precautions is even more important. Understanding and controlling building ventilation can improve the quality of the air we breathe and reduce the risk of indoor health concerns including prevent the virus that causes COVID-19 from spreading indoors.” ARCHITECT STAFF (2021, p.2)

2.5 Conclusion of the Literature Review

From the literature review, the healthcare systems should be sustainable to provide the services needed especially when in pandemics such as the current one which is the Covid-19. The research will enable me to develop the methodology part where I will conduct surveys related to the buildings converted for receiving the Covid-19 cases in Lebanon, and focusing on the ventilation in the buildings and the specific rooms where the patients spend mostly their time. The reading done in literature review focused on the importance of natural ventilation in a room especially in a room with infections, as the current Covid-19 pandemic. International organizations such as the World Health Organization- ASHRAE- the LEED and others highlighted in their current studies of the Covid-19 that the ventilation can help in reducing the infection therefore helping in controlling the spread of the virus.

Furthermore, the natural ventilation is a sustainable process to build in the future. And to note that the natural ventilation can be mixed with the mechanical ventilation for better results depending on each building and its location with its function. This current pandemic, pushed the architects and engineers to reconsider the way they are designing and building houses all over the world. New strategies and implementation are being taken into consideration for future design.

Analysis, interviews and software will be used to tackle the chapter three of the thesis which is the methodology, while relying on the data of the literature review. The methodology chapter will be mainly focusing on the data of the buildings being converted to receive the Covid-19 patients in Lebanon, while making a comparison focusing on the ventilation in the buildings and the rooms where the patients will have to spend 14 days of isolation.

3. METHODOLOGY

This chapter introduces the methodology that I will work on during this research, it will cover five main sections to obtain a conclusion for this chapter. The focus in the thesis is on the buildings that are being converted to receive the patients of the Covid-19 in this pandemic in Lebanon. It will investigate the possible sustainable criteria to implement in such spaces. The data will be taken from trustworthy administration such as the municipalities in Lebanon, the federation of the municipalities, the public ministry of the Lebanese health, the Lebanese Red Cross, and the patients that were once infected by the Covid-19 and their experiences with the isolation in the rooms.

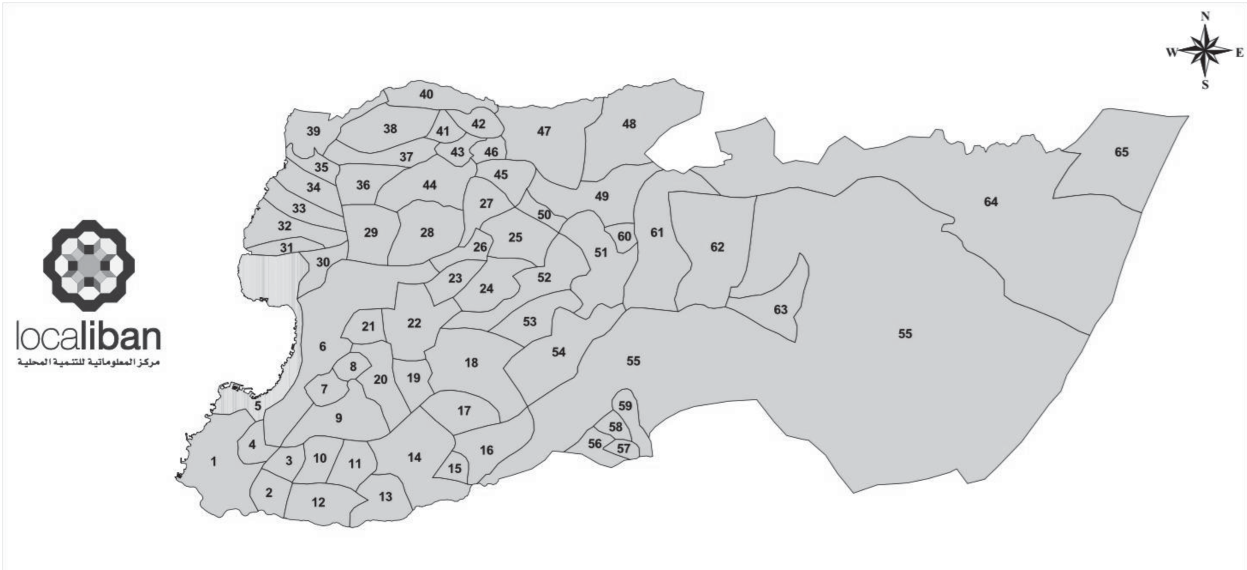
3.1 Selection of the study area

To note that the selection of the location of the buildings is affected by the Beirut blast on the 4th of august 2020, the revolution that is leading to road closure and the lack of information in the public administration.

3.1.1. Kesserwan District – Mount of Lebanon

The focus in this thesis is Kesserwan – Lebanon, Kesserwan is located in Mount Lebanon with Jounieh considering it its capital. "The Governorates of Beirut and Mount Lebanon are considered the heart of Lebanon's social, economic, political and cultural activities. Beirut is predominantly urban, while Mount Lebanon has urban and rural areas. Administratively, Mount Lebanon is divided into six districts, namely Jbeil, Keserwan, Metn, Aley, Baabda and Chouf." (UNHCR, 2020).

Figure 14: The Map of Lebanon



1. Zouk Mosbeh
2. Mazraet El Ras
3. Aintoura
4. Zouk Mikael
5. Kfer Yassine
6. Ghazir
7. Harissa
8. Batha
9. Daraaoun
10. Ain el Rihani
11. Souhailet el Fawqa
12. Jiita
13. Balloune
14. Ajaltoun
15. Mazraet Mhar el Mir
16. El Qlaaiat
17. Rayfoun
18. Achkout
19. Bzoummar
20. Ghosta
21. Chnanaayr
22. Dlebta
23. Aaramoune
24. Eghbeh
25. Chahtoule
26. El Qattine
27. El Husseine
28. El Kfour
29. Fatka
30. Adma ed Dafna
31. Tabarja
32. Es Safra
33. El Bouar
34. El Oukaibe
35. Boukak el Dine
36. Nammoura et Nar Jerif
37. Ez Zaytoun
38. El Mouaisra
39. Nahr Ibrahim
40. Bezhel
41. Zaaitre
42. El Mradiye
43. El Azra
44. Mammouret
45. Ghabe
46. Jouret Bedrane
47. Yahchouche
48. El Abri Et Chouan
49. El Mehete
50. Jouret Mhad
51. Ouata El Jaouz
52. Raachine
53. Boqaata
54. Faitroun
55. Mazraet Kfar Debian
56. Boqaata
57. Kfertai
58. Bekaatet Kanaan
59. Bekaatouta
60. Ain el Delbe
61. Mayrouba
62. Hrajel
63. Faraya
64. El Harajliye
65. Zeinie Mazraet Beit Mechak

Figure 15: The Map of the Municipalities in Kesserwan

Keserwan has 65 municipalities, with the Christianity being the dominant population in this area. Kesserwan is named following a Persian clan Kesra who settled in this area.

3.2 Data collection

The data will be formed of statistics taken from questionnaires, interviewing, from drawings and graphs while dealing with the ventilation in the specified buildings. The buildings converted to Covid-19 are chosen by the Lebanese government and the municipalities, therefore I will conduct a research to choose a sample that represent the different buildings.

The first part of the research is to obtain the data regarding the specified buildings converted for isolation to receive the patients infected by Covid-19 in Kesserwan. The method I will use is the qualitative method. In this method, interviews, and observations will be done and elaborated. The interview will be focusing on the persons who are either the patients infected by Covid-19 and stayed in such buildings, and the owner of the buildings and the municipality.

أماكن الحجر الصحي لعزل المصابين بفيروس الكورونا

المحافظة: محافظة جبل لبنان

	المكان	المنطقة	القضاء	اتحاد البلديات	البلدية	نوع العقار/طريقة اشغاله	المساحة (م2)	عدد الغرف	عدد الحمامات	الجهة المالكة	نقطة الإتصال	رقم الجوال	ملاحظات
	قضاء كسروان- أماكن جاهزة												
1	Domino Hotel		كسروان			فندق		20	20	الشركةالدولية لتطوير الفنادق	روجيه	09/213717-871/778022	كل وحدة مؤلفة من غرفة وصالون ومطبخ وحمام ضمن محيط سكني فقط
2	فندق Century Park		كسروان			فندق		52	53	بنك الإعتماد اللبناني للإستثما ر ش.م.ل	الإدارة العامة للمصرف	09/832893-01/608099	مجهز بالكامل-لا يعمل حاليا - سهل الوصول إليه - الكسليك
3	ذوق أوتيل	الذوق	كسروان			أوتيل ضمن محيط سكني		32	32		جورج شحادة	09/215900-1-2-3	
4	شقق مفروشة -مفرق دار سيدة الجبل -فتقا	فتقا	كسروان		فتقا	شقق مفروشة				الياس الشدياق	الياس الشدياق	03/392909	
5	فندق Doux reves- عين الريحانة	عين الريحانة	كسروان		عين الريحانة	فندق		10	10	وليد نجيم	وليد نجيم	03/258830	غرف مستقلة تم حجزها من قبل البلدية
6	موتيل أنطوان عقيقي- فيطرون	فيطرون	كسروان		فيطرون	فندق		34	34	أنطوان عقيقي	أنطوان عقيقي	03/924142	قرار بالقبول غير نهائي * بدل ايجار مرتفع
7	فندق قصر الصنوبر- ريفون	ريفون	كسروان		ريفون	فندق	600	15	7	فيكتور صفير	فيكتور صفير	03/464375	مؤقت وفرش
8	فندق السان روك- ريفون	ريفون	كسروان		ريفون	فندق	100	60	60	جورج صفير	جورج صفير		محتمل
9	ذوق مصبح -أوتيل Grand Gabriel	ذوق مصبح	كسروان		ذوق مصبح	فندق							
10	روكز ريزيدنس-ذوق مصبح	ذوق مصبح	كسروان		ذوق مصبح	فندق							
11	ذوق مصبح - Relax ريزيدانس	ذوق مصبح	كسروان		ذوق مصبح	فندق							
12	فوايبه حكيم عقار رقم 669- رعشين	رعشين	كسروان		رعشين	فندق	400	15	15	سيمون الحكيم	سيمون الحكيم	03/490775	بحاجة للتجهيز ولم يتم الإتفاق مع مالكه لغاية تاريخه ، ولا تزال المفاوضات قائمة لغاية الساعة
13	العذرا Azurama Hotel		كسروان			فندق		47	47	د. موريس عساد	د. موريس عساد	76/199978	معظمه مؤجر للرعايا السوريين
14	العذرا Private Hotel		كسروان			فندق		11	11	شربل مونس	شربل مونس	03/607778	فارغ
15	نيو سانتا تيريزا بيتش - العقيبة	العقيبة	كسروان		العقيبة	منتجع سياحي		60		القنصل مارسيل أبي شديد	القنصل مارسيل أبي شديد	71/739977	مجهز ولكن أصحابه يرفضون تقديمه للحجر الصحي
16	سام سور مار -العقيبة	العقيبة	كسروان		العقيبة	منتجع سياحي		40		سمير إدمون بو صادر	سمير إدمون بو صادر	03/279669	مجهز ولكن أصحابه يرفضون تقديمه للحجر الصحي
17	العقيبة Aqua Dream	العقيبة	كسروان		العقيبة	منتجع سياحي		25		بيار مطر	بيار مطر	03/435456	مجهز ولكن أصحابه يرفضون تقديمه للحجر الصحي
18	العقيبة River Side	العقيبة	كسروان		العقيبة	منتجع سياحي		32		إيلي يوسف الكلاسي	إيلي يوسف الكلاسي	03/703050	مجهز ولكن أصحابه يرفضون تقديمه للحجر الصحي
19	أوتيل محقان المظلوم-	وطى الجوز	كسروان		وطى الجوز	فندق					جوزف الخويري	03/944776	
20	أوتيل عين الجرن-وطى الجوز	وطى الجوز	كسروان		وطى الجوز	فندق					روجيه الهيتي	03/723366	مغلق منذ زمن
21	غدراس white hoel	غدراس	كسروان		غدراس	فندق		25	25	نظمي حساب	نظمي حساب	03/248188	صالح للإستعمال لكنه يطلب ايجارا" مرتفعا" علما" أن هذا الفندق يقع على حدود بلدتي غدراس والكفور حيث انه لا يوجد لا دير ولا أوتيل
22	الكفور white hoel	الكفور	كسروان		الكفور	فندق		25		نظمي حساب	نظمي حساب	03/248188	صالح للإستعمال لكنه يطلب ايجارا" مرتفعا"
23	أوتيل ريشارد - الكفور	الكفور	كسروان		الكفور	فندق		10	10	جاكلين حرفوش	جاكلين حرفوش	03/230051	مقفل من أكثر من 50 سنة وبحاجة إلى صيانة
	قضاء كسروان - أماكن غير جاهزة												
1	القليعات	القليعات	كسروان		القليعات	شقة	250m2	10	9	شربل كاي	شربل كاي	03/337673	
2	عين الريحاني	عين الريحاني	كسروان		عين الريحاني	شقتين		10	10	أستاذ بستاني	أستاذ بستاني	03/245585	2 Floors
3	دير الراهبات الباسليات الشويريات		كسروان			دير الراهبات الباسليات الشويريات ومأوى للعجزة والمسنين				الرهبنة الباسلية الشويرية	الرهبنة الباسلية الشويرية	09/210253	دير الراهبات الباسليات الشويريات ومأوى للعجزة والمسنين
4	دير مار مخايل الرهبنة الحلبية		كسروان			دير مار مخايل الرهبنة الحلبية						09/210095	دير للراهبات قديم أثري يوجد 20 راهبة
5	دير مار يوسف لراهبات المحبة		كسروان			دير ومدرسة العازارية للأيتام والمشردين -راهبات المحبة						09/210045-6	
6	دير البشارة الحارة للراهبات الحبيسات		كسروان			دير البشارة الحارة للراهبات الحبيسات						09/210272	يوجد 15 راهبة حبيسة بداخله
7	دير سيدة الجبل -فتقا	فتقا	كسروان		فتقا	دير سيدة الجبل -فتقا				راهبات العائلة المقدسة المارونيات	الأخت روز سلوم	09/740350	

	03/272171 03/730710	الرئيس الأب نادر نادر الأب القيم أنطوان صعب	الرهبنة اللبنانية الأنطونية				دير مار نهرا القنزوح -فتقا	فتقا		كسروان	فتقا	دير مار نهرا القنزوح -فتقا	8
دير يوحنا المعمدان حراش - آخر شارع رقم 2- عين الريحانة	03/512988	الأم صوفيا أصاف	راهبات مار يوحنا				دير يوحنا المعمدان حراش	حراش		كسروان	حراش	دير يوحنا المعمدان حراش	9
آخر شارع رقم 5 -حدود البلدة مع بلدة جعيتا -عين الريحانة	09/233586	الأخت مرتا	دير مار يوسف الظهور				دير مار يوسف الظهور			كسروان		دير مار يوسف الظهور	10
صالح للحجر يلزمه تأمين ماكينات أوكسيجين	03/290487	الأب جوزيف فهد	دير مار مبارك حاليا	10	10		ير مار مبارك حاليا	دلبتا		كسروان	دلبتا	دير الترابيست سابقا" ومار مبارك حاليا" -دلبتا	11
بحاجة للترميم والفرش		الأب آغا	دير سيدة الحقلة		20		دير سيدة الحقلة-دلبتا	دلبتا		كسروان	دلبتا	دير سيدة الحقلة-دلبتا	12
ملائم جدا"-محاولات حثيثة بالتعاون مع الإتحاد تقابل بالرفض - كبير جدا" مع حدائق	76/968661	الأخت ماجدة	راهبات الناصرة				دير سيدة النور	فيطرون		كسروان	فيطرون	دير سيدة النور-فيطرون	13
غير مجهز	03/739698						وقف الدحداح	غبالة		كسروان	غبالة	دير مار انطونيوس-غبالة	14
غير مجهز	03/275570	جوزف يزبك					وقف الخيرالله	غبالة		كسروان	غبالة	دير سيدة الشقيف-غبالة	15
بحاجة الى صيانة -صالح للحجر	03/331806	الأب ميلاد سقيم	ملك جمعية الأباء المرسلين	10	10		دير الكريم-مدرسة ال apotres-ميروبا	ميروبا		كسروان	ميروبا	دير الكريم-مدرسة ال apotres-ميروبا	16
غير مؤهل	76/161928	الأخت آغات شويري	دير سيدة النياح	10	22		دير سيدة النياح	بقعتوتة		كسروان	بقعتوتة	دير سيدة النياح-بقعتوتة	17
مجهزة ولكن لا تجاوب من مالكيها لوضعها بتصرف الحجر الصحي في حال الحاجة			دير يسوع الملك				دير يسوع الملك	ذوق مصبح		كسروان	ذوق مصبح	ذوق مصبح-دير يسوع الملك	18
مجهزة ولكن لا تجاوب من مالكيها لوضعها بتصرف الحجر الصحي في حال الحاجة			دير سيدة اللويزة				دير سيدة اللويزة	ذوق مصبح		كسروان	ذوق مصبح	دير سيدة اللويزة-ذوق مصبح	19
تم الأتصال بالأخ كارلوس وكان إيجابيا" وأمهلنا مهلةلمراجعة رؤسائه على أن يرسلوا الجواب خلال يومين .هذا المكان هوبتصرف أبناء حراجل وفاريا كونه يقع على حدود البلدتين	03/176567	الأخ كارلوس والأخ ماريو ماكوين	الأخوة الماريست	20	20		دير الفرير-حراجل	حراجل		كسروان	حراجل	دير الفرير-حراجل	20
بانتظار الرد النهائي من الراهبات للمباشرة بتجهيز المكان وانشاء مدخل خاص به وعزل ذم عن الدير .كما سيتم تجهيزه بالكهرباء ومولد كهربائي وانترنيت ودش	09/233407 09/233433		الراهبات المخلصيات	11	11	400	دير حاملات الطيب	جعيتا		كسروان	جعيتا	دير حاملات الطيب-جعيتا	21
	71/829337	الأخت فيرا أبي خرس	راهبات المحبة/البزنسون	42	103		سكن للراهبات المسنات ودير الإبتداء ومدرسة متوسطة	الكفور		كسروان	الكفور	ديرراهبات البزنسون	22
جميع الغرف مشغولة	70/571075	الأخت هدى الحلو	السريان الكاثوليك				دير الرهبات الإفراميات	بطحا		كسروان	بطحا	دير الراهبات الإفراميات -بطحا	23
في حال تأمين التجهيزات، صالح للحجر	03/648242	الاب جورج كميد	الرهبنة اللبنانية المارونية				دير مار أنطونيوس	بطحا		كسروان	بطحا	دير مار أنطونيوس - بطحا	24
الغرف معزولة عن الجناح الثاني يتضمن صالون عدد 2 ويوجد مطبخ	70/984906	جوزف أبي راشد	جمعية الصديق بالتعاون مع المطران غي نجيم	9	10	250	دير مار جريس	القليعات		كسروان	القليعات	دير مار جريس-الرومية القليعات	25

					Kesserwan District								
Notes	Contact Phone Number	Person to Contact		Nb. Of WC	Nb. Of Room	Area	Type of The Building	Municipality		District	Region	Place	
Each room has its own kitchen bathroom and a salon In a residential area	09/213717-871/778022	Roger	The Hotel's company in Lebanon	20	20		Hotel			Kesserwan		Domino Hotel	1
Equipped It is not occupied now Residential area	09/832893-01/608099	The Bank Central	Credit Bank Lebanon	53	52		Hotel			Kesserwan	Kaslik	Century Park Hotel	2
Residential area	09/215900-1-2-3	Georges Chehade	Georges Chehade	32	32		Hotel			Kesserwan	Zouk	Zouk Hotel	3

Residential area	03/392909	Elias El Chidiac	Elias El Chidiac				Apartme nts	Fatqa		Kesserwan	Fatqa	Furnished and Equipped Apartments	4
Apartments - Residential area	03/258830	Walid Njeim	Walid Njeim	10	10		Hotel	Ain El Rihani		Kesserwan	Ain El Rihani	Hotel Doux Reves	5
High rent Still not approved to be transformed to quarantine (Covid-19)	03/924142	Antoine Akiki	Antoine Akiki	34	34		Hotel	Faytroun		Kesserwan	Faytroun	Hotel – Antoine Akiki	6
For temporary use Fully equipped	03/464375	Viktor Sfeir	Viktor Sfeir	7	15	600	Hotel	Rayfoun		Kessserwa n	Rayfoun	Hotel Of Pines	7
Still not approved to be transformed to quarantine (Covid-19)		Georges Sfeir	Georges Sfeir	60	60	100	Hotel	Rayfoun		Kesserwan	Rayfoun	Hotel St. Rock Rayfoun	8
No further data							Hotel	Zouk Mosbeh		Kesserwan	Zouk Mosbeh	Zouk Mosbeh Hotel Le Grand Gabriel	9
No further data							Hotel	Zouk Mosbeh		Kesserwan	Zouk Mosbeh	Roukoz Residences Zouk Mosbeh	10
No further data							Hotel	Zouk Mosbeh		Kesserwan	Zouk Mosbeh	Relax Residences Zouk Mosbeh	11
For temporary use Fully equipped Still not approved to be transformed to quarantine (Covid-19)	03/490775	Simon el Hakim	Simon el Hakim	15	15	400	Hotel	Raachine		Kesserwan	Raachine	Foyer Hakim	12
It still have few places/roo ms	76/199978	Dr. Moris Imad	Dr. Moris Imad	47	47					Kesserwan		Azurama Hotel	13
Empty	03/607778	Charbel Mouannes	Charbel Mouanne s	11	11					Kesserwan		Private Hotel	14

Equipped But the owners are refusing to be transformed into a quarantine for the patients	71/739977	Marcel Abi Chedid	Marcel Abi Chedid		60		Beach Resort	El Okaibe		Kesserwan	El Okaibe	New Santa Teresia Beach	15
Equipped But the owners are refusing to be transformed into a quarantine for the patients	03/279669	Samir Edmond Bou Sader	Samir Edmond Bou Sader		40		Beach Resort	El Okaibe		Kesserwan	El Okaibe	Sam Sur Mer	16
Equipped But the owners are refusing to be transformed into a quarantine for the patients	03/435456	Pierre Matar	Pierre Matar		40		Beach Resort	El Okaibe		Kesserwan	El Okaibe	Aqua Dream	17
Equipped But the owners are refusing to be transformed into a quarantine for the patients	03/703050	Elie Youssef El Kellassy	Elie Youssef El Kellassy		32		Beach Resort	El Okaibe		Kesserwan	El Okaibe	River Side	18
No Data	03/944776	Joesph El Khoueiry	Joesph El Khoueiry				Hotel	Wata El Jozz		Kesserwan	Wata Al Jozz	Hotel Al Mazloum	19
Closed long time ago	03/723366	Roger El Hachi	Roger El Hachi				Hotel	Wata El Jozz		Kesserwan	Wata Al Jozz	Hotel Ain El Jeren	20
But the owners are refusing to be transformed into a quarantine for the patients	03/248188	Nazmi Hissab	Nazmi Hissab	25	25		Hotel	Ghedras		Kesserwan	Ghedras	White Hotel_ Ghedras	21
Equipped but high rental issues	03/248188	Nazmi Hissab	Nazmi Hissab	25			Hotel	El Kfour		Kesserwan	El Kfour	White Hotel_ El Kfour	22
Closed for over 50 years and it needs maintenance	03/230051	Jacqueline Harfouche	Jacqueline Harfouche	10	10		Hotel	El Kfour		Kesserwan	El Kfour	Hotel Richard	23

No further data	03/337673	Charbel Kai	Charbel Kai	9	10	250 m2	One Apartment	El Qlaaiat		Kesserwan	El Qlaaiat	El Qlaaiat	24
2 Floors	03/245585	Mr. Boustany	Mr. Boustany	10	10		Two Apartments	Ain El Rihani		Kesserwan	Ain El Rihani	Ain El Rihani	25
No further data	09/210253	The Monastery	The Monastery				Monastery for the nuns			Kesserwan	Kesserwan	Monastery for the nuns	26
It is an old building	09/210095	The Monastery	The Monastery				Monastery of St. Michael			Kesserwan	Kesserwan	Monastery of St. Michael	27
No further data	09/210045-6	The Monastery	The Monastery				Monastery of St. Joseph			Kesserwan	Kesserwan	Monastery of St. Joseph	28
No further data	09/210272	The Annunciation Monastery of The Locked Nuns	The Annunciation Monastery of The Locked Nuns				The Annunciation Monastery of The Locked Nuns			Kesserwan	Kesserwan	The Annunciation Monastery of The Locked Nuns	29
No further data	09/740350	The nun Rose Salloum	Family Nuns Holy Maronites				The Monastery of St. Mary	Fatqa		Kesserwan	Fatqa	The Monastery of St. Mary	30
No further data	03/272171 03/730710	The priests; Nader Nader and Antine Saab	The Lebanese Order Antonine				The Monastery of St Nohra	Fatqa		Kesserwan	Fatqa	The Monastery of St Nohra	31
No further data	03/512988	The nun Sophia Assaf	The nuns of the monastery				John the Baptist Monastery	Hrash		Kesserwan	Hrash	John the Baptist Monastery	32
No further data	09/233586	The nun Marta	The Monastery of St. Joseph				The Monastery of St. Joseph			Kesserwan		The Monastery of St. Joseph	33
It is well equipped, but needs oxygen machines for the patients	03/290487	The priest Joseph Fahed	The Monastery of Dlebta	10	10		The Monastery of Dlebta	Dlebta		Kesserwan	Dlebta	The Monastery of Dlebta	34
The buildings needs restoration and furniture		The priest Agha	The Monastery of St. Mary		29		The Monastery of St. Mary	Dlebta		Kesserwan	Dlebta	The Monastery of St. Mary	35
The building is very suitable with new furniture	76/968661	The nun Majda	The Monastery of St. Mary				The Monastery of St. Mary	Faytroun		Kesserwan	Faytroun	The Monastery of St. Mary	36

and gardens surrounding it, but it was not approved by the monastery													
Not equipped	03/739698						The Monastery of ST. Antoine	Ghbele		Kesserwan	Ghbele	The Monastery of ST. Antoine	37
Not equipped	03/275570	Joseph Yazbeck					The Monastery of St. Mary	Ghbele		Kesserwan	Ghbele	The Monastery of St. Mary	38
It needs maintenance Ready to accept the patients for quarantine	03/331806		The Priest Milad Sqim	10	10		Apotres School	Mayrouba		Kesserwan	Mayrouba	Apotres School	39
Not suitable for quarantine	76/161928	The nun Agath Choueiry	The Monastery in Bqaatouta	10	22			Bqaatouta		Kesserwan	Bqaatouta	The Monastery in Bqaatouta	40
It is suitable for quarantine, but no response/ approval		Jesus Christ Monastery	Jesus Christ Monastery					Zouk Mosbeh		Kesserwan	Zouk Mosbeh	Jesus Christ Monastery	41
It is suitable for quarantine, but no response/ approval		NDL	NDL					Zouk Mosbeh		Kesserwan	Zouk Mosbeh	NDL	42
The priests approved of the idea of the quarantine, but they are waiting for further approval. The monastery is located between Hrajel and Faraya.	03/176567	Fr. Carlos and Fr. Mario	Monastery Hrajel	20	20			Hrajel		Kesserwan	Hrajel	Monastery Hrajel	43
The nuns approved that the convent be used for quarantine, It needs some maintenance and building a new	09/233407 09/233433			11	11	400	Myrrophores Convent	Jeita		Kesserwan	Jeita	Myrrophores Convent	44

separate entrance for the patients													
	71/829337	Nun Vera Abi Kharas	The nuns of the convent	42	103		Convent of the Bizonsons Nuns	El Kfour		Kesserwan	El Kfour	Convent of the Bizonsons Nuns	45
All the rooms in the convent are used by the nuns	70/571075	Nun Houda						Batha		Kesserwan	Batha	Convent of the Nuns	46
The building needs restoration, and can be used for quarantine	03/648242	Priest Georges Kmeid						Batha		Kesserwan	Batha	Convent St. Antoine	47
The rooms have a separate entrance with a kitchen	70/984906	Joseph Abi Rached		9	10	250		El Qlaiaat		Kesserwan	El Qlaiaat	Convent St. Georges	48

Table 1: The quarantine facilities in Mount of Lebanon

After contacting the Federation of Keserwan with collaboration with the Red Cross and the Disaster Management Sector in Lebanon, I collected the data of the buildings that could be isolated to receive the patients of Covid-19 that have mild symptoms and do not require to be in a hospital.

Above are the list of buildings that could be transformed in case of pandemics to quarantine; there are residential apartments- hotels- monasteries and resorts. They are distributed as following: sixteen hotels, three apartments, four resorts and twenty two monasteries. Furthermore, till now four monasteries are ready and some even started receiving patients. The role of the municipalities in such cases is very important; references such as: The Role of Governorates, Districts, Unions of Municipalities, Municipalities, and Mukhtars.

The Covid-19 pandemic increased the amount of problems in Lebanon. During March 2021, when the pandemic hit Lebanon, there was a revolution along with an economic crisis in the country. The system was corrupted, therefore there was no plan to overcome the pandemic with minimum damage.

In Mount Lebanon _ Kesserwan, the federation of Kesserwan had put a list of all the buildings that can be converted to quarantine, after talking to their owners.

The four monasteries that can receive the patients are the Convent of Mother of God in Ajaltoun دير ام الله, Myrrophores Convent in Jeita دير حاملات الطيب, Convent of Saint Famille in Sarba دير عبرين, and the Convent of ST. JOHN in Ghosta دير مار يوحنا.

3.3 Data collected of the four convents

DATA	**Convent of Mother of God** دير ام الله	**Myrrophores Convent** دير حاملات الطيب	**Convent of Saint Famille** دير عبرين	**ST. JOHN** دير مار. يوحنا
OWNER	**Nun Josephine**	**Nun Simone Khalil**	**Nun Clotilde**	**Priest Omar El Hachem**
LOCATION	AJALTOUN	JEITA	SARBA	GHOSTA
SURROUNDING	RESIDENTIAL BUILDINGS	FAR FROM THE RESIDENTIAL AREA	RESIDENTIAL BUILDINGS	TREES/ FAR FROM THE RESIDENTIAL AREA
ACCESSIBILITY	SECONDARY ROAD LEADING TO THE HIGHWAY ZOUK MOSBEH - FARAYA	PRIVATE ROAD	SECONDARY ROAD	PRIVATE ROAD
NUMBER OF FLOORS	3 FLOORS	3FLOORS	NO DATA	3 FLOORS
FLOOR DEDICATED FOR COVID-19	FIRST FLOOR	FIRST FLOOR	ALL THE BUILDING	ALL THE BUILDING
ENTRANCE FOR THE PATIENTS	PRIVATE ENTRANCE	PRIVATE ENTRANCE (THEY DESTRUCTED A BALCONY AND CREATED A RAMP)	NO DATA	PRIVATE ENTRANCE
ROOM OF THE PATIENT	SINGLE BED WTH A PRIVATE BATHROOM	SINGLE BED WITH A PRIVATE BATHROOM	NO DATA	NO DATA
RELATION OF THE ROOM WITH THE WHOLE BUILDING	THE FLOOR IS SEPARATED BY A LOCKED DOOR	THE FLOOR IS SEPARATED BY A LOCKED DOOR	NO DATA	INDEPENDENT BUILDING
BALCONY OF THE ROOM	PRIVATE BALCONY FOR EACH ROOM SEPARATED BY GLASS	PRIVATE BALCONY FOR EACH WIH A VIEW	NO DATA	PRIVATE BALCONY
PATIENTS	NO PATIENTS TILL NOW	THEY RECEIVED PATIENTS FOR THE PAST 6 MONTHS	NO PATIENTS TILL NOW	NO PATIENTS TILL NOW
FUTURE PLAN	THE NUNS ARE AFRAID TO RECEIVE PATIENTS	NO PROBLEM FOR FUTURE USE	NO PROBLEM	NO PROBLEM

	THE MUNICIPALITY WILL USE IT, IF THE NUMBER OF PATIENTS INCREASES			
MUNICIPALITY ROLE	THE MUNICIPALITY PROVIDED FURNITURE-WIFI- AND DOORS SEPARATING THE FLOOR FROM THE BUILDING	THE NUNS ARE TAKING ALL THE RESPONSABILTIY	NO DATA	THE PRIEST WILL TAKE ALL THE RESPONSABILITY
DRAWINGS	I GOT THE DRAWINGS FROM THE MUNICIPALITY	I GOT THE DRAWINGS FROM THE MUNICIPALITY	NO RESPONSE FROM THE NUN	NO RESPONSE FROM THE PRIEST
SITE VISIT	YES	YES	NO	YES

Table 2: Data collection of the quarantine facilities available

3.3.1 Site visit of the convents

A. Preparatory work

Materials used: the materials and tools used during the survey are a camera and the table that contains the buildings designated by the federation of the municipality to be converted to quarantine. After eliminating the buildings that are still not ready to receive the patients of the Covid-19, the site visits were limited to the available quarantine places for time management.

Purpose of the visits/ site visits: the purpose of the site visits is to take photographs of the buildings and the surroundings/neighborhoods, as well as to interact and interview the occupants and gain more information about the process of quarantine.

1. Convent of Mother of God_ Ajaltoun

Figure 16: The monastery's main entrance

The figure 16 shows the building's entrance.

Source: By Author

The single room with its private balcony

Figure 17: The room designated for quarantine

Door separating the floors

Figure 18: The vertical circulation inside the monastery

The figure 16 show the entrance of the Convent of Mother of God_ Ajaltoun.

The figure 18 show the door separating the floors, and the figure 17 shows the room with the private bathroom and the private balcony.

The balconies of each room is separated by a glass separation, to decrease the risk of spreading the Covid-19 virus between the occupants.

