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A STUDY OF SEIR MODELLING OF THE SARS-COV-2 (WITH SPECIAL REFERENCE TO RAJASTHAN STATE)

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ABSTRACT

This research paper is developed to create and designed to propose a Conurbation Prevention Policy which pertains the operational stratagem to further administer the pandemic situations, where researchers proposed data-driven epidemic simulations, based on the SEIR model, with social distancing and quarantining as variables in order to estimate the ideal conditions for punctilious procedural recommencing of educational institutions. The simulations are based upon the data, collected from various statistical provenances, having similar initial states (i.e., Reproductive Number, Susceptible, Exposed, Infected and Removed population etc.) with reference to the state of Rajasthan (India). The predictive capability of the model has been validated with real data of infection cases reported during October 5 – 15, 2020. On the behalf of the projected results from the simulations, researchers have developed the feasible policy paradigm, which helps to reinstate the entire system in terms of Urban Domain. The research paper is divided into four sections - Introduction, Research Methodology, Results & Discussion and Conclusion. Research is aimed at providing policymakers an unbiased direction over the opening of Educational Institutions in Rajasthan.

Keywords: *SEIR, SEIR Model, SEIR Simulation, Epidemic Simulations, SEIR Model Calculator.*

Introduction

In this researcher paper, researchers have presented an updated version of the predictive model of epidemic phenomena based on the approach called SEIR (Susceptible-Exposed-Infective-Recovered), widely used to analyse infection data during the different stages of an epidemic outbreak. The SEIR model represents one of the most widely adopted mathematical models to characterize epidemic dynamics and to predict possible contagion scenarios. The SEIR model can be useful in evaluating the effectiveness of various measures, such as blocking, from an infectious disease outbreak. It is based on a series of dynamic ordinary differential equations that take into account the number of the population prone to infection, the trend over time of individuals recovering after infection, and individuals who sadly die.[1]

This work was carried out during the crucial phase of development of the epidemic in Rajasthan (mid-October 2020), with operational difficulties linked to the impossibility of verifying and validating databases, and with the difficulty of comparing and calibrating the results with other studies. The objective, however, is to provide a useful and easy-to-read tool that can help policy makers, those responsible for strategic decisions, to assess the social and economic scenarios linked to the development of the epidemic.

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1 Parham, P.E.; Michael, E. Outbreak properties of epidemic models: The roles of temporal forcing and stochasticity on pathogen invasion dynamics. J. Theor. Biol. 2011, 271, 1–9.

The generalized SEIR model is based on a system of differential equations, as discussed by Peng et al. (2020)[1] in the analysis of the SARS-CoV-2 epidemic in China. The model, which adds complexity to the classic SIR or SEIR models, represents the different conditions of susceptible and infected individuals during an epidemic (especially quarantined people, who cannot infect others during an epidemic, their quarantine). The coefficients of the equations represent the rates of variation over time of the different categories of individuals, that is, infected, dead and cured.[2]

Database

The analysis is based on data collected and available through central govt. of India and state govt of Rajasthan at Career Point University, Kota. They represent an official database because they collect data from different official bodies such as the Coronavirus Outbreak in India-covid19india.org, Bing COVID-19 data sources, India Ministry of Health and Family Welfare, India Today, World Health Organization (WHO) from the India and other organizations. This Indian data is collected in its entirety via the covid19India real time system website. The number of people living in the studied regions is reported in Table 1.

Table 1: Population (approximated) for Rajasthan Included in the Following Analysis

Regions	Population	Database (Year)
Rajasthan	7,72,64,000	Based on 2019 population projection by NCP report
Ajmer	41,66,594	Tentative Population Evaluation based on average population increased by 21.31% in this decade compared (2001-2011) Census 2011 published by Govt. of India for Rajasthan state.
Alwar	41,53,608	
Banswara	37,87,172	
Baran	35,47,849	
Barmer	31,56,762	
Bharatpur	30,83,180	
Bhilwara	30,62,481	
Bikaner	30,27,891	
Bundi	28,87,952	
Chittaurgarh	28,43,366	
Churu	26,16,474	
Dausa	25,18,976	
Dhaulpur	25,17,002	
Dungarpur	24,48,597	
Ganganagar	24,30,443	
Hanumangarh	23,08,159	
Jaipur	22,76,914	
Jaisalmer	22,54,121	
Jalor	21,13,838	
Jhalawar	20,23,767	
Jhunjhunun	19,37,677	
Jodhpur	19,00,755	
Karauli	18,90,558	
Kota	18,67,981	
Nagaur	18,14,980	
Pali	17,02,184	
Pratapgarh	16,85,945	
Rajsamand	16,36,026	
Sawai Madhopur	15,90,335	
Sikar	15,15,775	
Sirohi	13,47,277	
Tonk	11,49,348	
Udaipur	41,66,594	

Source: https://www.census2011.co.in/census/state/districtlist/rajasthan.html.

