Simulation of Coronavirus spread: Concerns and Facts

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Abstract

Evidently, simulation is used in a variety of applications, like engineering, science, and even the medical field. The use of simulation by researchers and scientists helps in experimenting virtually, identifying, and investigating different parameters in cases that cannot be performed in reality. Therefore, with the current state of the COVID-19 spread worldwide, simulation of various scenarios of the virus spread using diverse programs is extremely important for the world health organization (i.e. WHO), in order to come up with rules and safety precautions for citizens interacting in public and to avoid getting infected. In this paper, sundry COVID-19 simulation cases and scenarios collected from various research studies are discussed, hence broad conclusions are stated based on the results obtained.

Keywords
COVID-19, Simulation, Cough, Spread, Corona Virus

1. Introduction
COVID-19 is the latest descent of coronavirus that spreads between human beings and animals. For humans, the virus attacks the respiratory system and causes infections in the lungs, which can cause cough, difficulty in breathing, and in some severe cases, death. Since the virus is rapidly spreading due to its unknown causes and origins, limited information on the ways of transmission between infected and healthy people are being studied by researchers and scientists in order to find the most suitable rules and precautions for citizens in addition to quarantine.

In order to understand how the virus disperses between people, computer simulation of various scenarios, including infected people in a particular space, is used by problem solvers and researchers under complex homogenous and unpredictable situations. The use of computer simulation helps with the use of predictive imitation to understand the development, and henceforth find the most suitable vaccines.

In this paper, a literature review of current studies and simulations of cases, including spaces that are affected by the infection are examined, conclusions of all studies investigated are declared up to date.

2. Literature Review
2.1 Virus Spread
In order to understand how the virus spreads quickly between people, studies from the US published in the Washington post based on the curve in Figure 1 show that the relationship between the number of cases in the US with time is exponential, by moving along with the situation using mathematics only, the government predicted having a million cases in May.

Since the growth is very rapid, investigating the severity of the chances of spread, and simulating the situation is done while naming the disease in the computerized model to be "Simulitis", which is considered to be highly infectious, even more than coronavirus itself. By adding one person into the room and leaving people (i.e. dots) to be moving freely at any angle, and also assuming that a recovered person is immune to the disease, the following simulation results as shown in Figure 2 are obtained at different times since the beginning of investigation until the end where all people are immune and recovered (Capalbo, 2020).

