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## Analysing the infection pattern of COVID-19 among healthcare workers by implementing agent-based modelling

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**Abstract.** Covid-19 virus spreading is still continuing until the third wave. The government establish regulations to prevent the virus spreading massively such as implementing health protocols or 3M, reducing mobility, and staying at home. However, there is a crucial job that cannot be done at home, that is nursing patients in the hospital. That makes increasing the risk of virus transmission in hospitals and among healthcare workers. 3M's behavior is important to be implemented every time. However, in reality there are still negligence in its implementation. This study aims to understand the dynamics of health behavior among health workers and find out the most important protocols in its implementation. This study uses Agent-Based Modeling method by building scenarios of changing behavior in compliance with health protocols. The result is masks using and hand washing are important protocol to be implemented. If there are negligences in the use of masks, the highest average infection is 39.18 and if the maximum hand washing in its application has the lowest average infection, is 38.79. Masks are considered very important to be applied because they are easy to obtain and suit to the nature of virus transmission. Masks type considered to help prevent adequately the virus transmission are N95 with particle filtration rate up to 95%.

**Keywords:** covid-19, health protocol, healthcare workers, agent-based modelling

### 12. Introduction

Coronavirus Disease 19 (Covid-19) is a respiratory infection disease caused by a virus. This disease is still present today and has affected a large number of people, including healthcare workers. Healthcare workers are more likely to be infected than those in other professions because they work in hospitals, which have a high risk of virus transmission [1]. According to observations made by the World Health Organization (WHO), 14% of reported Covid-19 cases in Europe and America included healthcare workers [2]. The high infection rate among healthcare workers was further shown in a study conducted by Chou, R et al. [3], which found that the infection rate among these workers ranged from

0.4% to 49.6%. Laporan COVID-19 [4] reports that as of April 7 2022, there have been 2087 deaths of healthcare workers in Indonesia. As a result, Indonesia now has the highest Covid-19 fatality rate in Southeast Asian countries.

The government, through the ministry of health, issued a policy that governs infection prevention and control (IPC) in hospitals in order to prevent the rising number of infected healthcare personnel. The individual behavior of healthcare personnel is one of the crucial components that must be implemented in order to effectively implement IPC [2]. These behaviors are often referred to as health behaviors or known as the 3M health protocol. Wearing a mask, washing hands, and keeping distance are components of the 3M protocol. Transmission of the virus to healthcare workers is related to individual behavior [5]. We included the use of PPE in our case study because it is thought to be extremely important for healthcare workers, especially when they are in charge of treating patients. If it is not applied correctly, the number of infected healthcare workers will increase.

The relationship between protective or healthy behavior and fluctuations in Covid-19 infection cases is a complex one. So, in order to understand this phenomena, it can use Agent-Based Modeling. Many previous studies have the same object on health workers in hospitals, but it is found that no research use simulation on health behavior among health workers. There is research that examines socio-economic correlations and behavior towards COVID-19 infection in medical personnel at hospitals [6]. In addition, there is research that measures preventive behavior and identifies determinants of behavior using the Protection Motivation Theory but is not associated with the dynamics of COVID-19 transmission [7]. There is also research on the assessment of COVID-19 prevention behavior in health workers using the cross-sectional study method and statistical analysis [8]. This study aims to figure out the consequences of neglect in the application of one of the health protocols and which health protocol is thought to be the most crucial to apply in order to prevent widespread virus transmission. Because of the limitation of relevant information and data, this study use data from previous studies as data simulation [6].

## **13. Methods**

### **13.1. Agent-Based Modeling**

Agent-Based Modelling (ABM) is a model-based technique to describing and representing a complex system made of individual elements or agents [9]. In this simulation, the agents can represent and describe people, institutions, or other potentially heterogeneous entities [10]. The interactions and attributes of these systems will result in complex system behavior. A bottom-up approach is used in ABM, which entails modelling the behavior of micro-level agents to evaluate emergent properties at the macro-level [11]. Agents, environment, interaction, and emergence are crucial ABM elements that can enable the simulation to operate under the conditions of the real system.