2. Myrrophores Convent_ Jeita

Figure 19: Main entrance of the monastery *Figure 20: Entrance for the Covid-19 patients* *Figure 21: Vertical circulation*
of the monastery

Figure 22: The room of the patient *Figure 23: The*
surrounding/ View

The figure 20 show the entrance of the Myrrophores Convent, and the ramp is recently added by destructing the balcony of a room to create a private entrance for the patients far from the nuns.

The figure 21 show the door separating the floors, and the figure 22 is the room with the private bathroom.

3. Convent of St. John_ Ghosta

Figure 24: The monastery and the surrounding

Figure 25: The private building

The figure 25 represents the private building that is behind the monastery and has a private entrance. This building will be considered for quarantine, if the number of patients infected by the Covid-19 increased.

3.3.2 Selection of Convents

3.3.2.1 The convent of Mother of God in Ajaltoun

The municipality was able to provide me the technical drawings of the convent, while giving me access to the original maps that were hand drawn. And the senior nun gave me entree to the convent, and she showed me the rooms that were set to receive the patients that have no other solution than the convent for isolation during this pandemic.

3.3.2.2 The Myrrophores Convent in Jeita

The municipality of Jeita gave me the maps of this convent in a pdf format, that I will redraw using specific software. Then, after taking an appointment with the nun, I had access to the interior of the building.

3.3.2.3 The Convent of Saint Famille

I spoke with the nun responsible in this convent, but had no further contact. Therefore, I was not provided with any further information and no access to any map or data. And according to the municipality, this convent was a private property.

3.3.2.4. The Convent of St. John

I had access to the convent, but no further data as maps were given to me. The property was a private one, therefore the municipality could not provide me with any.

3.3.2.5. Conclusion

In conclusion, with the data that I could collect I can only proceed in analyzing two monasteries which are the convent of Mother of God in Ajaltoun and the Myrrophores Convent in Jeita.

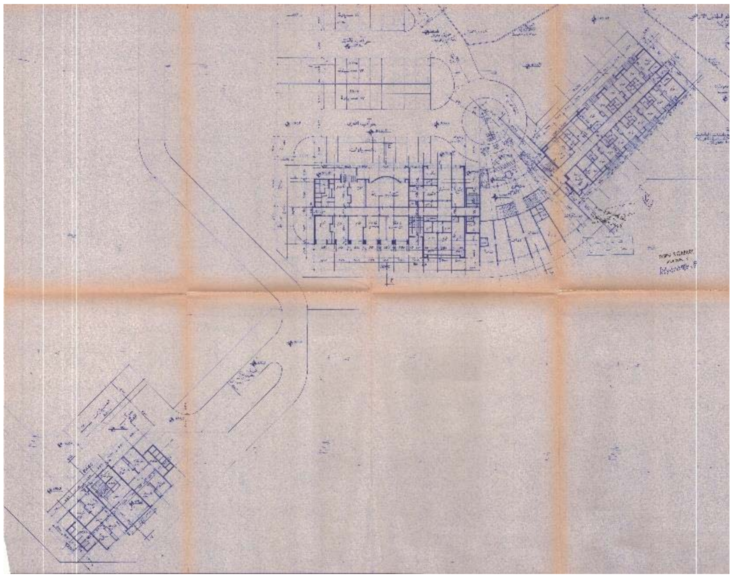
In the next section, I will redraw the plans of the convents based on the pdf format that I obtained from the municipalities of Jeita and Ajaltoun, then I will start the analysis of the ventilation in the bedrooms are designated to the patients of the Covid-19.

3.4 Mapping

The maps provided for the monasteries of Jeita and Ajaltoun were only in form of pdfs, no recent AutoCAD file is created. So, the next step after getting the drawings was to redraw them using a software named Revit to have a full 3D-Model of each convent.

This step will be later on be used while analyzing the buildings regarding the ventilation in the room of the patients of Covid-19.

Below is a sample of a plan of the Convent of Myrrophores_ Jeita:



Source: Municipality of Jeita Figure 26: Map (pdf) take from the municipality, for the convent of Jeita

3.5 Methods of data collection

The software that will be used are the SPSS for the statistics, and the CFD program which will help in the analysis of the ventilation of the rooms chosen in the buildings converted to receive the Covid-19 patients in Lebanon. Then, the next step is to read the results taken from the interviews and questionnaire done with the specified persons and the results from the software. The third and last step is the limitations which could be faced either while interviewing the people or while gaining specific documents on a certain building I want to analyze.

3.5.1 The software

- Autodesk Revit

The Autodesk Revit is a BIM program; Building Information Modeling, used mainly by the architects, structural/ mechanical/ electrical and plumbing engineers. A 3D model of the building is created using the tools in Revit, while creating the technical drawings. Furthermore, this software allows to identify the weather of the building by accessing the exact location of this building.

This tool will help in the analysis of the ventilation of the buildings that I want to build my study on.

- CFD program; Computational Fluid Dynamics Simulation

The Autodesk CFD is a software used by engineers and architects mainly to predict the performance of the designed building. This software calculate the required data to create the flow of fluids and the interaction of the fluid- liquid and gases while defining the boundaries of the building.

- SPSS software

The SPSS software is a statistic analysis program, which allows to calculate he input data and create a statistic using texts- numbers- algorithms and data. This program is not only used by architects, it is accessed by researchers- marketing or health, companies- government and the education researchers. The data entry is done after doing interviews and questionnaires with a sample of the population targeted in the research.

3.6 Interviews

The first step was contacting the responsible of managing the monasteries to get the data. For ethical reasons, I contacted the municipalities and the federation of Kesserwan by phone then I sent them each an email stating the requirements and the purpose of getting such private data. After receiving an approval I had a meeting scheduled in each municipality. Whereas the meeting with the federation of Kesserwan was through the phone. Then, the next step was scheduling an appointment with the nuns and priests of the monasteries.

I took an appointment from the nuns of the monasteries of Ajaltoun and Jeita, and they showed me the rooms that are reserved to receive the patients of the covid-19 in the region.

3.7 Data analysis

Each convent will be analyzed on its own using the Revit Autodesk program, the computational fluid dynamics and the green building simulation.

Then, an interpretation is done which consists of comparison and interpretation of the results to reach a conclusion that respond to the research question.

The data acquired will be compared in addition with the ASHRAE, WHO organizations regarding the rules that are required to have a healthy environment during this pandemic and decrease the spread of the virus.

3.7.1 Data Entry

Jeita or spelled as Jaita, is town that is located in Mount Lebanon; the Kesserwan district. This town is situated 20 kilometers north of Beirut with an altitude of 380 meters above the Mediterranean Sea.

3.7.1.1 Convent of Jeita

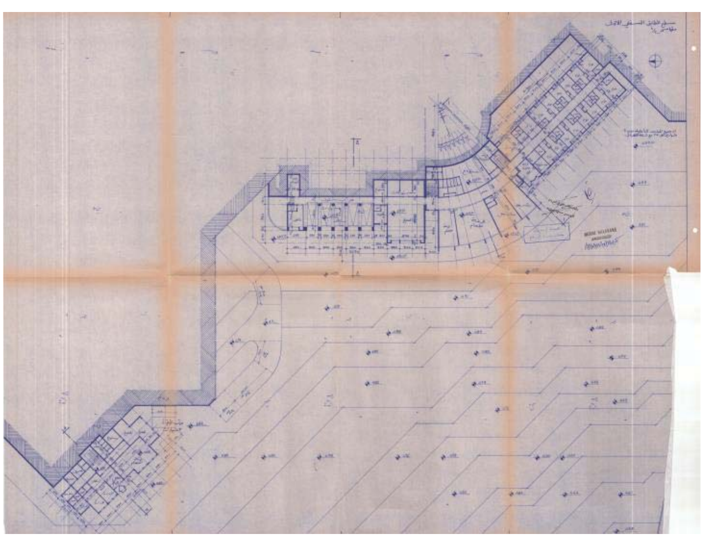


Figure 29: First floor of the Convent- Jeita

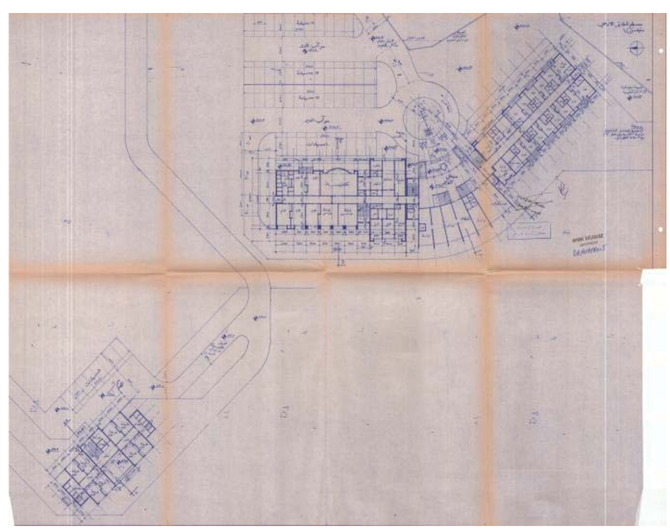


Figure 30: Ground floor of the Convent- Jeita

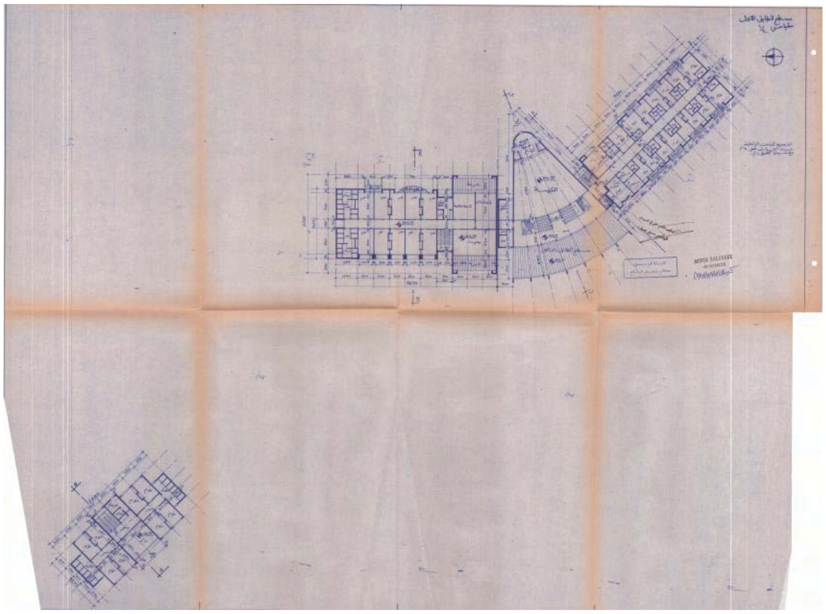


Figure 31: Underground floor of the Convent - Jeita

Above are the maps provided from the municipality that drawn by hand, so the first step was drawing the 3D model of this monastery by using the program Revit Autodesk.

Figure 32: Mass floor of the Cnvent in Jeita

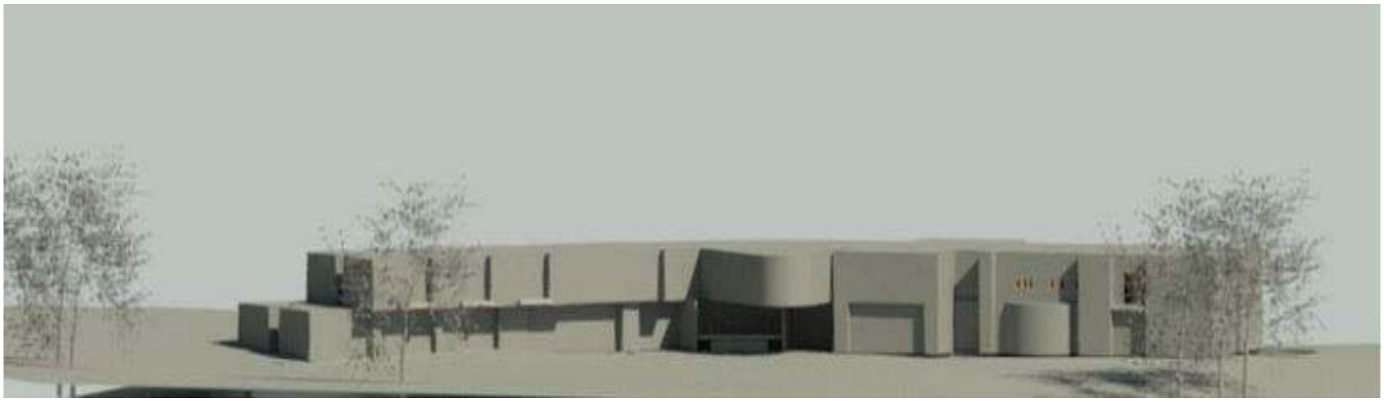
The only entrance to the monastery which is private.

From the three sides: one- two and three, trees surround the monastery.

The building has an underground floor, ground floor and a first floor. The ground and the underground floors are mainly for the public and contain living rooms, kitchen, church, and waiting areas. Whereas, the first floor is private for the nuns and groups that would like to meditate for a certain period of time, and it consists from single and double bedrooms,

Figure 33: 3D model of the convent in Jeita

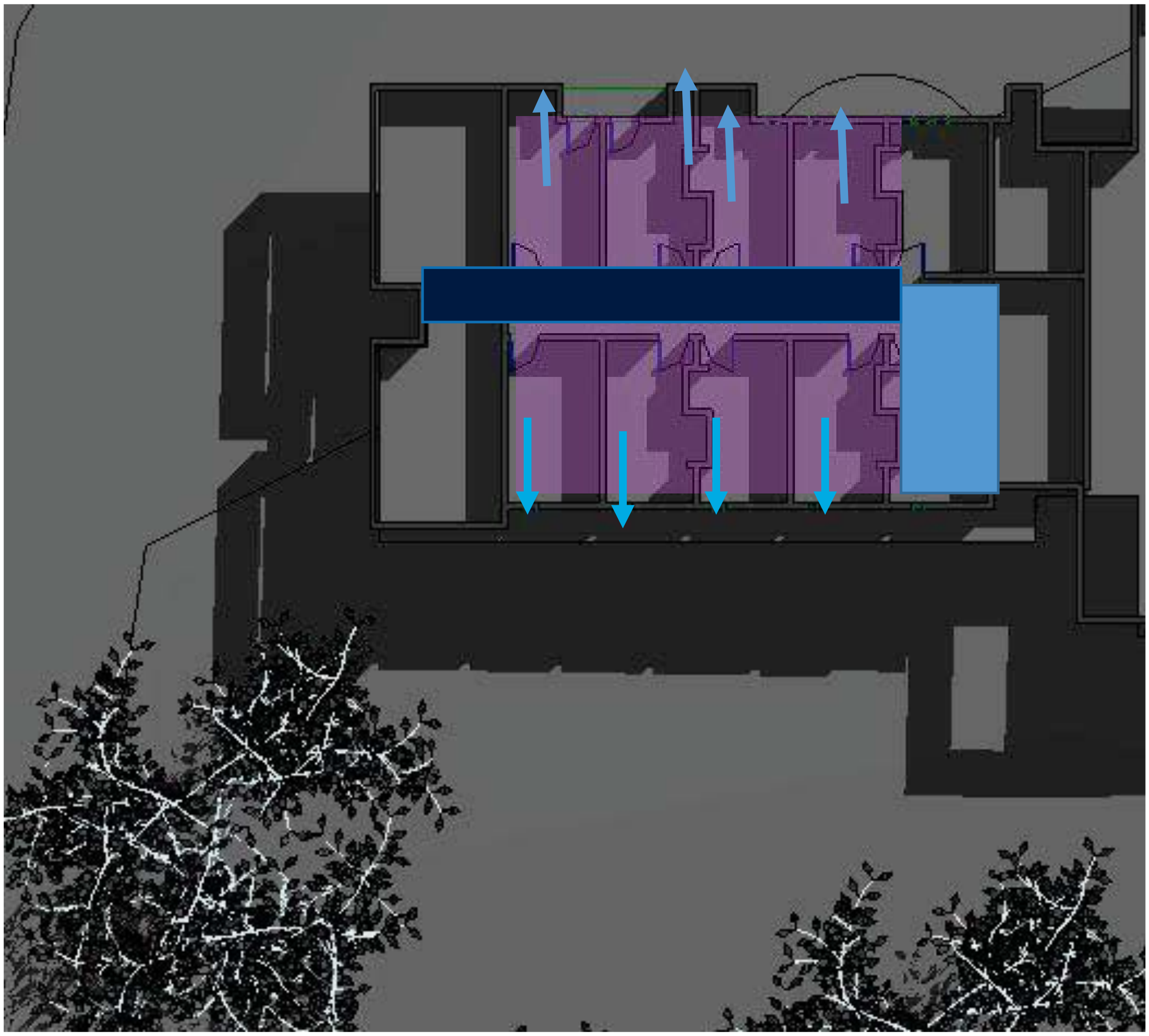
Figure 34: 3D model of the convent in Jeita



The building is isolated from the residential area, it has a private road leading to the main entrance. The footprint of the building is approximately 900 square meters. The convent contains 10 nuns living in it and some of them are old, which leads to having more strict rules to avoid the infection of any. Thus, the building should be both safe for the nuns and for the patients of the Covid-19 that come from this region Jeita.

A part of the first floor is dedicated to receive the patients of the Covid-19 which is separated from the whole building by doing changes as locating a new entrance for this part, creating an isolated area. The municipality helped the nuns to create this isolation, and were working together, hence the isolated part was not harming the health of the nuns. The double bedrooms were transformed into single bedrooms, and each room has openings with a small balcony, and its own private bathroom. Such room enabled the patient to feel comfortable during his healing process. To note that these patients were not in need for a special care (intensive care, oxygen machines, etc.), but they did not have a place isolated from their families to quarantine.

Below is the highlighted part seen in the image showing the isolated part in the monastery of Jeita_ Kesserwan.



Bedrooms

Vertical Circulation

Circulation- Corridor

Openings

Figure 35: Floor of the rooms designated for the patients of Covid-19

The changes that the municipality and the nuns had to do to isolate the part of the bedrooms.

A- Changes

Figure 36: Building a ramp for the Covid-19 patients

They created this ramp to have a direct access to the stairs leading to the first floor, by eliminating the small balcony. Moreover, they put a door that separate this part (image).

Figure 37: Indoor ve

Before studying the ventilation in this building, I used the Green Building Studio GBS, that shows the direction of the wind in this location.

Figure 38: Dry Bulb Frequency Distribution (Annual)

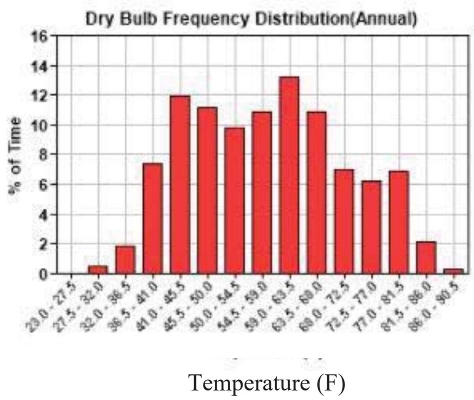
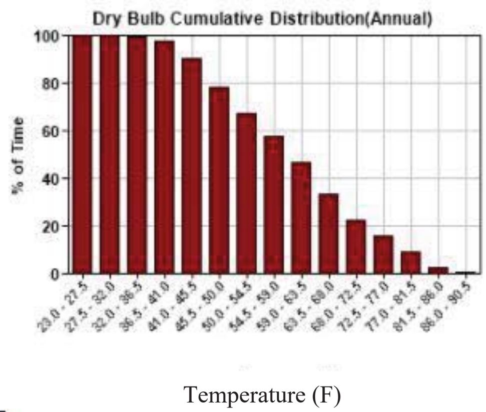


Figure 39: Dry Bulb Cumulative Distribution (Annual)



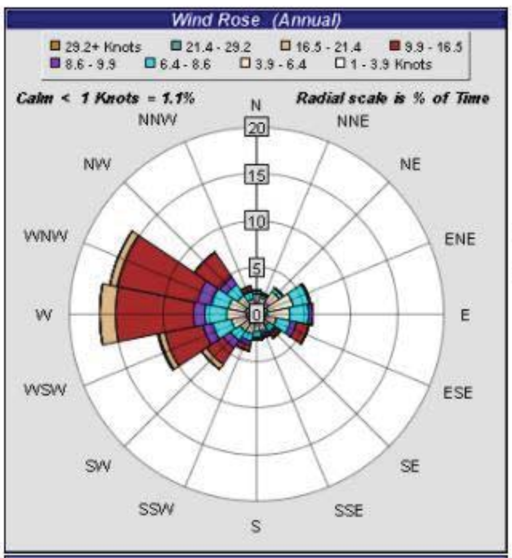


Figure 40: The wind rose (annual)

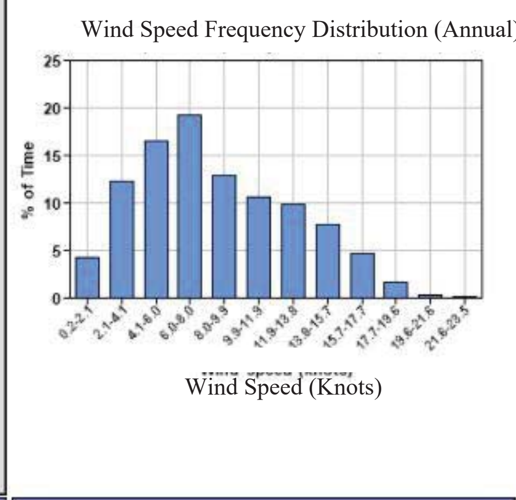


Figure 41: Wind Speed Frequency Distribution (Annual)

The wind rose shows the direction of the wind in most of the year.

By selecting the exact location of the monastery in Jeita, the annual wind rose indicates that mainly the wind comes from the West, thus it will help in analyzing the wind in the Computational Fluid Dynamics software CFD program.

Figure 42: The wind rose (Winter Jan- Mar)

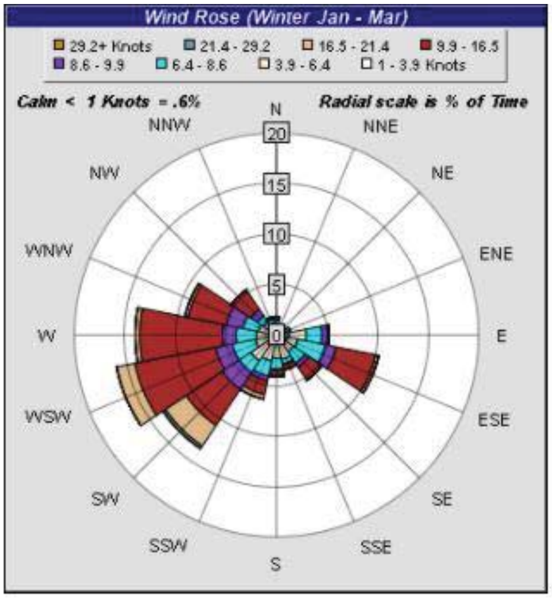
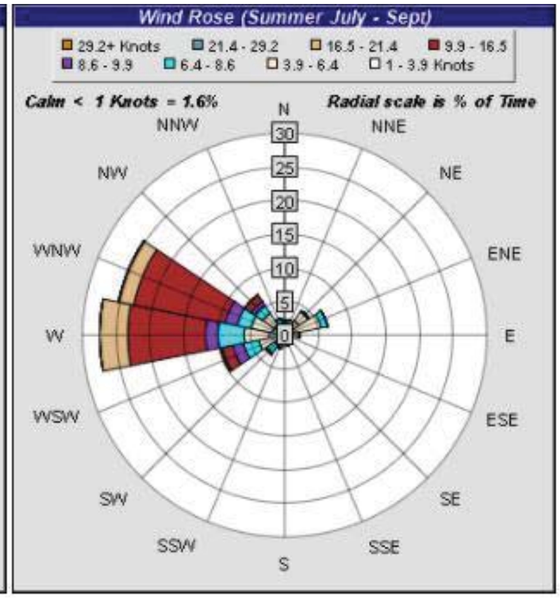
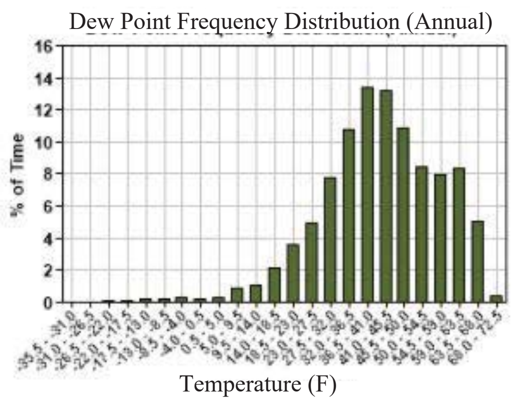
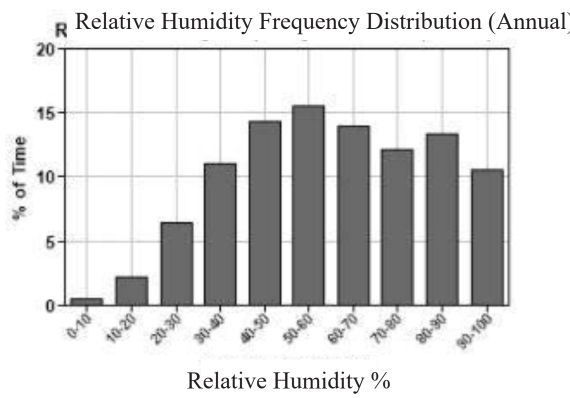


Figure 43: Wind rose (Summer July- Sept)







And the seasonal wind rose also indicates that the west is the most direction of the wind, where the wind differs from 6 to 21 knots.

From the east the wind increases to 9 knots, and from the north-east the wind is calm (< 1 knots).

The humidity during the year varies from 10 to 80%.

The GBS is an online program that locates the building and analyzes the weather in the specified area.

The data collected and drawn using the Revit Autodesk program, are then analyzed using the Computational Fluid Dynamics software (CFD) to study the ventilation in the isolated rooms.

3.8 CFD program

3.8.1 Materials

The first step in the CFD program, is to give each element of the building a specified material.

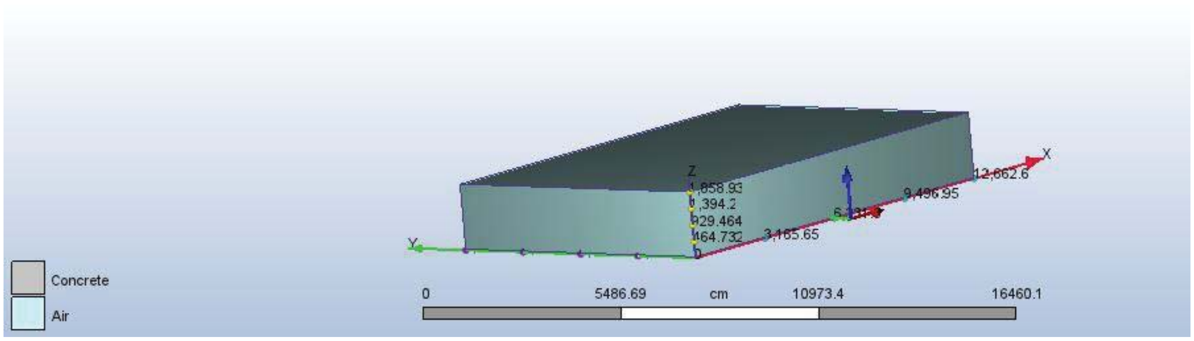


Figure 44: 3D model of the air

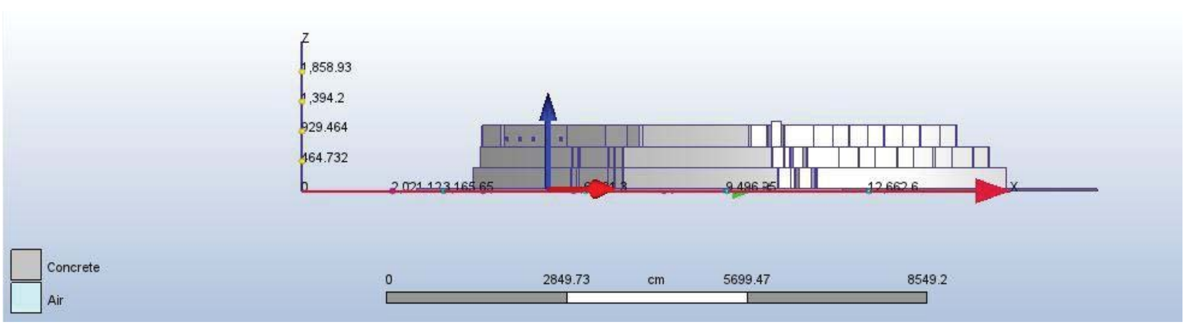


Figure 45: 3D model of the building

The blue box is created in Revit before using the CFD program.

The blue box is the wind that envelops the building, thus it is given a fluid material, whereas the building's materials are solid as in concrete (gray color).

3.8.2 Boundaries

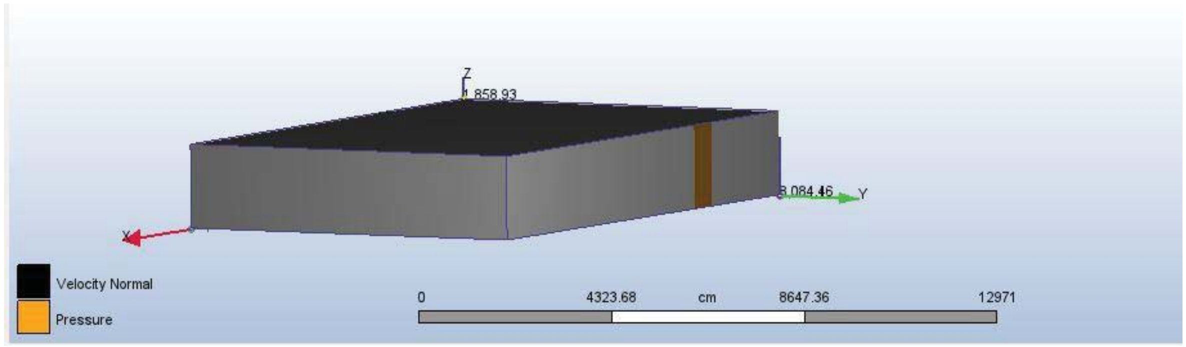


Figure 46: The boundaries on the wind box

The second step in CFD, is setting the boundaries, selecting the direction of the wind that is mostly common in the area. Based on the wind rose taken from the GBS program, the velocity is selected on the west with 10 m/s, and a pressure is set on the east side with 0 m/s.

The pressure is seen as an orange rectangle and the pressure as a black rectangle on the fluid box.

3.8.3 Mesh

An auto sized mesh is created, represented by blue dotes on the fluid box.

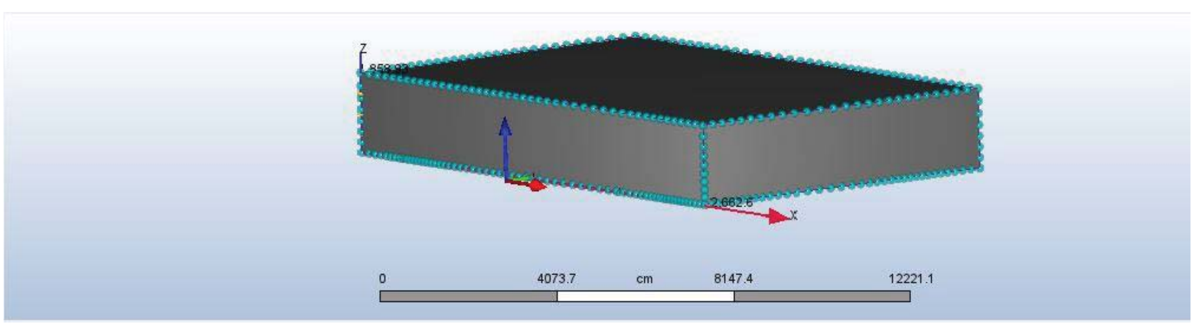
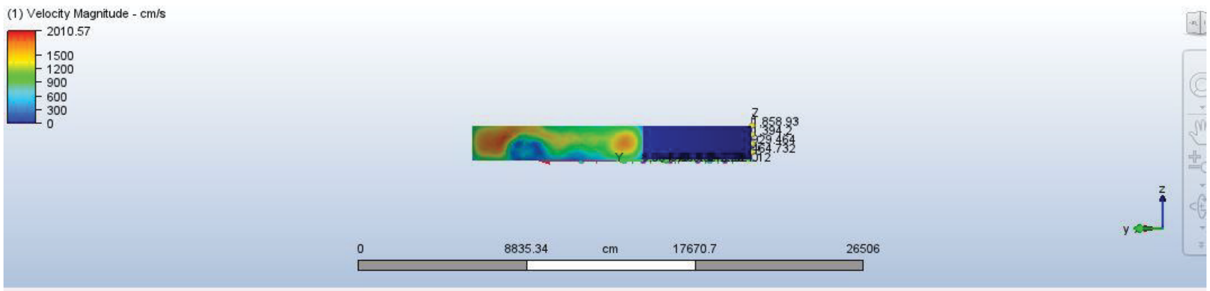


Figure 47: The auto sized mesh

3.8.4 Solve – Results

After all the three steps, the CFD will solve the ventilation by analyzing it.