[1] Peng, L.; Yang,W.; Zhang, D.; Zhuge, C.; Hong, L. Epidemic analysis of COVID-19 in China by dynamical modeling. MedRxiv Epidemiol. 2020.

[2] Bacaër, N. A Short History of Mathematical Population Dynamics; Springer: London, UK, 2011.

A Brief Introduction to SEIR Model

Most of the diseases have a latent phase during which the individual is infected but not yet infectious. This delay between the acquisition of infection and the infectious state can be incorporated within the SIR model by adding a latent/exposed population, E, and letting infected (but not yet infectious) individuals move from S to E and from E to I.

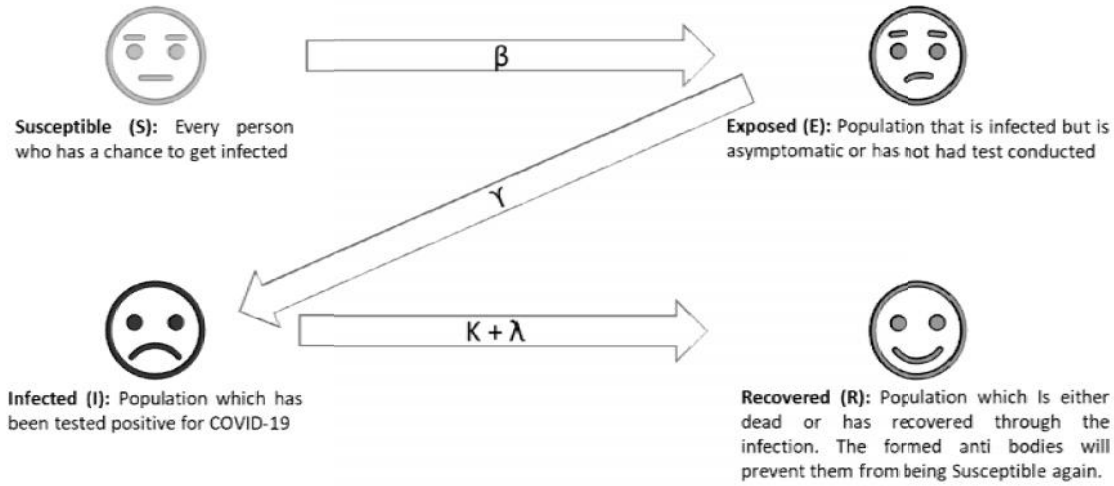


Figure 1: SEIR Model

- **Overview of the Generalized SEIR Model**

The SEIR model simulates the temporal history of an epidemic phenomenon. In its classic form, it models the mutual and dynamic interaction of people between four different conditions, susceptible (S), exposed (E), infectious (I) and cured (R). The classical SEIR model can be described by a series of ordinary differential equations.

$$\frac{dS(t)}{dt} = -\beta \mathrm{I}\,(\mathrm{t}) \cdot \frac{S(t)}{N} \quad (1)$$

$$\frac{dE(t)}{dt} = \beta \mathrm{I}\,(\mathrm{t}) \cdot \frac{S(t)}{N} - \gamma E(t) \quad (2)$$

$$\frac{dI(t)}{dt} = \gamma E(\mathrm{t}) - (\lambda + \kappa) I(t) \quad (3)$$

$$\frac{dR(t)}{dt} = (\lambda + \kappa) I(t) \quad (4)$$

The people who are Susceptible (S) are potential subjects to the virus. Unlike the traditional methods of taking the susceptible population as a whole, this research would be focusing on the part of population which are not yet COVID affected. The Exposed (E) is the fraction of the population that has been infected but does not show symptoms yet, and at this stage, the disease can be infectious, partially infectious or not infectious. The Infective (I) population comprises the transition of exposed population after the time of incubation. The Recovered (R) population are the people who have moved from the infectious stage. It comprises both dead and recovered populations. The Recovered population can neither advance the disease to others and can neither get infected.

