Research and Establishment of SIR Model based on COVID-19

Lingxuan Liu[1, *]

[1]*College of Mathematics and Systems Science, Shandong University of Science and Technology, Qingdao, Shandong, China, 266590*
[*]*Corresponding author. Email: Lingxuan_Liu00@163.com*

ABSTRACT
In the context of the Covid-19 sweeping the world, countries around the globe have adopted different approaches to control the spread of disease, and in order to find better control methods, this paper explores the influence of people's awareness on SIR model. On the basis of the SIR model, this paper studies the SEIR model with the exposure period parameter, calculates the feasible region R-naught disease-free point, and analyzes the method of controlling the spread of the disease according to R-naught, which shows that lockdown has a significant effect on the control of COVID-19. In addition, this paper also established a model affected by disease awareness, adding a factor of news media and religious awareness. The feasible region is calculated, and the reality situation based on India is analyzied. The conclusion proved that people's awareness has a greater influence on the spread of diseases.

Keywords: *COVID-19, Disease Awareness, Epidemic, SIR Model, Prediction*

1. INTRODUCTION

Many infectious diseases have been breaking out in recent decades. Examples include the SARS-CoV[1], which broke out in Guangdong, China, in 2002 and subsequently spread throughout Southeast Asia and the world, and the Ebolavirus[2-3], which first appeared in the United States in 2014. At the end of 2019, an outbreak of an infectious disease called covid-19 occurred.

After many countries have taken measures to combat the epidemic by increasing the social distance, Many researchers have built modified SIR models to predict the spread of neocrown pneumonia based on objective facts, such as the inclusion of isolators and vaccine efficiency, but there is not enough research on the role that individuals play in infectious diseases, and even when the influence of people's consciousness has been studied, there is still room for further investigation in terms of the extremely different habits of thought across countries. Therefore, this paper attempts to find the basis for such approaches in mathematical models. In addition, this paper tries to develop new models to demonstrate that people's awareness is a factor to influence the model, such as India will be applied to the analysis as it is a pious and religious nation where people's consciousness is not easily to change. It hopes that the research may help governments to control the spread of virus through information dissemination.

2. A COMMON FORM OF SIR MODEL—SEIR

Many new models are derived on the basis of the SIR model[4-5]. Among them, the SEIR model can be used to better learn and analyze COVID-19.

2.1 SIR：

Figure 1 SIR Model

$\frac{dS}{dt} = -\frac{\beta SI}{N}$ （1）

$\frac{dI}{dt} = \frac{\beta SI}{N} - \gamma I$ （2）

$\frac{dR}{dt} = \gamma I$ （3）

2.2 Putting Exposed Node into SIR Model—SEIR Model

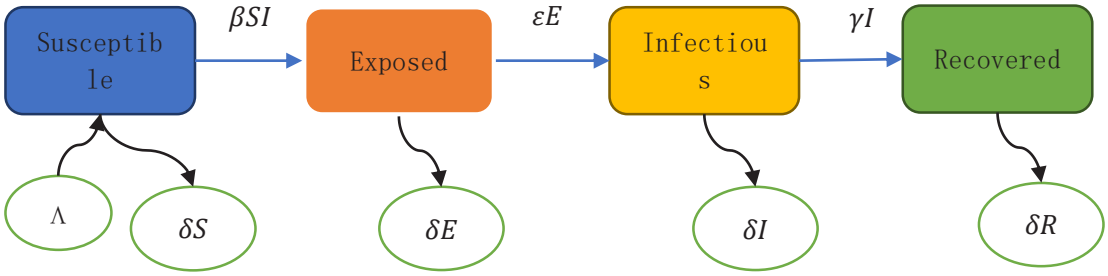

Figure 2 SEIR Model

2.2.1 Description

δ： death rate—constant (assumed the same)

Λ： influx of new susceptible population

ε： latency transfer rate to infectious

γ： recovery rate of infectious

2.2.2 Model：

$\frac{dS}{dt} = \Lambda - \beta SI - \delta S$ (4)