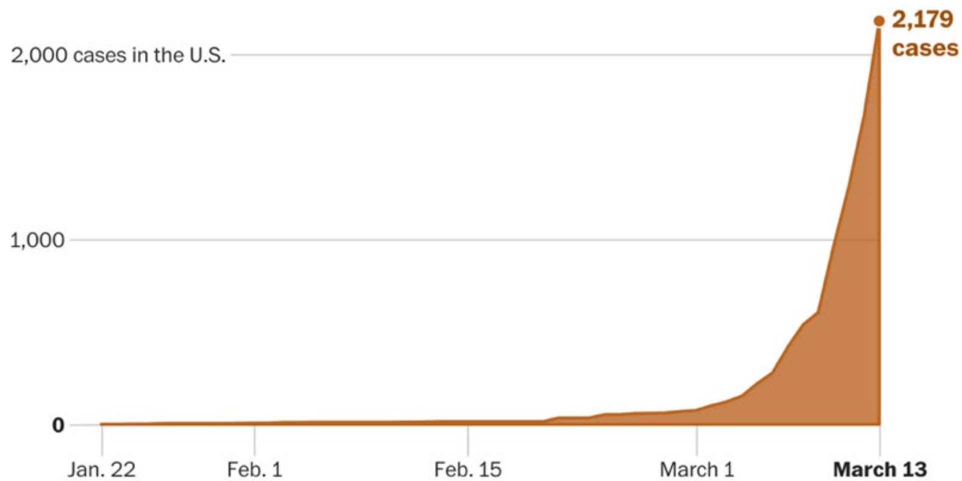

Figure 1. Exponential Curve improvising the number of cases in the US

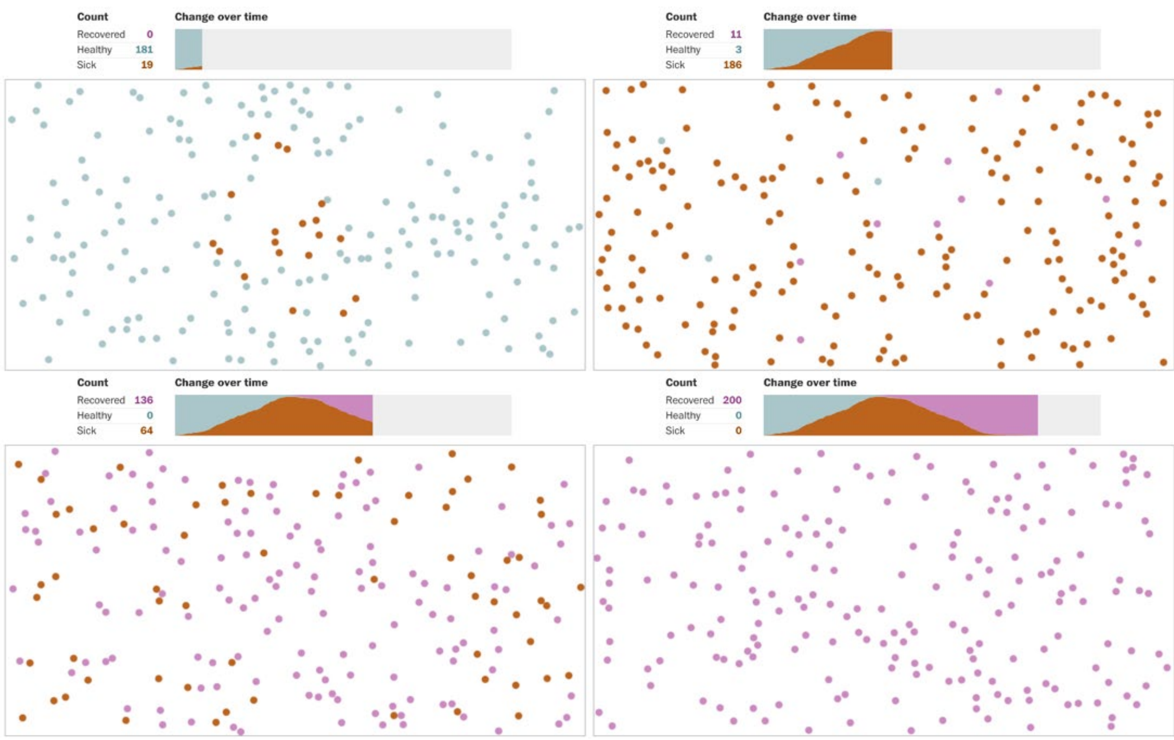

Figure 2. Simulation of Infection spread with time

Since quarantine was suggested by the government on citizens, a study on how it is going to affect the rapid growth is undertaken. By adding a forced quarantine to the population prepared at hand, results shown in Figure 3 proves that quarantine cannot stop the virus from spreading, however, it is going to slow down the infection rate rapidly, which will make it a lot easier on the government to handle the cases of people who caught the disease.

Analysis of different cases as shown in Figure 4 while limiting the movements of people in public show the effect of quarantine on the original exponential curve as in Figure 1.