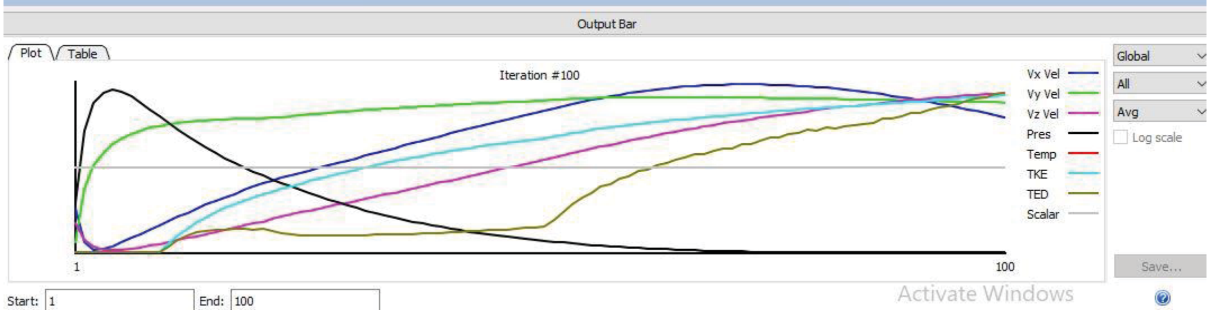
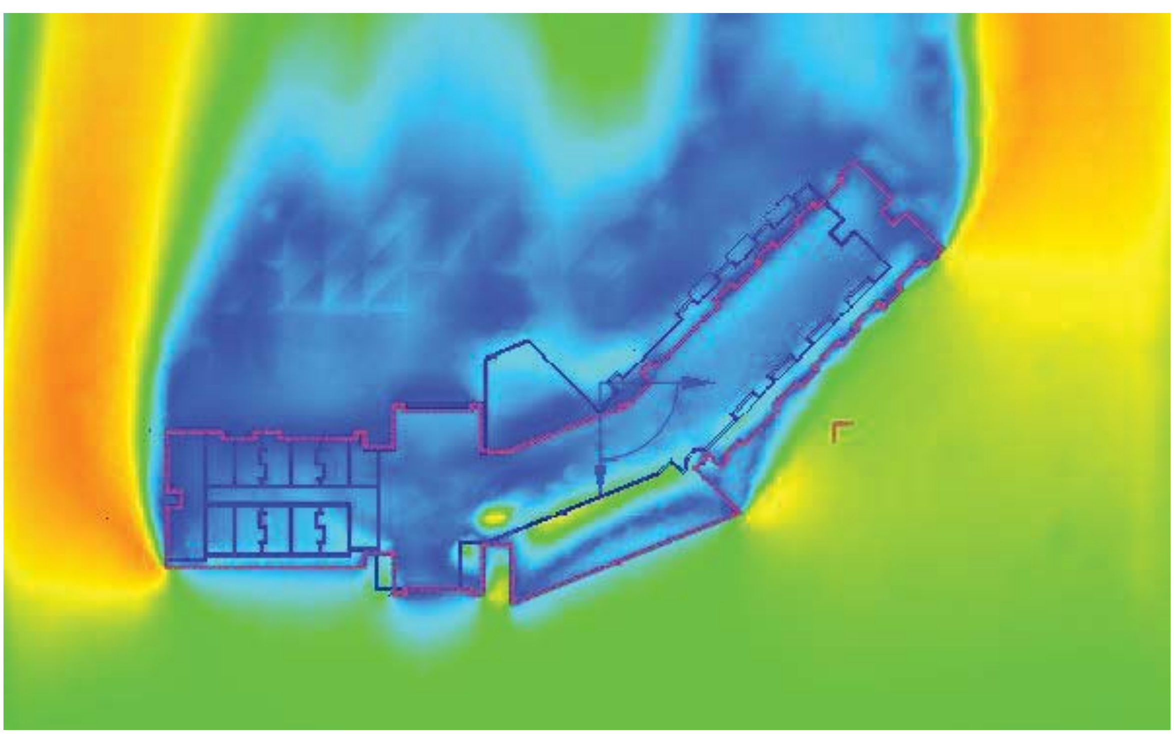


Figure 48: The velocity magnitude

Figure 49: The iteration graph

The graph has the iterations between 1 and 100 that will be seen on the model reflecting the velocity and the direction of the wind.

Figure 50: Plan showing the velocity of the wind



The top view of the model has colors that each represents the speed of the wind from the 0 to 15 m/s.

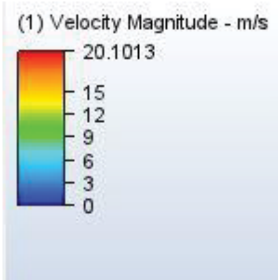


Figure 51: The velocity magnitude

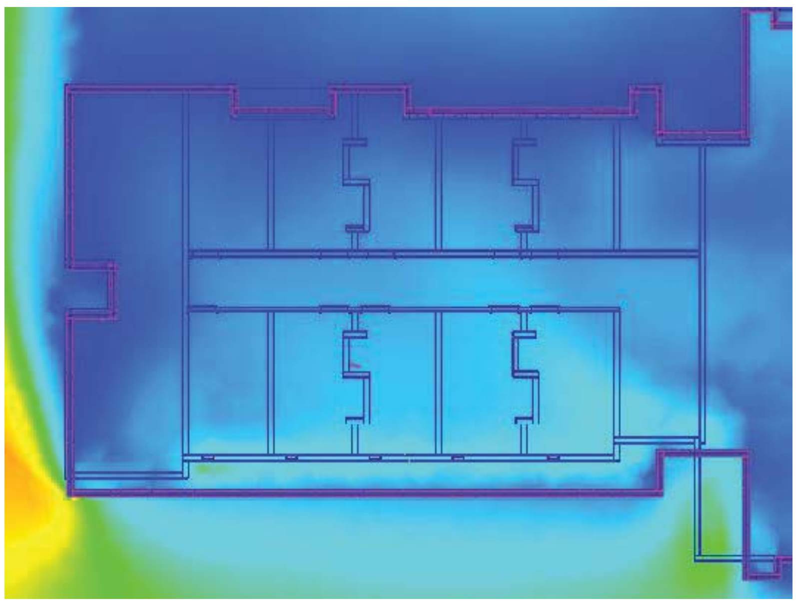


Figure 52: A section of the plan - focusing on the rooms of the patients

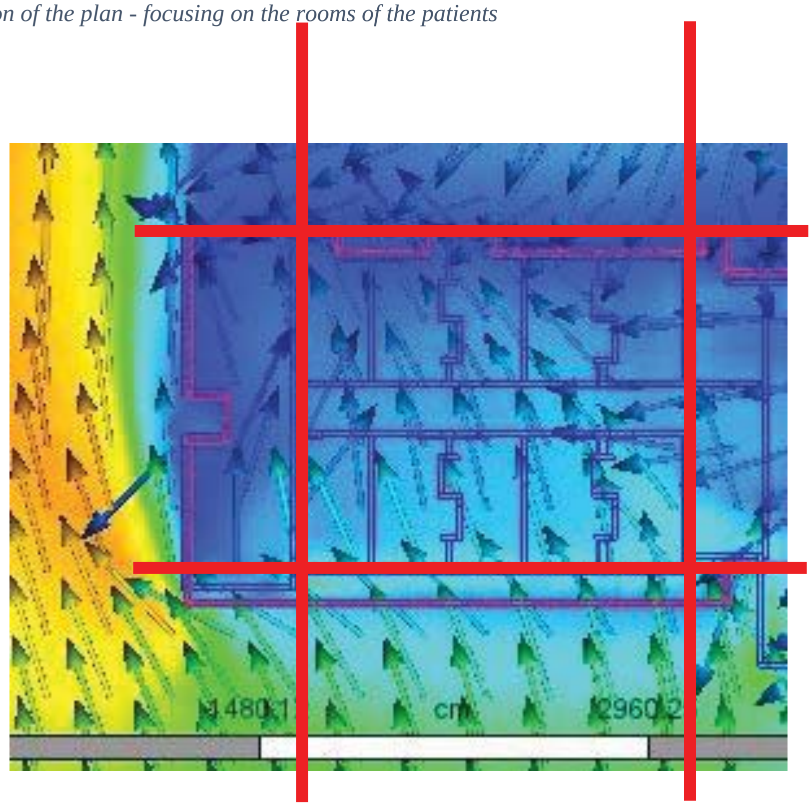


Figure 53: The wi

The vector X`

The wind penetrates the isolated part (between the red lines), through the openings with a speed that varies between 3 and 9 m/s according to the legend.

3.8.5 Conclusion _ Jeita Kesserwan

The Convent in Jeita being located on a 300 m above sea level, according to the wind rose the main wind direction comes from the West and East. When the data was inserted in the Computational Fluid Dynamics software CFD program, the results showed that the wind that enters through the buildings- especially the bedrooms of the patients- is low, to note that th doors of each bedroom (of the main corridor) are considered closed. So the main entry of the wind is from the openings of each bedroom.

The doors of the bedrooms were considered closed to minimize any transmission of the virus between the patients. Therefore, the bedroom with its own bathroom is considered isolated with the windows as the only way of wind penetration. To note that the doors are close also to forbid any transmission of the disease to the nuns living there.

3.9.1 Monastery of Ajaltoun

Figure 54: PDF ground floor of the convent in Ajaltoun

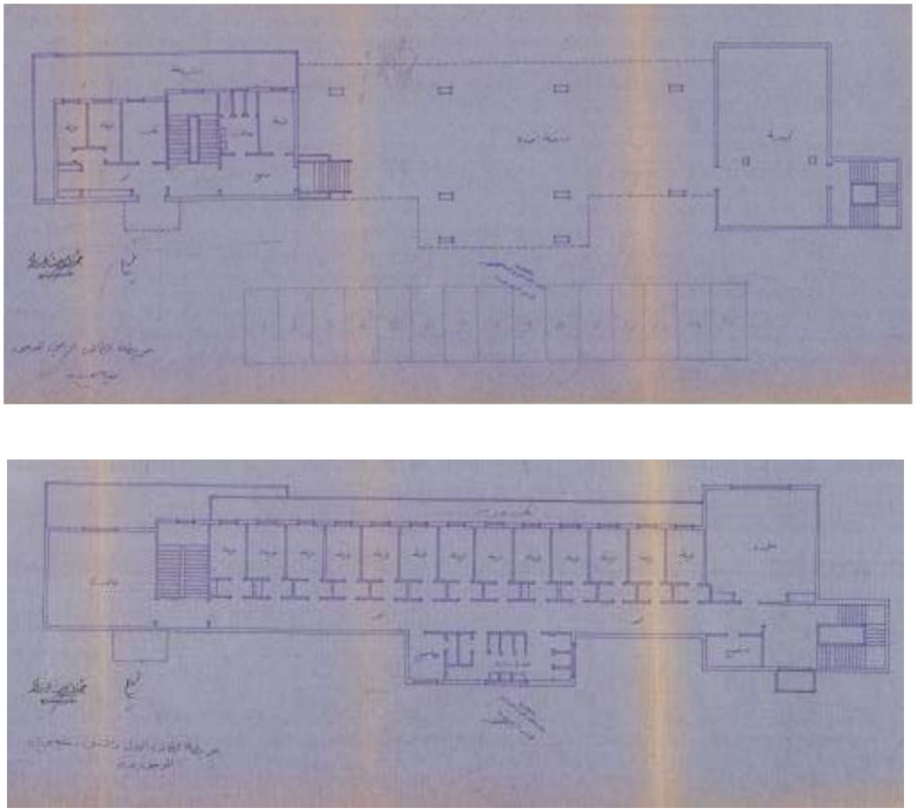


Figure 55: PDF first floor of the convent in Ajaltoun

Above are the maps provided from the municipality that drawn by hand, so the first step was drawing the 3D model of this monastery by using the program Revit Autodesk.

Figure 56: 3D view of the convent, by author

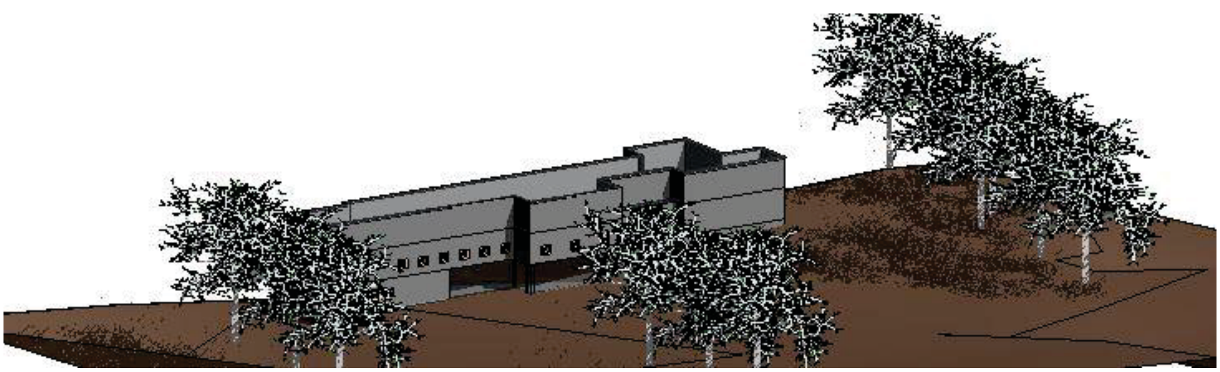


Figure 57: 3D view of the convent, by author

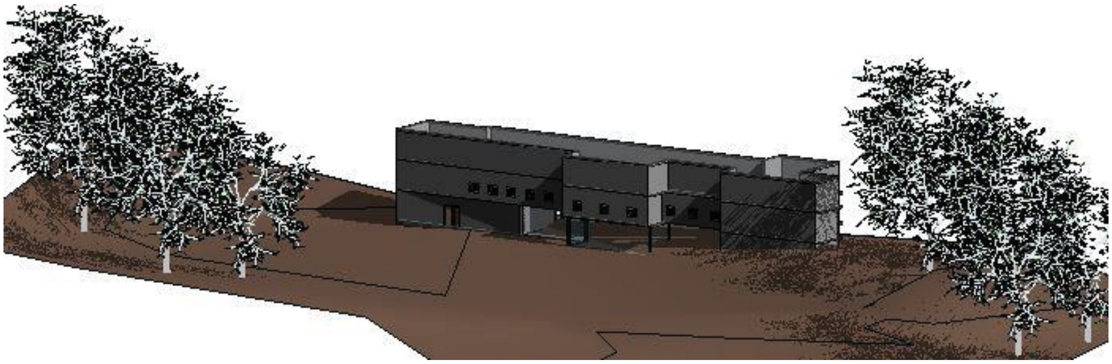
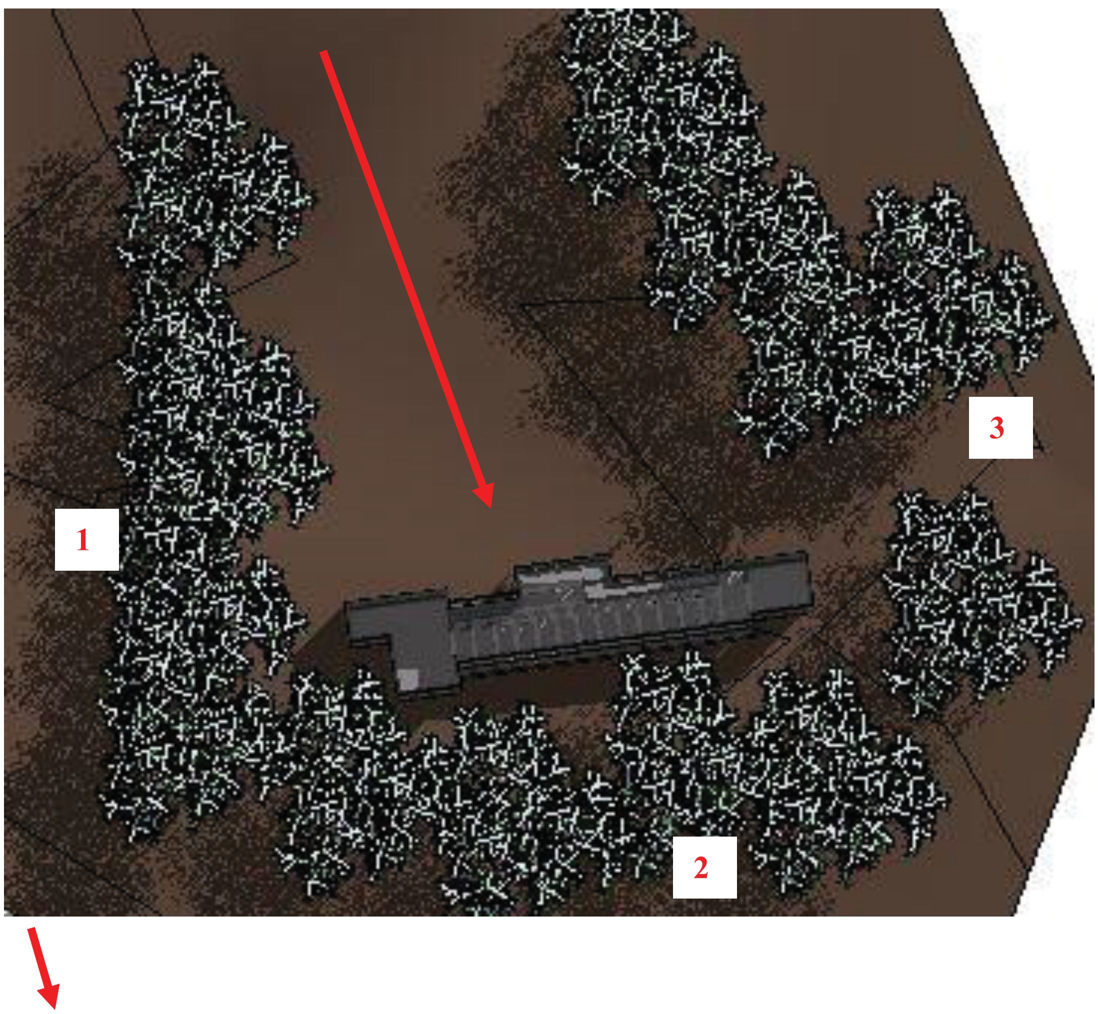


Figure 58: 3D view of the convent, by author



Ajaltoun, a town located in the Kesserwan District of the Mount Lebanon, is situated 24 km north of Beirut. It has as altitude 850 meters above sea level.

The convent of Mother of God, is located within the residential area of Ajaltoun, but has a private access (private road) with a large scale of green area surrounding it. The building has private rooms for the nuns, rooms for the people who would like to meditate, a church and a large hall for meetings.

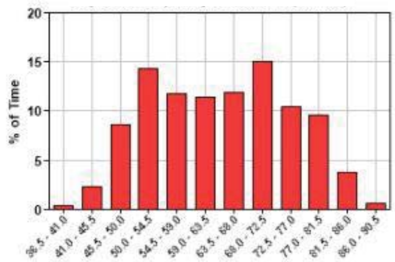
The first floor is designated to receive the patients of the Covid-19 from Ajaltoun in coordination with the municipality. The double bedrooms are revised to only receive one patients who will have access to a private bathroom. As for the balconies of each room are being separated by a glass frame to decrease the contamination between the patients. As for the whole floor, it is isolated by creating a door.

Figure 59: Vertical circulation in the building

Figure 60: Glass separation on the balconies of the bedroom

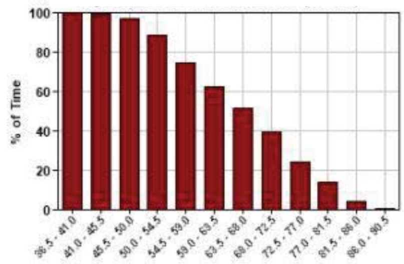
Before studying the ventilation in this building, I used the Green Building Studio (GBS), that shows the direction of the wind in this location.

Dry Bulb Frequency Distribution (Annual)

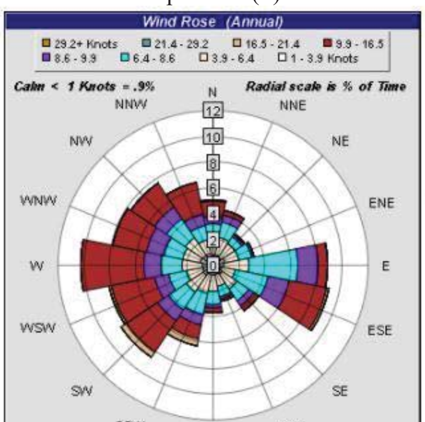


Temperature (F)

Dry Bulb Frequency Distribution (Annual)

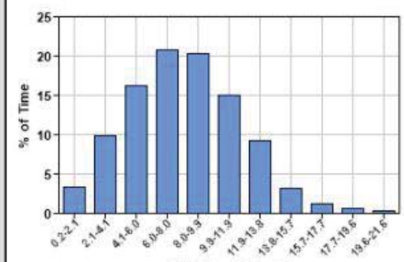


Temperature (F)

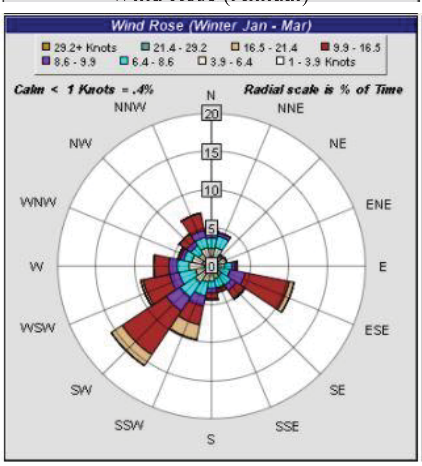


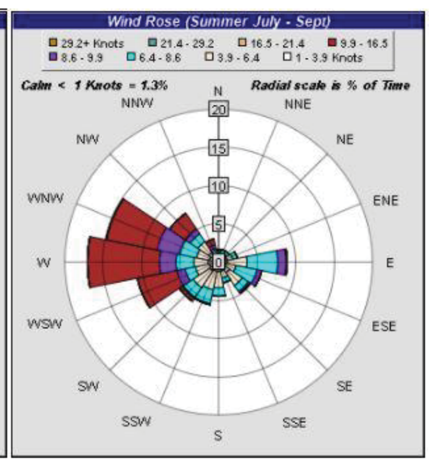
Wind Rose (Annual)

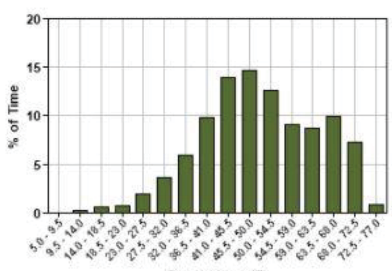
Wind Speed Frequency Distribution (Annual)



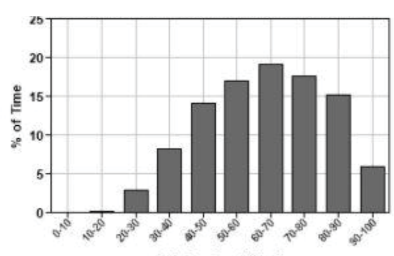
Wind Speed (Knots)







Dew Point Frequency Distribution (Annual)



Relative Humidity Frequency Distribution (Annual)

The wind rose, is an analysis taken from the GBS program that shows the direction of the wind in most of each year. After indicating the exact location of the convent in Ajaltoun, the wind rose indicates that the wind varies: west, west north and from the west south sides, and sometimes from the east side.

During the winter, the wind direction is mainly from the South West side, whereas during the summer the wind direction is from the West.

In brief, the main direction that the study will be based on is the West direction.

3.9.1.2 CFD program

3.9.1.2.1 Materials

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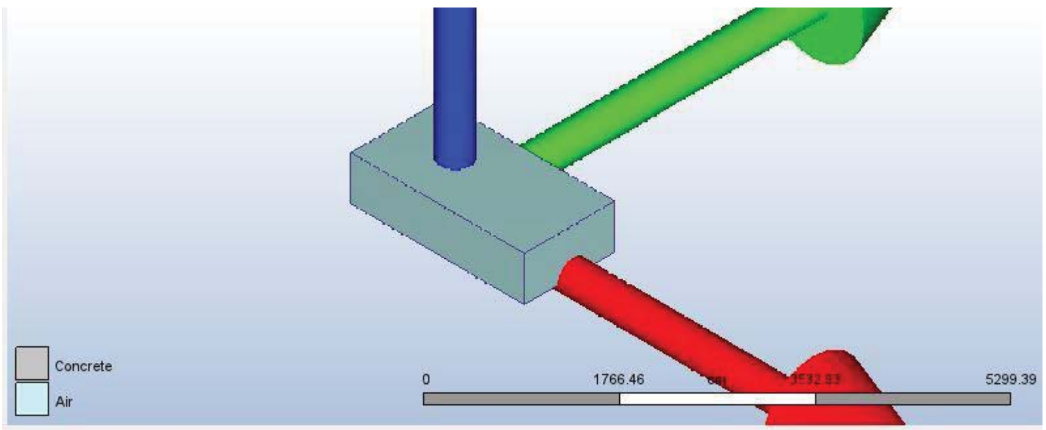


Figure 61: Air box surrounding the convent

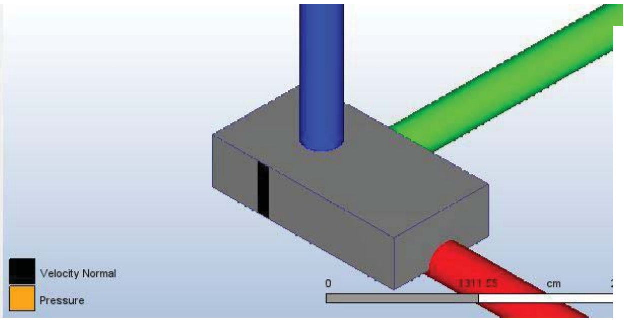
The box that envelops the building, has a fluid material representing the air in the region (blue rectangle).

The building has a solid material representing the concrete (gray color).

3.9.1.2.2 Boundaries

The second step is setting the boundaries of the air flow. It is represented by the pressure and the velocity of the wind.

According to the wind rose, the wind mostly comes from the West side, therefore the boundaries are set as follow: the pressure 0m/s will be set on the fluid box on the east side, and the velocity on the west side with 10m/s.



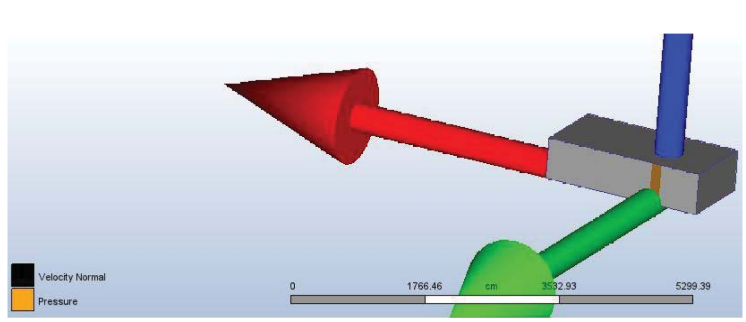


Figure 62: The velocity boundary on the air box

Figure 63: The pressure boundary on the air box

3.9.1.2.2 Mesh

Meshing command in the CFD program is a necessity, a mesh divides a geometry into many elements. These are used by the CFD solver to construct control volumes. And the result appears as blue small dots all along the surfaces of the rectangle air box and the model of the building.

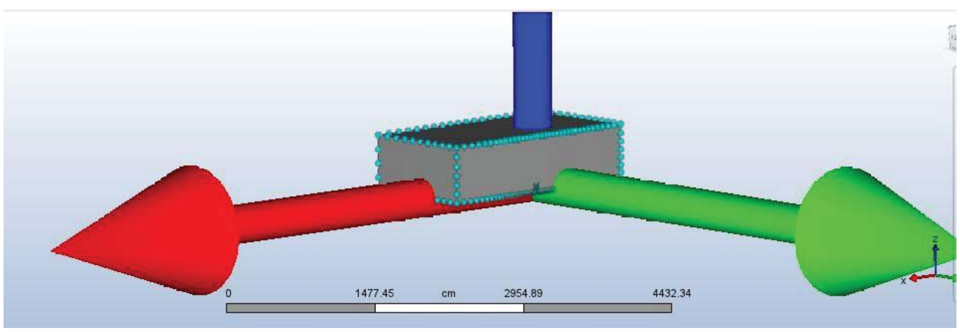


Figure 64: The auto sized mesh

3.9.1.2.2 Solve/ Results

This is the final step before the final results of the model.

The solve command will create a graph with iteration that I already set between 1 and 100, as the figure shows.

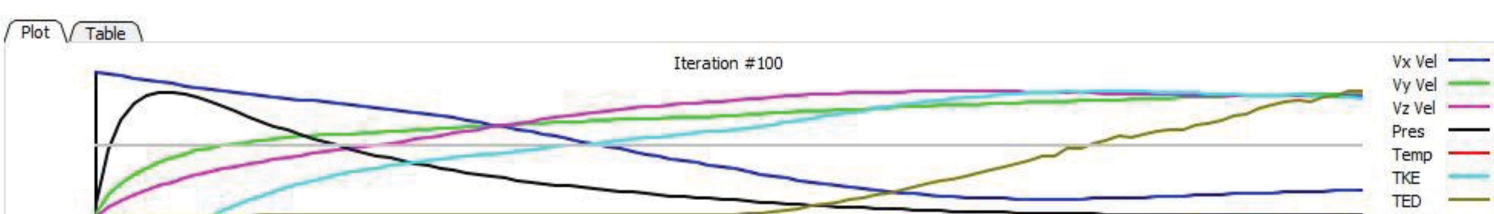
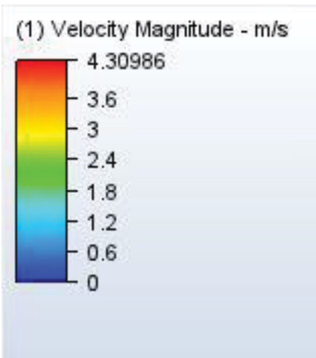


Figure 65: Graph showing the iteration of the velocity

The final results is seen by adding a plan on the model, with vectors that go along the XY axis.

Each color seen is defined by a certain velocity of the air that penetrates through the building.



The units are in m/s.

Figure 66: The velocity magnitude

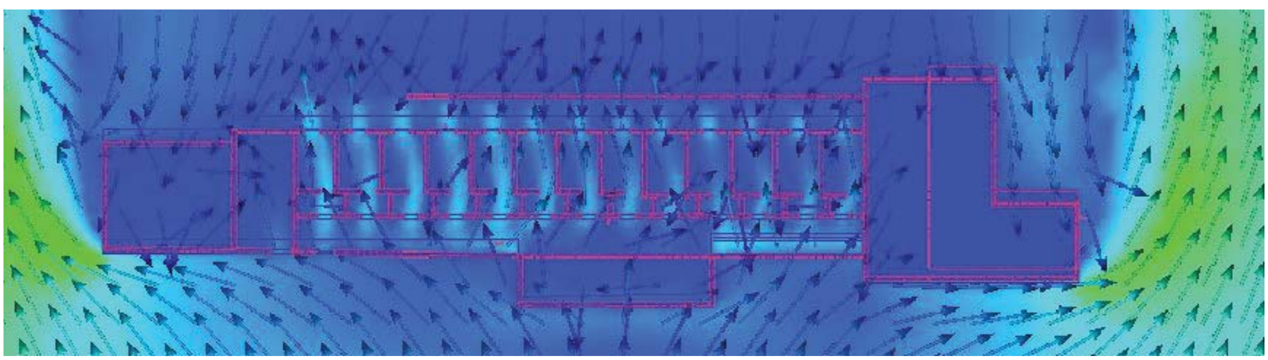


Figure 67: The wind direction and velocity in the convent

This figure shows the plan of the first floor designed to receive the patients of the Covid-19.

The vectors penetrating through the openings of the bedrooms, are in blue in color and differ in the concentration. Therefore, the velocity of the wind varies between 0.6 and 1.2 m/s.

3.9.2 Conclusion of the Convent in Ajaltoun

The convent in Ajaltoun is located ~ 600 m above sea level, on a hill with the wind direction coming mainly from two sides the East and the West. The convent contains seven nuns that mostly are old. The fear from getting infected from the virus was stopping the transformation of the convent for quarantine.

The part designated for the patients was isolated from the whole building.

The wind direction result taken after the analysis in the Computational Fluid Dynamics software CFD program show that the velocity of the wind in each bedroom of isolation is 0.6 and 1.2 m/s. Thus this result can be further developed to obtain a healthier environment for the patients.

4. Limitations of the empirical work

The empirical work was done during a critical phase in Lebanon, where there was the Covid-19 pandemic along an economic crisis, the explosion of the 4th of August in Beirut and the protests all over the country.

The data was given to me relying on being a student holding an identification card from the Notre Dame University _ Zouk Mosbeh.

4.1 Limitation of the convent in Jeita

There were some limitations while gaining access to the data. At first, the municipality remained closed for a long period of time due to the pandemic, so I got delayed with collecting the maps.

Moreover, the maps of the buildings were very old and were hand drawn, so I had to redraw them again. To note that there is a difference between the maps and the built convent (changes were done over the years without relying on any map).

Some changes were made while constructing this convent.

4.2 The buildings converted to quarantine

There were some issues at first by locating the buildings that can be converted to receive the patients. The ministry of health in Lebanon has no data regarding any building that can be possibly be used for quarantine, neither the Lebanese Red Cross that I tried to reach.

So I tried to reach different persons before contacting the federation of the municipalities in Kesserwan. After setting an appointment with an engineer in the federation, I was allowed access to the plan set during this pandemic that have different buildings ready to be used immediately when the number of cases increase and another set of buildings that require further maintenance and approval from the owners. To note that the municipalities in Kesserwan did not convert any public building for quarantine.

After further discussion with the federation of the municipalities, I had the mostly approved buildings that require nor or less changes and can be directly used by the patients in these areas.

4.3 Limitation of the convents of St John and Sainte Famille

There were no responses from neither the priest of St. John and the nun of Sainte Famille, even after reaching them many times. This problem resulted in eliminating these two convents from my analysis part of the thesis due to the lack of data and limiting it to two convents.

And being a private properties, the municipalities of Jounieh and Harissa were not allowed to give me access to any data without the approval of the owner or the responsible person during this period of time.

4.4 Limitation of the convent in Ajaltoun

The municipality has an old non updated map of the convent. I had to set a meeting with the municipality to overview the changes that were done during the years in the convent. To note that the maps are hand drawn and no digital data was found. Therefore, I was obliged to draw it according to the maps found in the municipality.