### **13.2. The Application of ABM in Public Health Sector**

ABM has been extensively used in the health sector to model the spread and control of infectious diseases. This method is used because it is seen to be appropriate for interactions that take place between people or with the environment, which greater probability in phenomena. ABM can also be applied for diseases that are not infectious [12]. Susceptible-Infected-Recovered (SIR) is a fundamental framework that is frequently applied in ABM for infectious diseases [13]. The Centers for Disease Control and Prevention (CDC) frequently uses ABM in infectious diseases to evaluate infection control programs and develop prevention plans [14].

### **13.3. Data Collection**

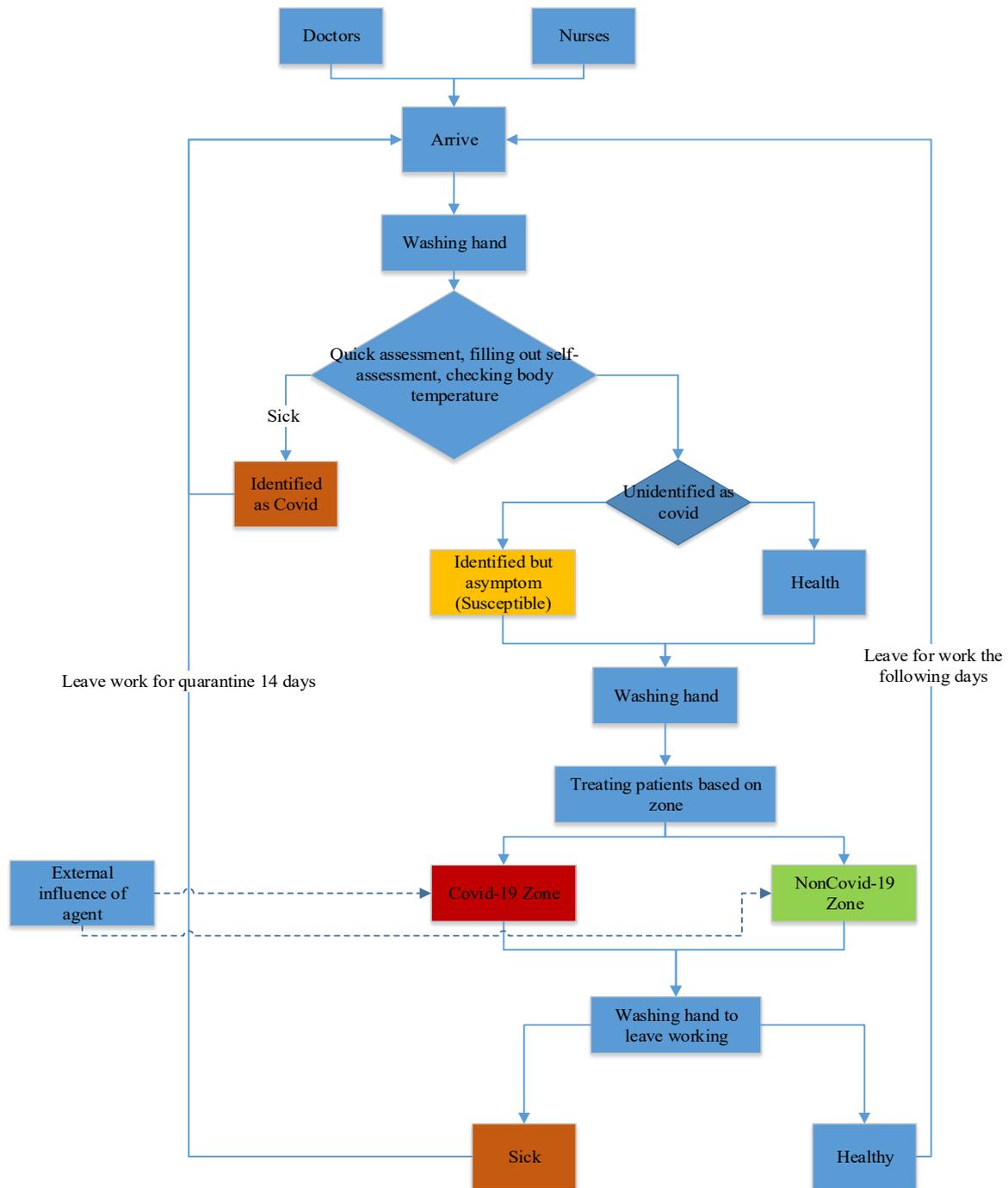
This study focus on COVID-19 spreading simulation among healthcare workers in hospital that classified as class B. In the real systems, every hospital has different number of doctors and nurses. But,

