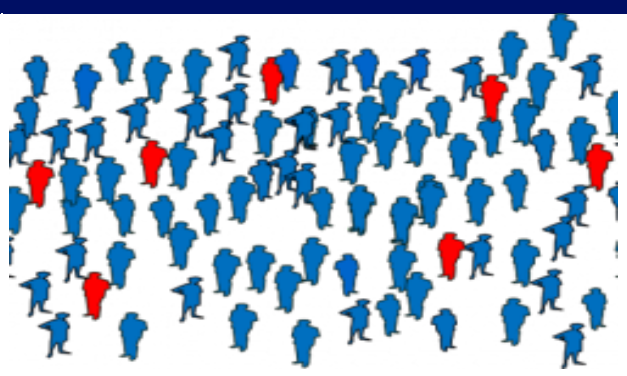
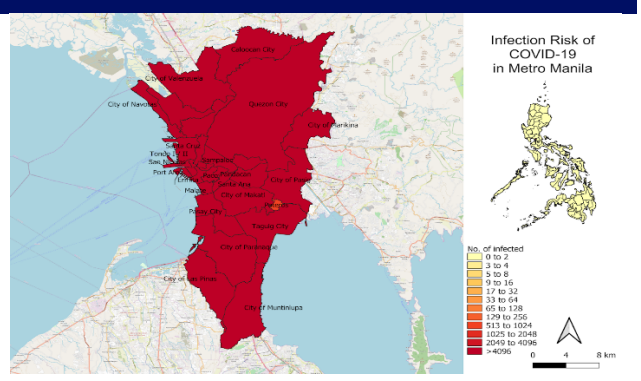
Modeling of COVID-19 Transmission in Philippine Workplaces

Diane Carmeliza N. Cuaresma, Azra May B. Kabiri, Edd Francis O. Felix, Kyrell Vann B. Verano,
Eleanor B. Gemida, Angelo E. Marasigan, and Jonathan B. Mamplata
Institute of Mathematical Sciences and Physics, University of the Philippines Los Baños





REPRODUCTION NUMBER | **OUTBREAK THRESHOLD** | **EXPECTED NUMBER OF INFECTED**

Introduction

The coronavirus disease 19 (COVID-19) is a human-transmittable viral disease. On 11 March, the World Health Organization (WHO) has declared COVID-19 as a pandemic, which is characterized by spreading into a wide geographic area and affecting an exceptionally high proportion of the population (WHO, 2020). Being a novel disease, a lot is still unknown, and researchers are rushing to add more to the current knowledge to curb the transmission of the disease and to develop effective medicines and vaccines against it. Currently, the best strategy that the WHO offers for prevention is frequent hand washing, not touching the face, proper coughing and sneezing etiquette, and social distancing (3 ft by WHO, 6 ft by CDC).

On 17 March, the Philippine government declared an enhanced community quarantine (ECQ) in the entire island of Luzon and other parts of the county for a month and later on extended until 14 May to curb the transmission of the disease. Under ECQ, strict home quarantine is imposed, mass gatherings are prohibited, classes are suspended, mass public transport are suspended, works are reduced to skeleton forces and most are forced to work from home, and only those establishments that provide necessary services (such as medical and food) may be opened (PCOO, 2020).

However, with the ECQ, the economy and production inevitably suffer. In a report by the National Economic and Development Authority (NEDA) on 19 March (NEDA, 2020), COVID-19 pandemic is expected to have an impact on travel and tourism, exports, remittances, and consumption. NEDA also estimated that ECQ over Luzon could lead to a loss of gross value added of up to PHP 1.1 trillion and is expected to reduce employment for up to 1 million.

As people expect the ECQ to be relaxed for some parts of Luzon, a modified community quarantine or general community quarantine will commence. Many hope that the economy can be restarted. However, without vaccines and with the country's limited health care capacity, another wave of infection looms as the ECQ is lifted.

This study aims to provide a strategy to minimize the risk of COVID-19 infection or outbreak in a company. This is done by classifying the employees based on risk profiles and by modeling how fast COVID-19 will be transmitted within the company. With this, the company may be able to select which employees will be allowed to work on-site and who will continue to work from home.