Due to the covid-19 outbreak in Lebanon, and the total lockdown set by the government an appointment with the nun was postponed several times. So after a certain amount of time I had the chance to visit and interview the nun while taking the required precautions.

5. Conclusion

In conclusion, the two convents of Jeita and Ajaltoun need to be compared to choose one convent for further analysis. This comparison will be done following the WHO and LEED guidelines regarding the Covid-19 virus and the ventilation in the closed areas.

The purpose of the methodology chapter is to obtain a relation between the sustainability of the spaces in the buildings with the health of the patients or even the staff of the healthcare systems, and following the sustainable health standards. Moreover, I will set the guidelines regarding the healthcare facilities that should be followed in the future while converting buildings in such pandemics.

4. Analysis

The chapter four of the thesis is an important chapter where the data will be analyzed in order to have the final results of the study. The data collected in the methodology part is going to be analyzed in this chapter.

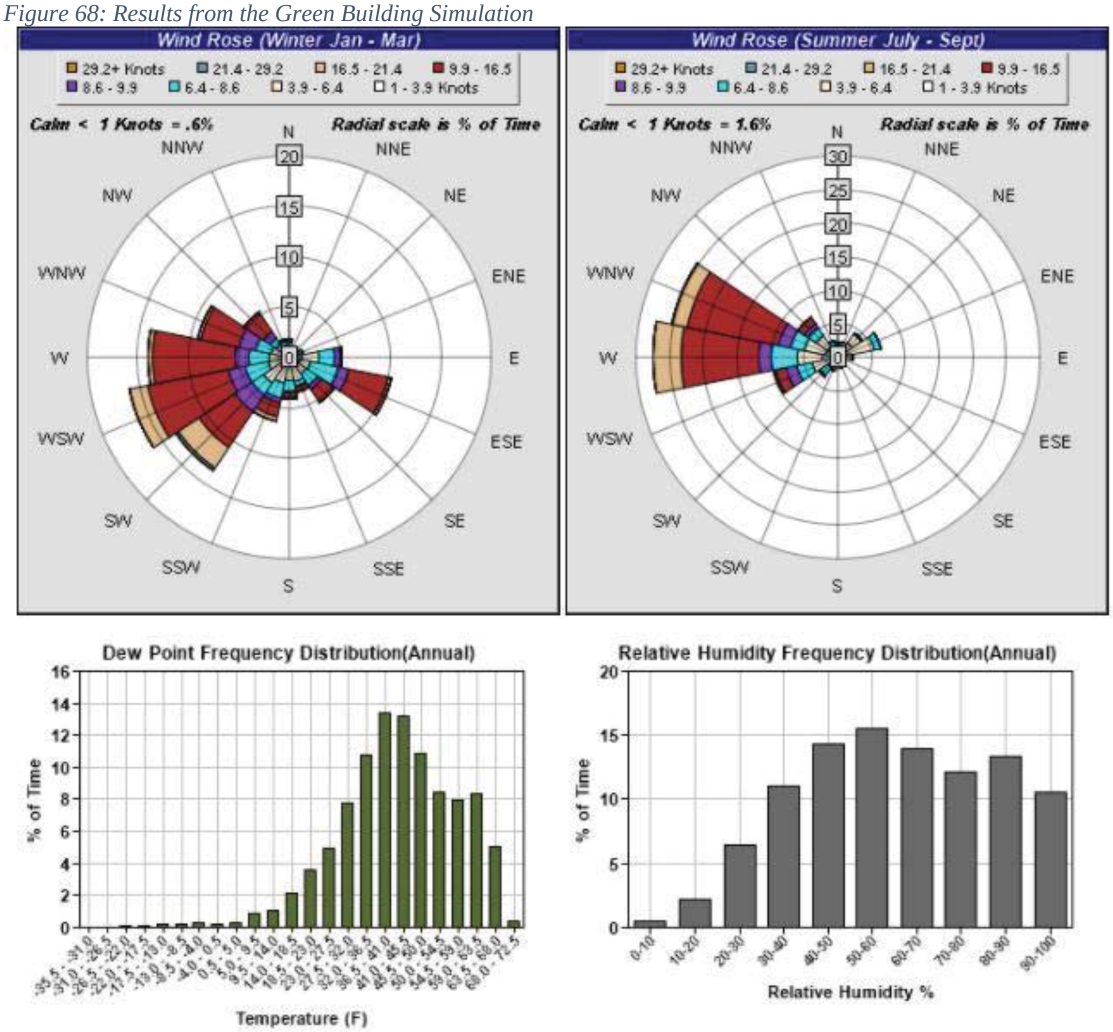
The analysis will be done on both the convent in Jeita and Ajaltoun, using the CFD software.

4.1 Analyzing different scenarios for the Convent in Jeita

The first convent is the Myrrophores Convent in Jeita- Kesserwan.

Step 1: Analyzing the ventilation of the rooms considered to be for quarantine using the CFD program.

Figure 68: Results from the Green Building Simulation



To note that this convent is not surrounded by any building, therefore there is no obstacles for the wind path that can create a shift in its direction or its velocity.

According to the Green Building Simulation (GBS), the wind rose through winter and summer enable us to know the most dominant wind direction with the velocity of the wind (knots).

1 knot is equal to 0.5 m/s.

In winter from January till March; the wind rose indicates that the west side wind is 15 % of the time, the east side wind is 8 to 10 % of the time, and the north side wind is barely visible nearly null 0%, and the south side wind is between 3 and 4% of the time. (Radial scale)

In summer from July till September; the wind rose indicates that the west side is 26 to 28 % of the time, the east side wind is approximately near 5 % of the time, the north side wind is barely visible nearly null 0 %, and the south side wind is approximately 3 % of the time. (Radial scale)

The dominant wind direction throughout the year is from the west. Never less, the analysis using the CFD program should be related to the four sides. Taking into consideration that the wind throughout the day can be null.

The case of the Myrrophores Convent in Jeita- Kesserwan, will be analyzed according to twelve cases. The wind will be analyzed according to the four initial sides (North- South- East and West) with different velocity of the wind; normal velocity 6 m/s, medium velocity 3 m/s and a null velocity 0 m/s.

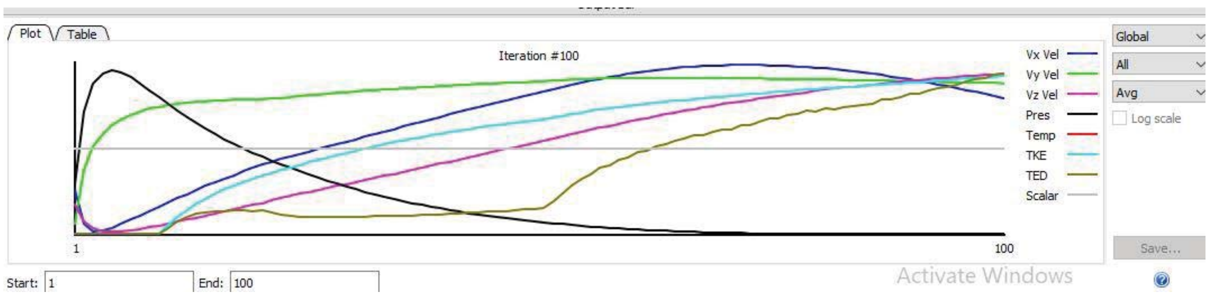
Velocity of the wind is 6 m/s

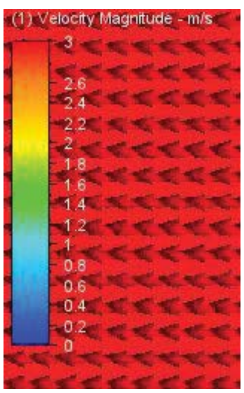
West Side

The first step in the CFD program, is to give each element of the building a specified material.

The blue box is created in Revit before using the CFD program. The blue box is the wind that envelops the building, thus it is given a fluid material, whereas the building’s materials are solid as in concrete.

The second step in CFD, is setting the boundaries, selecting the direction of the wind that is mostly common in the area. Based on the wind rose taken from the GBS program, the velocity is selected on the west with 6 m/s, and a pressure is set on the east side with 0 m/s. The pressure is seen as an orange rectangle and the pressure as a black rectangle on the fluid box. An auto sized mesh is created, represented by blue dotes on the fluid box. The graph has the iterations between 1 and 100 that will be seen on the model reflecting the velocity and the direction of the wind.





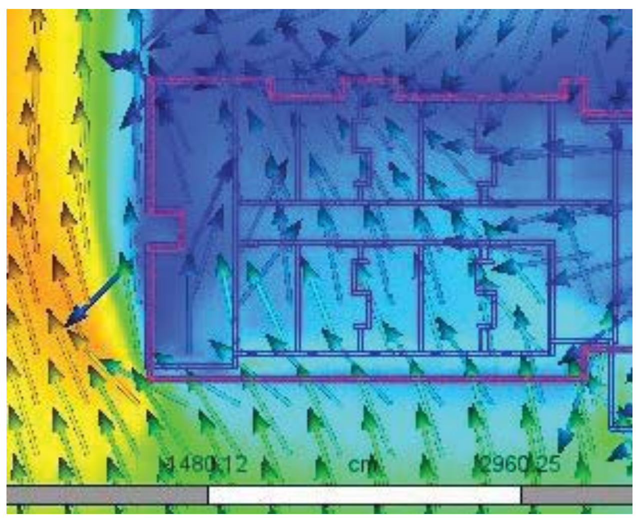


Figure 69: Plan of the ventilation in the rooms designated for quarantine

Figure 70: Plan with vectors indicating the direction of the wind

Figure 71: Velocity Magnitude

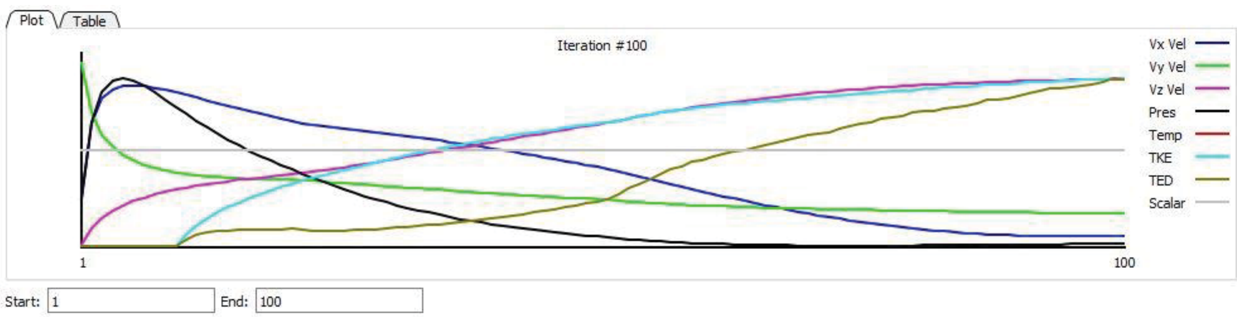
The wind velocity is 1.2 m/s.

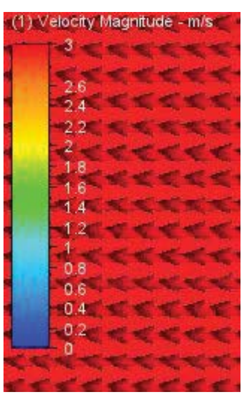
East Side

The first step in the CFD program, is to give each element of the building a specified material.

The blue box is created in Revit before using the CFD program. The blue box is the wind that envelops the building, thus it is given a fluid material, whereas the building's materials are solid as in concrete.

The second step in CFD, is setting the boundaries, selecting the direction of the wind that is mostly common in the area. Based on the wind rose taken from the GBS program, the velocity is selected on the west with 6 m/s, and a pressure is set on the east side with 0 m/s. The pressure is seen as an orange rectangle and the pressure as a black rectangle on the fluid box. An auto sized mesh is created, represented by blue dotes on the fluid box. The graph has the iterations between 1 and 100 that will be seen on the model reflecting the velocity and the direction of the wind.





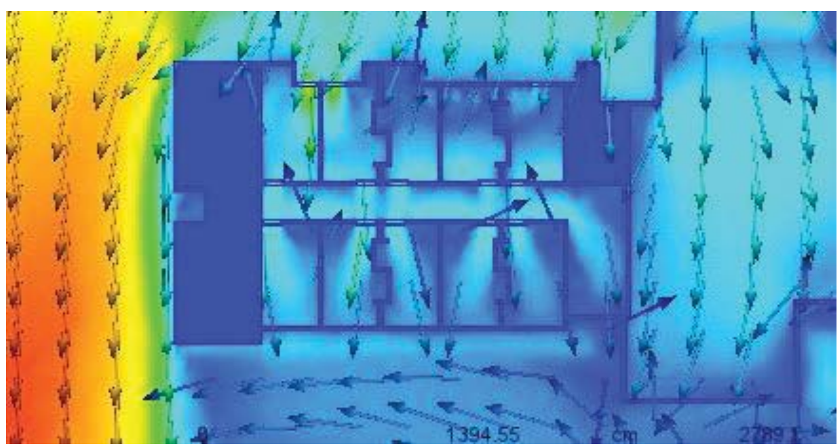


Figure 72: The resulted graph from the CFD

Figure 73: Plan showing the vectors and the velocity of the wind

Figure 74: Velocity magnitude

The wind velocity is 0.8 m/s.

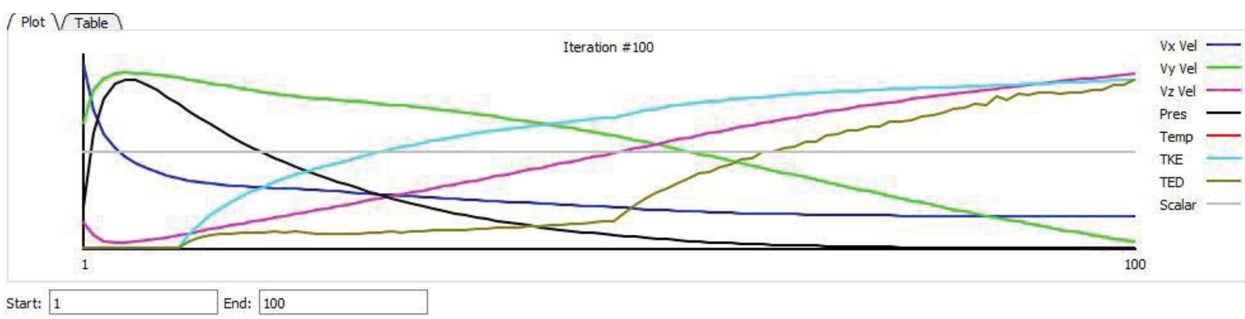
North Side

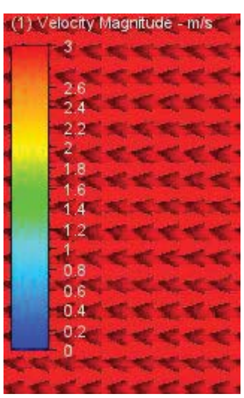
From the north side, according to the wind rose, the velocity of the wind does not reach 6 m/s, so it has a calm atmosphere from this side approximately 0.5 m/s (maximum).

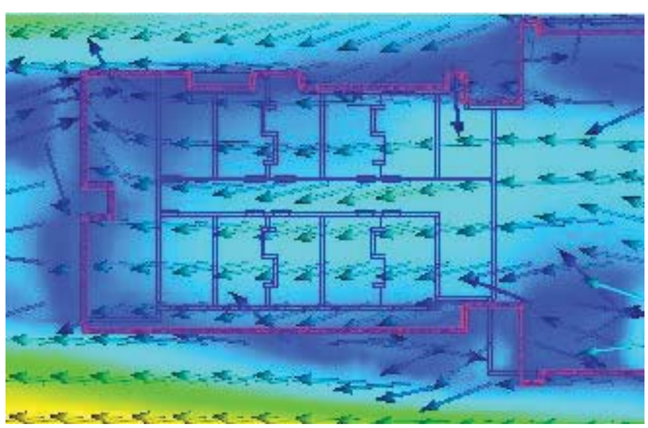
South Side

The first step in the CFD program, is to give each element of the building a specified material.

The blue box is created in Revit before using the CFD program. The blue box is the wind that envelops the building, thus it is given a fluid material, whereas the building's materials are solid as in concrete. The second step in CFD, is setting the boundaries, selecting the direction of the wind that is mostly common in the area. Based on the wind rose taken from the GBS program, the velocity is selected on the west with 6 m/s, and a pressure is set on the east side with 0 m/s. The pressure is seen as an orange rectangle and the pressure as a black rectangle on the fluid box. An auto sized mesh is created, represented by blue dotes on the fluid box. The graph has the iterations between 1 and 100 that will be seen on the model reflecting the velocity and the direction of the wind.







The wind velocity is 1 m/s

Figure 75: The resulted graph from the CFD

Figure 76: Plan showing the vectors and the velocity of the wind

Figure 77: The velocity magnitude

Velocity of the wind is 3 m/s

Same steps will be followed using the computation fluid dynamics (CFD) program to obtain the results of the ventilation in the building.

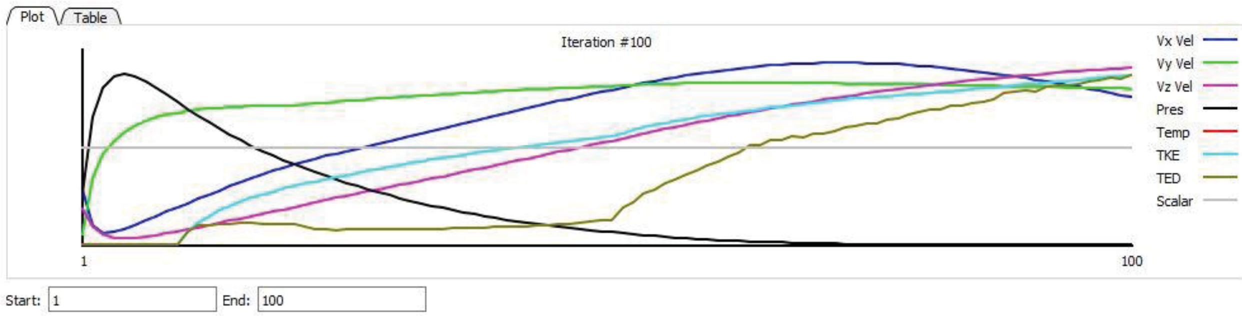
West Side

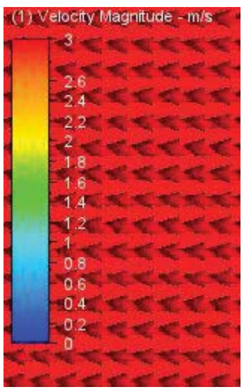
The results of the west side ventilation is illustrated in the below figures;

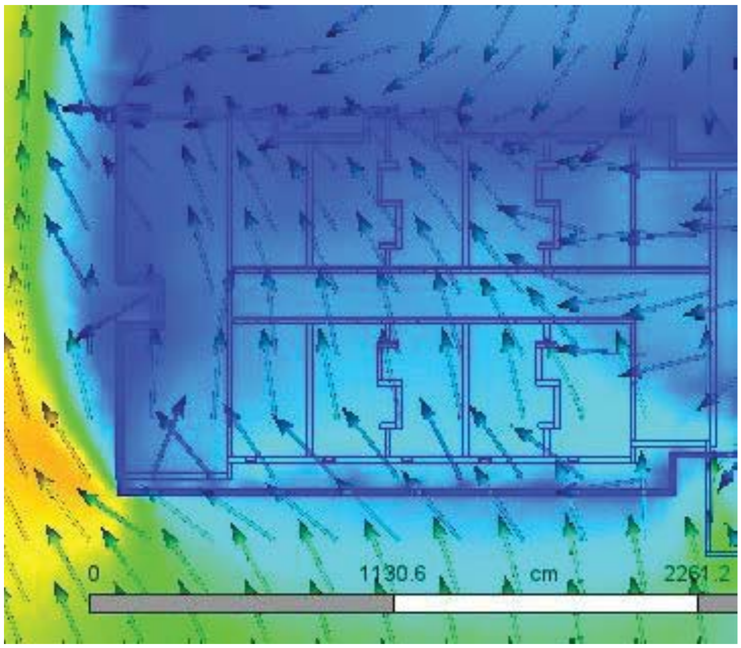
The first step in the CFD program, is to give each element of the building a specified material.

The blue box is created in Revit before using the CFD program. The blue box is the wind that envelops the building, thus it is given a fluid material, whereas the building's materials are solid as in concrete.

The second step in CFD, is setting the boundaries, selecting the direction of the wind that is mostly common in the area. Based on the wind rose taken from the GBS program, the velocity is selected on the west with 6 m/s, and a pressure is set on the east side with 0 m/s. The pressure is seen as an orange rectangle and the pressure as a black rectangle on the fluid box. An auto sized mesh is created, represented by blue dotes on the fluid box. The graph has the iterations between 1 and 100 that will be seen on the model reflecting the velocity and the direction of the wind.







The wind velocity is between 0.4 and 0.8 m/s.

Figure 78: The resulted graph from the CFD

Figure 79: Plan showing the vectors and the velocity of the wind

Figure 80: The velocity magnitude

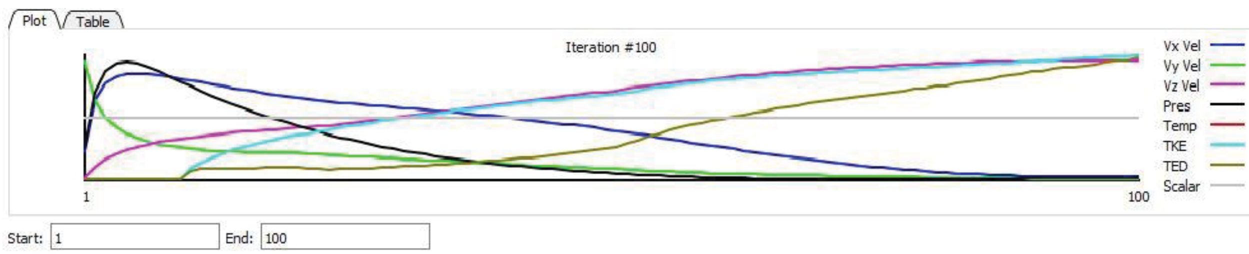
East side:

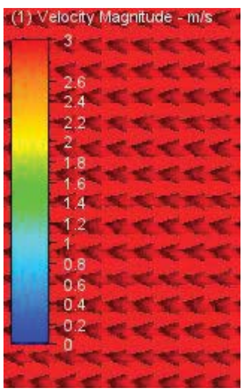
The first step in the CFD program, is to give each element of the building a specified material.

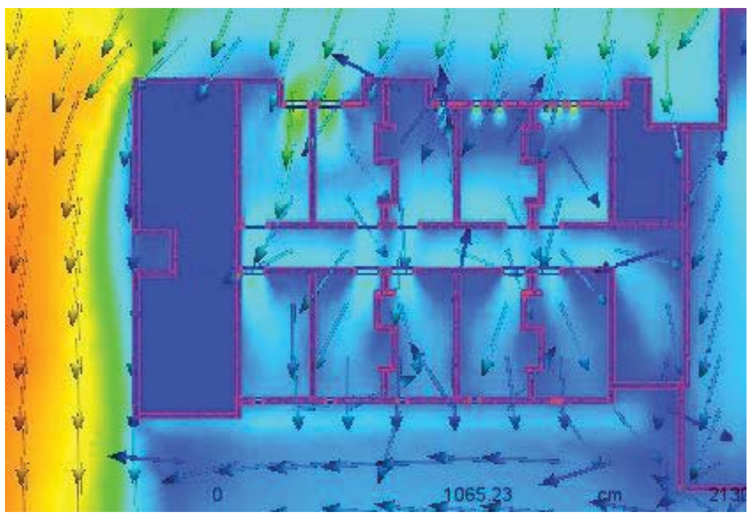
The blue box is created in Revit before using the CFD program. The blue box is the wind that envelops the building, thus it is given a fluid material, whereas the building's materials are solid as in concrete.

The second step in CFD, is setting the boundaries, selecting the direction of the wind that is mostly common in the area. Based on the wind rose taken from the GBS program, the velocity is selected on the west with 6 m/s, and a pressure is set on the east side with 0 m/s. The pressure is seen as an orange rectangle and the pressure as a black rectangle on the fluid box. An auto sized mesh is created, represented by blue dotes on the fluid box. The graph has the iterations between 1 and 100 that will be seen on the model reflecting the velocity and the direction of the wind.

The results of the east side ventilation is illustrated in the below figures







The wind velocity is 1 m/s

Figure 81: The resulted graph from the CFD

Figure 82: Plan showing the vectors and the velocity of the wind

Figure 83: The velocity magnitude

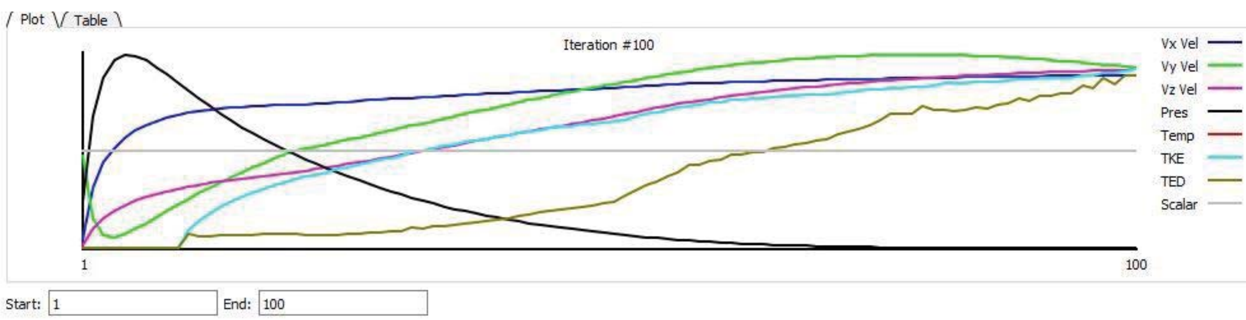
North side:

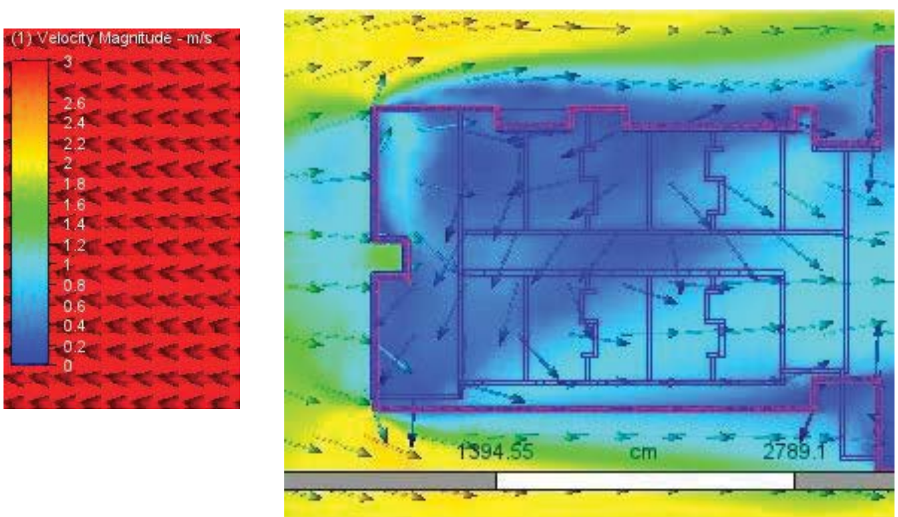
The first step in the CFD program, is to give each element of the building a specified material.

The blue box is created in Revit before using the CFD program. The blue box is the wind that envelops the building, thus it is given a fluid material, whereas the building's materials are solid as in concrete.

The second step in CFD, is setting the boundaries, selecting the direction of the wind that is mostly common in the area. Based on the wind rose taken from the GBS program, the velocity is selected on the west with 6 m/s, and a pressure is set on the east side with 0 m/s. The pressure is seen as an orange rectangle and the pressure as a black rectangle on the fluid box. An auto sized mesh is created, represented by blue dotes on the fluid box. The graph has the iterations between 1 and 100 that will be seen on the model reflecting the velocity and the direction of the wind.

The results of the north side ventilation is illustrated in the below figures;





The wind velocity is 0.2 m/s

Figure 84: The resulted graph from the CFD

Figure 85: Plan showing the vectors and the velocity of the wind

Figure 86: The velocity magnitude

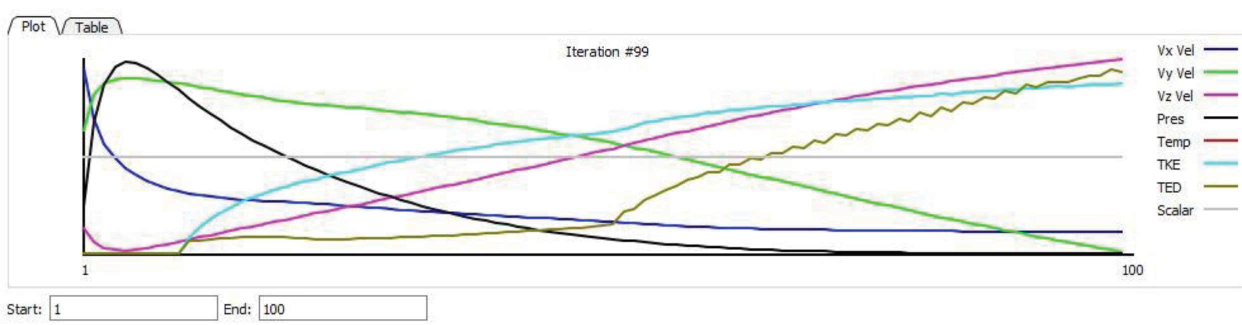
South side:

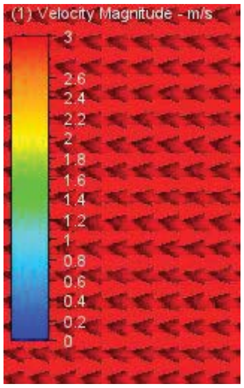
The first step in the CFD program, is to give each element of the building a specified material.

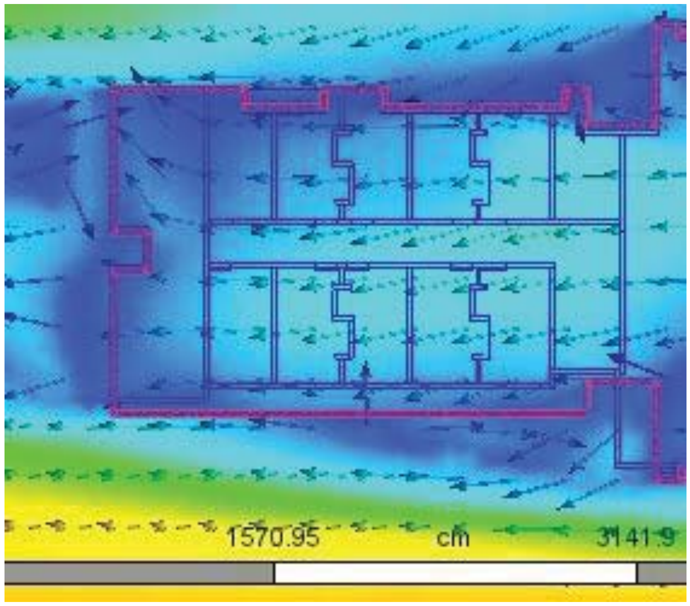
The blue box is created in Revit before using the CFD program. The blue box is the wind that envelops the building, thus it is given a fluid material, whereas the building's materials are solid as in concrete.

The second step in CFD, is setting the boundaries, selecting the direction of the wind that is mostly common in the area. Based on the wind rose taken from the GBS program, the velocity is selected on the west with 6 m/s, and a pressure is set on the east side with 0 m/s. The pressure is seen as an orange rectangle and the pressure as a black rectangle on the fluid box. An auto sized mesh is created, represented by blue dotes on the fluid box. The graph has the iterations between 1 and 100 that will be seen on the model reflecting the velocity and the direction of the wind.

The results of the south side ventilation is illustrated in the below figures;







The wind velocity is 0.15 m/s

Figure 87: The resulted graph from the CFD

Figure 88: Plan showing the vectors and the velocity of the wind

Figure 89: The velocity magnitude

Velocity of the wind is 0 m/s

A velocity of 0 m/s should be taken into consideration, it might be the case through a day.

Below in the table that includes all the cases, to be compared later;

	North	South	East	West
Velocity 6 m/s	0.5 m/s	1 m/s	0.8 m/s	1.2 m/s
Velocity 3 m/s	0.2 m/s	0.15 m/s	1 m/s	0.4 – 0.8 m/s
Velocity 0 m/s	0	0	0	0

Table 3: The velocity of the wind for the 12 cases

Step 2: Ventilation rate calculation

According to the World Health Organization WHO (2020), regarding the spread of the Covid-19:

"Owners and building managers should consider evaluating their building systems to check that they are operating in proper order (per design or current operational strategies), are capable of being modified to align with HVAC mitigation strategies, and to identify deficiencies that should be repaired. Several recommendations should be considered in consultation with HVAC professionals", stated by WHO (2020, p. 16).

The minimum ventilation rate / natural ventilation system is estimated following a specific formula. As a rule of thumb, wind-driven natural ventilation rate through a room can be calculated as follows:

Ventilation rate [L/s] = k x wind speed [m/s] x smallest opening area [m2] x 1000 [L/m3]

k = 0.05 in the case of single-sided ventilation

k = 0.65 in the case of cross ventilation

K in the case of mosquito net presence = ventilation rate x 0.5

Whereas the minimum recommended ventilation rate in a room for one person in a non-residential setting is equal to 10 L/s.

In the case of the rooms in the convent in Jeita- Kesserwan, the formula will be applied regarding the 12 cases.

The K in the formula will be considered equal 0.05 because it is the case of a single- sided ventilation, and the result will later on be multiplied by 0.5 because each opening of the room has a mosquito net.