there is a regulation that regulate the minimal number of doctors and nurses in each class type of hospital [15]. This simulation also need another data such as probability of each health protocol implementation, infection rate of doctors and nurses, and work shift in a day. Because of the limitation of information and data reported in hospital about healthcare worker infection, so this study use reference data from previous study [6] and regulation [15]. The summary of data using can be seen in Table 2.

#### 13.4. Conceptual Model

In this simulation, there are two types of agents: nurses and doctors. These agents have different rates of infection. In the simulation, there are three states for agents: healthy or susceptible, infected, and recovered. In this study, agents interacted with one another and spread a virus when they were close to each other and moved to a different location when they neglected to implement health behaviors. The environment in this simulation is the hospital setting as well as the hospital's outside area. The hospital's outside area consists of a quarantine zone and a home patch, which in actual systems can be interpreted as an agent's house. Meanwhile, the hospital environment is divided into three zones: quick assessment, covid zone, and non-covid zone. The infection rate differs between the covid and non-covid zones.

The conceptual model for this study is shown in Figure 1. In this figure, the model is based on the activities of the agents, i.e., from the time the agents arrive at the hospital until they leave for work the following day or self-quarantine for those who are infected. Agents implement health protocols or health behaviors in all of their activities while working. In this model, an agent with a susceptible status can continue work because it is recognized that the agent does not have Covid symptoms but is actually an infected agent. Immunity can change an agent's status. Agent immunity is randomly generated through simulation.



**Figure 1.** Conceptual model of simulation

### 13.5. Model Implementation

In this model, there are two agents: doctors and nurses. These agents are modeled in the same environment as one another. The behavior of the agents used is the behavior of complying with the implementation of health protocols (3M), which include wearing masks, washing hands, and using PPE. For distancing behavior will be automatically randomized by the simulation. The agent work flow uses

the agent actions when the agent enters the work area to conduct a quick assessment till the agent leaves. Because of a lack of data, we used information from previous studies [6] and associated laws. This simulation was run on Netlogo software version 6.3.0. Table 1 provides a brief overview of the variables and parameters used in this simulation.

**Table 1.** Attribute variable and behavior of agent

<b>Agent</b>	<b>Attribute Variable</b>	<b>Behavior</b>
Doctors, Nurses	Covid-19 infection case	Behavior related to individual agent's decisions in implementing 3M, use of PPE and agent immunity.  Activities related to providing care and relationships amongst individuals when in a hospital setting.

### 13.6. Verification and Validation

The model that has been developed needs to be verified and validated before it can be used. This step ensures that the model has been running according to the rules developed based on the code in the application and that it is adequate and can represent the real system. Verification can use the button verification feature in the software. Due to the lack of data on healthcare worker infection in this study, model validation was done using face validity. The simulation results are validated by comparing to the existing theory.

### 13.7. Case Study Scenario

People's compliance with health protocols is changing over time as the Covid-19 outbreak continues. There are those who are becoming more submissive, but there are also those who are dismissive. This happens not only to people in the general population, but also to healthcare workers. It should also be highlighted that the rise in the number of infections is not just attributable to a failure to implement health protocols; there are numerous affecting variables. Through this behavioral phenomena, we hope to find out which health protocols have a significant impact on the number of cases of Covid-19 infection among healthcare workers. The simulation runs for 1000 shifts, with three shifts per day. The simulation's parameters are listed in Table 2.