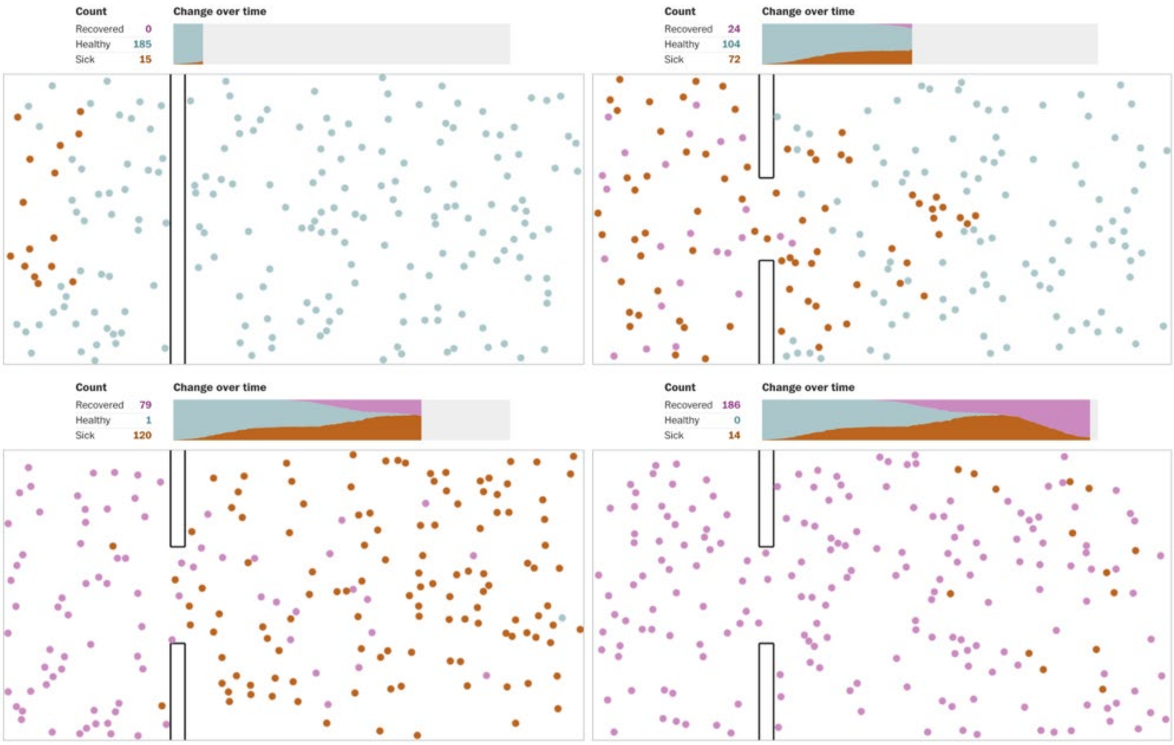

Figure 3. Simulation of Infection spread with time with forced quarantine

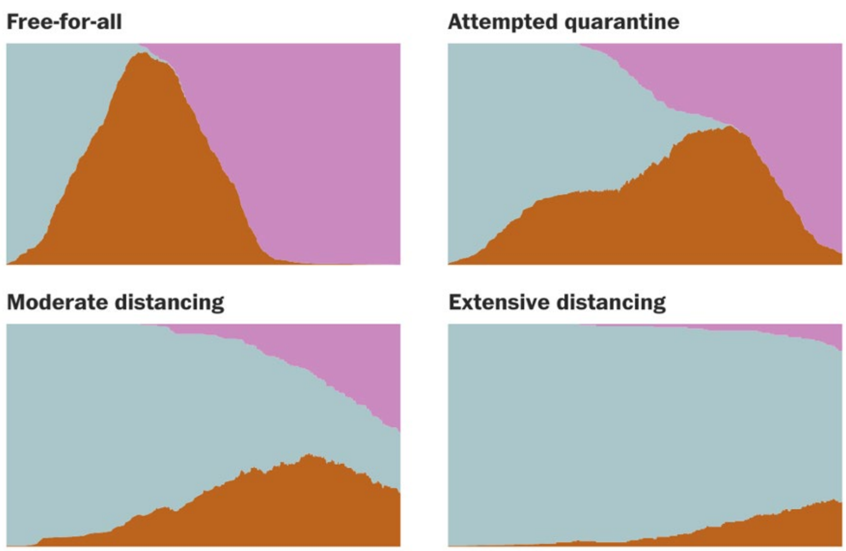

Figure 4. Exponential curve changes due to quarantine

Understanding the nature of fluid mechanics and droplets is one of the key essential studies that should be undertaken in order to get familiar with the coronavirus. Studies from Toho University, NHK, and a group of researchers in Japan have used high-sensitivity cameras and laser beams to investigate microdroplets (i.e., particles less than 0.1 micrometers) found in the air.[3] Sneezing and coughing produce around 100,000 particles, while some are larger than 1 millimeter and can be captured using basic cameras as shown in Figure 5, while also noting that these larger particles fall quickly into the ground, emphasizing that the infection type is not the usually known droplet infection, but a micro-droplet disease (Broom, 2020).

Figure 5. Normal Camera Capturing Sneezing

Simulating the case of a person sneezing in a poor-ventilated room, and watching microdroplets' behavior, as shown in Figure 6, microdroplets stayed in the air even after 20 minutes, researchers suggest opening windows and having a good air circulation unit is the best solution to avoid particles staying in enclosed spaces (Graham, 2020).

Figure 6. Time-lapse of Microdroplets in the Air

2.2 Social Distancing

Research done from the Kyoto Institute of Technology on the importance of social distancing was done by simulating a sick person coughing in an area where other individuals are present (Parshina-Kottas et al., 2020)
. As shown from Figure 7, cough generates respiratory droplets of different sizes, while the larger ones fall into the ground, or break into little droplets.

Simulating a space of 600 square feet, particles behave differently under the same conditions, while heavy coughs produce about a quarter of a teaspoon of fluid, the particles that quickly immerse in the air.

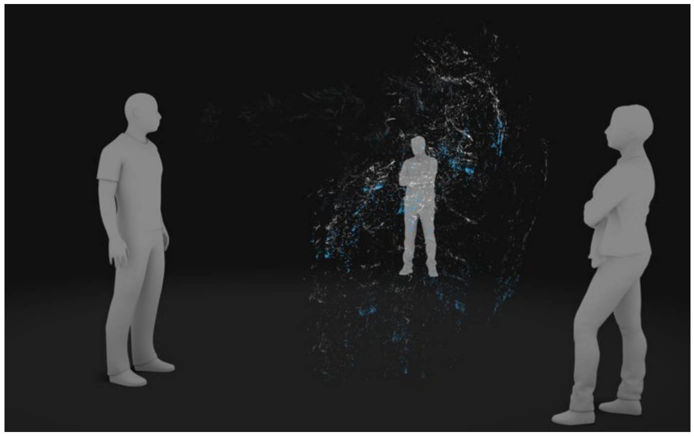

Figure 7. Cough Spread Simulation

Keeping at least six feet away from other people lowers the chance of infection as the C.D.C says, but that chance is only possible when large droplets are the main type, ignoring the tiny aerosols that remain in the air for long time before landing on surfaces. With that being investigated, results from research in M.I.T showed that coughing can reach about 16 feet, and sneezing reaches as far as 26 feet (Dizikes, 2014), which is why people should consider social distancing in order to avoid contact and consider distances larger than 6 feet as shown in Figure 8.

