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DESIGN AND DEVELOPMENT OF COVID-19 AGENT-BASED MODELLING BASED ON SOCIAL DISTANCE

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Abstract: *COVID-19 is a fatal global pandemic that have been spread throughout the world rapidly. Based on the global statistics, the confirmed cases have been reached 176 million cases at the mid of June 2021. The statistics show how human susceptible to the COVID-19 and how easy the COVID-19 to be spread. Typically, the COVID-19 is transmitted when a healthy person is closed contact with the infected person via the respiratory droplet or saliva. Therefore, social distance has been defined as the main factor that trigger the spread of COVID-19. With the reopening of the primary and secondary schools in Malaysia from March 2021, the formation of new clusters become more seriously. As until 21st April 2021, there are total of 83 COVID-19 clusters is reported that related to the education sector since from early January 2021. The students may come back to the campus for conducting academic activities. Therefore, this study is proposed to analyze the COVID-19 infection inside the campus using Agent-Based Modelling (ABM). The designed ABM has three different settings, which are lecture room, laboratory and office. FABU students and staffs are the agents for the simulation inside the FABU buildings. The factors of COVID-19 infection by the agents are not only considered the social distance between the people, but also ventilation condition of building and exposure time of contact. The designed ABM consists of the parameters such as number of people and social distance to allow the users to analyze the effect towards the COVID-19 infection. Through this model, the administrators could use to plan the classrooms and laboratories to the students for returning back to the campus. This paper suggests to extend the research by developing the designed ABM using AnyLogic software.*

Keywords: *COVID-19, Social Distance, Agent-Based Modelling (ABM), AnyLogic*

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Introduction

Coronavirus (COVID-19) has been recognized as the main issue for worldwide since year 2020. It is a fatal global pandemic that is caused by severe acute respiratory syndrome coronavirus 2 (SARSCoV2) (WHO, 2020a). From the global statistics of mid of June 2021, the cumulative confirmed COVID-19 cases has been reached 176 million, whereas 662 thousand cases in Malaysia (JHU CSSE, 2021).

The pandemic is transmitted directly or indirectly when contact with the infected person via their saliva or respiratory droplets (WHO, 2020b). WHO advises people to stay at least 1.0 m of physical distance and stay at home as much as possible because an estimation of 92% of cases will be lowered if the proper social distancing practices are conducted by the community (Prem et al., 2020). Thus, the social distance is considered the main factor to control the COVID-19 spread. For the indoor environment, the COVID-19 infection risk is affected by social distance, ventilation condition and exposure time of contact (Burridge et al., 2021). Ministry of Health Malaysia (MOH) has urged the public to stay away at least 1.0 m from each other to prevent the COVID-19 transmission risk whether staying inside the room or outdoor (MOH, 2020). The Ministry of Higher Education Malaysia (MoHE) allows the students to come back campus for conducting academic activities, but all the activities should compliance with the Standard of Procedures (SOP) like maintaining social distance, wearing masks and using disinfectants.

Computational models like Agent-Based Modelling (ABM) is a recent popular effective tools to analyze diseases spread in terms of geographical and demographic aspects (Dignum, 2021). An ABM is comprised of interacting agents and their autonomous behaviors within an environment (Hooshangi & Alesheikh, 2017). The repetitive dynamic processes are allowable to show the agent interaction over the time (Macal & North, 2014).

In Malaysia, the reopening of the primary and secondary schools started to implement since March and April 2021 respectively. The reopening of the schools have triggered the movement of people to gather in the school area. While on 21st April 2021, the cumulative total of 83 COVID-19 clusters from 1st January 2021 until 21st April 2021 is reported that related to the education sector (Bernama, 2021). 59% of the clusters are still active. Through this statistic, it is clearly showed that educational area is a high-risk place to create the new COVID-19 clusters. In this study, an agent-based simulation model of COVID-19 infection that consider the social distance, ventilation condition and exposure time within building will be conducted. It is used to simulate the student movement into the building of campus during COVID-19 pandemic and predict the spread of COVID-19 based on social distance using ABM.

Literature Review

The infection risk of COVID-19 is affected by social distance, ventilation and exposure time (Burridge et al., 2021). In a confined space, only considering the social distance is not enough to prevent the COVID-19 infection.

Social Distance

Social distance describes the physical distance that maintained between the individuals. With the outbreak of COVID-19, WHO advised people to stay at least 1.0 m of physical distance to each other to reduce the contact between people (WHO, 2020c).

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Xie et al. (2020) has summarized the social distancing rules for some countries (Table 1). The countries stated have followed the WHO rule with keeping at least of 1.0 m between the individuals.