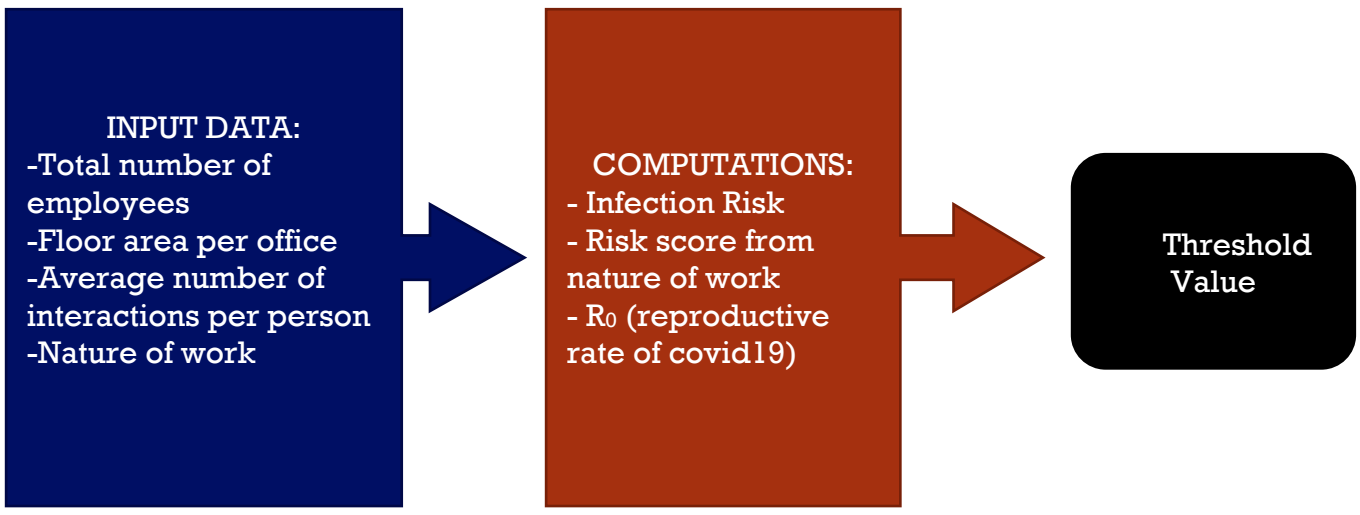
Photos retrieved from https://webstockreview.net/startdownload.html, https://www.verywellhealth.com/covid-19-pre-existing-conditions-4801962, https://sites.google.com/up.edu.ph/initialcovid19phestimates/home/metro-manila?authuser=0

WORKPLACE OUTBREAK THRESHOLD

We want to answer the question:

How many infected individuals (may be undetected) would cause an outbreak in the company?

It is important to know the threshold so that the company can countermeasure the outbreak by determining how many employees could come to the office physically to avoid the outbreak. Also, the company could select who among the employees can come to work in such a way that the risk of the disease outbreak is minimal. The following flowchart shows a picture of how the threshold value is computed.



Mainly, the threshold value depends on the infection risk and R_0. The **infection risk** depends on the density of each office and the average number of interactions per person. On the other hand, the R_0 depends on the risk from the nature of work and the average number of interactions. The risk score ranges from 0 to 5, where 5 means the nature of work entails the highest risk, which means that the spread of the virus is highly probable for each interaction among the employees.

SAMPLE COMPUTATION

INPUT:

TOTAL NUMBER OF EMPLOYEES	100
NUMBER OF OFFICE TYPES/FLOORS	3

OFFICE TYPE/FLOOR	Floor Area	No. of Employees	Average number of interactions
1	100	55	3
2	65	15	3
3	35	30	3
4	0	0	0
…	…		

RISK (based on nature of work)	
Human Resources Managers	0.50225

OUTPUT:

90% Probability of an outbreak

	No. of Employees	Threshold	R_0
	100	0.87277407	3.30135
80%	80	2.37089551	2.64108
60%	60	3.36878622	1.98081
40%	40	8.28146645	1.32054
20%	20	8.28146645	1.10045

INTERPRETATION:

Approximately 1 COVID-19 infected employee (from 100) will cause an outbreak with 90% chance of happening.