In the case of the velocity considered 6 m/s;

North side:

Ventilation rate [L/s] = k x wind speed [m/s] x smallest opening area [m2] x 1000 [L/m3]

Ventilation rate [L/s] = 0.05 x 0.5 x (0.5 x 2.1) x 1000

Ventilation rate [L/s] = 26.25 L/s

K in the case of mosquito net presence = ventilation rate x 0.5

- ➔ 26.25 x 0.5 = 13.12 L/s in a room

Each room in the convent of Jeita can have 2 persons for quarantine, therefore the result will be divided by 2 to obtain the ventilation rate for a 1 person.

Ventilation rate [L/s] is divided by 2 = 13.12 / 2 = 6.56 L/s

The ventilation rate from the north side 6.56 L/s is smaller than 10 L/s which is the minimum recommendation. Other alternatives should be added to obtain a healthy environment.

South side:

Ventilation rate [L/s] = k x wind speed [m/s] x smallest opening area [m2] x 1000 [L/m3]

Ventilation rate [L/s] = 0.05 x 1 x (0.5 x 2.1) x 1000

Ventilation rate [L/s] = 52.5 L/s

K in the case of mosquito net presence = ventilation rate x 0.5

➔ 52.5 x 0.5 = 26.25 L/s in a room

Each room in the convent of Jeita can have 2 persons for quarantine, therefore the result will be divided by 2 to obtain the ventilation rate for a 1 person.

Ventilation rate [L/s] is divided by 2 = 26.25 / 2 = 13.12 L/s

The ventilation rate from the north side 13.12 L/s is larger than 10 L/s which is the minimum recommendation. The rooms have a healthy indoor air quality from this side.

East side:

Ventilation rate [L/s] = k x wind speed [m/s] x smallest opening area [m2] x 1000 [L/m3]

Ventilation rate [L/s] = 0.05 x 0.8 x (0.5 x 2.1) x 1000

Ventilation rate [L/s] = 42 L/s

K in the case of mosquito net presence = ventilation rate x 0.5

➔ 42 x 0.5 = 21 L/s in a room

Each room in the convent of Jeita can have 2 persons for quarantine, therefore the result will be divided by 2 to obtain the ventilation rate for a 1 person.

Ventilation rate [L/s] is divided by 2 = 21 / 2 = 10.5 L/s

The ventilation rate from the east side 10.5 L/s is larger than 10 L/s which is the minimum recommendation. The rooms have a healthy indoor air quality from this side.

West side:

Ventilation rate [L/s] = k x wind speed [m/s] x smallest opening area [m2] x 1000 [L/m3]

Ventilation rate [L/s] = 0.05 x 1.2 x (0.5 x 2.1) x 1000

Ventilation rate [L/s] = 63 L/s

K in the case of mosquito net presence = ventilation rate x 0.5

➔ 63 x 0.5 = 31.5 L/s in a room

Each room in the convent of Jeita can have 2 persons for quarantine, therefore the result will be divided by 2 to obtain the ventilation rate for a 1 person.

Ventilation rate [L/s] is divided by 2 = 31.5 / 2 = 15.75 L/s

The ventilation rate from the east side 15.75 L/s is larger than 10 L/s which is the minimum recommendation. The rooms have a healthy indoor air quality from this side.

In the case of the velocity considered 3 m/s;

North side:

Ventilation rate [L/s] = k x wind speed [m/s] x smallest opening area [m2] x 1000 [L/m3]

Ventilation rate [L/s] = 0.05 x 0.2 x (0.5 x 2.1) x 1000

Ventilation rate [L/s] = 10.5 L/s

K in the case of mosquito net presence = ventilation rate x 0.5

➔ 10.5 x 0.5 = 2.1 L/s in a room

Each room in the convent of Jeita can have 2 persons for quarantine, therefore the result will be divided by 2 to obtain the ventilation rate for a 1 person.

Ventilation rate [L/s] is divided by 2 = 2.1 / 2 = 1.05 L/s

The ventilation rate from the north side 1.05 L/s is smaller than 10 L/s which is the minimum recommendation. Other alternatives should be added to obtain a healthy environment.

South side:

Ventilation rate [L/s] = k x wind speed [m/s] x smallest opening area [m2] x 1000 [L/m3]

Ventilation rate [L/s] = 0.05 x 0.15 x (0.5 x 2.1) x 1000

Ventilation rate [L/s] = 7.87 L/s

K in the case of mosquito net presence = ventilation rate x 0.5

➔ 7.87 x 0.5 = 4 L/s in a room

Each room in the convent of Jeita can have 2 persons for quarantine, therefore the result will be divided by 2 to obtain the ventilation rate for a 1 person.

Ventilation rate [L/s] is divided by 2 = 4 / 2 = 2 L/s

The ventilation rate from the north side 2 L/s is smaller than 10 L/s which is the minimum recommendation. Other alternatives should be added to obtain a healthy environment

East side:

Ventilation rate [L/s] = k x wind speed [m/s] x smallest opening area [m2] x 1000 [L/m3]

Ventilation rate [L/s] = 0.05 x 1 x (0.5 x 2.1) x 1000

Ventilation rate [L/s] = 52.5 L/s

K in the case of mosquito net presence = ventilation rate x 0.5

➔ 52.5 x 0.5 = 26.25 L/s in a room

Each room in the convent of Jeita can have 2 persons for quarantine, therefore the result will be divided by 2 to obtain the ventilation rate for a 1 person.

Ventilation rate [L/s] is divided by 2 = 26.25 / 2 = 13.12 L/s

The ventilation rate from the north side 13.12 L/s is larger than 10 L/s which is the minimum recommendation. The rooms have a healthy indoor air quality from this side.

West side:

Ventilation rate [L/s] = k x wind speed [m/s] x smallest opening area [m2] x 1000 [L/m3]

Ventilation rate [L/s] = 0.05 x 0.8 x (0.5 x 2.1) x 1000

Ventilation rate [L/s] = 42 L/s

K in the case of mosquito net presence = ventilation rate x 0.5

➔ 42 x 0.5 = 21 L/s in a room

Each room in the convent of Jeita can have 2 persons for quarantine, therefore the result will be divided by 2 to obtain the ventilation rate for a 1 person.

Ventilation rate [L/s] is divided by 2 = 21 / 2 = 10.5 L/s

The ventilation rate from the north side 10.5 L/s is larger than 10 L/s which is the minimum recommendation. The rooms have a healthy indoor air quality from this side.

In the case of the velocity considered 0 m/s;

North side:

Ventilation rate [L/s] = k x wind speed [m/s] x smallest opening area [m2] x 1000 [L/m3]

Ventilation rate [L/s] = 0.05 x 0 x (0.5 x 2.1) x 1000

Ventilation rate [L/s] = 0 L/s

K in the case of mosquito net presence = ventilation rate x 0.5

➔ 0 x 0.5 = 0 L/s in a room

Each room in the convent of Jeita can have 2 persons for quarantine, therefore the result will be divided by 2 to obtain the ventilation rate for a 1 person.

Ventilation rate [L/s] is divided by 2 = 0 / 2 = 0 L/s

The ventilation rate from the north side 0 L/s is smaller than 10 L/s which is the minimum recommendation. Other alternatives should be added to obtain a healthy environment.

South side:

Ventilation rate [L/s] = k x wind speed [m/s] x smallest opening area [m2] x 1000 [L/m3]

Ventilation rate [L/s] = 0.05 x 0 x (0.5 x 2.1) x 1000

Ventilation rate [L/s] = 0 L/s

K in the case of mosquito net presence = ventilation rate x 0.5

➔ 0 x 0.5 = 0 L/s in a room

Each room in the convent of Jeita can have 2 persons for quarantine, therefore the result will be divided by 2 to obtain the ventilation rate for a 1 person.

Ventilation rate [L/s] is divided by 2 = 0 / 2 = 0 L/s

The ventilation rate from the north side 0 L/s is smaller than 10 L/s which is the minimum recommendation. Other alternatives should be added to obtain a healthy environment.

East side:

Ventilation rate [L/s] = k x wind speed [m/s] x smallest opening area [m2] x 1000 [L/m3]

Ventilation rate [L/s] = 0.05 x 0 x (0.5 x 2.1) x 1000

Ventilation rate [L/s] = 0 L/s

K in the case of mosquito net presence = ventilation rate x 0.5

➔ 0 x 0.5 = 0 L/s in a room

Each room in the convent of Jeita can have 2 persons for quarantine, therefore the result will be divided by 2 to obtain the ventilation rate for a 1 person.

Ventilation rate [L/s] is divided by 2 = 0 / 2 = 0 L/s

The ventilation rate from the north side 0 L/s is smaller than 10 L/s which is the minimum recommendation. Other alternatives should be added to obtain a healthy environment.

West side:

Ventilation rate [L/s] = k x wind speed [m/s] x smallest opening area [m2] x 1000 [L/m3]

Ventilation rate [L/s] = 0.05 x 0 x (0.5 x 2.1) x 1000

Ventilation rate [L/s] = 0 L/s

K in the case of mosquito net presence = ventilation rate x 0.5

➔ 0 x 0.5 = 0 L/s in a room

Each room in the convent of Jeita can have 2 persons for quarantine, therefore the result will be divided by 2 to obtain the ventilation rate for a 1 person.

Ventilation rate [L/s] is divided by 2 = 0 / 2 = 0 L/s

The ventilation rate from the north side 0 L/s is smaller than 10 L/s which is the minimum recommendation. Other alternatives should be added to obtain a healthy environment.

Below is the table that contains the results of the convent regarding the ventilation rate:

Ventilation L/s Ventilation m/s	North Side	South Side	East Side	West Side
6 m/s	6.56 L/s For one person	13.12 L/s For one person	10.5 L/s For one person	15.75 L/s For one person
3 m/s	1.05 L/s For one person	2 L/s For one person	13.12 L/s For one person	10.5 L/s For one person
0 m/s	0 L/s For one person	0 L/s For one person	0 L/s For one person	0 L/s For one person

Table 4: The ventilation rate results according to the formula

Step 3: Analysis of the Cinvent in Jeita

The convent of the Myrrophores Convent in Jeita- Kesserwan was analyzed according to three cases of ventilation in reference to the wind rose. The 6 m/s, 3 m/s, and 0 m/s ventilation gave 12 different cases.

The results are divided into two categories: the results that are larger than 10 L/s do not require an additional of mechanical ventilation, and the results that are smaller than 10 L/s do require an additional tool of ventilation for a healthy ventilation.

According to the road map for the spread of the Covid-19 in the years 2020 and 2021 put by the World Health Organization (WHO), the non- residential building that are used for quarantine require a 10 L/s ventilation rate for one person in a room. If the ventilation rate is smaller than 10 L/s, the room requires the use of a mechanical ventilation.

➔ If the ventilation rate is smaller than 10 L/s:

To increase the ventilation in a room; the use of a pedestal fan that should be closed to an opening. The use of air extractors, and to consider using a stand-alone air cleaner with MERV 14 / ISO ePM1 70-80% filter.

"The air cleaner should be positioned in the areas used by people and close to people. Air cleaner capacity should at least cover the gap between the minimum requirement and the measured ventilation rate – compare the device clean air delivery rate (CADR) (m^3/hr) with the room ventilation rate. Note: Consider that filtered recirculated air does not replace ventilation in any circumstance." (American Society of Heating, Refrigerating and Air-Conditioning Engineers; 2020).

	Smaller than 10 L/s	Larger than 10 L/s
North Side	6.56 L/s, 1.05 L/s, 0 L/s	No results
South Side	2 L/s , 0 L/s	13.12 L/s
East Side	0 L/s	10.5 L/s , 13.12 L/s
West Side	0 L/s	15.75 L/s , 10.5 L/s

Table 5: The comparison between the ventilation rate results

The table above is divided into two parts, it includes the final results of the ventilation rate obtained. It will help in the calculation of additional mechanical ventilation when the results are smaller than 10 L/s for one person in a room.

Each case will be analyzed to obtain the percentage of the time that mechanical ventilation is needed to obtain a healthy indoor environment.

North side

. If the velocity is 6 m/s; the ventilation rate in the room is 6.56 L/s

- ➔ Therefore, the ventilation in the rom has 65.6% of natural ventilation and requires 34.4 % of support from the mechanical ventilation.

. If the velocity is 3 m/s; the ventilation rate in the room is 1.05 L/s

- ➔ Therefore, the ventilation in the room has 10.5% of natural ventilation and requires 89.5% support from the mechanical ventilation.

. If the velocity is 0 m/s; the ventilation rate in the room is 0 L/s

- ➔ Therefore, the room requires support from the mechanical ventilation.

South side

. If the velocity is 6 m/s; the ventilation rate in the room is 13.12 L/s

- ➔ Therefore, the ventilation in the rom has the minimum requirements of the required ventilation for a healthy environment; 100 %.

. If the velocity is 3 m/s; the ventilation rate in the room is 2 L/s

- ➔ Therefore, the ventilation in the room has 20% of natural ventilation and requires 80% support from the mechanical ventilation.

. If the velocity is 0 m/s; the ventilation rate in the room is 0 L/s

à Therefore, the room requires support from the mechanical ventilation.

East side

. If the velocity is 6 m/s; the ventilation rate in the room is 10.5 L/s

- ➔ Therefore, the ventilation in the rom has the minimum requirements of the required ventilation for a healthy environment; 100 %.

. If the velocity is 3 m/s; the ventilation rate in the room is 13.12 L/s

- ➔ Therefore, the ventilation in the rom has the minimum requirements of the required ventilation for a healthy environment; 100 %.

. If the velocity is 0 m/s; the ventilation rate in the room is 0 L/s

- ➔ Therefore, the room requires support from the mechanical ventilation

West side

. If the velocity is 6 m/s; the ventilation rate in the room is 15.75 L/s

- ➔ Therefore, the ventilation in the rom has the minimum requirements of the required ventilation for a healthy environment; 100 %.

. If the velocity is 3 m/s; the ventilation rate in the room is 10.5 L/s

- ➔ Therefore, the ventilation in the rom has the minimum requirements of the required ventilation for a healthy environment; 100 %.

. If the velocity is 0 m/s; the ventilation rate in the room is 0 L/s

- ➔ Therefore, the room requires support from the mechanical ventilation

Step 4: Conclusion of the ventilation of the Convent in Jeita

	North Side	South Side	East Side	West Side
Ventilation 6 m/s	65.6% Natural	100%	100%	100%

	Ventilation 34.4 % Mechanical Ventilation	Natural Ventilation 0% Mechanical Ventilation	Natural Ventilation 0% Mechanical Ventilation	Natural Ventilation 0% Mechanical Ventilation
Ventilation 3 m/s	10.5% Natural Ventilation 89.5% Mechanical Ventilation	20% Natural Ventilation 80% Mechanical Ventilation	100% Natural Ventilation 0% Mechanical Ventilation	100% Natural Ventilation 0% Mechanical Ventilation
Ventilation 0 m/s	0% Natural Ventilation 100% Mechanical Ventilation	0% Natural Ventilation 100% Mechanical Ventilation	0% Natural Ventilation 100% Mechanical Ventilation	0% Natural Ventilation 100% Mechanical Ventilation

Table 6: The natural vice the mechanical ventilation needed

% of the time	North Side	South Side	East Side	West Side
Ventilation 6 m/s	1 % of the time	3% of the time	5% of the time	15% of the time
Ventilation 3 m/s	1 and 2% of the time	2% of the time	3 or 4 % of the time	8% of the time

Ventilation 0 m/s	We should take it into consideration	We should take it into consideration	We should take it into consideration	We should take it into consideration

Table 7: The percentage of the time of natural ventilation

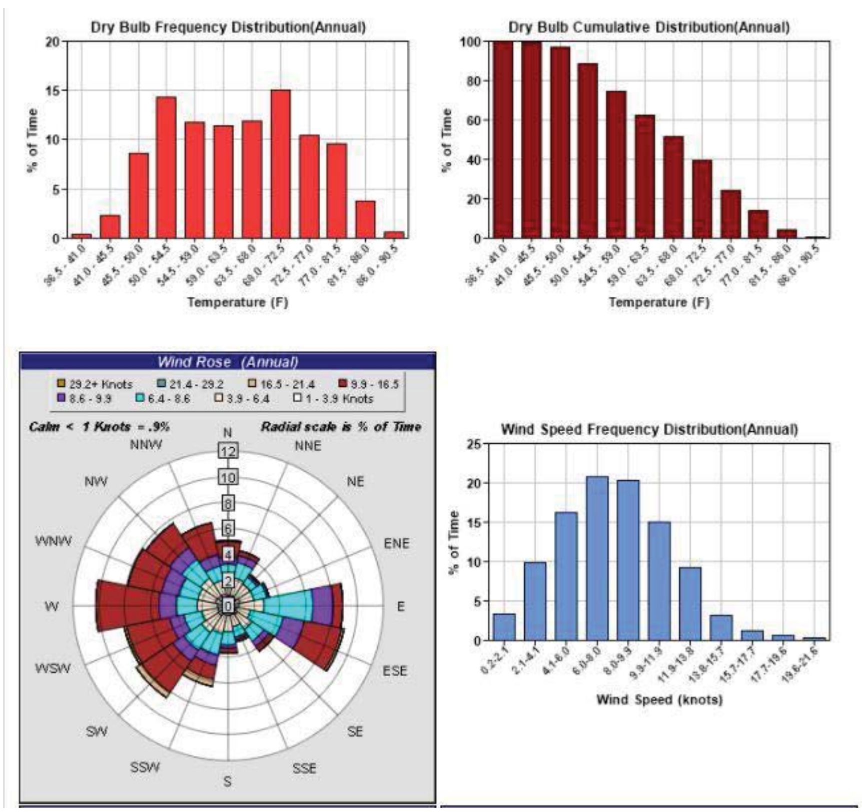
	North Side	South Side	East Side	West Side
Ventilation 6 m/s	65.6% Natural Ventilation 34.4 % Mechanical Ventilation	100% Natural Ventilation 0% Mechanical Ventilation	100% Natural Ventilation 0% Mechanical Ventilation	100% Natural Ventilation 0% Mechanical Ventilation
Ventilation 3 m/s	10.5% Natural Ventilation 89.5% Mechanical Ventilation	20% Natural Ventilation 80% Mechanical Ventilation	100% Natural Ventilation 0% Mechanical Ventilation	100% Natural Ventilation 0% Mechanical Ventilation
Ventilation 0 m/s	0% Natural Ventilation 100% Mechanical Ventilation	0% Natural Ventilation 100% Mechanical Ventilation	0% Natural Ventilation 100% Mechanical Ventilation	0% Natural Ventilation 100% Mechanical Ventilation

4.2 Analyzing different scenarios for the Convent in Ajaltoun- Mount of Lebanon

The second convent is the Convent of Mother of God in Ajaltoun - Kesserwan.

Step 1: Analyzing the ventilation of the rooms considered to be for quarantine using the CFD program.

To note that this convent is not surrounded by any building, therefore there is no obstacles for the wind path that can create a shift in its direction or its velocity.



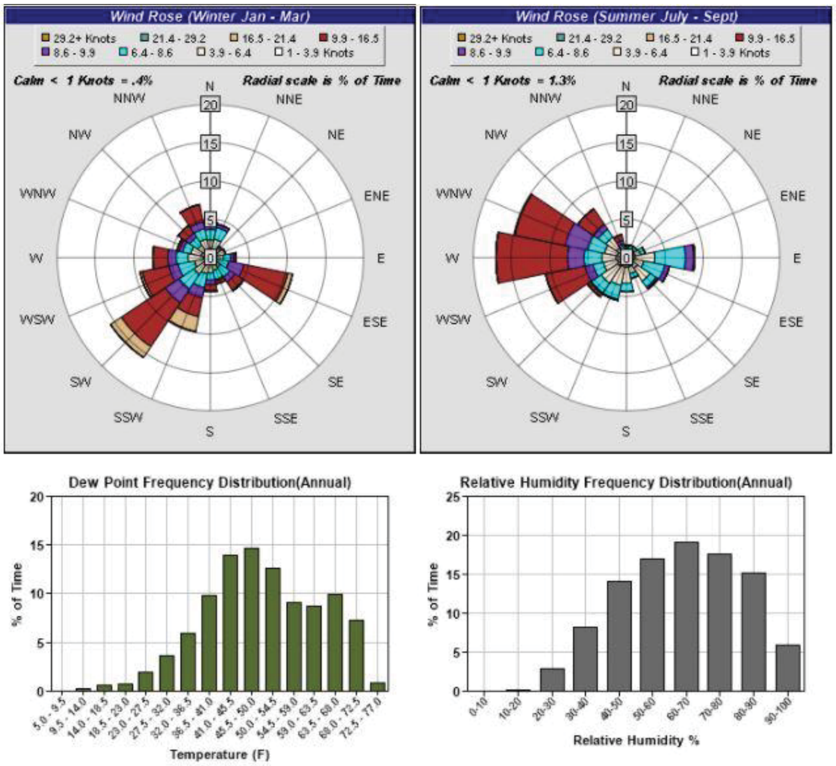


Figure 90: Wind rose from the CFD

According to the Green Building Simulation (GBS), the wind rose through winter and summer enable us to know the most dominant wind direction with the velocity of the wind (knots).

1 knot is equal to 0.5 m/s.

In winter from January till March; the wind rose indicates that the south west side wind is 15 % of the time, the east south side wind is 8 to 10 % of the time, the north west side wind is near to 7 % of the time, and the north east side wind is between 3 and 4% of the time. (Radial scale)

In summer from July till September; the wind rose indicates that the west side is 17 to 19 % of the time, the east side wind is approximately near 9 % of the time, the north side wind is barely visible nearly null 0 %, and the south side wind is approximately 3 % of the time. (Radial scale)

The dominant wind direction throughout the year is from the west. Never less, the analysis using the CFD program should be related to the four sides. Taking into consideration that the wind throughout the day can be null.

The case of the Convent of Mother of God in Ajaltoun - Kesserwan, will be analyzed according to twelve cases. The wind will be analyzed according to the four initial sides (North- South- East and West), and in addition to the south west side- north west side and the east west side with different velocity of the wind; normal velocity 6 m/s, medium velocity 3 m/s and a null velocity 0 m/s.

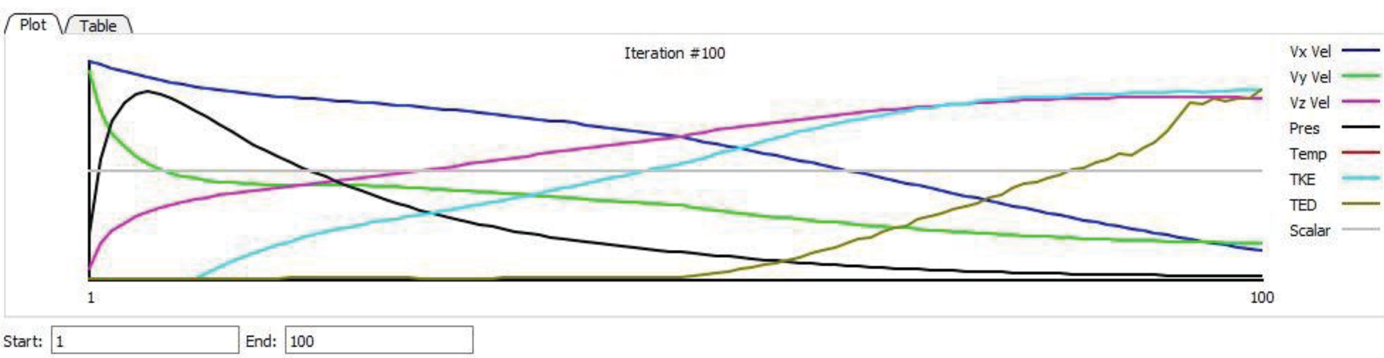
Velocity of the wind is 6 m/s

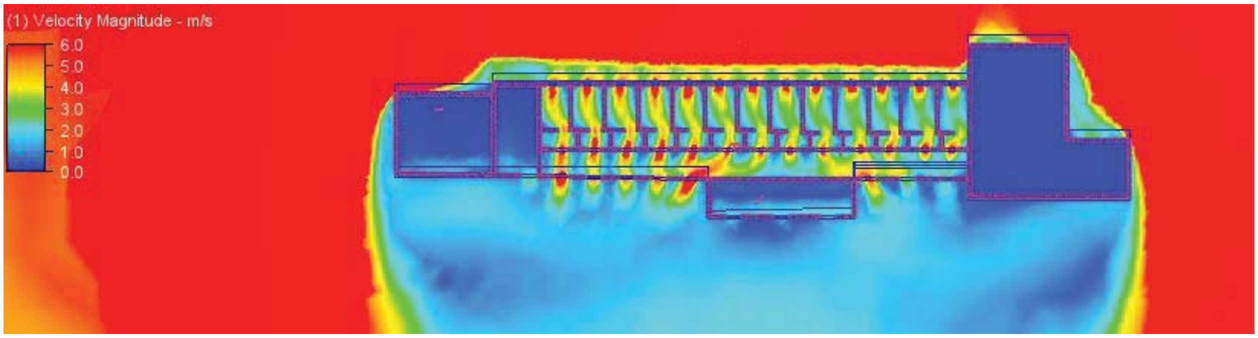
West Side

The first step in the CFD program, is to give each element of the building a specified material.

The blue box is created in Revit before using the CFD program. The blue box is the wind that envelops the building, thus it is given a fluid material, whereas the building's materials are solid as in concrete.

The second step in CFD, is setting the boundaries, selecting the direction of the wind that is mostly common in the area. Based on the wind rose taken from the GBS program, the velocity is selected on the west with 6 m/s, and a pressure is set on the east side with 0 m/s. The pressure is seen as an orange rectangle box and the pressure as a black rectangle box on the fluid box. An auto sized mesh is created, represented by blue dotes on the fluid box. The graph has the iterations between 1 and 100 that will be seen on the model reflecting the velocity and the direction of the wind.





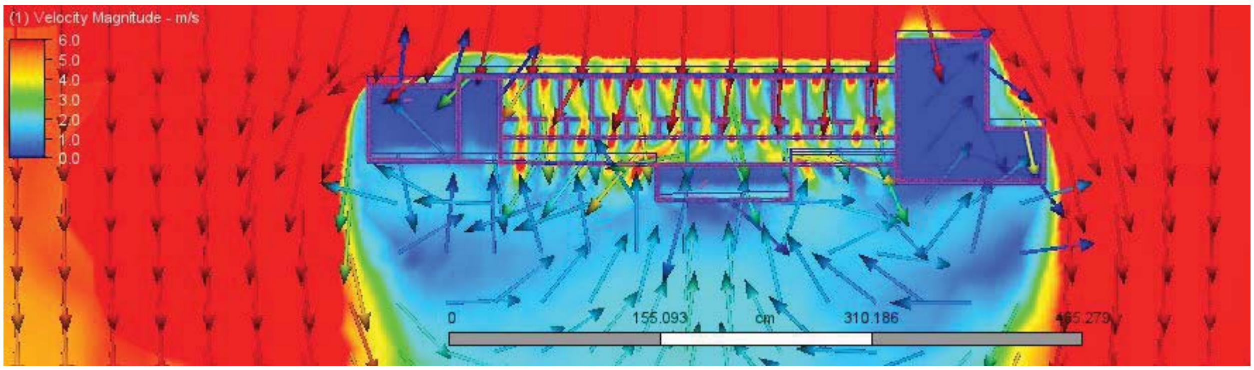


Figure 91: The resulted graph from the CFD

Figure 92: Plan showing the velocity

Figure 93 : Plan showing the vectors and the velocity of the wind

According to XY vectors that are shown on the plan, figure 93, the velocity of the wind in the room of the patients is between 2 and 3 m/s.

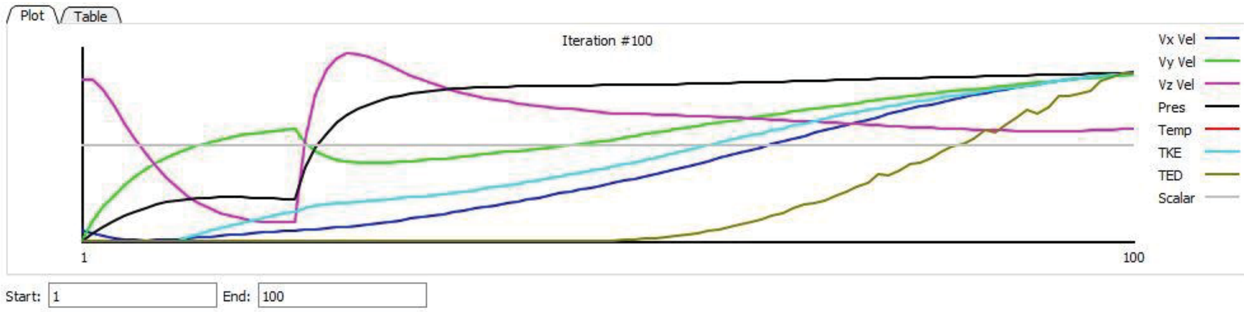
East Side

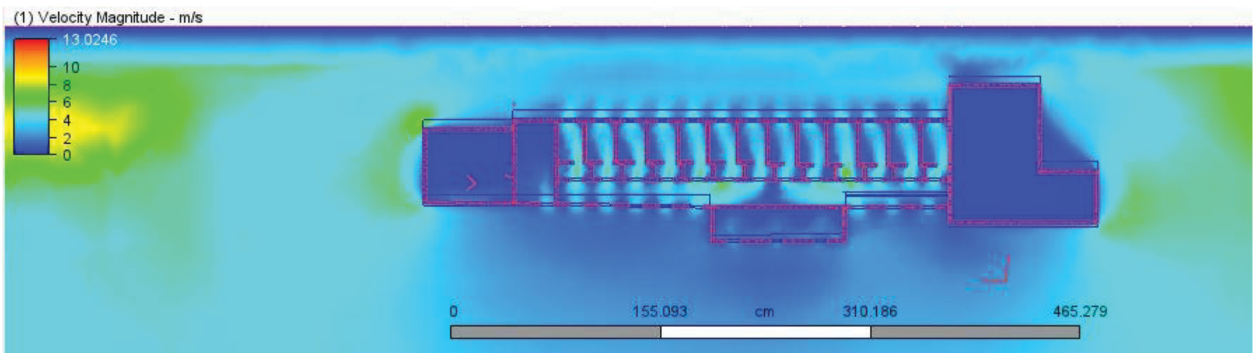
The first step in the CFD program, is to give each element of the building a specified material.

The blue box is created in Revit before using the CFD program. The blue box is the wind that envelops the building, thus it is given a fluid material, whereas the building's materials are solid as in concrete.

The second step in CFD, is setting the boundaries, selecting the direction of the wind that is mostly common in the area. Based on the wind rose taken from the GBS program, the velocity is selected on the east with 6 m/s, and a pressure is set on the west side with 0 m/s. The pressure is seen as an orange rectangle and the pressure as a black rectangle on the fluid box. An auto sized mesh is created, represented by blue dotes on the fluid box. The graph has the iterations between

1 and 100 that will be seen on the model reflecting the velocity and the direction of the wind. The results of the east side ventilation is illustrated in the below figures.





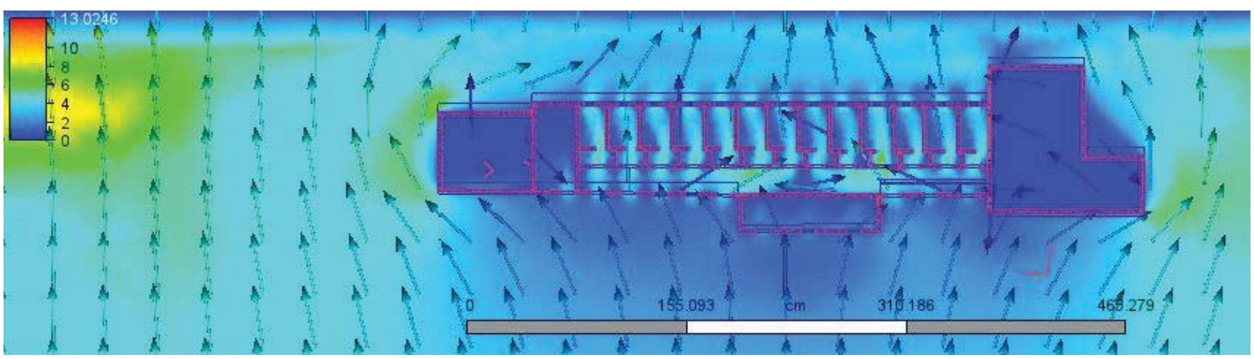


Figure 94: The resulted graph from the CFD

Figure 95: Plan showing the velocity of the wind

Figure 96: Plan showing the vectors and the velocity of the wind

According to XY vectors that are shown on the plan, figure 96, the velocity of the wind in the room of the patients is 0.3 m/s.