Because of this assumption of closed population, the total population (N) at any time would be:

$$S(t) + E(t) + I(t) + R(t) = N \quad (5)$$

A disadvantage of this method is that researcher not considered the exposed people directly transitioning to the removed population. Here R_0 = Reproductive Number

Research Methodology

Objective of the Study

The present study has been undertaken with the following objectives:

- To identify & analyse the classic SEIR model by means of a stochastic solver.
- To develop the understanding regarding the acceptance of SEIR model in reinstating the recommencement of the educational institutions and bodies.

- To estimate the ideal conditions for punctilious procedural recommencing of educational institutions and bodies.
- To developed the feasible policy paradigm, which helps to reinstate the entire system in terms of Urban Domain.

Scope of the Study

This research will be helpful to reinitiate and re-establishment of the education from primary to higher educational mechanism. Some scope & expected contribution of the study is as follows:

- The proposed study includes the extensive use of SEIR model to understand, develop and acceptance regarding the re-establishment of education system.
- The finding of the study will be helpful for policymaker to design and develop the procedural paradigm in reinstating of Schools, Colleges, Universities and Coaching institutes and will also suggest remedial measures.
- The conclusions of the study will be helpful in checking out modalities for making effective policies & technical methodology in reinstating of educational institutions.

Sources of Data

The study is based on the secondary data, extracted from various govt and official online portals like Coronavirus Outbreak in India-covid19india.org, Bing search COVID-19 data sources, India Ministry of Health and Family Welfare, India Today, World Health Organization (WHO) from the India and other organizations.

Universe

Population of the Rajasthan approx. 7,72,64,000, based on 2019 population projection by NCP report.

Type of Data

The present study is quantitative in nature and secondary data will be used for the purpose of analysis.

Tools & Methods Used

The data collected was analysed with the help of SEIR Model Calculator. This calculator offers a visualization of the SEIR (Susceptible-Exposed-Infected-Removed) epidemic model in graphic form.

Time Period of Study

The data from the time line for the study is considered from 5th Oct 2020 to 15th Oct 2020.

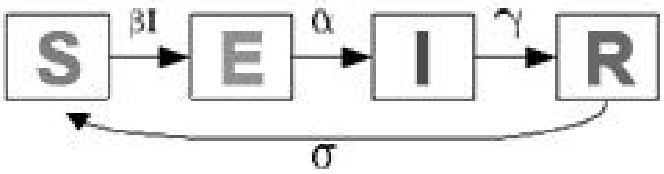
Results & Discussion

In this section researchers have presented the data obtained by the standard deterministic approach and the data series obtained by the stochastic approach, based on the Particle Swarm Optimization (PSO) algorithm.

Initial Parameters

Where, the simulator takes the input data as in following parameters:

- Start Date
- Basic Reproduction Number, R0
- Latency Period, 1/α (in days)
- Infectious Period, 1/γ (in days)
- Immunity Period, 1/σ (from base value as 1 week to permanent)
- Mixing Parameter, η
- Days



Source: https://goodcalculators.com/seir-model-calculator/

Figure 2: SEIR Simulation Modelling

Where:

N = S + E + I + R is the total population size, S, E, I, R denote the proportions of susceptible, exposed, infected, and recovered individuals respectively. With help of the above input data the simulator will identifies the following SEIR parameters for the simulations:

- Beta (β):
- Alpha (α):
- Gamma (γ):
- Sigma **(σ)**

Equations

The above model shown in figure 1.2 is described by the following equations:

$$\frac{dS}{dt} = -\beta I \cdot \left(\frac{S}{N}\right)^{\eta} + \sigma R$$

$$\frac{dE}{dt} = \beta I \cdot \left(\frac{S}{N}\right)^{\eta} - \alpha E$$

$$\frac{dI}{dt} = \alpha E - \gamma I$$

$$\frac{dR}{dt} = \gamma I - \sigma R$$

$$\beta = R_0 \cdot \gamma$$

First, researchers analyse the Rajasthan framework at a regional scale. Then, they have provided the results of SEIR modelling for two different scenarios.

Scenario Based Graphical Representation

Here researcher have separated the simulation in two different value-basedcases and results.