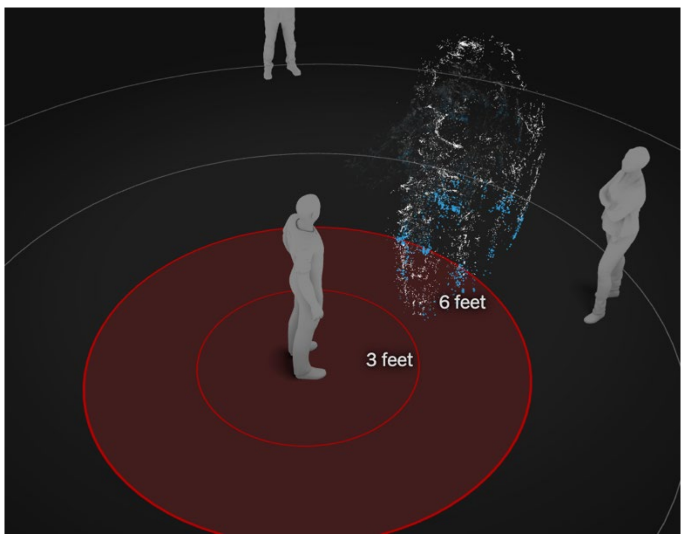

Figure 8. Safe Distance Simulation

A team of experts from Dassault Systemés using SIMULIA Software, specifically CFD (i.e. contract of difference) , have been using simulation for over nine years to investigate droplets spraying out of tires, however, in the time of need for simulating the droplet infection due to cough and sneezing from the respiratory tract, the team had the available physics at hand, and created the following simulation as shown in Figure 9.

The main objective behind the research done in the simulation was by studying different PPE (i.e. Personal Protective Equipment) used in the industry, and by trying out sundry types, their studies concluded that the safest type of PPE is masks that go along the forehead, and are completely sealed from the top to ensure that particles do not descend on the person and enters from an open gap (Scott, 2020), just as the example in Figure 9.

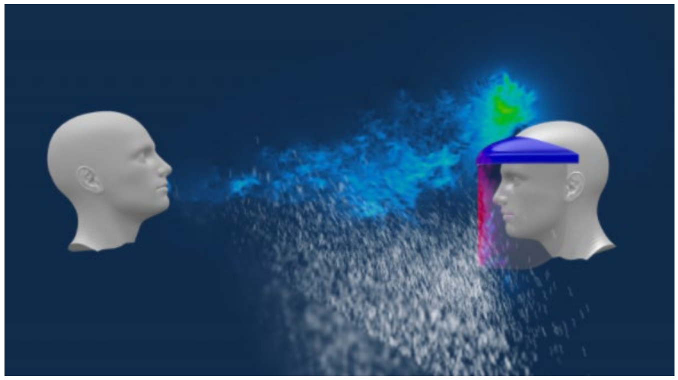

Figure 9. Sneezing Droplet Simulation

Another simulation done by the same team showed how droplets transfer with an elbow sneeze in a crowded air-conditioned office, as shown in Figure 10. Worrying conclusions from various simulations indicate that particles from infectious individuals can stay in the air after they cough or sneeze, and then turn into surface infections and stay for hours, but since particles are small in size, it can return to the air again by any action happening in that space, and that is how people are infected even though they haven't been anywhere near someone sick.