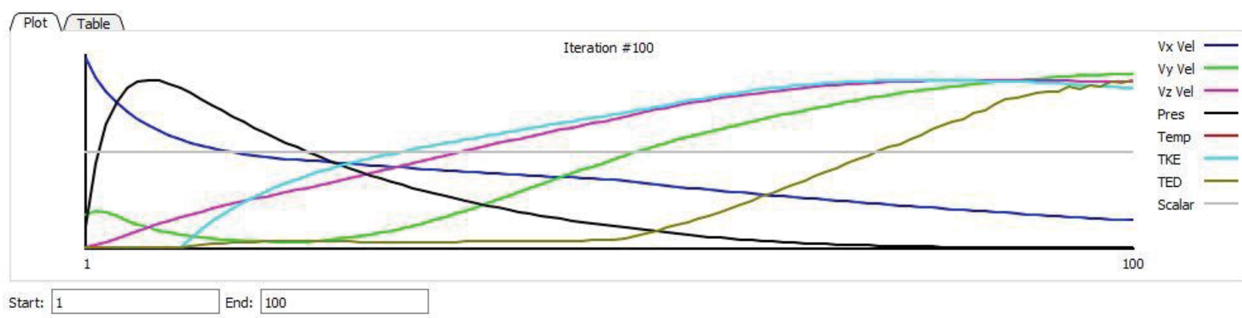
North Side

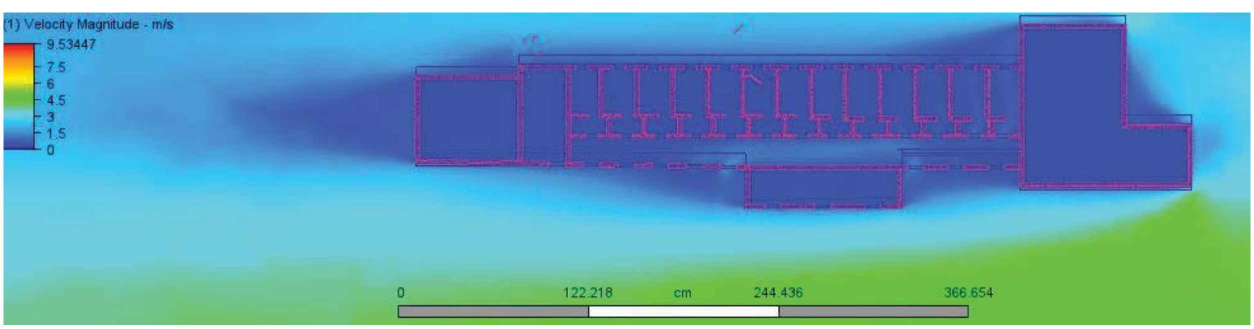
The first step in the CFD program, is to give each element of the building a specified material.

The blue box is created in Revit before using the CFD program. The blue box is the wind that envelops the building, thus it is given a fluid material, whereas the building's materials are solid as in concrete.

The second step in CFD, is setting the boundaries, selecting the direction of the wind that is mostly common in the area. Based on the wind rose taken from the GBS program, the velocity is selected on the north with 6 m/s, and a pressure is set on the south side with 0 m/s. The pressure is seen as an orange rectangle and the pressure as a black rectangle on the fluid box. An auto sized mesh is created, represented by blue dotes on the fluid box. The graph has the iterations between 1 and 100 that will be seen on the model reflecting the velocity and the direction of the wind.

The results of the north side ventilation is illustrated in the below figures.





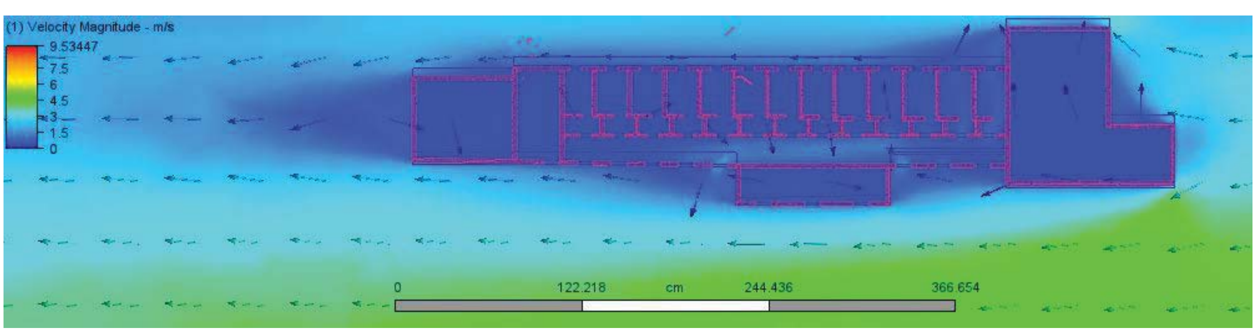


Figure 97: The resulted graph from the CFD

Figure 98: Plan showing the velocity

Figure 99: Plan showing the vectors and the velocity of the wind

According to XY vectors that are shown on the plan, figure 99, the velocity of the wind in the room of the patients is nearly null 0.1 m/s.

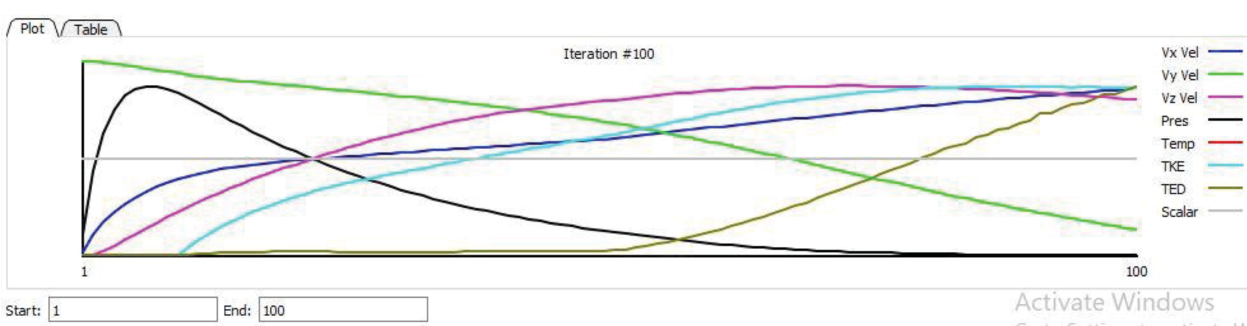
South Side

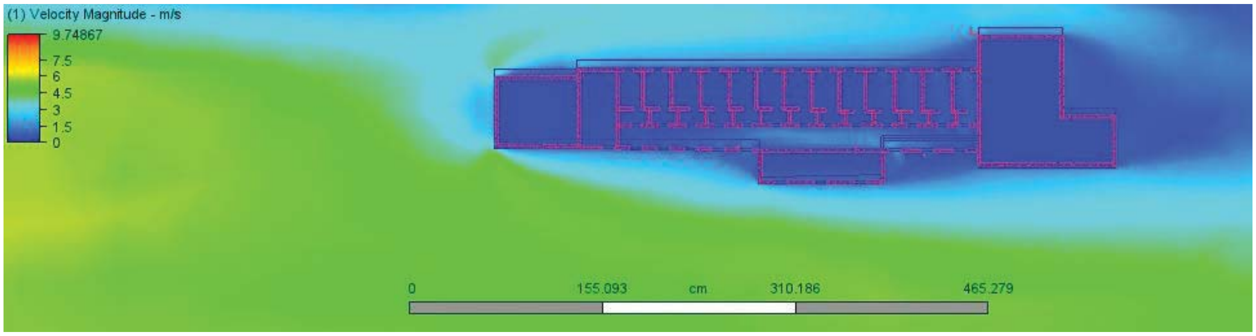
The first step in the CFD program, is to give each element of the building a specified material.

The blue box is created in Revit before using the CFD program. The blue box is the wind that envelops the building, thus it is given a fluid material, whereas the building's materials are solid as in concrete.

The second step in CFD, is setting the boundaries, selecting the direction of the wind that is mostly common in the area. Based on the wind rose taken from the GBS program, the velocity is selected on the south with 6 m/s, and a pressure is set on the north side with 0 m/s. The pressure is seen as an orange rectangle and the pressure as a black rectangle on the fluid box. An auto sized mesh is created, represented by blue dotes on the fluid box. The graph has the iterations between 1 and 100 that will be seen on the model reflecting the velocity and the direction of the wind.

The results of the south side ventilation are illustrated in the below figures.





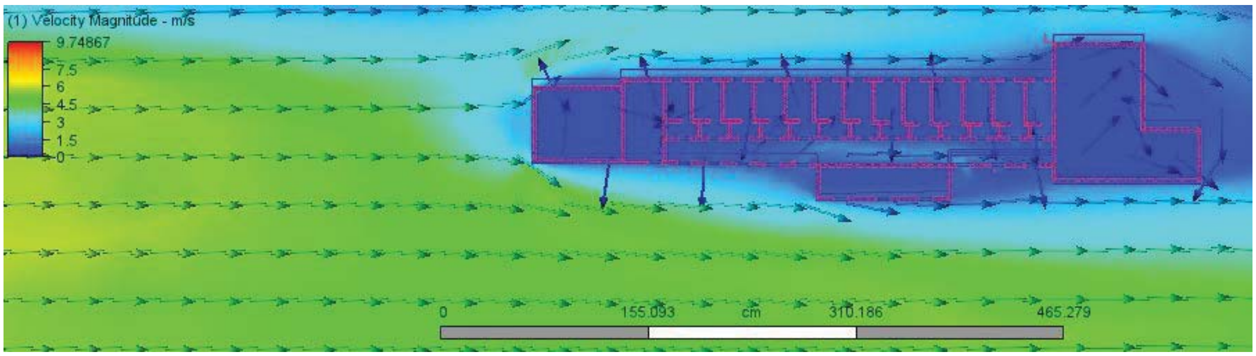


Figure 100: The resulted graph from the CFD

Figure 101: Plan showing the velocity

Figure 102: Plan showing the vectors and the velocity of the wind

According to XY vectors that are shown on the plan, figure 102, the velocity of the wind in the room of the patients is nearly null 0.1 m/s.

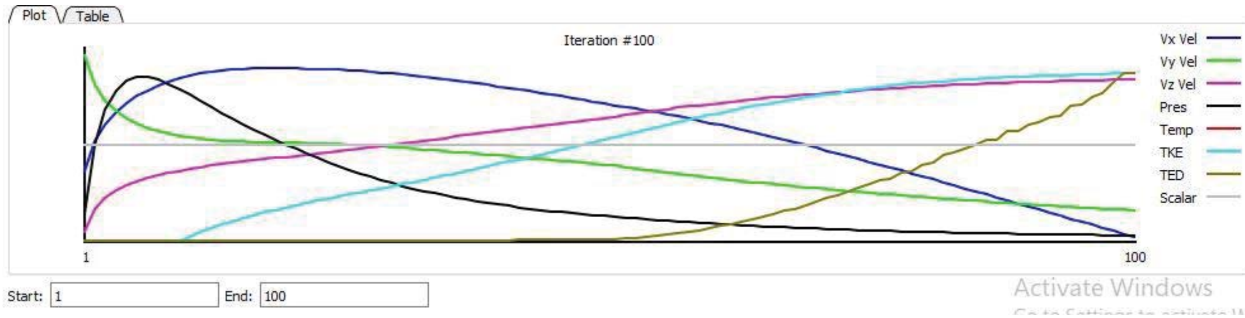
South West Side

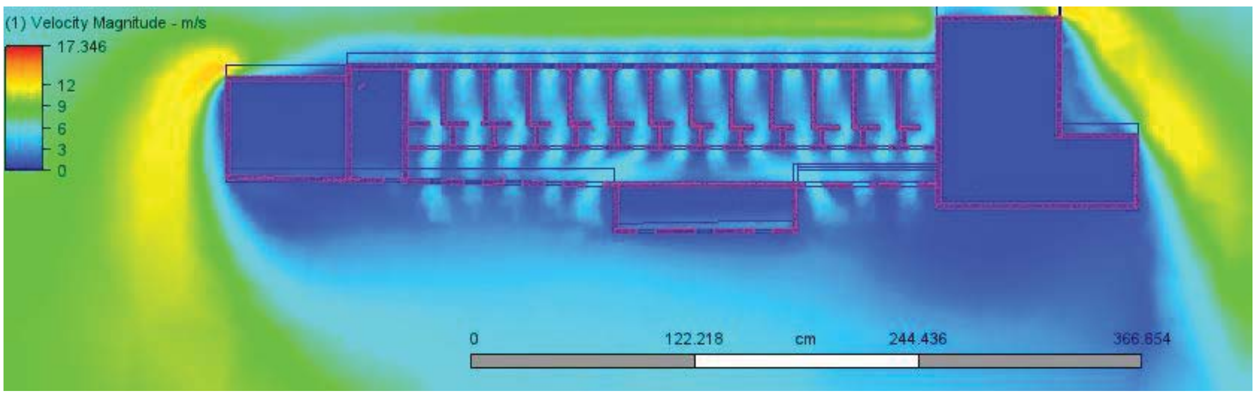
The first step in the CFD program, is to give each element of the building a specified material.

The blue box is created in Revit before using the CFD program. The blue box is the wind that envelops the building, thus it is given a fluid material, whereas the building's materials are solid as in concrete.

The second step in CFD, is setting the boundaries, selecting the direction of the wind that is mostly common in the area. Based on the wind rose taken from the GBS program, the velocity is selected on the south west with 6 m/s, and a pressure is set on the north east side with 0 m/s. The pressure is seen as an orange rectangle and the pressure as a black rectangle on the fluid box. An auto sized mesh is created, represented by blue dotes on the fluid box. The graph has the iterations between 1 and 100 that will be seen on the model reflecting the velocity and the direction of the wind.

The results of the south side ventilation are illustrated in the below figures.





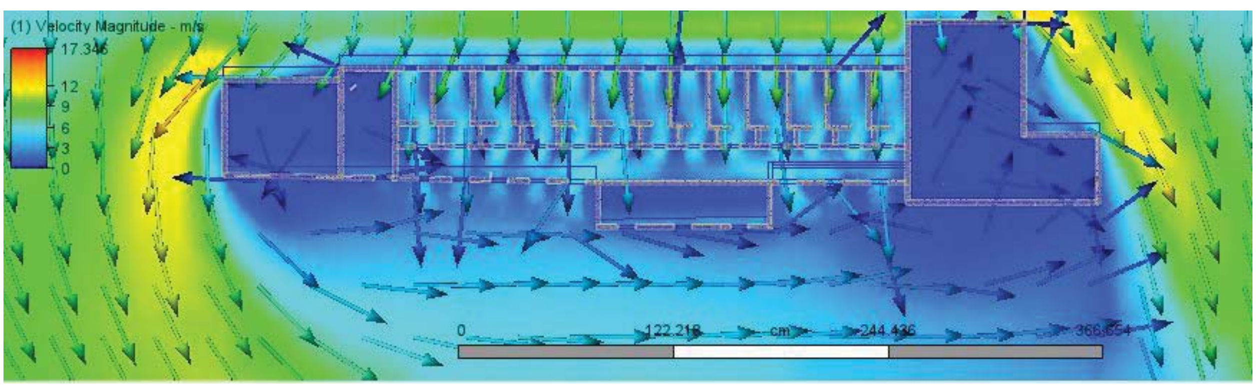


Figure 103: The resulted graph from the CFD

Figure 104: Plan showing the velocity

Figure 105: Plan showing the vectors and the velocity of the wind

According to XY vectors that are shown on the plan, figure 105, the velocity of the wind in the room of the patients is nearly null 3.5 m/s.

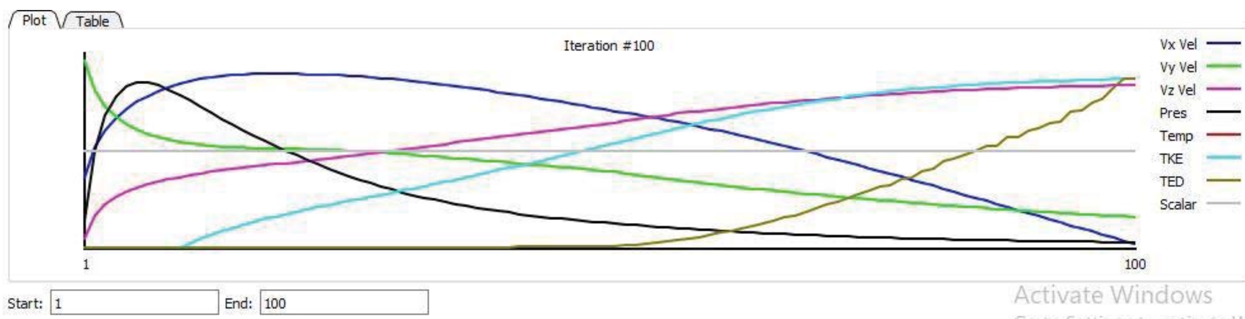
North West Side

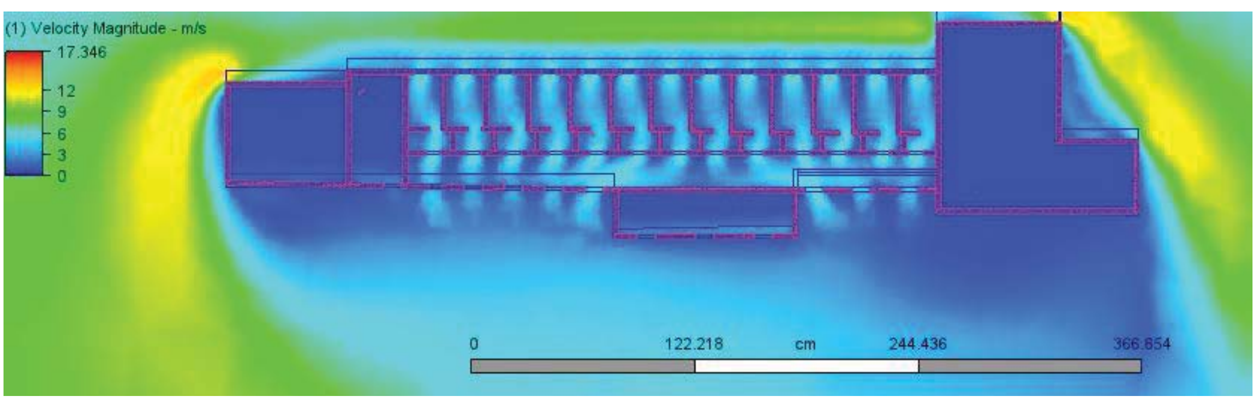
The first step in the CFD program, is to give each element of the building a specified material.

The blue box is created in Revit before using the CFD program. The blue box is the wind that envelops the building, thus it is given a fluid material, whereas the building's materials are solid as in concrete.

The second step in CFD, is setting the boundaries, selecting the direction of the wind that is mostly common in the area. Based on the wind rose taken from the GBS program, the velocity is selected on the north west side with 6 m/s, and a pressure is set on the south east side with 0 m/s. The pressure is seen as an orange rectangle and the pressure as a black rectangle on the fluid box. An auto sized mesh is created, represented by blue dotes on the fluid box. The graph has the iterations between 1 and 100 that will be seen on the model reflecting the velocity and the direction of the wind.

The results of the south side ventilation are illustrated in the below figures.





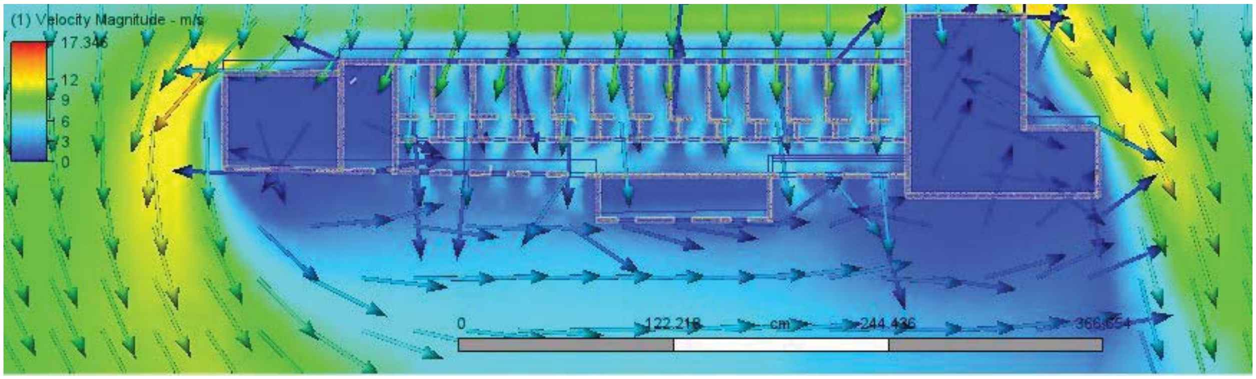


Figure 106: The resulted graph from the CFD

Figure 107: Plan showing the velocity

Figure 108: Plan showing the vectors and the velocity of the wind

According to XY vectors that are shown on the plan, figure 108, the velocity of the wind in the room of the patients is nearly 3.5 m/s.

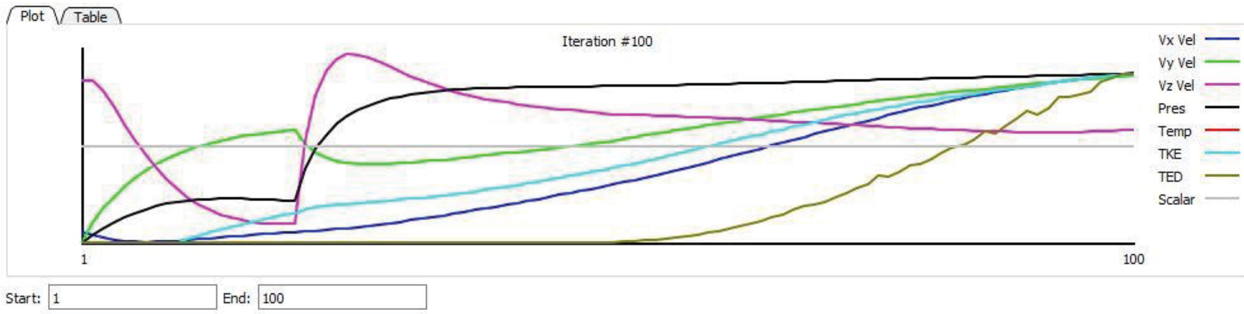
North East Side

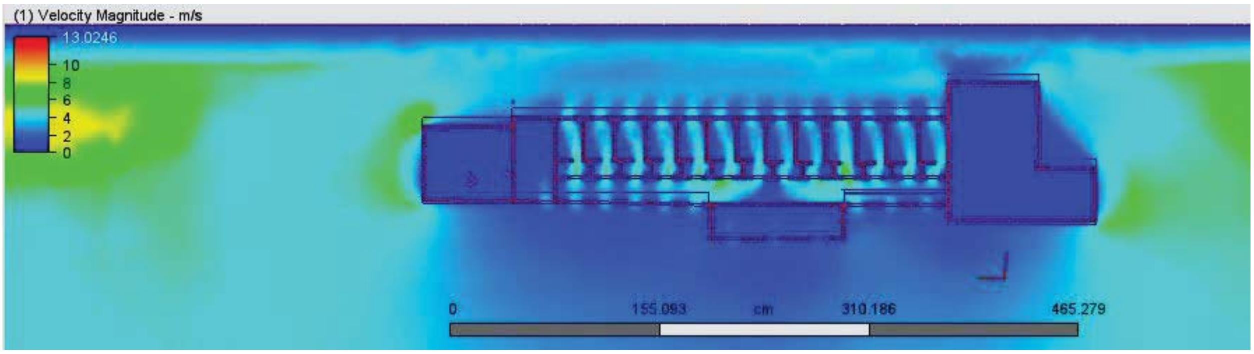
The first step in the CFD program, is to give each element of the building a specified material.

The blue box is created in Revit before using the CFD program. The blue box is the wind that envelops the building, thus it is given a fluid material, whereas the building's materials are solid as in concrete.

The second step in CFD, is setting the boundaries, selecting the direction of the wind that is mostly common in the area. Based on the wind rose taken from the GBS program, the velocity is selected on the north east side with 6 m/s, and a pressure is set on the south west side with 0 m/s. The pressure is seen as an orange rectangle and the pressure as a black rectangle on the fluid box. An auto sized mesh is created, represented by blue dotes on the fluid box. The graph has the iterations between 1 and 100 that will be seen on the model reflecting the velocity and the direction of the wind.

The results of the south side ventilation are illustrated in the below figures.





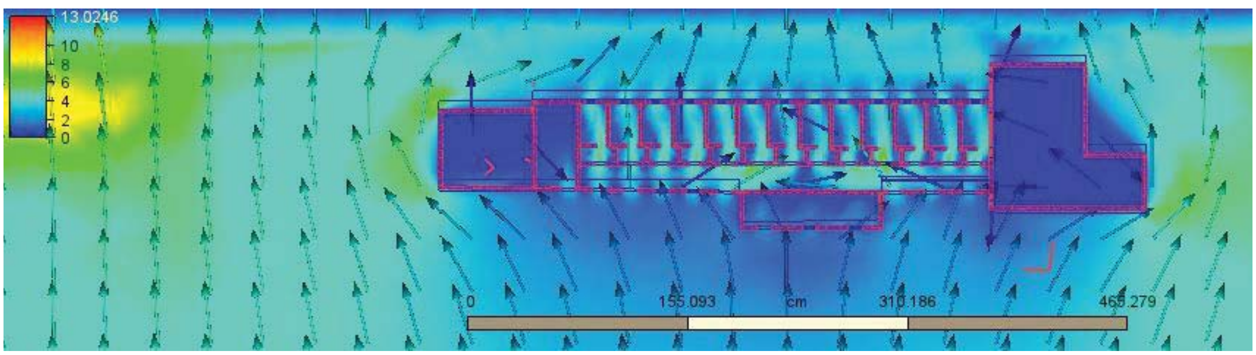


Figure 109: The resulted graph from the CFD

Figure 110: Plan showing the velocity

Figure 111: Plan showing the vectors and the velocity of the wind

According to XY vectors that are shown on the plan, figure 111, the velocity of the wind in the room of the patients is nearly null 0.1 m/s.

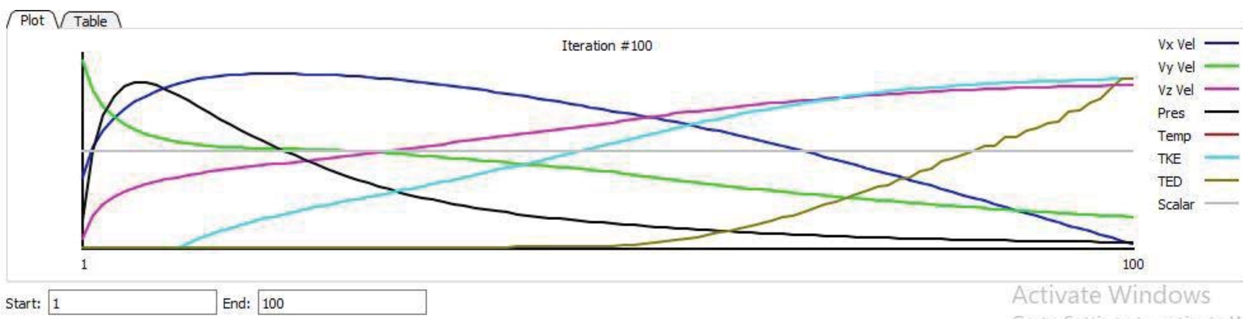
South East Side

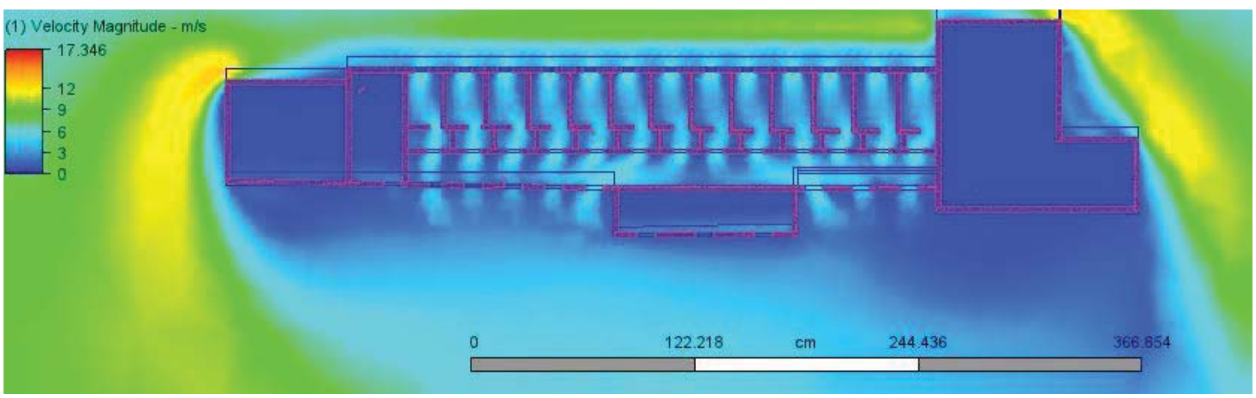
The first step in the CFD program, is to give each element of the building a specified material.

The blue box is created in Revit before using the CFD program. The blue box is the wind that envelops the building, thus it is given a fluid material, whereas the building's materials are solid as in concrete.

The second step in CFD, is setting the boundaries, selecting the direction of the wind that is mostly common in the area. Based on the wind rose taken from the GBS program, the velocity is selected on the south east side with 6 m/s, and a pressure is set on the north west side with 0 m/s. The pressure is seen as an orange rectangle and the pressure as a black rectangle on the fluid box. An auto sized mesh is created, represented by blue dotes on the fluid box. The graph has the iterations between 1 and 100 that will be seen on the model reflecting the velocity and the direction of the wind.

The results of the south side ventilation are illustrated in the below figures.





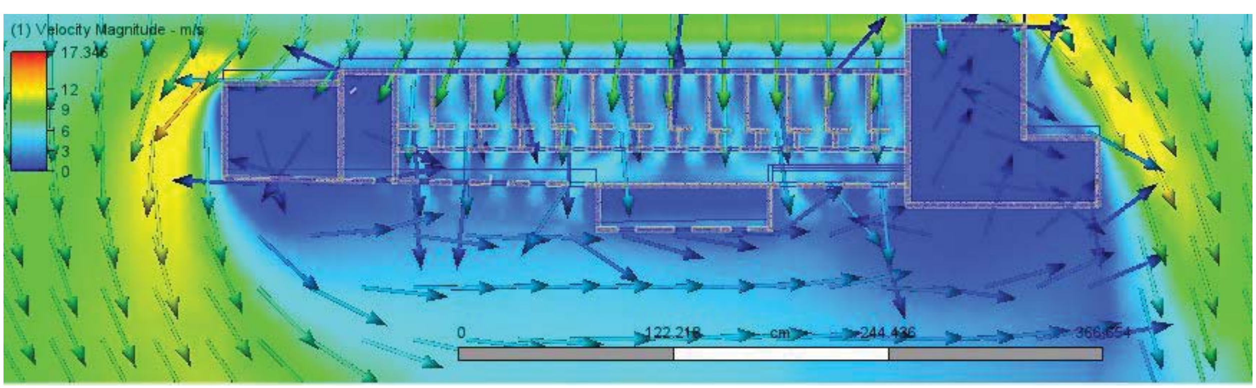


Figure 112: The resulted graph from the CFD

Figure 113: Plan showing the velocity

Figure 114: Plan showing the vectors and the velocity of the wind

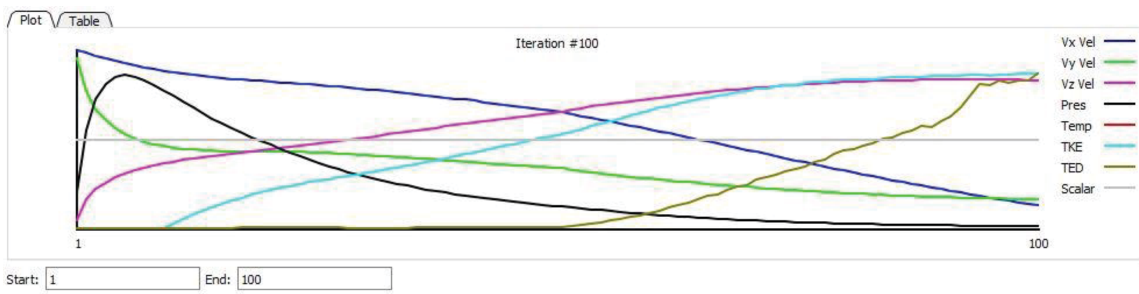
According to XY vectors that are shown on the plan, figure 114, the velocity of the wind in the room of the patients is between 3 and 3.5 m/s.

Velocity of the wind is 3 m/s

Same steps will be followed using the computation fluid dynamics (CFD) program to obtain the results of the ventilation in the building.

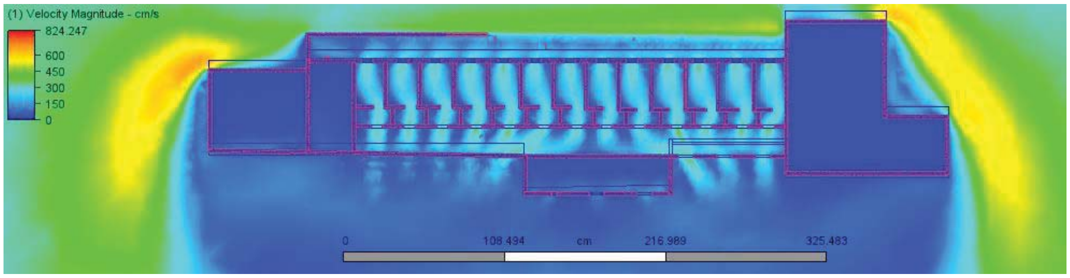
West Side

The results of the west side ventilation is illustrated in the below figures. The first step in the



CFD program, is to give each element of the building a specified material.

The blue box is created in Revit before using the CFD program. The blue box is the wind that envelops the building, thus it is given a fluid material, whereas the building's materials are solid as in concrete. The second step in CFD, is setting the boundaries, selecting the direction of the wind that is mostly common in the area. Based on the wind rose taken from the GBS program, the velocity is selected on the west with 3 m/s, and a pressure is set on the east side with 0 m/s. The pressure is seen as an orange rectangle and the pressure as a black rectangle on the fluid box. An auto sized mesh is created, represented by blue dotes on the fluid box. The graph has the iterations between 1 and 100 that will be seen on the model reflecting the velocity and the direction of the wind. Furthermore, the assigned XY vectors will indicate the velocity and the direction of the wind.