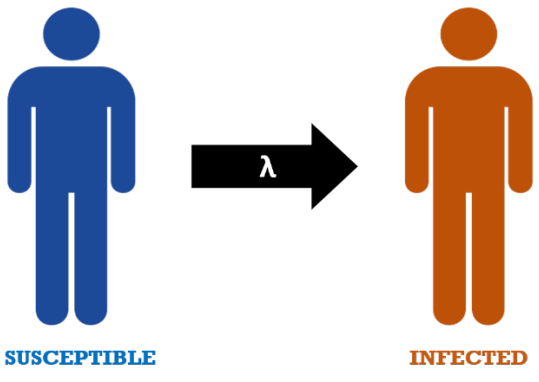
The threshold computation has already accounted the 1-meter physical distancing as prescribed by WHO. Adding more protection measures such as regular handwashing and use of appropriate masks is expected to reduce the rate of infection and thus, increase the threshold value.

Current Limitation:

The computation of the reproductive number, R_0, is planned to include risk factors associated with the employees' geographical locations and their mode of transportation. We are yet to find data on this.

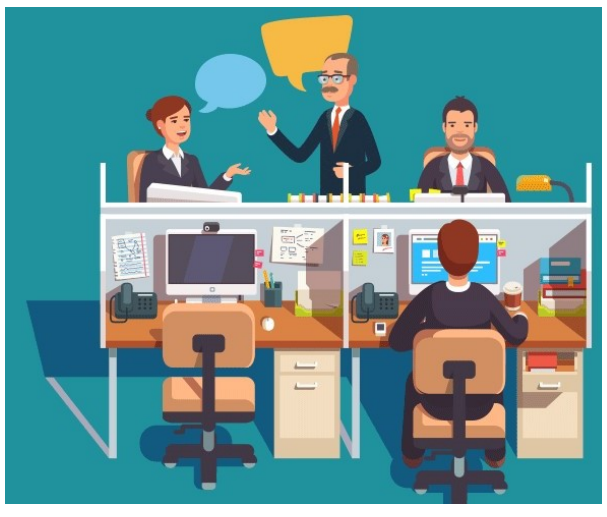
SIMULATION MODEL TO COMPUTE THE EXPECTED NUMBER OF INFECTED INDIVIDUALS IN THE WORKPLACE

FORCE OF INFECTION

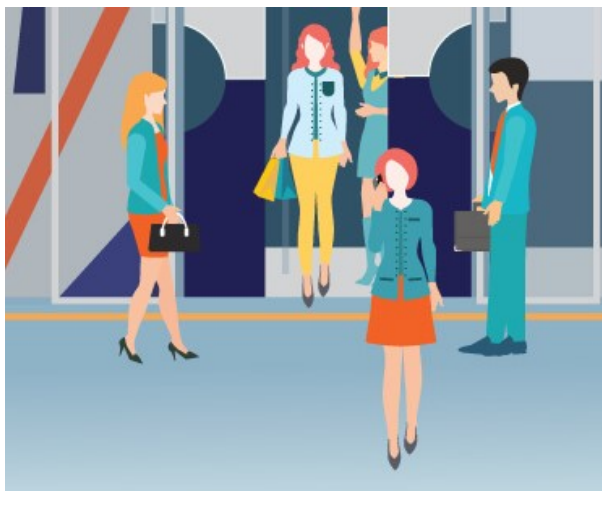


The **force of infection** of an employee, λ, is the rate at which the susceptible employee will be exposed to COVID-19. It is computed as $\lambda = (1 - P)(\beta_L + \beta_M + \beta_H + z)$.

P $(0 \leq P \leq 1)$ accounts for the observance of preventive measures such as washing of hands, wearing of face masks, physical distancing, etc. Having these preventive measures will make the value of λ smaller.