$\frac{dE}{dt} = \beta SI - \varepsilon E - \delta E$ (5)

$\frac{dI}{dt} = \varepsilon E - \delta I - \gamma I$ (6)

$\frac{dR}{dt} = \gamma I - \delta R$ (7)

2.2.3 Feasible Region Σ

$\frac{dN}{dt} = \frac{dS}{dt} + \frac{dE}{dt} + \frac{dI}{dt} + \frac{dR}{dt} = \Lambda - \delta(S + E + I + K)$ (8)

$\frac{dN}{dt} = \Lambda - \delta N \geq 0$ $\Lambda \geq$ δn $\frac{\Lambda}{\delta} \geq N$

$\Sigma = \left\{(S, E, I, R) \in R^4 | S + E + I + R \leq \frac{\Lambda}{\delta}\right\}$ (9)

2.2.4 Equilibria in the Feasible Region

$\varepsilon E = (\delta + \gamma)I \longrightarrow I = \left(\frac{\varepsilon}{\delta+\gamma}\right)E$ (10)

$\gamma I - \delta R = 0 \longrightarrow R = \frac{\gamma}{\delta}I = \frac{\gamma}{\delta}(\frac{\varepsilon}{\delta+\gamma})E$ (11)

CASE1.$E^* \neq 0, I^* = 0, R^* = 0$

from(4)： $0 = \Lambda - \delta S^*$ $S^* = \frac{\Lambda}{\delta}$

Disease free equilibrium $P_0 = \left(\frac{\Lambda}{\delta}, 0,0,0\right)$

CASE2. $E^* \neq 0, I^* \neq 0, R^* = 0$

from(5)(6)：$(\beta SI - \varepsilon E - \delta E) + \varepsilon E - \delta I - \gamma I = 0$

$S^* = \frac{(\varepsilon + \delta)(\gamma + \delta)}{\beta\varepsilon}$

2.2.5 R-naught

$S^* \geq \frac{\Lambda}{\delta} \longrightarrow 1 \geq \frac{\Lambda\beta\varepsilon}{\delta(\delta+\gamma)(\delta+E)} = R_0$ (12)

$R_0 \leq 1 \longrightarrow P_0 = \left(\frac{\Lambda}{\delta}, 0,0,0\right)$ (13)

2.2.6 Analysis

Related to R0 are beta, sigma, delta, gamma, E, so the ways to suppress covid-19 is to reduce sigma through vaccines, and increase social distancing (lockdown, etc.) to increase the recovery rate(γ). Thereby R0 will be reduced.

2.2.7 Drawing with R

2.2.7.1 Before Lockdown

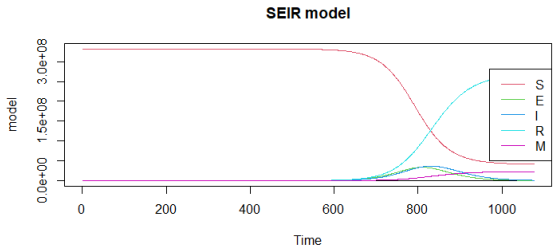

Figure 3 Before lockdown

Using Rstudio to build a SEIR model, the analysis shows that all the model factors are predicted to reach equilibrium at a time point of approximately 900 accordingly before lockdown.