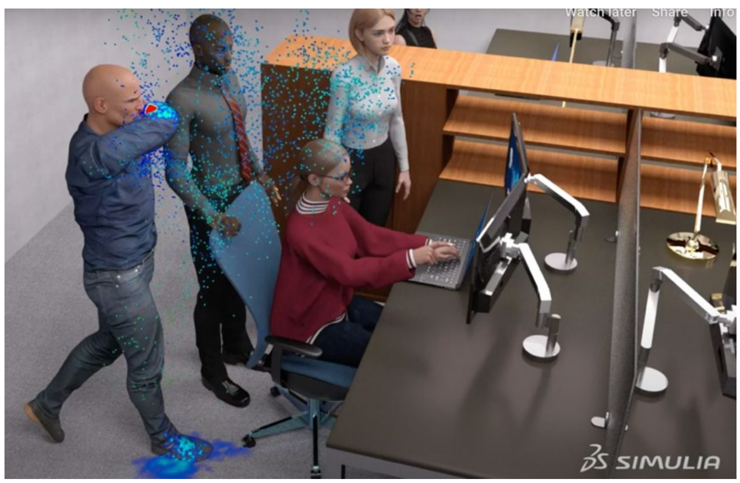

Figure 10. Crowded Air-Conditioned Spaces Simulation

2.3 Case Study: Outdoor Activities

Evidently, people perform some activities outdoors, which cannot be ignored, like jogging and working out. In a Belgian-Dutch study done by ANSYS partners Bert Blocken and Fabio Malizia at the Eindhoven University of Technology and KU Leuven, the simulation was used in order to find the best suitable distance for runners outside in order to reduce the impact of the spread of the virus (Marchal, 2020). Since runners breathe heavily outside while also moving at a relatively higher speed than the wind, the slipstream behind each individual is where all the particles containing contaminants propagate from that person who takes around few minutes to reach the ground, and is where other people should not be close to, as shown in Figure 11, hence, after checking the distance advised by the government between individuals (i.e. 2 meters) it has been concluded that it is not enough to cover the time for the particles to reach the ground, which can lead to contaminants on the lower body of the person behind, therefore, it is advised based on the results, that people walk diagonally in order to avoid being in the slipstream of another person, to leave 4-5 meters between people walking on the same line, 10 meters for people slow biking or running, since they do not have face masks on (which can reduce the impact by 600%) (Parker and Olivia, 2020).

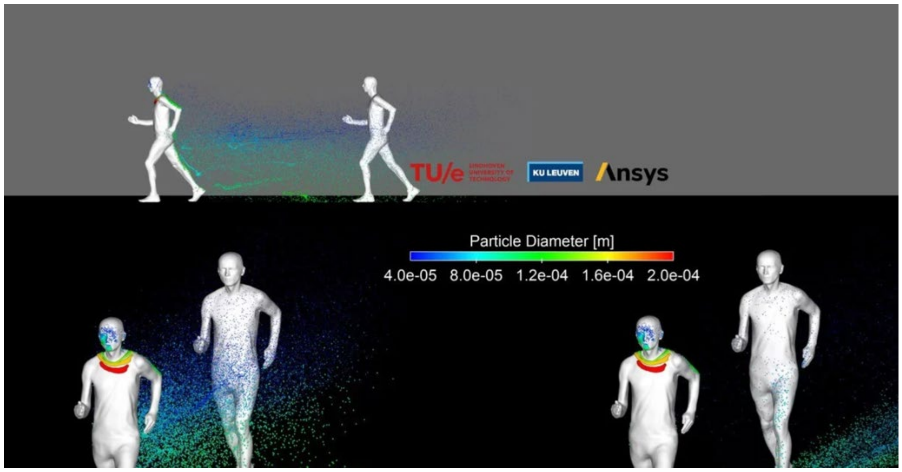

Figure 11: Slipstream ANSYS Simulation

2.4 Case Study: Grocery Stores

In a study carried out by the developers of the "Unity" simulation program (Fort et. al,2020), using a mathematical model that represents a realistic case of the phenomenon at hand, a simulation of grocery stores is investigated. Unity is a software that accepts realistic simulation of time interactively, as well as having a quick frame simulation in an offline mode. Unity software is exceptionally functional since it has the ability to simulate the effects of over 50 individuals in the course of 10 minutes, as shown in Figure 13.

By defining the environment that contains all the objects in the studied space in 3-D and the different parameters that can be changed in each simulation, which should be analyzed by the developers for conclusions, researchers create various scenarios with complex parameters. By doing that, the emerging dynamics of each space in its' individual situation will indicate how many people are exposed. The project's virtual space is shown in Figure 12, where all objects and counters are created.

Figure 12. Virtual Space

Allowable paths of the virtual individuals using this space is also indicated in the 3D model while stating three possible types of people: healthy (blue), infectious (red), and exposed (yellow), whenever the distance between a healthy and an infectious person decreased, the individual becomes in an exposure zone.

Analyzing the results at hand from the simulation, there is a linear relationship between the infection probability and distance between people, until a maximum probability of 1 whilst physical contact. Healthy individuals may become exposed to infection by the model's tuning parameters in Figure 13, while simulating, some people become exposed after a period of time, noting that a store does not have control over the number of infectious people shopping, which was set to be a variable parameter in the simulator.

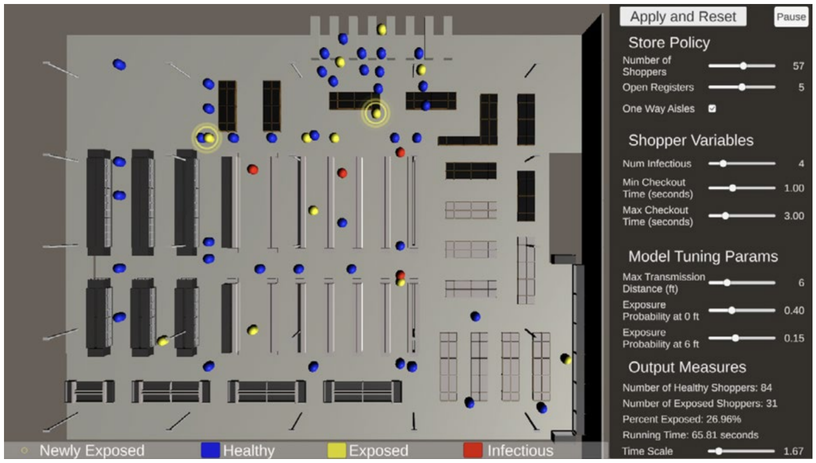

Figure 13. Unity Demo Application Window

After simulating for 10,000 instances in the simulator, sensitive data analysis is done by a tornado diagram and formed into the following graph in Figure 14