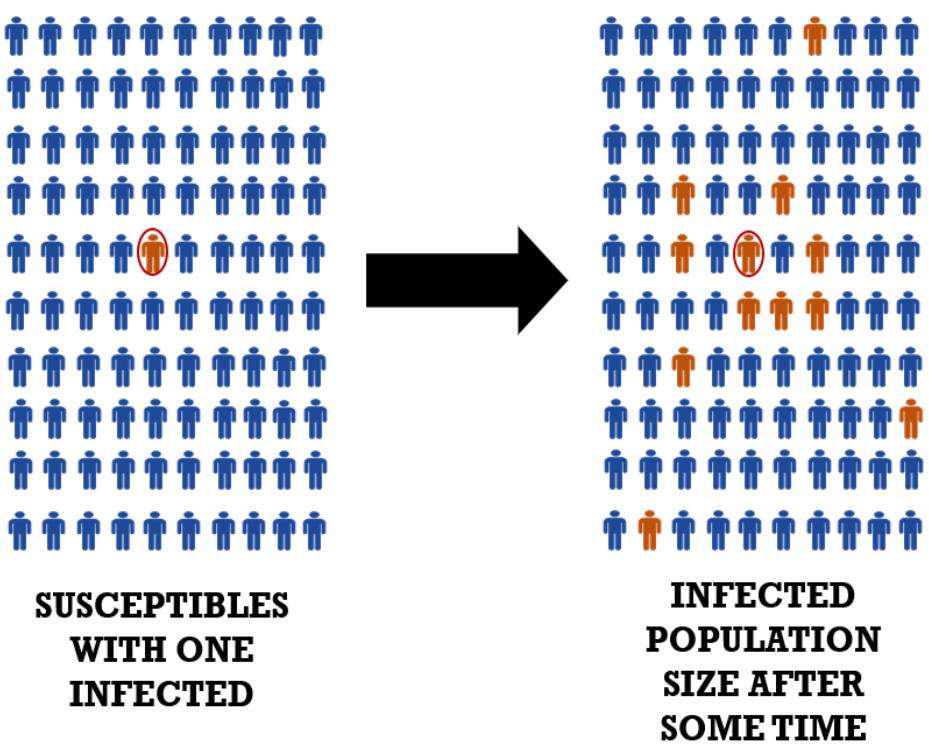


$\beta_L + \beta_M + \beta_H$ accounts for the cumulative risks from the interactions of the individual with infected employees who are classified as low-risk, medium-risk, and high-risk, respectively. This embodies the risk obtained internally in the company.



z represents the risk from external factors such as residence location and interactions from outside the company.

NUMBER OF INFECTED INDIVIDUALS



The **number of infected individuals** after time t, denoted by $I(t)$, is computed as

$$I(t) = \sum_{\substack{not\ initially \\ infected\ ind\ j}} X_j + N.$$

$X_j = 1$ if employee j is exposed by t with probability

$$1 - \exp\left\{-\int_0^t \lambda_j(t)\right\},$$

otherwise, it is 0.

N is an assumed number of initially infected employees who happened to be physically working in the office.

Photos retrieved from https://genhq.com/how-to-easily-engage-gen-z-employees-in-the-workplace/, https://www.kwqc.com/content/news/Should-you-wear-a-face-mask-to-protect-yourself-569306151.html, https://www.insperity.com/blog/commuter/.