**Table 2.** Parameters or variable in simulation

<b>Variable</b>	<b>Value Range</b>	<b>Reference</b>
Number of agent: Doctors and Nurses	23 and 90	Minimum number of healthcare workers in B class hospital [15]
Wearing masks	25% - 100%	[6]
Using PPE	25% - 100%	[6]
Washing hand	25% - 100%	[6]
Infection Rate of Doctors	1.92	[16]
Infection rate of Nurses	2.2	[16]

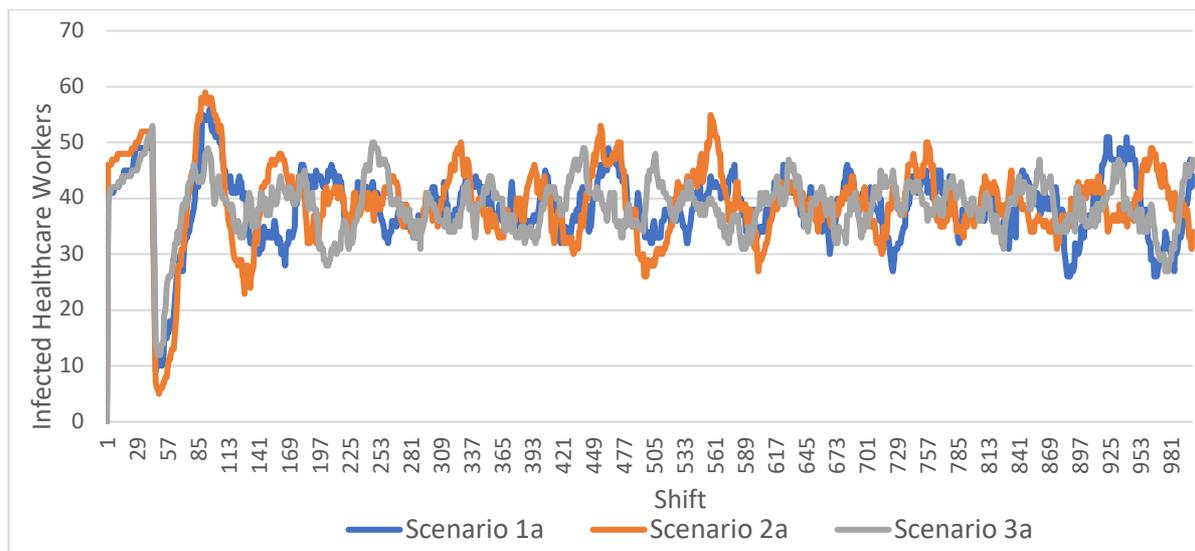
As a result, the scenario used in this study involves raising and lowering the proportion of health protocol application. With this scenario, it is possible to identify which parameters or protocols have the most influence on the number of instances of Covid-19 infection. Six scenarios are used. The used scenarios are shown in Table 3. In scenario A, one of the parameters is reduced by 25% while the other values remain at 100%. For example, in scenario 1, the amount of PPE implementation is lowered to 25%, while mask use and hand washing implementation are both 100%. This aims to see how the use of PPE affects the number of infection cases when there is negligence. While scenario B is the inverse of scenario a, it raises the percentage of one parameter. This seeks to determine which protocol, when applied optimally, can minimize the virus's rate of spread.

**Table 3.** Parameter's value for model's scenario

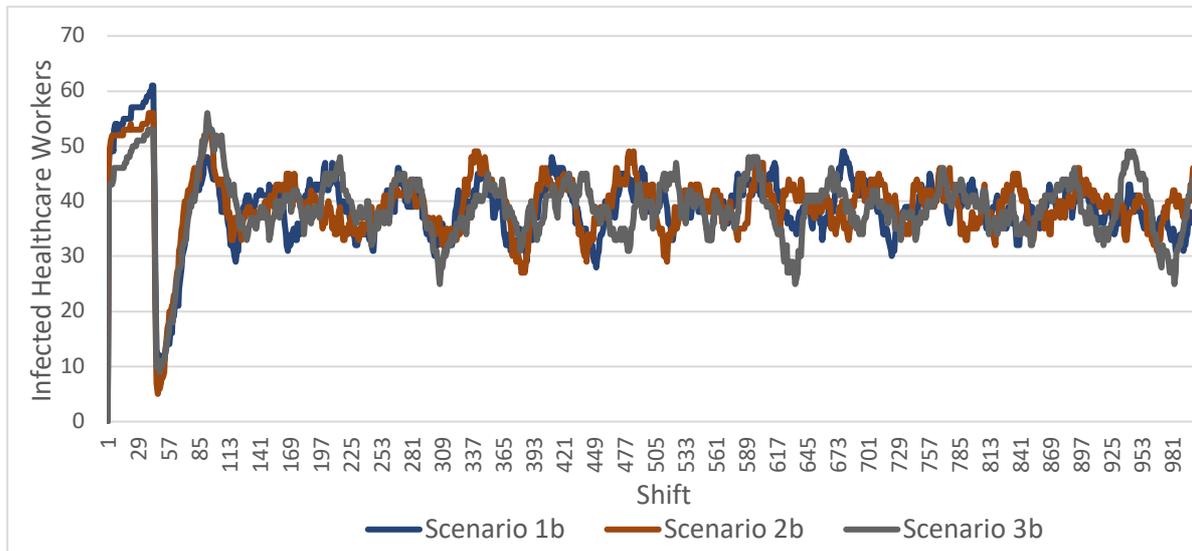
Scenario	Lowering Parameter (A)	Raising Parameter (B)
	Percentage distribution (PPE/Mask/Hand-Wash)	Percentage distribution (PPE/Mask/Hand-Wash)
1	25% / 100% / 100%	100% / 25% / 25%
2	100% / 25% / 100%	25% / 100% / 25%
3	100% / 100% / 25%	25% / 25% / 100%

