

Chapter 5

Extended Compartmental Model

ABSTRACT

In this chapter, a new compartmental model that extends the classical SIR model by incorporating various infectious stages of the COVID-19 epidemic in Sultanate of Oman for a period of 145 days is presented. This incorporates the various stages of infection such as mildly infected, moderately infected, hospitalized, and critically infected. The transmission stage of the disease is categorized as pre-symptomatic transmission, asymptomatic transmission, and symptomatic transmission. The various transmission as well as transition parameters are estimated during the period from June 4th – October 26th, 2020 along with the pandemic size for a period of 400 days. Sensitivity analysis is performed on transition parameters and the parameter gamma due to the contact with the symptomatic moderately infected is found to be more significant in spreading the disease. As the value of basic reproduction number (R_0) is 0.6088 during the period from June 8th – October 26th, 2020, the disease-free equilibrium is stable, and isolation and tracing the contact are suggested to control the spread of disease.

INTRODUCTION

In this research, we formulate the transmission mechanism of COVID-19 using a compartmental model which is deterministic in nature. To formulate the mathematical model, the total population is grouped into nine mutually

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exclusive compartments based on their disease status (Thurber & Wittrup, 2012, Dukic & Polson 2012). The class of Susceptible individuals (S) are those who have never been infected with and thus have no immunity against COVID-19. Susceptible individuals become exposed once they are infected with the disease. The Exposed individuals (E) are those who are in the infected stage, but not yet infectious to others. The exposed classes are divided into two separate classes namely E_N defines no symptom or transmission and E_T with no symptom but can transmit the virus (“pre-symptomatic transmission”). The class (A) of infected individuals are those with no symptom or mild symptom developed. Individuals with these symptoms may have a fever and cough, but their chest X-rays are normal. Depending on the severity of the disease, these individuals may either improve or progress to the Moderate stage. Those in the Moderate class (M) are suffering from moderate symptoms of infection like fever and cough, and may have mild pneumonia, but don't require hospitalization. It is likely that they will show symptoms of fever and cough, and the chest X-ray will show major bilateral abnormalities, pneumonia, or infiltrations/patchy shadowing. There is a possibility that this individual could either improve or progress to the severe stage. The hospitalized individuals (H) have severe infections and pneumonia, which require hospitalization. People who belong to the critical (C) category have a critical infection like failure of the respiratory system, septic shock, and/or malfunction in numerous organs, which necessitates treatment in the intensive care unit (ICU), sometimes with mechanical ventilation. During the disease, these people may get better or die.

The corresponding equation of the model from (Varghese & Kolamban, 2021) is

$$S'(t) = -S(t) [\alpha E_T(t) + \beta A(t) + \gamma M(t) + \delta H(t)]$$

$$E_N'(t) = S(t) [\alpha E_T(t) + \beta A(t) + \gamma M(t) + \delta H(t)] - \varepsilon E_N(t)$$

$$E_T'(t) = \varepsilon E_N(t) - \nu(\theta_1 + \theta_2 + \theta_3) E_T(t)$$

$$A'(t) = \theta_1 E_T(t) - (\sigma + r_1) A(t)$$

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