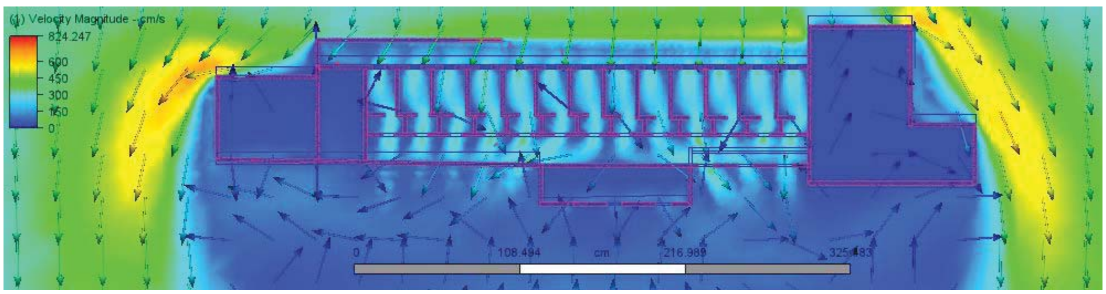


Figure 115: The resulted graph from the CFD

Figure 116: Plan showing the velocity

Figure 117: Plan showing the vectors and the velocity of the wind

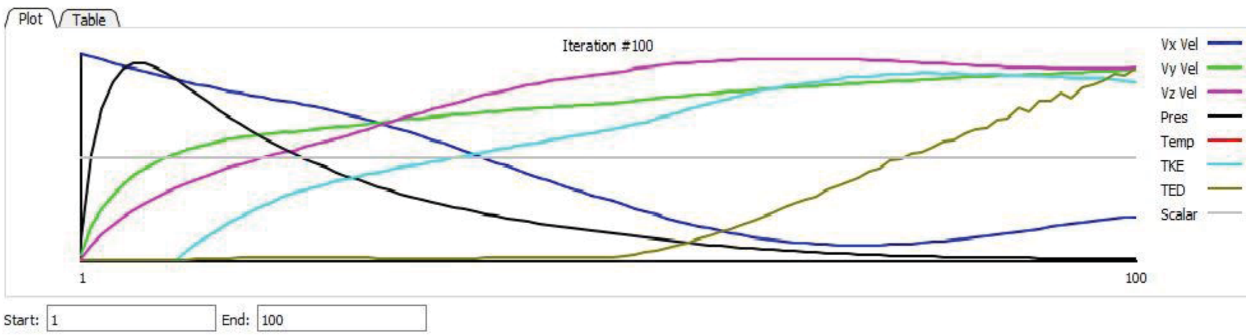
According to XY vectors that are shown on the plan, figure 117, the velocity of the wind in the room of the patients is 1 m/s.

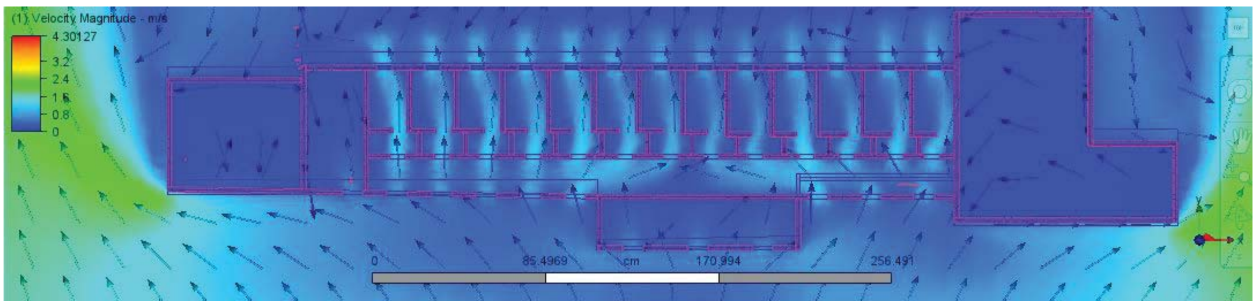
East Side

The first step in the CFD program, is to give each element of the building a specified material.

The blue box is created in Revit before using the CFD program. The blue box is the wind that envelops the building, thus it is given a fluid material, whereas the building's materials are solid as in concrete. The second step in CFD, is setting the boundaries, selecting the direction of the wind that is mostly common in the area. Based on the wind rose taken from the GBS program, the velocity is selected on the east with 3 m/s, and a pressure is set on the west side with 0 m/s. The pressure is seen as an orange rectangle and the pressure as a black rectangle on the fluid box. An auto sized mesh is created, represented by blue dotes on the fluid box. The graph has the iterations between 1 and 100 that will be seen on the model reflecting the velocity and the direction of the wind. Furthermore, the assigned XY vectors will indicate the velocity and the direction of the wind.

The results of the east side ventilation is illustrated in the below figures:





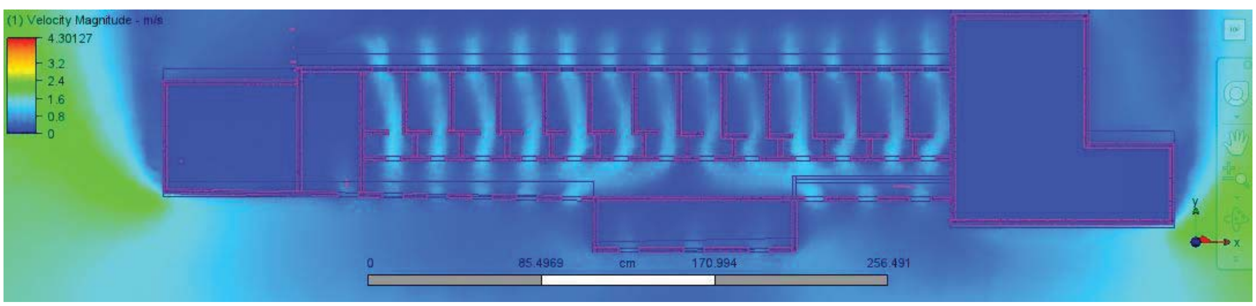


Figure 118: The resulted graph from the CFD

Figure 119: Plan showing the velocity

Figure 120: Plan showing the vectors and the velocity of the wind

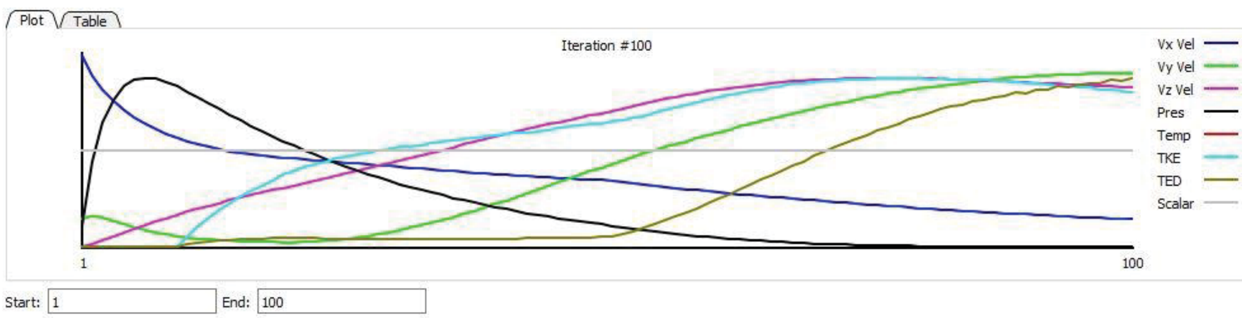
According to XY vectors that are shown on the plan, figure 120, the velocity of the wind in the room of the patients is between 0.8 and 1 m/s.

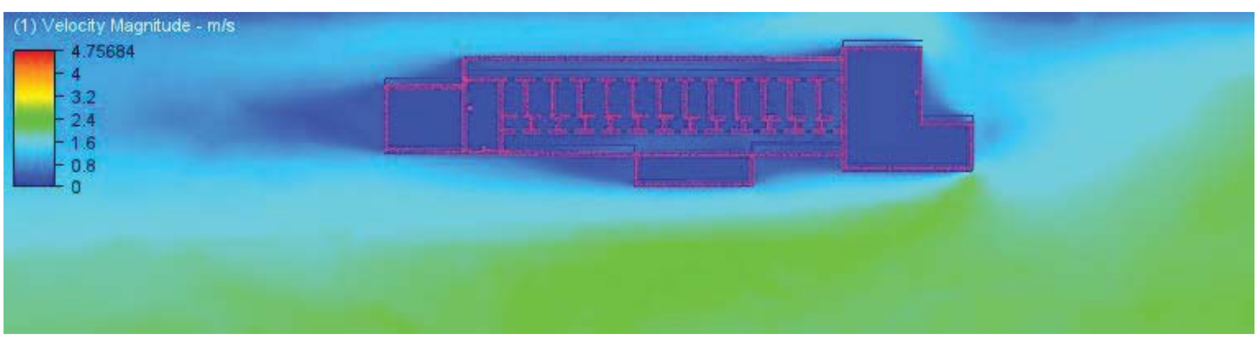
North Side

The results of the east side ventilation is illustrated in the below figures:

Same steps will be followed in the CFD program to obtain the desired results. The first step in the CFD program, is to give each element of the building a specified material.

The blue box is created in Revit before using the CFD program. The blue box is the wind that envelops the building, thus it is given a fluid material, whereas the building's materials are solid as in concrete. The second step in CFD, is setting the boundaries, selecting the direction of the wind that is mostly common in the area. Based on the wind rose taken from the GBS program, the velocity is selected on the north with 3 m/s, and a pressure is set on the south side with 0 m/s. The pressure is seen as an orange rectangle and the pressure as a black rectangle on the fluid box. An auto sized mesh is created, represented by blue dotes on the fluid box. The graph has the iterations between 1 and 100 that will be seen on the model reflecting the velocity and the direction of the wind. Furthermore, the assigned XY vectors will indicate the velocity and the direction of the wind.





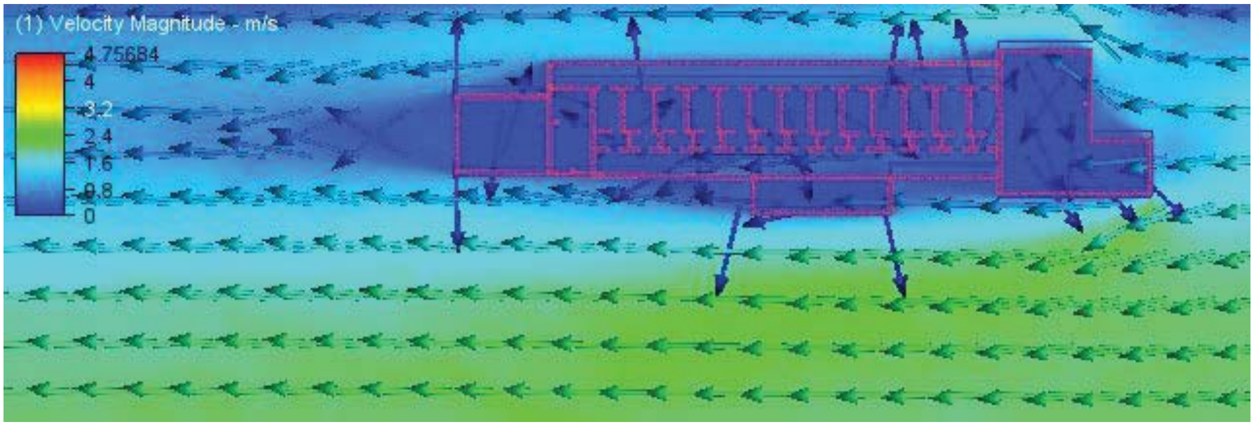


Figure 121: The resulted graph from the CFD

Figure 122: Plan showing the velocity

Figure 123: Plan showing the vectors and the velocity of the wind

According to XY vectors that are shown on the plan, figure 123, the velocity of the wind in the room of the patients is nearly null 0.1 m/s.

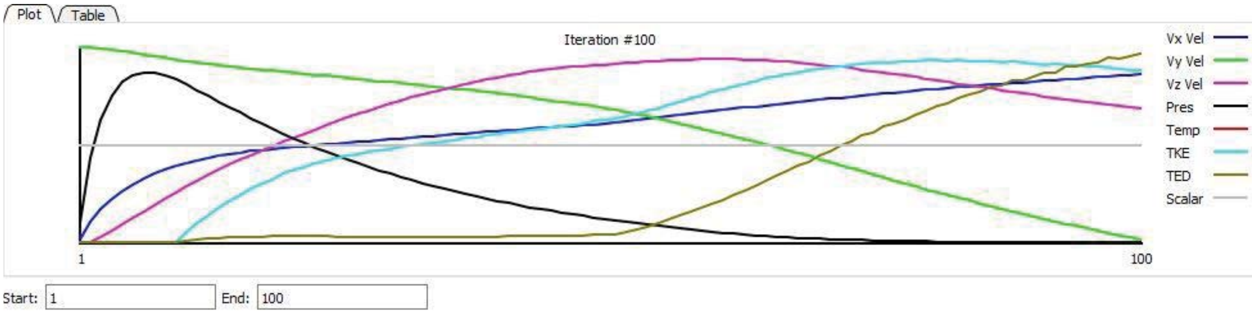
South Side

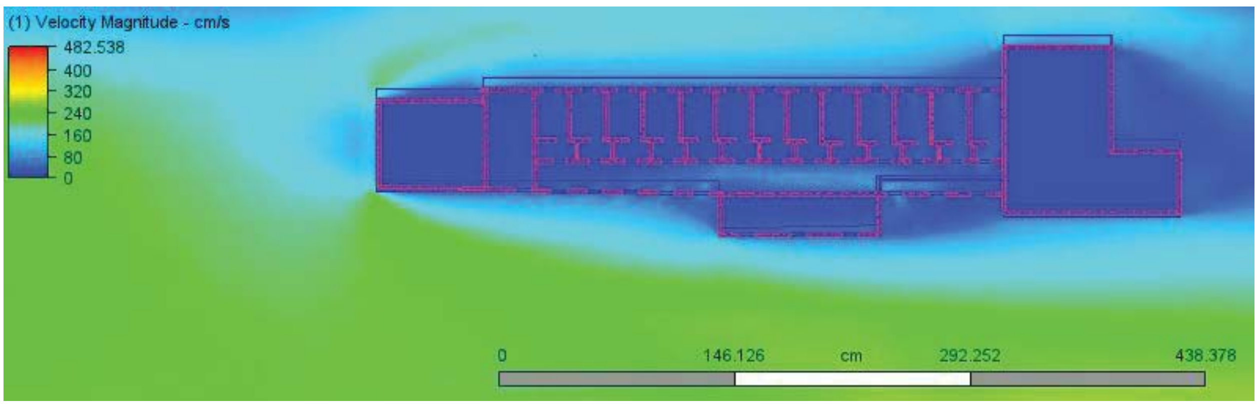
The first step in the CFD program, is to give each element of the building a specified material.

The blue box is created in Revit before using the CFD program. The blue box is the wind that envelops the building, thus it is given a fluid material, whereas the building's materials are solid as in concrete.

The second step in CFD, is setting the boundaries, selecting the direction of the wind that is mostly common in the area. Based on the wind rose taken from the GBS program, the velocity is selected on the south with 3 m/s, and a pressure is set on the north side with 0 m/s. The pressure is seen as an orange rectangle and the pressure as a black rectangle on the fluid box. An auto sized mesh is created, represented by blue dotes on the fluid box. The graph has the iterations between 1 and 100 that will be seen on the model reflecting the velocity and the direction of the wind.

The results of the south side ventilation are illustrated in the below figures.





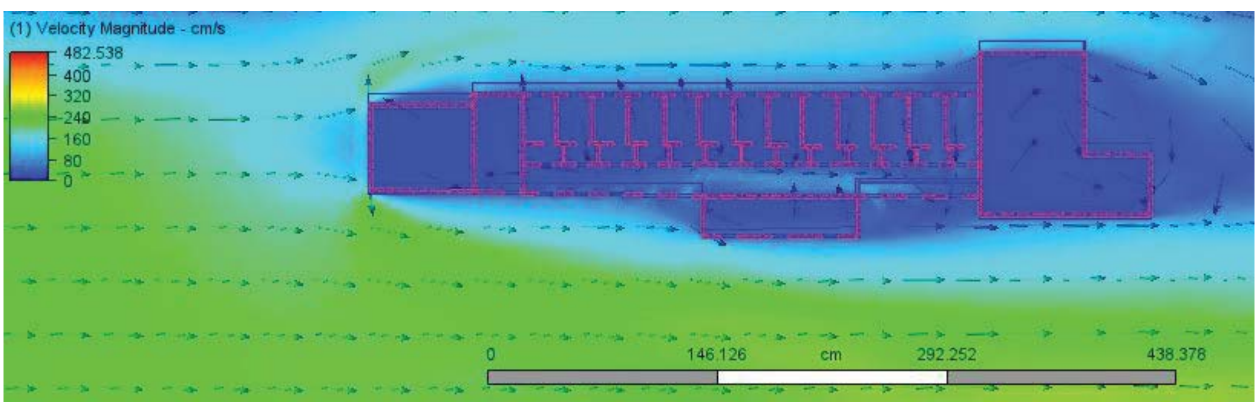


Figure 124: The resulted graph from the CFD

Figure 125: Plan showing the velocity

Figure 126: Plan showing the vectors and the velocity of the wind

According to XY vectors that are shown on the plan, figure 126, the velocity of the wind in the room of the patients is nearly null 0.05 m/s.

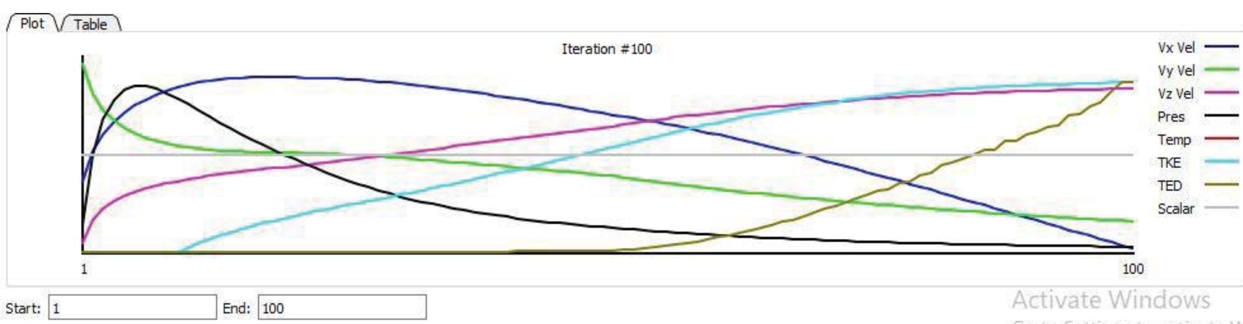
South West Side

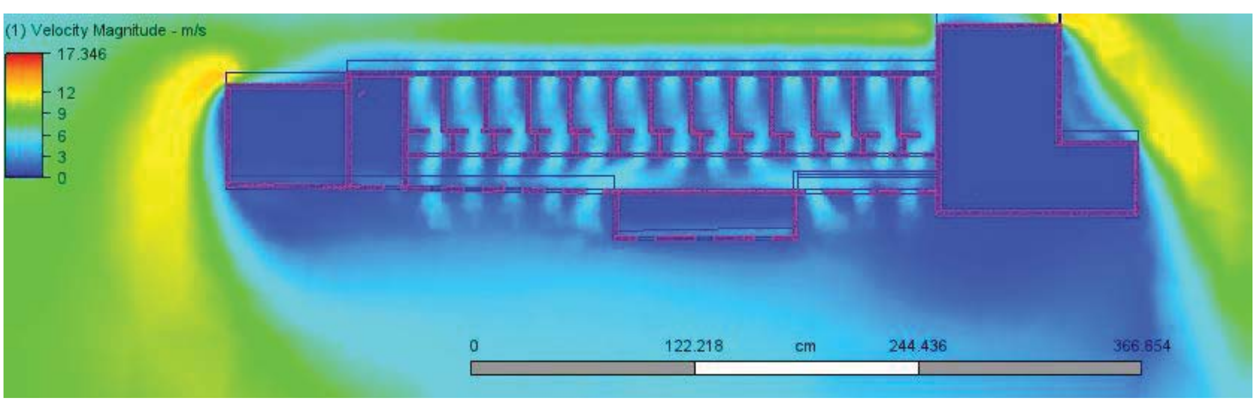
The first step in the CFD program, is to give each element of the building a specified material.

The blue box is created in Revit before using the CFD program. The blue box is the wind that envelops the building, thus it is given a fluid material, whereas the building's materials are solid as in concrete.

The second step in CFD, is setting the boundaries, selecting the direction of the wind that is mostly common in the area. Based on the wind rose taken from the GBS program, the velocity is selected on the south west with 3 m/s, and a pressure is set on the north east side with 0 m/s. The pressure is seen as an orange rectangle and the pressure as a black rectangle on the fluid box. An auto sized mesh is created, represented by blue dotes on the fluid box. The graph has the iterations between 1 and 100 that will be seen on the model reflecting the velocity and the direction of the wind.

The results of the south side ventilation are illustrated in the below figures.





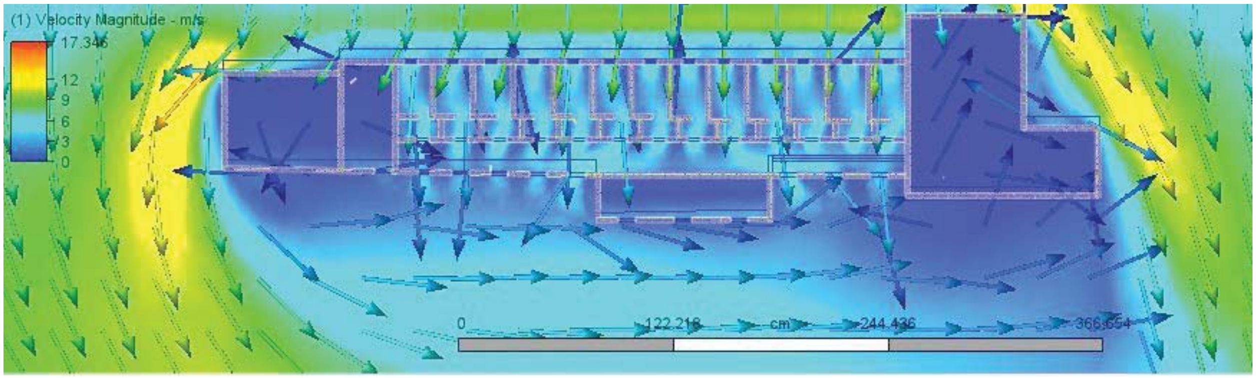


Figure 127: The resulted graph from the CFD

Figure 128: Plan showing the velocity

Figure 129: Plan showing the vectors and the velocity of the wind

According to XY vectors that are shown on the plan, figure 129, the velocity of the wind in the room of the patients is between 2.5 m/s and 3 m/s.

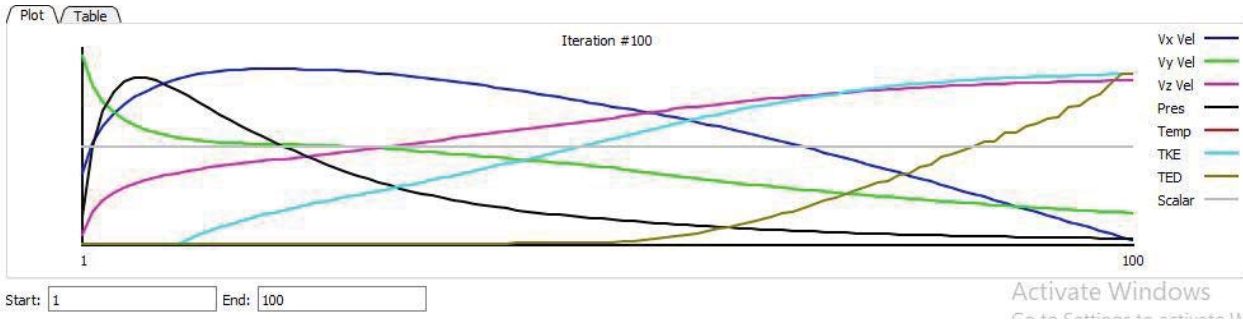
North West Side

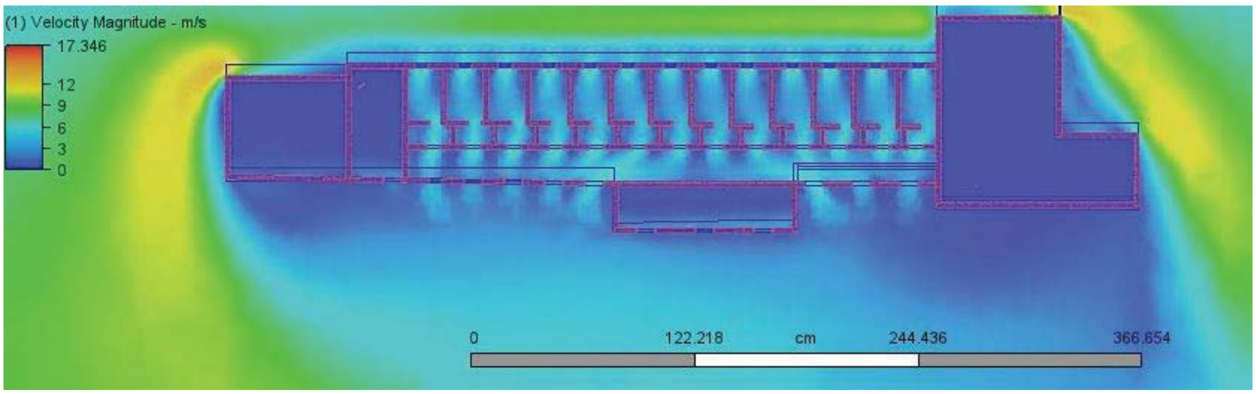
The first step in the CFD program, is to give each element of the building a specified material.

The blue box is created in Revit before using the CFD program. The blue box is the wind that envelops the building, thus it is given a fluid material, whereas the building's materials are solid as in concrete.

The second step in CFD, is setting the boundaries, selecting the direction of the wind that is mostly common in the area. Based on the wind rose taken from the GBS program, the velocity is selected on the north west side with 3 m/s, and a pressure is set on the south east side with 0 m/s. The pressure is seen as an orange rectangle and the pressure as a black rectangle on the fluid box. An auto sized mesh is created, represented by blue dotes on the fluid box. The graph has the iterations between 1 and 100 that will be seen on the model reflecting the velocity and the direction of the wind.

The results of the south side ventilation are illustrated in the below figures.





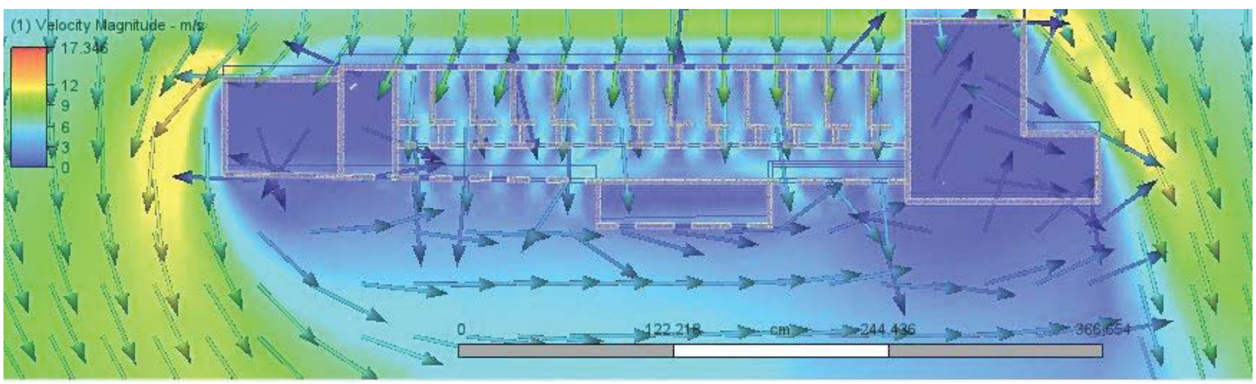


Figure 130: The resulted graph from the CFD

Figure 131: Plan showing the velocity

Figure 132: Plan showing the vectors and the velocity of the wind

According to XY vectors that are shown on the plan, figure 132, the velocity of the wind in the room of the patients is between 2.5 m/s and 3 m/s.

North East Side

The first step in the CFD program, is to give each element of the building a specified material.

The blue box is created in Revit before using the CFD program. The blue box is the wind that envelops the building, thus it is given a fluid material, whereas the building's materials are solid as in concrete.

The second step in CFD, is setting the boundaries, selecting the direction of the wind that is mostly common in the area. Based on the wind rose taken from the GBS program, the velocity is selected on the north east side with 3 m/s, and a pressure is set on the south west side with 0 m/s. The pressure is seen as an orange rectangle and the pressure as a black rectangle on the fluid box. An auto sized mesh is created, represented by blue dotes on the fluid box. The graph has the iterations between 1 and 100 that will be seen on the model reflecting the velocity and the direction of the wind.

The velocity of the wind coming from the north east side is barely visible, nearly to 0.05 m/s.

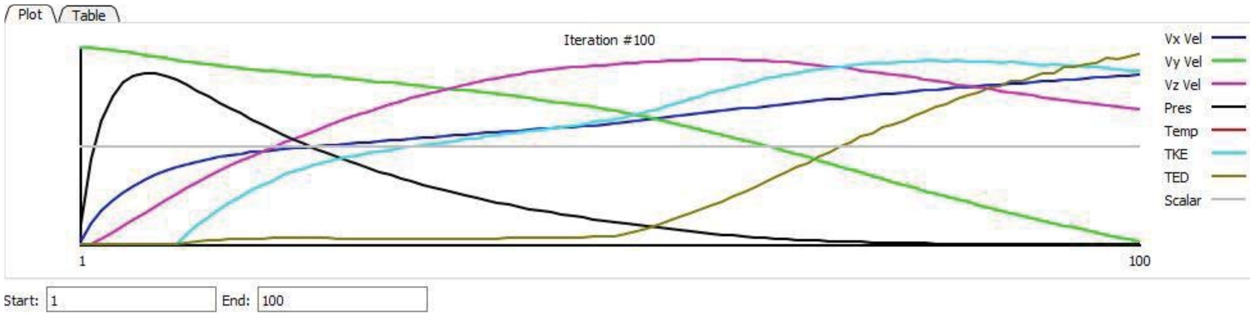
South East Side

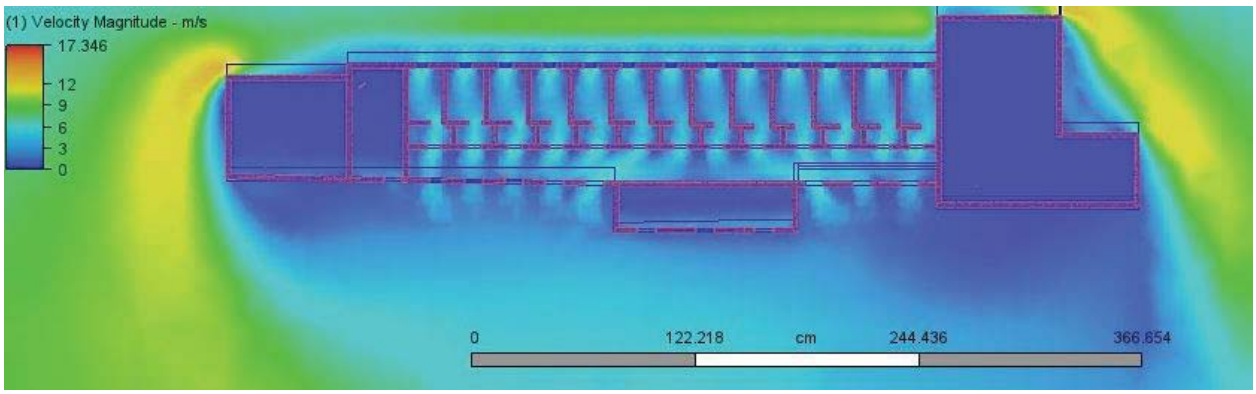
The first step in the CFD program, is to give each element of the building a specified material.

The blue box is created in Revit before using the CFD program. The blue box is the wind that envelops the building, thus it is given a fluid material, whereas the building's materials are solid as in concrete.

The second step in CFD, is setting the boundaries, selecting the direction of the wind that is mostly common in the area. Based on the wind rose taken from the GBS program, the velocity is selected on the south east side with 3 m/s, and a pressure is set on the north west side with 0 m/s. The pressure is seen as an orange rectangle and the pressure as a black rectangle on the fluid box. An auto sized mesh is created, represented by blue dotes on the fluid box. The graph has the iterations between 1 and 100 that will be seen on the model reflecting the velocity and the direction of the wind.

The results of the south side ventilation are illustrated in the below figures.





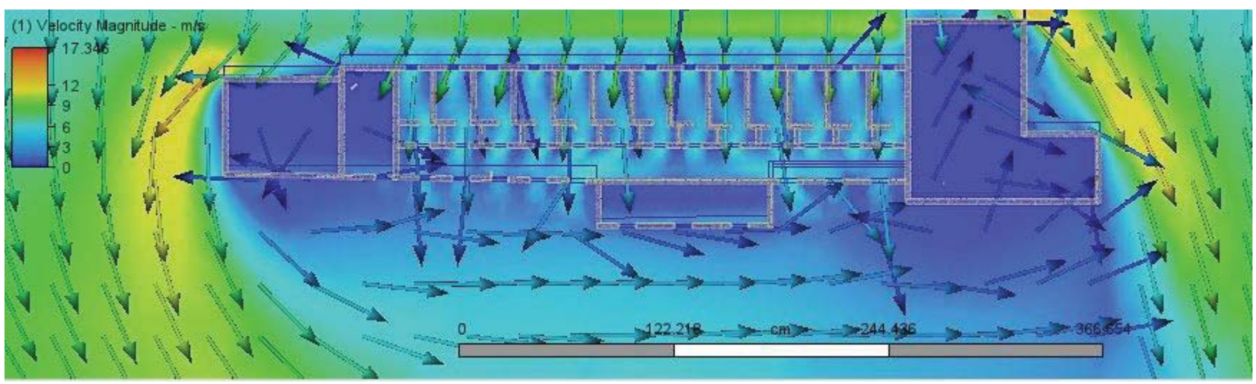


Figure 133: The resulted graph from the CFD

Figure 134: Plan showing the velocity

Figure 135: Plan showing the vectors and the velocity of the wind

According to XY vectors that are shown on the plan, figure 135, the velocity of the wind in the room of the patients is between 2 m/s.