- **Case-I: (Infectious Period 1/α: 7 days and Immunity Period 1/γ: 1 week)**

In Case-I, the Infectious Period (1/α)is 7 days and the Immunity Period (1/γ) is 1 week was taken. The result & analysis of the same is as under:

Table 2: SEIR Model Simulator / Calculator Value

Parameters	Value
Start Date	05-10-2020
Basic Reproduction Number, R0	2.2
Latency Period, 1/α (in days)	5
Infectious Period, 1/γ (in days)	7
Immunity Period, 1/σ (from base value as 1 week to permanent)	1 week
Mixing Parameter, η	1
Days	365

Table 3: SEIR Parametric Generated Value

SEIR Parameter	Generated Values
Beta (β):	0.31429
Alpha (α):	0.20000
Gamma (γ):	0.14286
Sigma (σ):	0.14286

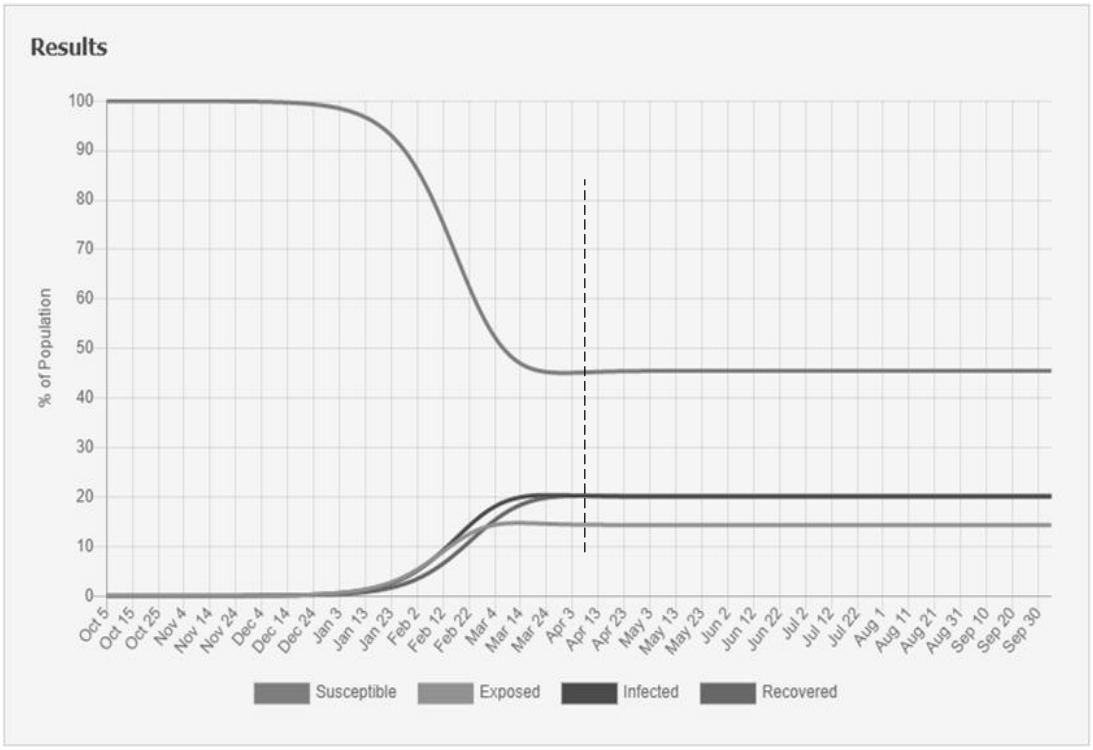


Figure 3: Case-I: Simulator Resultant Graph

On the observation and analysis of the SEIR Parametric Generated Value Table 1.3 and the Case-I Simulator Resultant Graph Figure 1.3 based on the SEIR Model Simulator / Calculator Value Table 1.2, results show that the after 170 days susceptible, exposed, infected, and recovered individuals' numbers gets saturated which can be cured after prominent medical care and the tentative availability of the vaccination up to ground level.

- **3.3.2 Case-II:(Infectious Period 1/α: 14 days and Immunity Period 1/γ: 1 Month)**

In Case-II, the Infectious Period (1/α)is14 days and the Immunity Period (1/γ) is 1 month was taken. The result & analysis of the same is as under:

Table 4: SEIR Model Simulator / Calculator Value

Parameters	Value
Start Date	10-10-2020
Basic Reproduction Number, R0	2.2
Latency Period, 1/α (in days)	7
Infectious Period, 1/γ (in days)	14
Immunity Period, 1/σ (from base value as 1 week to permanent)	1 Month
Mixing Parameter, η	1
Days	365

Table 5: SEIR Parametric Generated Value

SEIR Parameter	Generated Values
Beta (β):	0.15714
Alpha (α):	0.14286
Gamma (γ):	0.07143
Sigma (σ):	0.03333