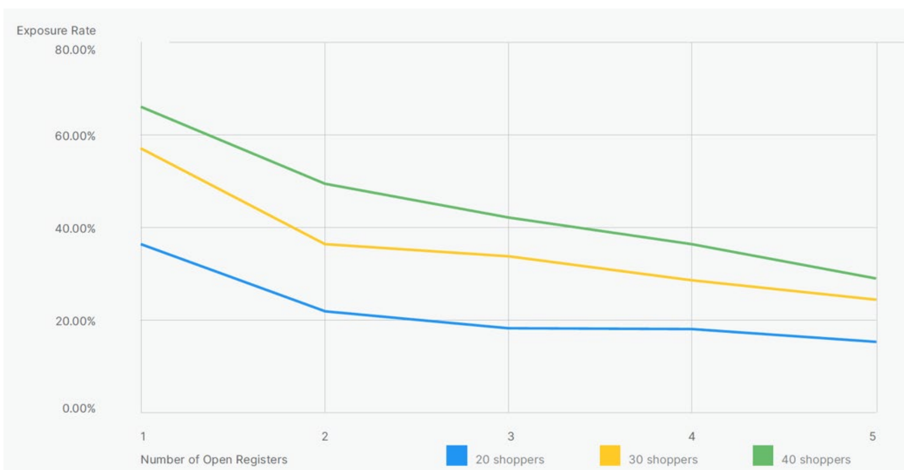

Figure 14: Exposure rate as a function of the number of open registers

With that being explained, results conclude that the exposure rate on costumers by infectious individuals can be impacted and lessened by opening a second register, hence opening more records as the number of shoppers increase, in order to reduce the spread of the virus.

Another case study on grocery stores is carried out by four Finnish research organizations using a supercomputer. Supercomputers are computers that have an extremely fast-processing ability compared to original computers, which are usually used by researchers to compute mathematical models in research (Anon, 2001). In this study, an infected person coughs in a grocery store as shown in Figure 15, throughout the simulation, droplets leaving the respiratory tract in that area stay in the air for a longer time than expected beforehand, which contains pathogens such as COVID-19, and can cause the droplet infection, which is the main transmission course of the exposure until now.

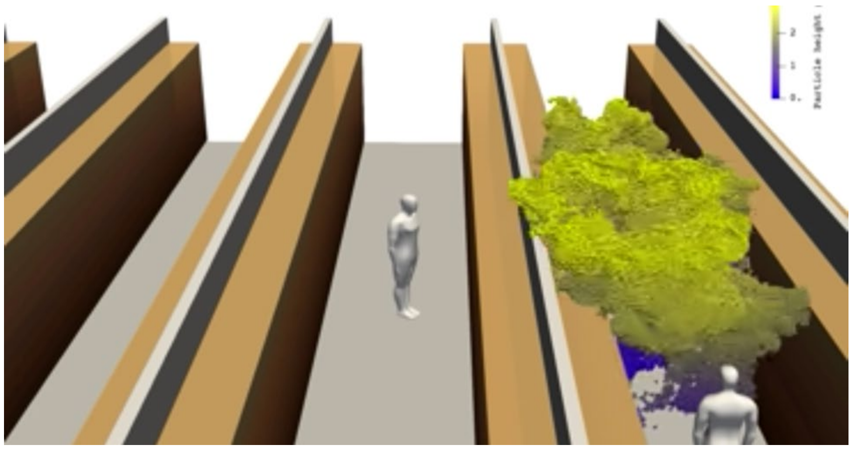

Figure 15: Propagation of virus in the air in grocery store

Results show that an infected person can cough or sneeze in some areas and leave behind them a zone full of contaminants, which concluded from this study that people should avoid busy indoor spaces, wear face masks to avoid being exposed to those areas, and to cough/sneeze onto a tissue or your sleeve for hygiene purposes.
Since one of the symptoms of the coronavirus is a dry cough, and the particle size is typically around 15 micrometers and less, which is considered very small, it cannot sink into the floor. Instead, it travels through the air. Studies also show that the coronavirus cannot be found until now in particles less than 5 micrometers (Vuorinen, 2020).