Velocity of the wind is 0 m/s

A velocity of 0 m/s should be taken into consideration, it might be the case through a day.

The rooms of the patients might have 0m/s as a ventilation speed throughout the day. This case should be taken into consideration, so the rooms will have another alternative to ensure a healthy indoor air quality.

Below in the table that includes all the cases, to be compared later;

	North Side	South Side	East Side	West Side	South West Side	North West Side	North East Side	South East Side
Velocity 6 m/s	0.1 m/s	0.1 m/s	0.3 m/s	3 m/s	3.5 m/s	3.5 m/s	0.1 m/s	3m m/s
Velocity 3 m/s	0.1 m/s	0.05 m/s	0.8 m/s	1 m/s	2.5 m/s	2.7 m/s	0.05 m/s	2 m/s
Velocity 0 m/s	0 m/s	0 m/s	0 m/s	0 m/s	0 m/s	0 m/s	0 m/s	0 m/s

Table 8: The velocity of the wind for the 12 cases

Step 2: Ventilation rate calculation

According to the World Health Organization WHO (2020), regarding the spread of the Covid-19:

"Owners and building managers should consider evaluating their building systems to check that they are operating in proper order (per design or current operational strategies), are capable of being modified to align with HVAC mitigation strategies, and to identify deficiencies that should be repaired. Several recommendations should be considered in consultation with HVAC professionals", stated by WHO (2020, p. 16).

The minimum ventilation rate / natural ventilation system is estimated following a specific formula. As a rule of thumb, wind-driven natural ventilation rate through a room can be calculated as follows:

Ventilation rate [L/s] = k x wind speed [m/s] x smallest opening area [m2] x 1000 [L/m3]

k = 0.05 in the case of single-sided ventilation

k = 0.65 in the case of cross ventilation

K in the case of mosquito net presence = ventilation rate x 0.5

Whereas the minimum recommended ventilation rate in a room for one person in a non-residential setting is equal to 10 L/s.

In the case of the rooms in the convent in Ajaltoun- Kesserwan, the formula will be applied regarding the 24 cases.

The K in the formula will be considered equal 0.05 because it is the case of a single- sided ventilation, and the result will later on be multiplied by 0.5 because each opening of the room has a mosquito net.

<u>In the case of the velocity considered 6 m/s;</u>

North side:

Ventilation rate [L/s] = k x wind speed [m/s] x smallest opening area [m2] x 1000 [L/m3]

Ventilation rate [L/s] = 0.05 x 0.1 x (0.5 x 2.2) x 1000

Ventilation rate [L/s] = 5.5 L/s

K in the case of mosquito net presence = ventilation rate x 0.5

- ➔ 5.5 x 0.5 = 2.75 L/s in a room

Each room in the convent of Ajaltoun can have 2 persons for quarantine, therefore the result will be divided by 2 to obtain the ventilation rate for a 1 person.

Ventilation rate [L/s] is divided by 2 = 2.75 / 2 = 1.375 L/s

The ventilation rate from the north side 1.375 L/s is smaller 10 L/s which is the minimum recommendation. Other alternatives should be added to obtain a healthy environment.

South side:

Ventilation rate [L/s] = k x wind speed [m/s] x smallest opening area [m2] x 1000 [L/m3]

Ventilation rate [L/s] = 0.05 x 0.1 x (0.5 x 2.2) x 1000

Ventilation rate [L/s] = 5.5 L/s

K in the case of mosquito net presence = ventilation rate x 0.5

➔ 5.5 x 0.5 = 2.75 L/s in a room

Each room in the convent of Ajaltoun can have 2 persons for quarantine, therefore the result will be divided by 2 to obtain the ventilation rate for a 1 person.

Ventilation rate [L/s] is divided by 2 = 2.75 / 2 = 1.38 L/s

The ventilation rate from the south side 1.375 L/s is smaller 10 L/s which is the minimum recommendation. Other alternatives should be added to obtain a healthy environment.

East side:

Ventilation rate [L/s] = k x wind speed [m/s] x smallest opening area [m2] x 1000 [L/m3]

Ventilation rate [L/s] = 0.05 x 0.3 x (0.5 x 2.2) x 1000

Ventilation rate [L/s] = 16.5 L/s

K in the case of mosquito net presence = ventilation rate x 0.5

➔ 16.5 x 0.5 = 8.25 L/s in a room

Each room in the convent of Ajaltoun can have 2 persons for quarantine, therefore the result will be divided by 2 to obtain the ventilation rate for a 1 person.

Ventilation rate [L/s] is divided by 2 = 8.25 / 2 = 4.12 L/s

The ventilation rate from the east side 4.12 L/s is smaller than 10 L/s which is the minimum recommendation. The rooms require an alternative support for a healthy indoor environment.

West side:

Ventilation rate [L/s] = k x wind speed [m/s] x smallest opening area [m2] x 1000 [L/m3]

Ventilation rate [L/s] = 0.05 x 3 x (0.5 x 2.2) x 1000

Ventilation rate [L/s] = 165 L/s

K in the case of mosquito net presence = ventilation rate x 0.5

➔ 165 x 0.5 = 82.5 L/s in a room

Each room in the convent of Ajaltoun can have 2 persons for quarantine, therefore the result will be divided by 2 to obtain the ventilation rate for a 1 person.

Ventilation rate [L/s] is divided by 2 = 82.5 / 2 = 41.25 L/s

The ventilation rate from the west side 41.25 L/s is larger than 10 L/s which is the minimum recommendation. The rooms have a healthy indoor air quality from this side.

South West side:

Ventilation rate [L/s] = k x wind speed [m/s] x smallest opening area [m2] x 1000 [L/m3]

Ventilation rate [L/s] = 0.05 x 3.5 x (0.5 x 2.2) x 1000

Ventilation rate [L/s] = 192.5 L/s

K in the case of mosquito net presence = ventilation rate x 0.5

➔ 192.5 x 0.5 = 96.25 L/s in a room

Each room in the convent of Ajaltoun can have 2 persons for quarantine, therefore the result will be divided by 2 to obtain the ventilation rate for a 1 person.

Ventilation rate [L/s] is divided by 2 = 96.25 / 2 = 48.125 L/s

The ventilation rate from the south west side 48.125 L/s is larger than 10 L/s which is the minimum recommendation. The rooms have a healthy indoor air quality from this side.

North West side:

Ventilation rate [L/s] = k x wind speed [m/s] x smallest opening area [m2] x 1000 [L/m3]

Ventilation rate [L/s] = 0.05 x 3.5 x (0.5 x 2.2) x 1000

Ventilation rate [L/s] = 192.5 L/s

K in the case of mosquito net presence = ventilation rate x 0.5

➔ 192.5 x 0.5 = 96.25 L/s in a room

Each room in the convent of Ajaltoun can have 2 persons for quarantine, therefore the result will be divided by 2 to obtain the ventilation rate for a 1 person.

Ventilation rate [L/s] is divided by 2 = 96.25 / 2 = 48.125 L/s

The ventilation rate from the north west side 48.125 L/s is larger than 10 L/s which is the minimum recommendation. The rooms have a healthy indoor air quality from this side.

North East side:

Ventilation rate [L/s] = k x wind speed [m/s] x smallest opening area [m2] x 1000 [L/m3]

Ventilation rate [L/s] = 0.05 x 0.1 x (0.5 x 2.2) x 1000

Ventilation rate [L/s] = 5.5 L/s

K in the case of mosquito net presence = ventilation rate x 0.5

➔ 5.5 x 0.5 = 2.75 L/s in a room

Each room in the convent of Ajaltoun can have 2 persons for quarantine, therefore the result will be divided by 2 to obtain the ventilation rate for a 1 person.

Ventilation rate [L/s] is divided by 2 = 2.75 / 2 = 1.38 L/s

The ventilation rate from the north east side 1.38 L/s is smaller than 10 L/s which is the minimum recommendation. Other alternatives should be added to obtain a healthy environment.

South East side:

Ventilation rate [L/s] = k x wind speed [m/s] x smallest opening area [m2] x 1000 [L/m3]

Ventilation rate [L/s] = 0.05 x 3 x (0.5 x 2.2) x 1000

Ventilation rate [L/s] = 165 L/s

K in the case of mosquito net presence = ventilation rate x 0.5

➔ 165 x 0.5 = 82.5 L/s in a room

Each room in the convent of Ajaltoun can have 2 persons for quarantine, therefore the result will be divided by 2 to obtain the ventilation rate for a 1 person.

Ventilation rate [L/s] is divided by 2 = 82.5/ 2 = 41.25 L/s

The ventilation rate from the east side 41.25 L/s is larger than 10 L/s which is the minimum recommendation. The rooms have a healthy indoor air quality from this side

In the case of the velocity considered 3 m/s;

North side:

Ventilation rate [L/s] = k x wind speed [m/s] x smallest opening area [m2] x 1000 [L/m3]

Ventilation rate [L/s] = 0.05 x 0.1 x (0.5x 2.2) x 1000

Ventilation rate [L/s] = 5.5 L/s

K in the case of mosquito net presence = ventilation rate x 0.5

➔ 5.5 x 0.5 = 2.75 L/s in a room

Each room in the convent of Ajaltoun can have 2 persons for quarantine, therefore the result will be divided by 2 to obtain the ventilation rate for a 1 person.

Ventilation rate [L/s] is divided by 2 = 2.75 / 2 = 1.38 L/s

The ventilation rate from the north side L/s is smaller than 10 L/s which is the minimum recommendation. Other alternatives should be added to obtain a healthy environment.

South side:

Ventilation rate [L/s] = k x wind speed [m/s] x smallest opening area [m2] x 1000 [L/m3]

Ventilation rate [L/s] = 0.05 x 0.05 x (0.5 x 2.2) x 1000

Ventilation rate [L/s] = 1.1 L/s

K in the case of mosquito net presence = ventilation rate x 0.5

➔ 1.1 x 0.5 = 0.55 L/s in a room

Each room in the convent of Ajaltoun can have 2 persons for quarantine, therefore the result will be divided by 2 to obtain the ventilation rate for a 1 person.

Ventilation rate [L/s] is divided by 2 = 0.55 / 2 = 0.3 L/s

The ventilation rate from the south side 0.7 L/s is smaller than 10 L/s which is the minimum recommendation. Other alternatives should be added to obtain a healthy environment.

East side:

Ventilation rate [L/s] = k x wind speed [m/s] x smallest opening area [m2] x 1000 [L/m3]

Ventilation rate [L/s] = 0.05 x 0.8 x (0.5 x 2.2) x 1000

Ventilation rate [L/s] = 44 L/s

K in the case of mosquito net presence = ventilation rate x 0.5

➔ 44 x 0.5 = 22 L/s in a room

Each room in the convent of Ajaltoun can have 2 persons for quarantine, therefore the result will be divided by 2 to obtain the ventilation rate for a 1 person.

Ventilation rate [L/s] is divided by 2 = 22 / 2 = 11 L/s

The ventilation rate from the east side 11 L/s is larger than 10 L/s which is the minimum recommendation. The rooms have a healthy indoor air quality from this side.

West side:

Ventilation rate [L/s] = k x wind speed [m/s] x smallest opening area [m2] x 1000 [L/m3]

Ventilation rate [L/s] = 0.05 x 1 x (0.5 x 2.2) x 1000

Ventilation rate [L/s] = 55 L/s

K in the case of mosquito net presence = ventilation rate x 0.5

➔ 55 x 0.5 = 27.5 L/s in a room

Each room in the convent of Ajaltoun can have 2 persons for quarantine, therefore the result will be divided by 2 to obtain the ventilation rate for a 1 person.

Ventilation rate [L/s] is divided by 2 = 27.5 / 2 = 13.75 L/s

The ventilation rate from the west side 13.75 L/s is larger than 10 L/s which is the minimum recommendation. The rooms have a healthy indoor air quality from this side.

South West side:

Ventilation rate [L/s] = k x wind speed [m/s] x smallest opening area [m2] x 1000 [L/m3]

Ventilation rate [L/s] = 0.05 x 2.5 x (0.5 x 2.2) x 1000

Ventilation rate [L/s] = 137.5 L/s

K in the case of mosquito net presence = ventilation rate x 0.5

➔ 137.5 x 0.5 = 68.75 L/s in a room

Each room in the convent of Ajaltoun can have 2 persons for quarantine, therefore the result will be divided by 2 to obtain the ventilation rate for a 1 person.

Ventilation rate [L/s] is divided by 2 = 68.75 / 2 = 34.38 L/s

The ventilation rate from the south west side L/s is larger than 10 L/s which is the minimum recommendation. The rooms have a healthy indoor air quality from this side.

North West side:

Ventilation rate [L/s] = k x wind speed [m/s] x smallest opening area [m2] x 1000 [L/m3]

Ventilation rate [L/s] = 0.05 x 2.7 x (0.5 x 2.2) x 1000

Ventilation rate [L/s] = 148.5 L/s

K in the case of mosquito net presence = ventilation rate x 0.5

➔ 148.5 x 0.5 = 74.25 L/s in a room

Each room in the convent of Ajaltoun can have 2 persons for quarantine, therefore the result will be divided by 2 to obtain the ventilation rate for a 1 person.

Ventilation rate [L/s] is divided by 2 = 74.25 / 2 = 37. 13 L/s

The ventilation rate from the north west side 37.13 L/s is larger than 10 L/s which is the minimum recommendation. The rooms have a healthy indoor air quality from this side.

North East side:

Ventilation rate [L/s] = k x wind speed [m/s] x smallest opening area [m2] x 1000 [L/m3]

Ventilation rate [L/s] = 0.05 x 0.05 x (0.5 x 2.2) x 1000

Ventilation rate [L/s] = 2.75 L/s

K in the case of mosquito net presence = ventilation rate x 0.5

➔ 2.75 x 0.5 = 1.375 L/s in a room

Each room in the convent of Ajaltoun can have 2 persons for quarantine, therefore the result will be divided by 2 to obtain the ventilation rate for a 1 person.

Ventilation rate [L/s] is divided by 2 = 1.375 / 2 = 0.69 L/s

The ventilation rate from the north east side 0.69 L/s is smaller than 10 L/s which is the minimum recommendation. Other alternatives should be added to obtain a healthy environment.

South East side:

Ventilation rate [L/s] = k x wind speed [m/s] x smallest opening area [m2] x 1000 [L/m3]

Ventilation rate [L/s] = 0.05 x 2 x (0.5 x 2.2) x 1000

Ventilation rate [L/s] = 110 L/s

K in the case of mosquito net presence = ventilation rate x 0.5

➔ 110 x 0.5 = 55 L/s in a room

Each room in the convent of Ajaltoun can have 2 persons for quarantine, therefore the result will be divided by 2 to obtain the ventilation rate for a 1 person.

Ventilation rate [L/s] is divided by 2 = 55 / 2 = 27.5 L/s

The ventilation rate from the south east side 27.5 L/s is larger than 10 L/s which is the minimum recommendation. The rooms have a healthy indoor air quality from this side

<u>In the case of the velocity considered 0 m/s;</u>

North side:

Ventilation rate [L/s] = k x wind speed [m/s] x smallest opening area [m2] x 1000 [L/m3]

Ventilation rate [L/s] = 0.05 x 0 x (0.5 x 2.2) x 1000

Ventilation rate [L/s] = 0 L/s

K in the case of mosquito net presence = ventilation rate x 0.5

➔ 0 x 0.5 = 0 L/s in a room

Each room in the convent of Ajaltoun can have 2 persons for quarantine, therefore the result will be divided by 2 to obtain the ventilation rate for a 1 person.

Ventilation rate [L/s] is divided by 2 = 0 / 2 = 0 L/s

The ventilation rate from the north side 0 L/s is smaller than 10 L/s which is the minimum recommendation. Other alternatives should be added to obtain a healthy environment.

South side:

Ventilation rate [L/s] = k x wind speed [m/s] x smallest opening area [m2] x 1000 [L/m3]

Ventilation rate [L/s] = 0.05 x 0 x (0.5 x 2.2) x 1000

Ventilation rate [L/s] = 0 L/s

K in the case of mosquito net presence = ventilation rate x 0.5

➔ 0 x 0.5 = 0 L/s in a room

Each room in the convent of Ajaltoun can have 2 persons for quarantine, therefore the result will be divided by 2 to obtain the ventilation rate for a 1 person.

Ventilation rate [L/s] is divided by 2 = 0 / 2 = 0 L/s

The ventilation rate from the north side 0 L/s is smaller than 10 L/s which is the minimum recommendation. Other alternatives should be added to obtain a healthy environment.

East side:

Ventilation rate [L/s] = k x wind speed [m/s] x smallest opening area [m2] x 1000 [L/m3]

Ventilation rate [L/s] = 0.05 x 0 x (0.5 x 2.2) x 1000

Ventilation rate [L/s] = 0 L/s

K in the case of mosquito net presence = ventilation rate x 0.5

➔ 0 x 0.5 = 0 L/s in a room

Each room in the convent of Ajaltoun can have 2 persons for quarantine, therefore the result will be divided by 2 to obtain the ventilation rate for a 1 person.

Ventilation rate [L/s] is divided by 2 = 0 / 2 = 0 L/s

The ventilation rate from the north side 0 L/s is smaller than 10 L/s which is the minimum recommendation. Other alternatives should be added to obtain a healthy environment.

West side:

Ventilation rate [L/s] = k x wind speed [m/s] x smallest opening area [m2] x 1000 [L/m3]

Ventilation rate [L/s] = 0.05 x 0 x (0.5 x 2.2) x 1000

Ventilation rate [L/s] = 0 L/s

K in the case of mosquito net presence = ventilation rate x 0.5

➔ 0 x 0.5 = 0 L/s in a room

Each room in the convent of Ajaltoun can have 2 persons for quarantine, therefore the result will be divided by 2 to obtain the ventilation rate for a 1 person.

Ventilation rate [L/s] is divided by 2 = 0 / 2 = 0 L/s

The ventilation rate from the north side 0 L/s is smaller than 10 L/s which is the minimum recommendation. Other alternatives should be added to obtain a healthy environment.

South West side:

Ventilation rate [L/s] = k x wind speed [m/s] x smallest opening area [m2] x 1000 [L/m3]

Ventilation rate [L/s] = 0.05 x 0 x (0.5 x 2.2) x 1000

Ventilation rate [L/s] = 0 L/s

K in the case of mosquito net presence = ventilation rate x 0.5

➔ 0 x 0.5 = 0 L/s in a room

Each room in the convent of Ajaltoun can have 2 persons for quarantine, therefore the result will be divided by 2 to obtain the ventilation rate for a 1 person.

Ventilation rate [L/s] is divided by 2 = 0 / 2 = 0 L/s

The ventilation rate from the south west side 0 L/s is larger than 10 L/s which is the minimum recommendation. The rooms have a healthy indoor air quality from this side.

North West side:

Ventilation rate [L/s] = k x wind speed [m/s] x smallest opening area [m2] x 1000 [L/m3]

Ventilation rate [L/s] = 0.05 x 0 x (0.5 x 2.2) x 1000

Ventilation rate [L/s] = 0 L/s

K in the case of mosquito net presence = ventilation rate x 0.5

➔ 0 x 0.5 = 0 L/s in a room

Each room in the convent of Ajaltoun can have 2 persons for quarantine, therefore the result will be divided by 2 to obtain the ventilation rate for a 1 person.

Ventilation rate [L/s] is divided by 2 = 0 / 2 = 0 L/s

The ventilation rate from the North West side 0 L/s is larger than 10 L/s which is the minimum recommendation. The rooms have a healthy indoor air quality from this side.

North East side:

Ventilation rate [L/s] = k x wind speed [m/s] x smallest opening area [m2] x 1000 [L/m3]

Ventilation rate [L/s] = 0.05 x 0 x (0.5 x 2.2) x 1000

Ventilation rate [L/s] = 0 L/s

K in the case of mosquito net presence = ventilation rate x 0.5

➔ 0 x 0.5 = 0 L/s in a room

Each room in the convent of Ajaltoun can have 2 persons for quarantine, therefore the result will be divided by 2 to obtain the ventilation rate for a 1 person.

Ventilation rate [L/s] is divided by 2 = 0 / 2 = 0 L/s

The ventilation rate from the north east side 0 L/s is larger than 10 L/s which is the minimum recommendation. The rooms have a healthy indoor air quality from this side.

South East side:

Ventilation rate [L/s] = k x wind speed [m/s] x smallest opening area [m2] x 1000 [L/m3]

Ventilation rate [L/s] = 0.05 x 0 x (0.5 x 2.2) x 1000

Ventilation rate [L/s] = 0 L/s

K in the case of mosquito net presence = ventilation rate x 0.5

➔ 0 x 0.5 = 0 L/s in a room

Each room in the convent of Ajaltoun can have 2 persons for quarantine, therefore the result will be divided by 2 to obtain the ventilation rate for a 1 person.

Ventilation rate [L/s] is divided by 2 = 0 / 2 = 0 L/s

The ventilation rate from the south east side 0 L/s is larger than 10 L/s which is the minimum recommendation. The rooms have a healthy indoor air quality from this side

Below is the table that contains the results of the convent regarding the ventilation rate:

Ventilation L/S / Ventilation m/s	North Side	South Side	East Side	West Side
6 m/s	1.38 L/s For one person	1.38 L/s For one person	4.12 L/s For one person	41.25 L/s For one person
3 m/s	1.38 L/s For one person	0.3 L/s For one person	11 L/s For one person	13.75 L/s For one person
0 m/s	0 L/s For one person	0 L/s For one person	0 L/s For one person	0 L/s For one person

Ventilation L/S / Ventilation m/s	South West Side	North West Side	North East Side	South East Side
6 m/s	48.12 L/s For one person	48.12 L/s For one person	1.38 L/s For one person	41.25 L/s For one person

3 m/s	34.38 L/s For one person	37.13 L/s For one person	0.7 L/s For one person	27.5 L/s For one person
0 m/s	0 L/s For one person	0 L/s For one person	0 L/s For one person	0 L/s For one person

Table 9: The ventilation rate according the ventilation

Step 3: Analysis of the Convent in Ajaltoun

The convent of the Convent of Mother of God in Ajaltoun- Kesserwan was analyzed according to three cases of ventilation in reference to the wind rose. The 6 m/s, 3 m/s, and 0 m/s ventilation gave 24 different cases.

The results are divided into two categories: the results that are larger than 10 L/s do not require an additional of mechanical ventilation, and the results that are smaller than 10 L/s do require an additional tool of ventilation for a healthy ventilation.

According to the road map for the spread of the Covid-19 in the years 2020 and 2021 put by the World Health Organization (WHO), the non- residential building that are used for quarantine require a 10 L/s ventilation rate for one person in a room. If the ventilation rate is smaller than 10 L/s, the room requires the use of a mechanical ventilation.

- ➔ If the ventilation rate is smaller than 10 L/s:

To increase the ventilation in a room; the use of a pedestal fan that should be closed to an opening. The use of air extractors, and to consider using a stand-alone air cleaner with MERV 14 / ISO ePM1 70-80% filter.

“The air cleaner should be positioned in the areas used by people and close to people. Air cleaner capacity should at least cover the gap between the minimum requirement and the measured ventilation rate – compare the device clean air delivery rate (CADR) (m^3/hr) with the room ventilation rate. Note: Consider that filtered recirculated air does not replace ventilation in any circumstance." (American Society of Heating, Refrigerating and Air-Conditioning Engineers; 2020).

	Smaller than 10 L/s	Larger than 10 L/s
North Side	1.38 L/s, 1.38 L/s, 0 L/s	No results
South Side	1.3 L/s, 0 L/s, 0.3 L/s	No results
East Side	4.12 L/s, 0 L/s	11 L/s
West Side	0 L/s	41.25 L/s, 13.75 L/s
South West Side	0 L/s	48.12 L/s, 34.38 L/s
North West Side	0 L/s	48.12 L/s, 37.13 L/s
North East Side	1.38L/s, 0.7 L/s, 0 L/s	No results
South East Side	0 L/s	41.25 L/s, 27.5 L/s

Table 10: The results of the ventilation rate

The table above is divided into two parts, it includes the final results of the ventilation rate obtained. It will help in the calculation of additional mechanical ventilation when the results are smaller than 10 L/s for one person in a room.

Each case will be analyzed to obtain the percentage of the time that mechanical ventilation is needed to obtain a healthy indoor environment.

North side

. If the velocity is 6 m/s; the ventilation rate in the room is 1.38 L/s

- ➔ Therefore, the ventilation in the rom has 13.8 % of natural ventilation and requires 86.2 % of support from the mechanical ventilation.

. If the velocity is 3 m/s; the ventilation rate in the room is 1.38 L/s

- ➔ Therefore, the ventilation in the room has 13.8 % of natural ventilation and requires 86.2% support from the mechanical ventilation.

. If the velocity is 0 m/s; the ventilation rate in the room is 0 L/s

- ➔ Therefore, the room requires support from the mechanical ventilation.

South side

. If the velocity is 6 m/s; the ventilation rate in the room is 1.38 L/s

- ➔ Therefore, the ventilation in the rom has 13.8 % of natural ventilation and requires 86.2 % of support from the mechanical ventilation.

. If the velocity is 3 m/s; the ventilation rate in the room is 0.3 L/s

- ➔ Therefore, the ventilation in the room has 3 % of natural ventilation and requires 97 % support from the mechanical ventilation.

. If the velocity is 0 m/s; the ventilation rate in the room is 0 L/s

à Therefore, the room requires support from the mechanical ventilation.

East side

. If the velocity is 6 m/s; the ventilation rate in the room is 4.12 L/s

- ➔ Therefore, the ventilation in the room has 41.2 % of natural ventilation and requires 58.8% support from the mechanical ventilation.

. If the velocity is 3 m/s; the ventilation rate in the room is 11 L/s

- ➔ Therefore, the ventilation in the rom has the minimum requirements of the required ventilation for a healthy environment; 100 %.

. If the velocity is 0 m/s; the ventilation rate in the room is 0 L/s

➔ Therefore, the room requires support from the mechanical ventilation

West side

. If the velocity is 6 m/s; the ventilation rate in the room is 41.25 L/s

➔ Therefore, the ventilation in the rom has the minimum requirements of the required ventilation for a healthy environment; 100 %.

. If the velocity is 3 m/s; the ventilation rate in the room is 13.75 L/s

➔ Therefore, the ventilation in the rom has the minimum requirements of the required ventilation for a healthy environment; 100 %.

. If the velocity is 0 m/s; the ventilation rate in the room is 0 L/s

➔ Therefore, the room requires support from the mechanical ventilation

South West side

. If the velocity is 6 m/s; the ventilation rate in the room is 48.12 L/s

➔ Therefore, the ventilation in the rom has the minimum requirements of the required ventilation for a healthy environment; 100 %.

. If the velocity is 3 m/s; the ventilation rate in the room is 34.38 L/s

➔ Therefore, the ventilation in the rom has the minimum requirements of the required ventilation for a healthy environment; 100 %.

. If the velocity is 0 m/s; the ventilation rate in the room is 0 L/s

➔ Therefore, the room requires support from the mechanical ventilation

North West side

. If the velocity is 6 m/s; the ventilation rate in the room is 48.2 L/s

➔ Therefore, the ventilation in the rom has the minimum requirements of the required ventilation for a healthy environment; 100 %.

. If the velocity is 3 m/s; the ventilation rate in the room is 37.13 L/s

- ➔ Therefore, the ventilation in the rom has the minimum requirements of the required ventilation for a healthy environment; 100 %.

. If the velocity is 0 m/s; the ventilation rate in the room is 0 L/s

- ➔ Therefore, the room requires support from the mechanical ventilation

North East side

. If the velocity is 6 m/s; the ventilation rate in the room is 1. 38L/s

- ➔ Therefore, the ventilation in the rom has the 13.8 % of the natural ventilation; and it requires 86.2% support from the mechanical ventilation.

. If the velocity is 3 m/s; the ventilation rate in the room is 0.7 L/s

- ➔ Therefore, the ventilation in the rom has the 7 % of the natural ventilation; and it requires 93% support from the mechanical ventilation.

. If the velocity is 0 m/s; the ventilation rate in the room is 0 L/s

- ➔ Therefore, the room requires support from the mechanical ventilation

South East side

. If the velocity is 6 m/s; the ventilation rate in the room is 41.25 L/s

- ➔ Therefore, the ventilation in the rom has the minimum requirements of the required ventilation for a healthy environment; 100 %.

. If the velocity is 3 m/s; the ventilation rate in the room is 27.5 L/s

- ➔ Therefore, the ventilation in the rom has the minimum requirements of the required ventilation for a healthy environment; 100 %.

. If the velocity is 0 m/s; the ventilation rate in the room is 0 L/s

- ➔ Therefore, the room requires support from the mechanical ventilation

Step 4: Conclusion of the ventilation of the Convent in Ajaltoun

	North Side	South Side	East Side	West Side
Ventilation 6 m/s	13.8 % Natural Ventilation	13.8 % Natural Ventilation	41.2 % Natural Ventilation	100 % Natural Ventilation
	86.2 % Mechanical Ventilation	86.2 % Mechanical Ventilation	58.8 % Mechanical Ventilation	0 % Mechanical Ventilation
Ventilation 3 m/s	13.8 % Natural Ventilation	3 % Natural Ventilation	100 % Natural Ventilation	100 % Natural Ventilation
	86.2 % Mechanical Ventilation	97 % Mechanical Ventilation	0 % Mechanical Ventilation	0 % Mechanical Ventilation
Ventilation 0 m/s	0 % Natural Ventilation	0 % Natural Ventilation	0 % Natural Ventilation	0 % Natural Ventilation
	100% Mechanical Ventilation	100% Mechanical Ventilation	100% Mechanical Ventilation	100% Mechanical Ventilation

	South West Side	North West Side	North East Side	South East Side
Ventilation 6 m/s	100 % Natural Ventilation	100 % Natural Ventilation	13.8 % Natural Ventilation	100 % Natural Ventilation
	0 % Mechanical Ventilation	0 % Mechanical Ventilation	86.2% Mechanical Ventilation	0 % Mechanical Ventilation
Ventilation 3 m/s	100 % Natural Ventilation	100 % Natural Ventilation	7 % Natural Ventilation	100 % Natural Ventilation
	0 % Mechanical Ventilation	0 % Mechanical Ventilation	93 % Mechanical Ventilation	0 % Mechanical Ventilation
Ventilation 0 m/s	0 % Natural Ventilation	0 % Natural Ventilation	0 % Natural Ventilation	0 % Natural Ventilation
	100% Mechanical Ventilation	100% Mechanical Ventilation	100% Mechanical Ventilation	100% Mechanical Ventilation

Table 11: The percentage of the natural ventilation and the mechanical ventilation

4.3 Conclusion of the analysis

From the chapter 4 of the thesis, the analysis done using the CFD program for both the monastery in Jeita and in Ajaltoun show that a support from the mechanical ventilation is needed to create a healthy indoor environment. The buildings that are chosen by the municipalities in Mount of Lebanon can ensure a healthy environment with a support from an alternative source.

In comparison between the two monasteries, the convent of Mother of God in Ajlatoun requires less support from the mechanical system according to the calculations done. The calculations were done according to the roadmap put by the World Health Organization.

5. Conclusion

The aim of this study was to analyze the buildings that are converted to quarantine facilities in Lebanon. However, due to the economical and regional problems in the country, each municipality had to work independently. There were many limitations faced while collecting the date such as the closure of the institutions due to the Covid-19, the revolutions on the streets in Lebanon and the lack of data. These problems limited my research to the Mount of Lebanon; the Kesserwan district. Interviews and site visits were done to collect the required data. The buildings in Kesserwan were limited to monasteries. The purpose of this study was to answer these questions; what are the requirements needed for buildings to be converted to receive the Covid-19 patients? how can these requirements meet sustainable standards for healthcare systems? on which aspect in sustainability the focus will be? what is the role of ventilation in the healthcare facilities?

The literature review chapter helped in understanding and highlighting the importance of the ventilation in the health care units or the buildings that are receiving patients infected by an airborne disease. Moreover, the World Health Organization stressed on the importance of the natural ventilation and other alternatives to ensure a healthy environment. The analysis was done on two chosen convents in Jeita and Kesserwan, using the CFD program. The results obtained showed that the rooms of the patients had a healthy indoor environment on some levels, but required further support from a mechanical system. The buildings were chosen randomly by the municipalities according to their availability at that time.

An important approach to lowering the concentrations of indoor air pollutants or contaminants including any viruses that may be in the air is to increase ventilation – the amount of outdoor air coming indoors. A healthy indoor environment is required for the patients to recover without infecting the other occupants of the buildings; the ventilation in the buildings should be analyzed before converting them to a future quarantine facility. In fact, CDChttps://www.cdc.gov/ (Centers for Disease Control) has stated that "Indoor spaces are more risky than outdoor spaces where it might be harder to keep people apart and there's less ventilation." Opening windows and doors (when the weather permits), operating window or attic fans, or running an air conditioner with the vent control open increases the outdoor ventilation rate in a home. Scientists stress that ventilation should be viewed as one strategy along with vaccination, which provides the best protection against infection, and high-quality, well-fitted masks, which can reduce a person's exposure to viral particles by 95%. Improved airflow provides an additional layer of protection — and can be a vital tool for people who have not been fully vaccinated, people with weakened immune systems, and children too young to be immunized.

Allen, who has long championed "healthy buildings," said he welcomes the new emphasis on indoor air, even as he and others are frustrated it took a pandemic to jolt the conversation among office workers. "This is a massive shift that is, quite honestly, 30 years overdue," Allen said. "It is an incredible moment to hear the White House says that the indoor environment matters for your health."

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- Sir Arthur Bliss (1891–1975), English conductor and composer, Professor of Composition at the Royal College of Music. In the 1930s, his works included musical scores for contemporary operas and ballets (Miracle in the Gorbals and Checkmate) and film music (Things to come and Conquest of the air).
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