Table 1: Social Distancing Rules by Countries

Country	Social Distancing Rule
Australia	Keep 1.5 m
Brazil	At least 2.0 m
Canada	At least 2.0 m
China	More than 1.0 m
Japan	At least 1.8 m
South Africa	At least 1.0 m
United Kingdom	At least 2.0 m
United State	Maintain 2.0m

Source: Xie et al. (2020)

Social distance of 1.0 m has been recognized as the minimum requirement of preventing COVID-19. However, maintaining of 1 m physical distance is not really the best social distance to combat COVID-19. The review of the studies that comparative meta-analysis with COVID-19, SARS and MERS by Chu et al. (2020) showed that the current policies that staying at least 1.0 m social distancing was just contributed on large reduction in infection. Among of the social distance, 2.0 m might be more effective than 1.0 m to control the spread of influenza disease.
There is strong association of proximity between the exposed individual with the risk of infection. The relative effect might decrease 2.02 times for every 1.0 m away of distancing (Chu et al., 2020) (Figure 1).

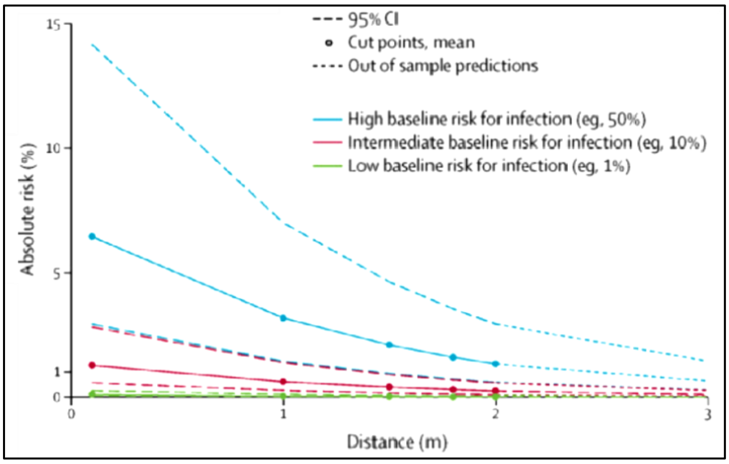

Figure 1: Relationship of Social Distance and COVID-19 Risk
Source: Chu et al. (2020)

Ventilation

COVID-19 is one of the airborne disease which could transmitted easier in a poor ventilation (Morawska et al., 2020). However, only maintaining the social distance is not enough to control the spread of COVID-19 especially in the indoor. There is necessary to increase the amount of air into the building from outdoor to dilute the indoor air (CDC, 2021a). Wells-Riley Model is a popular model to predict and examine the infection risk of disease (Equation 1). The purpose of this model is to examine the relationship of ventilation rate and the probability of infection.

$$\boldsymbol{P_I = 1 - exp\left(-\frac{Iqpt}{Q}\right)} \qquad \textbf{(1)}$$

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where P_I is the probability of infectious risk, I is number of infected persons, p is pulmonary ventilation rate of individual, q is quantum generation rate produced by an infector, t is exposure time and Q is the ventilation rate.

Since both ventilation and social distance affect the infection risk, Sun and Zhai (2020) have investigated and modified the Wells-Riley Model to model the infected probability of the COVID-19 in the confined space by adding the consideration of social distance probability (P_d) and effectiveness of the ventilation factor (E_z) (Equation 2). Through this model, the relationship of social distance, exposure time and effectiveness of ventilation factors towards the COVID-19 infection rate can be analyzed.

$$\boldsymbol{P_I = 1 - exp(-P_d \frac{Bqpt}{E_z \cdot Q/N})} \qquad \textbf{(2)}$$

where Q/N is the minimum ventilation rate per person and B is initial infection rate. B is represented by $B = I/N$. Q/N is referenced to the standard of American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) based on the occupancy settings (Table 2).

Table 2: Minimum Requirement of Ventilation Rate

Occupancy Category	People Outdoor Air Rate (L/s/person)
Lecture Classroom	3.8
Library	2.5
Office Space	2.5
University/College Laboratories	5.0

Source: ASHRAE (2019)

Exposure Time

As showing by the Equation 1 and Equation 2, the infection risk of the COVID-19 is affected by the the exposure time. CDC (2021b) also stated that the close contact increases the chances of getting infection. It describes close contact happened when the persons are contacted for at least 15 minutes within six feet (1.8 m) over 24 hours. If a healthy person is closed contact with an infected person, it is more likely infected by the COVID-19.

Methodology

Study Area

The study area is located at the Faculty of Built Environment and Surveying (FABU) in Universiti Teknologi Malaysia (UTM), Johor, Malaysia (Figure 2).