2.5 Case Study: Public Transportation

Scientists from the University of Oregon have created a simulation using MSC Software that shows how droplets from infected people are spread on the tube while people are talking as shown in Figure 16

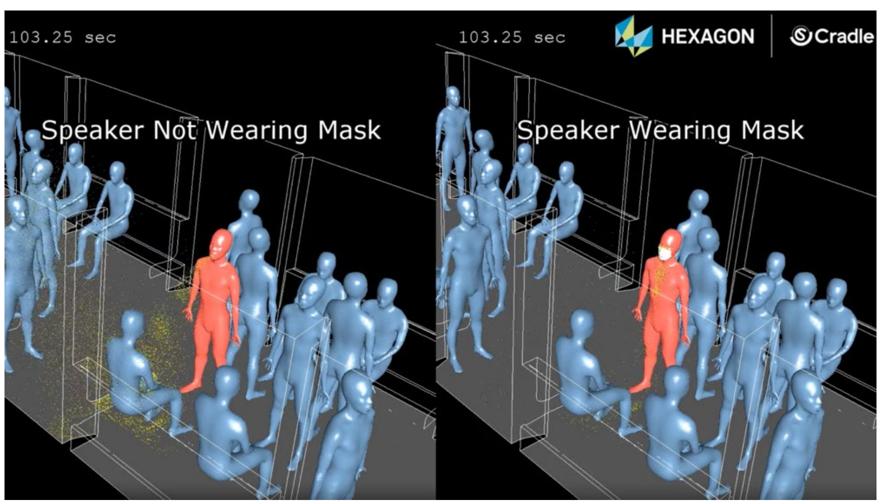

Figure 16: Infection coating by the failure of social distancing in two cases

Scientists also state that droplets do not travel as far as it does when someone sneezes (i.e., 7 meters), but talking can also infect other people. Hence, scientists and health specialists encourage people to always wash their hands regularly (Elvin, 2020).

A Hexagon's computer-aided engineering simulation specialist have developed simulations that show how sneezing can actually transfer droplets in the air in two cases: no protection, and elbow sneezing, as shown in Figure 17.

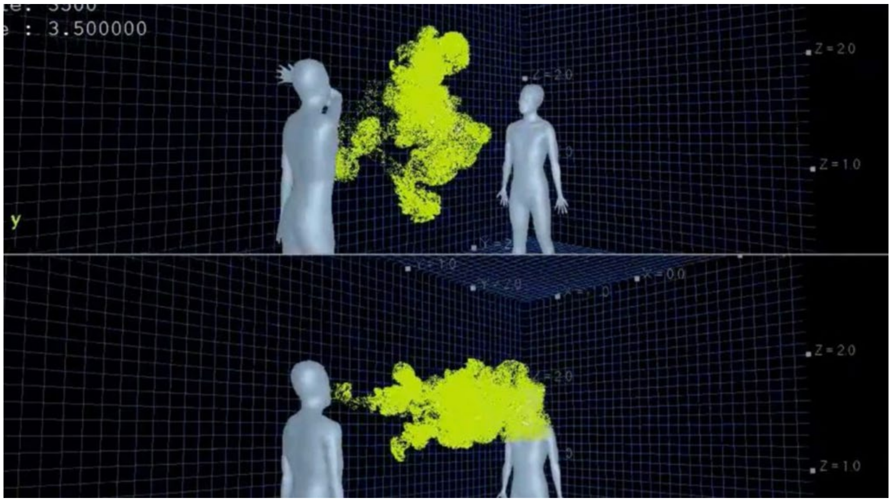

Figure 17: Simulation of sneezing at two cases: zero protection and elbow sneezing

Simulation results showed that elbow sneezing prevents droplets from reaching a person standing two meters away, while zero protection transfers out of range and is considered the most infectious. Hence comes the importance of face masks, which is also empowered by one of the simulations done by Hexagon, which shows how droplets travel in the air once a person sneezes in their face mask. As shown in Figure 18, the distance of droplets transfer is drastically minimized (Marcec, 2020).

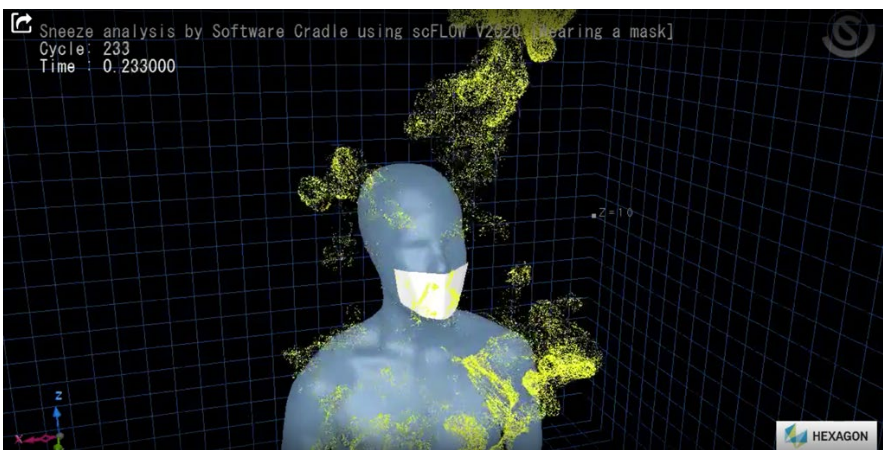

Figure 18: Droplets transfer when sneezing in a face mask

2.6 Case Study: Aircraft Cabins

Since aircraft are enclosed spaces, they're considered one of the risky places for catching COVID-19. In order to understand the behavior of particles inside a cabin, ANSYS CFD, and ANSYS Fluent prepared a model that explains the behavior of particles emitted from people coughing, once with no protection, and the other with face masks on as shown in Figure 19.