#### 14. Result and Discussion

The model needs to be validated before analysis based on scenarios can be conducted. Based on the validation results, the model is theoretically valid. The findings are in line with the theory that following health protocols serves to limit the widespread spread of Covid-19 [17]. After being declared valid, a scenario can be used to run a simulation. Figures 2 and 3 show graphs of the number of infected healthcare workers based on the scenarios described above.



**Figure 2.** Simulation's result of scenario A (lowering one parameter)



**Figure 3.** Simulation's result of scenario B (raising one parameter)

Figure 2 shows the effects of reducing one of the health parameters or protocols. Scenario 1A, in which the use of careless PPE results in an infection chart that can be claimed to be under control. This is seen by the wave deviation, which is not excessive. Similarly, in scenario 3A, where the infection wave is relatively controlled. In contrast to scenario 2A, where the infection wave has changed significantly. The high wave deviation in scenario 2A indicates that the number of infection cases is not being adequately controlled. Additionally, it is evident from Table 4's average number of infected agents. Comparing situations 2A to 1A and 3A, scenario 2A has the greatest average value of infected agents, indicating a higher infection rate as well.

**Table 4.** Simulation results of the average infected agent

Scenario	Average infected agent
1A	38.45254745
2A	39.17982018
3A	38.58241758
1B	38.93606394
2B	39.3966034
3B	38.79020979

Figure 3 shows the outcomes of raising one of the health parameters or protocols. The result of graphic in scenario B shows that scenario 3B has lowest deviation of another scenario B. Scenario 3B is maximizing the implementation washing hand. From these 2 scenarios result, it can be declared that using mask and washing hand implementation is very important to do to prevent the increasing of infection cases. But, using mask is easier to applied than another protocol. Also, using mask is an important protocol because it suits to the nature of COVID-19 spread that through aerosol or droplet by sneezing or coughing [2].

This finding does not mean that other protocols are not important to implement. To optimize the prevention of the virus's spread, it is crucial to apply all current health protocols. However, wearing

masks is believed absolutely essential in its application. Moreover, using PPE is also very important for healthcare workers that work in covid zone area.

From these result of study that have been done, this study still having many limitations such us data reference and simulation ability that just can be run only in few number of agents. So that, in future studies we hope it can be used as reference to improve another future studies in health behavior among healthcare workers using simulation method. For future studies need to use more vary parameters and add another parameter that are important and significantly take effect than this studies.

## 15. Conclusion

Based on the findings of the scenario simulation, it is possible to conclude that the role of wearing masks is highly crucial in health protocols to prevent Covid-19 infection. It shows that the average of infection for negligence in using masker is highest of another protocols, 39.18. Using mask is considered very important because it spread rapidly through droplets by sneezing or coughing. As a suggestion for infection prevention and control (IPC) team especially in hospital, using mask is needed to be more stringent. Other protocols (wearing PPE, hand washing, and keeping distance) must also be implemented when applying health protocols. Therefore, the infection cases in healthcare workers can still be controlled.

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