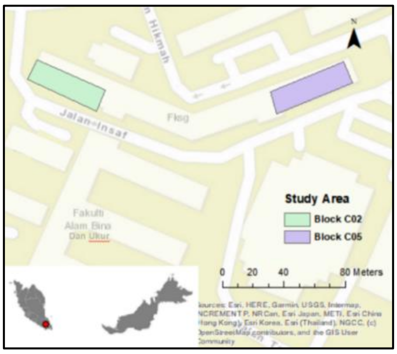

Figure 2: Location Map of Study Area

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Different room settings are represented by different floor level, just as shown in Table 3. The rooms are assigned their respective parameter of ventilation condition based on the ASHRAE standard (Table 2).

Table 3: Representative of Study Area

Block	Floor Level	Room Type
C02	2	Office
C02	4	Lecture Room
C05	2	Laboratory

Data Source

The shapefile of the FABU rooms based on different level and the interior layout of the rooms of the buildings are referred to the building layout map from Office of Asset Development (PHB) UTM.

The non-spatial data is composed of the number of FABU students and staffs that entering the UTM campus during the semester 2 session 2020/2021. The statistics of students is collected from the Office of Student Affair (HEP) UTM according to their course and type of students (undergraduate or postgraduate). The statistics of staff will be collected from Human Resource of FABU.

Design of Agent-Based Model

The environment of the ABM is set at FABU UTM. Each room has their specific ventilation condition based on ASHRAE standard (Table 2).

Agent

The simulation model consists of single agent to represent a person at a time. For this model, the agents are represented by FABU students and staffs. The initial state of the agents is healthy state. The agents are contacted to each other. The model is allowed to input the infected agent. If the healthy agent is contacted with an infected agent without the social distance, it is more likely to be affected. The state of the agent is changed to infected patient when the social distance and the ventilation condition are not favored. The state chart of agent is shown in Figure 3.

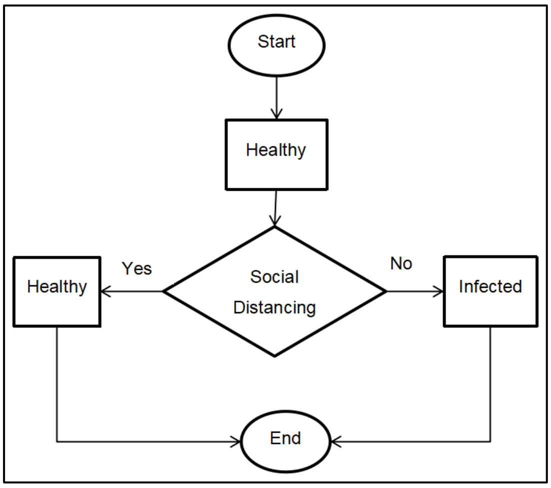

Figure 3: State of Agent

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Parameter

Table 4 depicts the parameters used for the ABM. They act as the variables of the ABM to analyze the COVID-19 infection.

Table 4: Representative of Study Area

Parameter	Source
Number of Students	HEP
Number of Staffs	FABU Human Resource
Social Distance (m)	Xie et al. (2020)
Infection Risk	Equation 2 (Sun & Zhai, 2020)

The Equation 2 is rearranged to find the time of becoming infectious, t just as shown in Equation 3.

$$t = -\frac{In\,(1-P_I)\cdot E_z\cdot Q/N}{P_d\cdot Bqp} \quad (3)$$

Some of the values of the parameters in Equation 3 are constant. For example, E_z, p, q and Q/N. E_z is referenced to ASHRAE standard. For this model, the E_z value is 1.0 that represent the ceiling supply of cool air. p is 0.3 m^3/h for the case the people are sitting or doing the light indoor activities (Duan, 2013). The value of q of COVID-19 is under the range of 0.238/s (Sun & Zhai, 2020). Q/N is referenced to Table 2. Other parameters like P_d, B and P_I have dynamic value. The users are allowed to change the value in the interface and analyze the effect of different value. P_d is associated with the social distance (d) and calculated from Equation 4.

$$P_d = -18.19\ln(d) + 43.276 \quad (4)$$

Model Scenario

This model is developed for analyzing the COVID-19 infection inside the building of campus. There are few scenarios can be simulated to observe the agent' behaviors (Table 5). An infected agent is added into the model and interacted with other agents. The number of infected persons is updated over the time. The scenarios are analyzed by different variables just as shown in Table 6 for COVID-19 infection.

Table 5: Scenario of Models

Room Type	Scenario
Office	- Staffs are moving to do the office stuffs and sitting back to the seats. - Staffs are moving to the reception counter when the visitors came.
Lecture Room	- Students are entering into the lecture class and sitting on the seats. - Students are accumulated into few groups for group discussion.
Laboratory	- Students are doing lab work and sitting on the seats. - Students are doing group lab work. - Students are moving from seat to lab stations and vice versa.