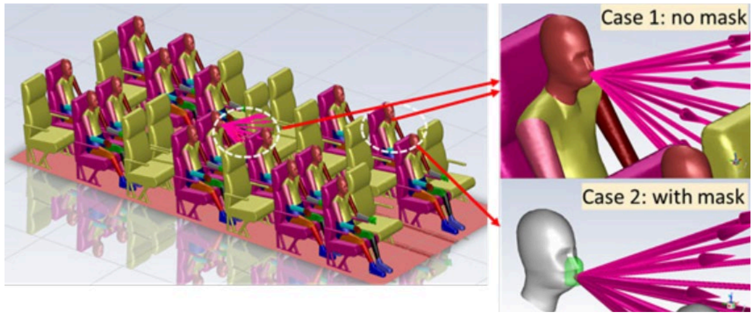

Figure 19: Aircraft Cabin Simulation in Two Cases: No Mask, and With Mask

Keeping in mind that the location of vent in and out from the whole cabin is significant, if the passenger coughing or sneezing is sitting in a position where the air circulation is exceptionally high, with no mask on, it could possibly be spread around the entire space causing infection for many passengers. However, as shown in Figure 20, people wearing a mask have eliminated the chance of spread in comparison to the case of no protection involved, where particles are heavily circulated in the entire cabin, infecting passengers, surfaces, and empty seats.

Figure 20: Cough Simulation of Two Cases: No Mask, With Mask

New simulations of aircraft cabins by Florida Atlantic University simulating aerosols in microns show that particles travel up to 10 feet inside the lodge within minutes, stating that it can survive on non-porous surfaces for almost a whole day, and hence travel through the human tissue to the lungs, if exposed.

Air that is supplied into aircraft cabins go through filters of high-efficiency particulate air (HEPA) that catches large particles, in addition, particles of air are then mixed with the air coming from the aircraft's' compressors, hence reaching the cabin and traveling in a unidirectional manner from top to bottom, exiting at the vents beside people's shoes.

Research also shows that the highest risk of infection happens when boarding and deplaning the lodge. At the same time, the on-flight situation is much safer because of having the HEPA system that gets rid of big particles, in addition to having passengers wear face masks, it is going to be much safer like this, researchers stated.

Wang, a former junior student in Vancouver, creates a simulation of a device that improves the availability of fresh air by 190% in order to reduce the concentration of contaminated air by 55 times (Yang, 2020), as shown in Figure 21. However, it might work theoretically, and in analysis, but not in real life, it is impossible to supply 190% of fresh air continuously to the cabin of passengers.

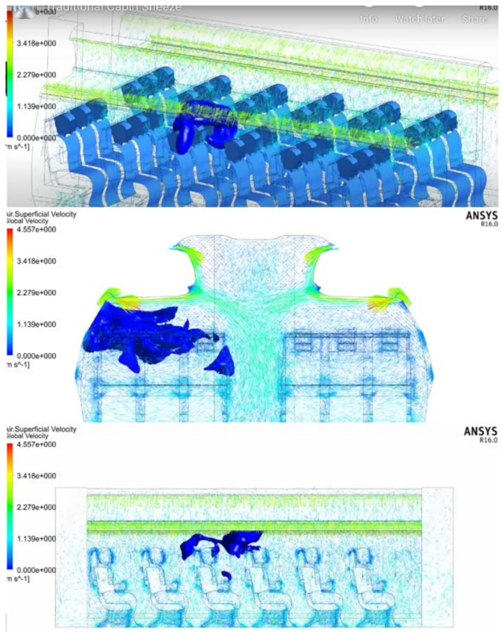

Figure 21. Air-Cabin Wang Design

3. Conclusions

After examining several articles/research papers on different simulations of the virus, it is concluded that coronavirus particles are extremely small in size, which makes it easier for the aerosols to stay in air for a longer time than expected, and could infect people using the exposed space with no protection. In addition, several studies emphasize on the importance of maintaining social distance at distances no less than 6 feet, to prevent any type of interaction between healthy people and infectious individuals, to always have personal protective equipment used, and to open windows, and heavy air-conditioning whenever an area composes of many people gathering. At times like this, it is essential to apply safety precautions in order to stop the spread of the virus until the development of a suitable vaccine is done.

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