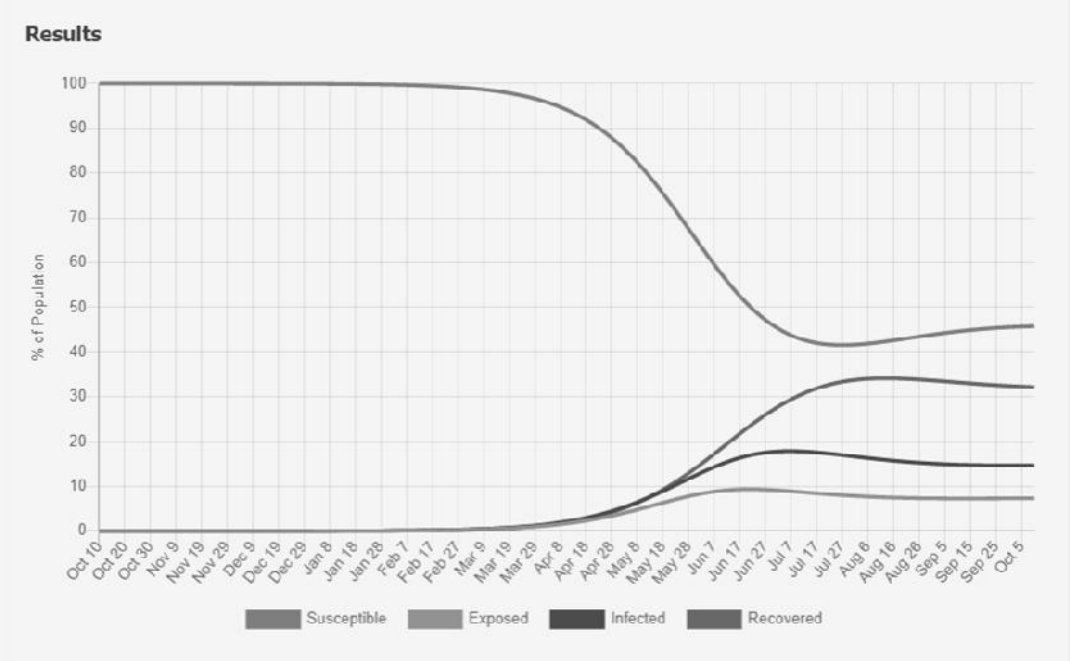


Figure 4: Case-II: Simulator Resultant Graph

On the observation and analysis of the SEIR Parametric Generated Value Table 1.4 and the Case-II Simulator Resultant Graph Figure 1.4 based on the SEIR Model Simulator / Calculator Value Table 1.4. results show that the after 350 days susceptible, exposed, infected, and recovered individuals' numbers tries to gets saturated which can be further deflect and fluctuate if the prominent medical care and the tentative availability of the vaccination up to ground level may not be available on time.

Conclusion

In this SEIR Model simulation, researchers have applied two different approaches for solving the equations of the SEIR model to describe the futuristic evolution of the epidemic phenomenon in Rajasthan. Researchers considered all the possible available data from 5th October 2020 to 15 October 2020. The main findings indicate that the deterministic approach is not appropriate to explore the possible solutions of the space-domain because the mathematical problem is underdetermined. Researchers suggested and recommended the fitting the data of this epidemic using a stochastic approach, such as the SEIR Simulator. Taking advantage of this approach, researchers estimated different scenarios for the 170 days to 350 days epidemic evolution. Every scenario refers to a different set of parameters estimated by the algorithm. The predicted scenarios are fairly similar and suggest that every Rajasthan region will reach the peak of the epidemic. The influence of the time-varying infection rate on the model prediction may open interesting discussions about the effect of lockdown policies on the evolution of the epidemic in the near and far future.

On considering the simulated results and research conclusions. Researchers proposed some applied recommendations regarding reinstatement of education institutions like Schools, Colleges Universities and Coaching Centres. Where the law-and-order establishment authorities and governing bodies can make operative policies to reinitiate the education system in the state from preliminary stage to full fledge working condition. The main emphasis of this simulation and its predicted result is indicating towards the level of immunity and infectious period. And this will lead to the availability and use of proper medication and effective and efficient guidelines for any system. This procedure will also work for the central location based epidemic simulation where the subjects get introduce and works together within the specific premises like building, working infrastructure, block, education institutions etc.

- By considering these simulated results, specific procedural policies can be formed to establish any infrastructural entity where, proper and control monitoring needs to be conducted and the effective operability and functioning can be instigated.

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