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Table 6: Parameters of Scenario of COVID-19 Analysis

Room Type	Occupancy Ratio of Total Number of Agents (%)	Time (min)	Social Distance (m)
Laboratory	100	15	1.0
Laboratory	50	15	1.0
Laboratory	100	30	1.0
Laboratory	100	15	1.5
Laboratory	100	15	1.8
Laboratory	100	15	2.0
Lecture Room	100	15	1.0
Lecture Room	100	15	1.5
Office	100	15	1.0
Office	100	15	1.5

Model Development

The simulation model can be developed using AnyLogic software. Although AnyLogic is a proprietary simulation software, it provides a free Personal Learning version for the beginner but limited in one hour simulation. The advantage of AnyLogic is it could expand and customize the model based on the users' needs by coding Java language into the program. It also has the GIS capabilities to place the agents and define their properties on the map (El Raoui et al., 2018).

The spatial data of FABU UTM can be imported into the AnyLogic software. They are overlaid with the GIS map provided by the AnyLogic software to act as the base map for the simulation. The students and staffs acted as the agents of the simulation.

AnyLogic software contains some available libraries such as Pedestrian Library to describe the movement and behaviors of pedestrian agents, whereas Statechart is used to construct the agent state. t that found in Equation 3 is integrated into the AnyLogic software as a trigger transition factor to change the agent state from healthy to infected. The slider and edit box from the Control Palette can be added into the model to dynamically change the value of P_d, B and P_I.

Expected Results

The expected results will consists of simulation model on maps and graph which showing the number of infection persons over the time. The simulation will depicted the movement of the agent entering and leaving the buildings of FABU UTM. The agent consists of students and staffs that maintaining the proper social distance when walking. The state of the agent is represented by the colour.

Just as shown in the example of Figure 4, the simulation model contains some variables, such as number of people and social distance which allow the users to test and analyze the effect of capacity of the room towards COVID-19 infection risk to prevent the formation of cluster in the campus.

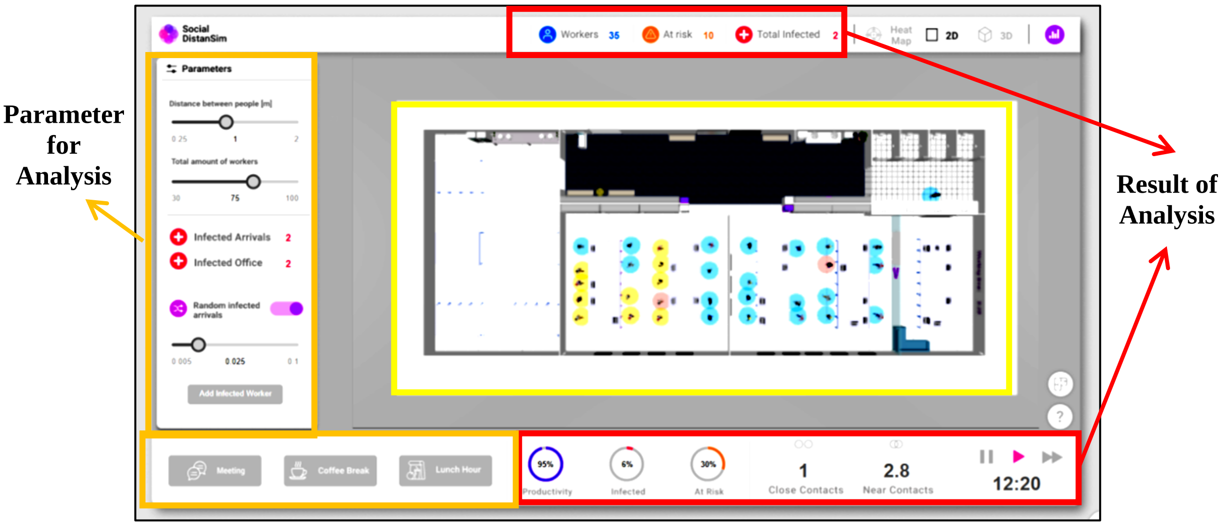

Figure 4: Example of COVID-19 ABM Model Developed by AnyLogic
Source: Accenture (2020)

Conclusion

The expected results will consist of simulation model on maps and graph which showing the number of infection persons over the time. The simulation will depicts the movement of the agent entering and leaving the buildings of FABU UTM. The agent consists of students and staffs that maintaining the proper social distance when walking. The state of the agent is represented by the colour.

ABM is a technique to analyze the spread of COVID-19 through agent's interaction. Besides social distance, the ventilation condition and exposure time of contact will also affect the COVID-19 infection inside the building.

As universities campus is one of the high-risk place in formation of COVID-19 cluster, this study propose and design the ABM for three settings inside the campus. The simulation is useful for the FABU administrators to plan the occupancy capacity for laboratory, lecture room and office.

This study can be extended by development the designed ABM using agent-based simulation software. The suggested software is AnyLogic software. It has existing Java libraries to simulate the human behaviors and allows the users to customize the functionality of the model.

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