2.2.7.2 After Lockdown

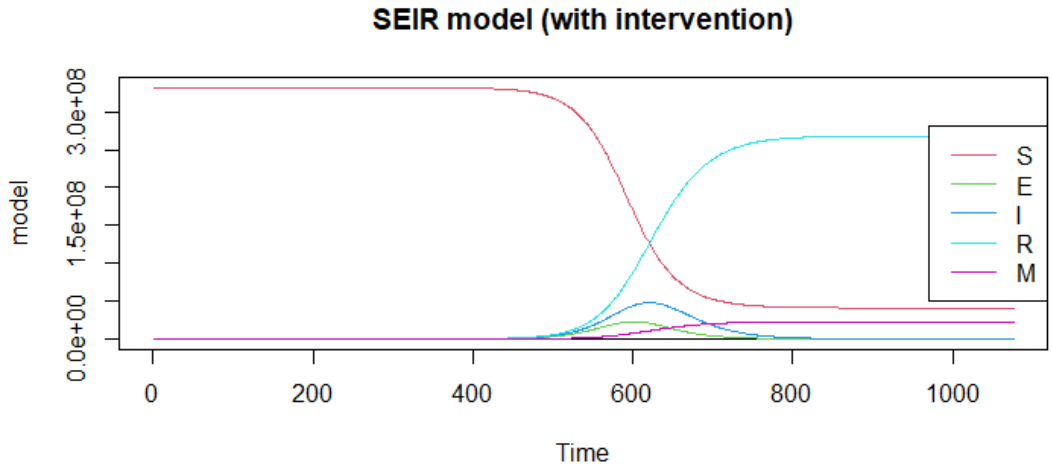

Figure 4 After lockdown

A SEIR model is built for the data after lockdown, and based on the visualization of the results, all factors will reach equilibrium at a time point of about 600. Compared to Figure 3, the time is advanced by 300 time points, which means the point in time when the spread of the epidemic is controlled is advanced.

2.2.8 Conclusion

The ways to suppress COVID-19 are to reduce sigma through vaccines, and increase social distancing (lockdown, etc.) , or develop new drugs to increase the recovery rate(γ). Thereby, R0 will be reduced.

3. NEW MODEL FOR INDIA

In considering a new model[6], given that people's awareness of disease or protection, etc., can have an impact on the spread of infectious diseases, and trying to model with India as the target, the factors of the main information transmission routes in India were added to the model. In this model, the impact of the spread of news information and the spread of religious information on people's awareness is mainly considered.

3.1 Model

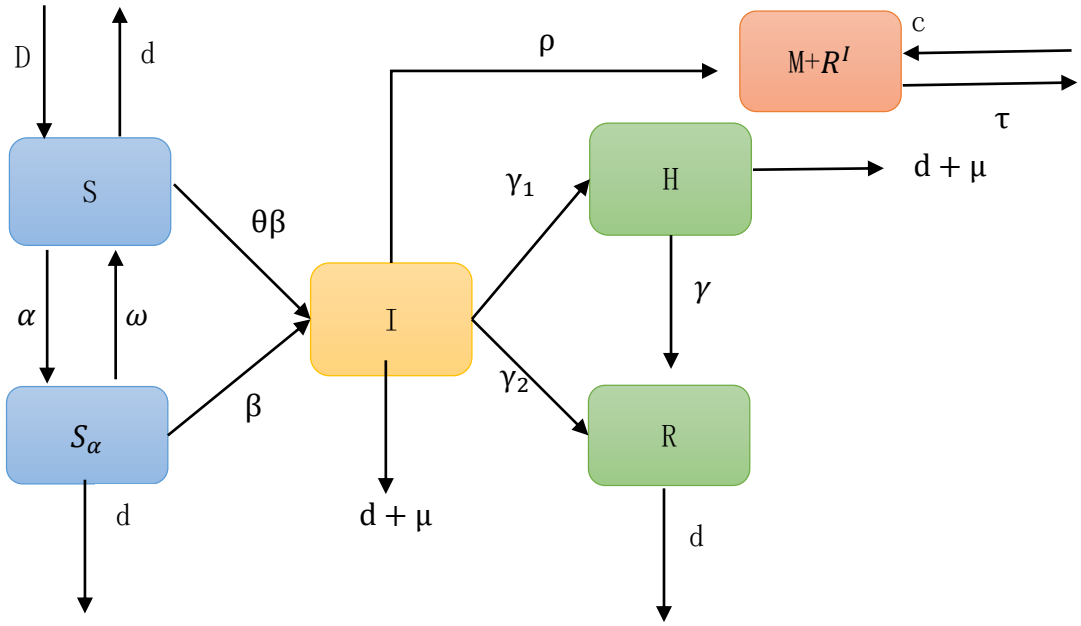

Figure 5 Model For India

3.2 Equilibrium analysis

$$\frac{dS}{dt} = D - \theta\beta SI - \alpha S(M + R^I) + \omega S_\alpha(M + R^I) - dS \quad (14)$$