NUMERICAL EXAMPLE

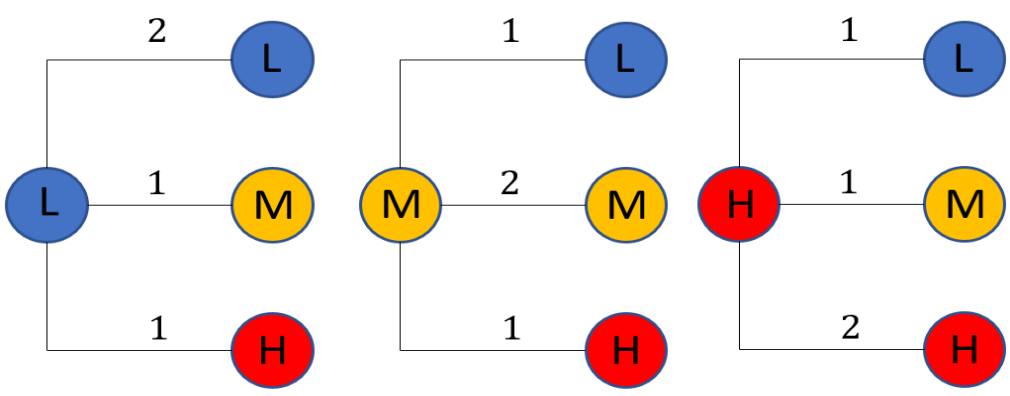
INPUTS AND ASSUMPTIONS

n NUMBER OF EMPLOYEES IN THE COMPANY	n_L NUMBER OF LOW-RISK EMPLOYEES	n_M NUMBER OF MEDIUM-RISK EMPLOYEES	n_H NUMBER OF HIGH-RISK EMPLOYEES
100	70	20	10

The employees of the company will be classified according to the following broad classes of risk of infection:
Low Risk (L), Moderate Risk (M), and High Risk (H).

For instance, under the high-risk classification, the employees are highly vulnerable to be infected due to their nature of job, i.e., front-desk officers. Under the low-risk classification, the employees have less to no interaction from the outside during office hours, i.e. back-office employees.

Assume that no employee is possible to be under several offices which make his/her classification varying through time. Otherwise, consider an additional criterion that further distinguishes an employee into a unique classification. Hence, $n = n_L + n_M + n_H$.



Assume that, on the average, employees on a specific risk classification have a contact rate with other employees per day specified by the figure at the left.

Wearing of face mask

***Probability: 100%**

Regular sanitization

***Probability: 100%**

Avoiding Crowded Places

***Probability: 100%**

We impose these protection measures, their rates of reduction with the corresponding probability of commitment to these measures. The maximum reduction to exposure is 50%.

*probability of committing to the measure (may vary)