$$\frac{dS_\alpha}{dt} = -\beta S_\alpha I + \alpha S_\alpha(M + R^I) - \omega S_\alpha(M + R^I) - dS_\alpha \quad (15)$$

$$\frac{dI}{dt} = \theta\beta S + \beta S_\alpha - (d + \mu)I - \gamma_1 I - \gamma_2 I \quad (16)$$

$$\frac{dH}{dt} = \gamma_1 I - (d + \mu + \gamma)H \quad (17)$$

$$\frac{dR}{dt} = \gamma_2 I + \gamma H - dR \quad (18)$$

$$\frac{d(M+R^I)}{dt} = c + \rho\gamma_1 I - \tau(M + R^I) \quad (19)$$

$$N(t) = S + S_\alpha + I + H + R \quad (20)$$

3.3 Description

Table 1 Parameters of the new model

D	Input rate. constant	d	Natural mortality rate
S	Unconscious susceptible individuals	S_α	Awareness susceptible individuals
α	Awareness acquisition rate	ω	Consciousness loss rate
θβ	Rate of infection in unconscious people	β	Rate of infection in conscious people
I	Infected	μ	Mortality rate due to disease
γ_1	Hospitalization rate of infected people	γ_2	Cure rate of infected people
H	Hospitalized	R	Removed
γ	Cure rate of hospitalized people	ρ	Response of the awareness project to the number of new cases
c	Input rate of information	τ	Dissipation rate of information
$M+R^I$	Media messages and religious awareness		

The initial conditions of the model are: $S(0) \geq 0$, $S_\alpha(0) \geq 0$, $I(0) \geq 0$, $H(0) \geq$

$0 \quad , R(0) \geq 0 \quad , M + R^I(0) \geq 0$（21）

$\frac{dN}{dt} = D - dN - \mu(I + H)$（22）

3.4 Feasible Region and R-naught

Feasible Region：

$\Sigma\left\{(S, S_\alpha, I, H, R, M + R^I) \in R^6 \quad | \quad 0 \leq S + S_\alpha + I + H + R \leq \frac{D}{d},\ 0 < M \leq \frac{c}{\tau}\right\}$[7]

R-naught：

when R-naught > 1 , the model exists the only equilibria E_0.

3.5Analysis

This model is an elementary and untested SIR model based on the consideration of people's consciousness. In the context of the government's efforts to promote "Hindu nationalism", conflicts between different religions and communities in India have been intensified[8]. Some people have been misinformed by believing in religious theories that have no scientific basis, which has a serious impact on the prevention and control of the COVID-19. This has hindered the prevention.

At the same time, Āyurveda[9-10], the traditional medicine of India, has played an active role in the awareness of the Indian people in the fight against the epidemic. Āyurveda, as a system of traditional medicine that focuses on harmony between humans and nature, combines prevention and treatment, and educates people on how to protect themselves from the virus. It has played an important role in India's efforts to combat the epidemic. However, it is also difficult to calculate whether the news media can properly promote the medical concepts of Āyurveda to raise people's awareness of protection.

4. CONCLUSION

This paper attempts to analyze whether India, which has undergone the Covid-19, will receive the influence of consciousness by building an altered SIR model. After building the model and adding the factors of people's consciousness and widespread Hindu religious thought in India, it can be found that consciousness has a great impact on the model. Particularly, if it is a small part of people's religious consciousness that does not have a scientific basis, it would be more likely to lead to an accelerated spread of the epidemic. In addition, given the famous Āyurveda medical system has been playing a positive role in India, a more deeper and scrutinized study would be needed to achieve a more comprehensive research result.

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