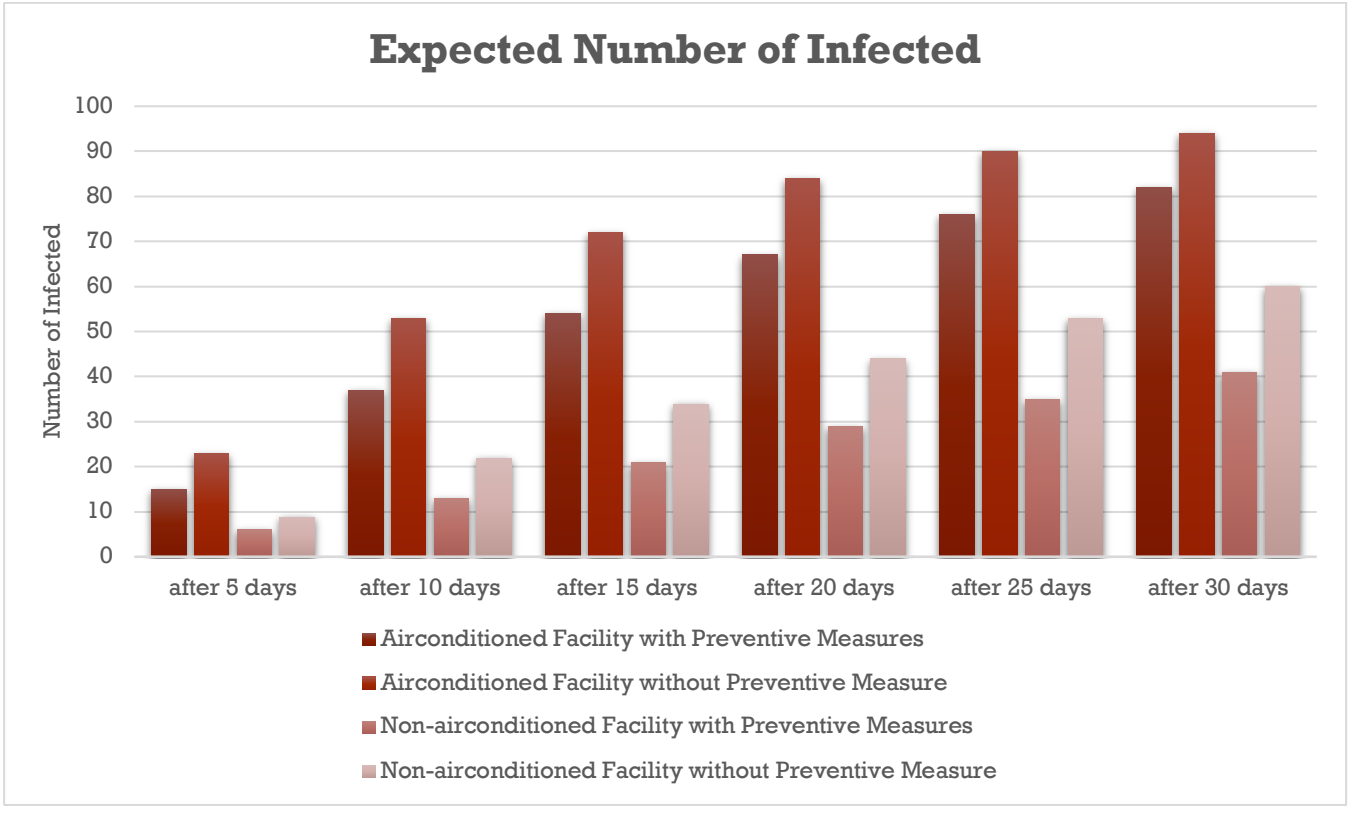
RESULTS

The following table summarizes the expected total number of infected employees inside the company t days after the resumption of work, assuming that there is **exactly one infected** who proceeds to work.

t days after	Expected Total Number of Infected			
	Air-Conditioned Facility		Non-Air-Conditioned Facility	
	with Preventive Measures	without Preventive Measures	with Preventive Measures	without Preventive Measures
5	15	23	6	9
10	37	53	13	22
15	54	72	21	34
20	67	84	29	44
25	76	90	35	53
30	82	94	41	60

Photos retrieved from https://www.bbc.com/.

The histogram below summarizes the result in the preceding table.



References:

Actuarial Society of the Philippines (ASP) Life Insurance Committee. 2017 Philippine Intercompany Mortality Study. Retrieved from http://www.actuary.org.ph/wp-content/uploads/2017/05/2017-PICM-Study-Final-Report-18May2017.pdf

G. Guzzetta , C. A. Marques-Toledo, R. Rosa, M. Teixeira, and S. Merler. (2018). Quantifying the spatial spread of dengue in a non-endemic Brazilian metropolis via transmission chain reconstruction. *Nature Communications* , 9 (1).

J.M. Elliot. (1971). Some methods for the statistical analysis of samples of benthic invertebrate*. Freshwater Biological Association Scientific*.

M. Hartfield and S. Alizon. (2013. Introducing the outbreak threshold in epidemiology. *PLoS pathogens,* 9.

National Economic Development Authority. (2020). Retrieved from http://www.neda.gov.ph/wp-content/uploads/2020/03/NEDA_Addressing-the-Social-and-Economic-Impact-of-the-COVID-19-Pandemic.pdf

Presidential Communications Operations Office. (2020). Retrieved from https://www.officialgazette.gov.ph/downloads/2020/03mar/20200316-MEMORANDUM-FROM-ES-RRD.pdf

S.A. Lauer, K.H. Grantz, Q. Bi, F.K. Jones, Q. Zheng, H.R. Meredith, A.S. Azman, N.G. Reich, and J. Lessler. (2020). The Incubation Period of Coronavirus Disease 2019 ({COVID}-19) From Publicly Reported Confirmed Cases: Estimation and Application. *American College of Physicians*.

S. Sanche, Y.T. Lin, C. Xu, E. Romero-Severson, N. Hengartner, and R. Ke. (2020). High contagiousness and rapid spread of severe acute respiratory syndrome coronavirus 2. *Emerg Infect Dis,* 2.

Worldometer. Age, Sex, Existing Conditions of COVID-19 Cases and Deaths. Retrieved from https://www.worldometers.info/coronavirus/coronavirus-age-sex-demographics/