Open Access Journal of Behavioural Science & Psychology
ISSN: 2642-0856
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Mini Review *Volume 8 Issue 1*

The Role of Mathematical Modelling in Pandemic Management

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Received Date: January 07, 2025; **Published Date:** January 31, 2025

Abstract

The mathematical models serve as an irreplaceable tool in the controlling and gaining an understanding of the pandemic. Furthermore, these models can guide and influence the public health decisions and be of immense help in forecasting the transmission and deciding intervention strategies. Inaccurate models raise problematic issues too by leading to inefficient treatment decisions and making incorrect predictions. It is indisputable that using an advanced model will decrease the level of accuracy bias, but with that comes the caveat of increasing attention and resources being diverted towards getting rid of the inaccuracy. Alongside dealing with these biases, advanced models can also improve the preparedness for future pandemics, making sure that having a model will be treated as a crucial factor. Models are to be calibrated with caution and policies should have the flexibility to deal with uncertainty associated with pandemic modeling. In this backdrop, the present study is an attempt to critically discuss the role of Mathematical Modelling in Pandemic Management. It is hoped that the review of research studies provided in the paper will provide valuable insights to the researchers, policy makers and other stakeholders related to management of pandemics.

Keywords: Pandemics; Forecasting; Modeling; Mathematical; Preparedness

Abbreviations

ARIMA: Autoregressive Integrated Moving Average; SIR: Susceptible Infected Recovered; ABMs: Agent Based Models.

Introduction

Even though a pandemic is something that is extremely difficult to predict, it's important to get ready to be able to prevent significant disability and economic turmoil, the effective preparedness is therefore of prime importance. In this regard, researchers around the world tried to objectively assess the strategies for the management of the COVID-19 pandemic during its outbreak through the evaluation of the best and the worst possible case scenarios of the pandemic.

Review of Literature

Over the years, researchers studying the dynamics of infectious diseases have relied on mathematical modelling quite a lot. Kermack WO and McKendrick AG [1] developed the SIR, framework standing for Susceptible, Infected, and Recovered model, in the beginning of the twentieth century, which continues to be an integral part of the practice of modern epidemiology. The SIR model is employed by the Researchers in order to analyse the progression of diseases and assess the impact of different control measures by partitioning the population into compartments. Mandal S, et al. [2] demonstrated if basic reproduction rate is 1.5, then in the best case scenario the cumulative incidence will decrease by 62%.

Mathematical models provide a structured way of understanding and predicting the patterns of infectious disease spread. These models show the complexities of human actions and medical illness and hence help in the planning of public health initiatives and decision making [3].

In relation to the mathematical modelling used to forecast the covid-19 outbreak, Sabherwal AK, Sood A and Shah MA [4] narrate that the most utilized forms were compartment models, which divide population into different compartments according to infection status, as demonstrated by researchers who employed the SIR (Susceptible-Infected-Recovered) model; agent-based models (ABMs), which model the actions of individual agents and their relations with the surroundings; spatial models that deal with spatial and temporal components in order to understand the spread of a disease geographically to explain the local spread and network models that explain the spread of disease in terms of social networks through which each person is represented as a node and the contacts as edges representing people's interactions.

To estimate the potential impacts of measures such as social distancing and vaccine campaign and the number of infected and healthcare services needed the world over, a number of predictive models were developed. For Example, Imperial College London model strongly shaped governments' response in many countries by providing accurate mortality prediction [5]. In addition, these models highlighted the importance of timely public health measures, while providing insight into the anticipated progression of the disease. Mathematical models have increased in sophistication over time to enhance the precision of forecasts, incorporating features like heterogeneities in the population, spatial and temporal heterogeneity [6]. Periodic retraining of mathematical models became increasingly necessary during the COVID-19 pandemic. According to Roosa K, et al. [7], mathematical models can describe the process of disease development well, help researchers reduce uncertainty related to disease occurrence, and improve the accuracy of the forecast.

Moreover, Laubenbacher R, et al. [8] highlighted that the epidemiological assessment can be significantly enhanced using agent–based models for simulating transmission. Mathematical modeling plays an important role in allocating resources, particularly in pandemics. These models use the data available to predict the expected pressure on healthcare systems, allowing the correct allocation of resources such as hospital beds, ventilators, and vaccines [9]. In addition, mathematical models can help to identify high-risk populations in need of targeted interventions so that healthcare measures are appropriately implemented. Benvenuto D, et al. [10] suggested the usage of autoregressive integrated moving average (ARIMA) models for COVID-19 forecasting.

While useful, mathematical modeling does face some challenges. According to Hall M [11], the accuracy of mathematical models in the early stages of an outbreak is heavily dependent on the quality of the input data. A further complication is the emergence of new variants over time and the variability of reporting patterns between research groups. These would require precaution in projecting the impact of the pandemic in order to effectively adapt measures. Coordination among public health professionals, mathematicians, and epidemiologists can ensure the same to a large extent.

Conclusion

Mathematical modeling is a crucial instrument for predicting pandemics, thereby significantly influencing the formulation of public health policy actions. It is essential to continuously modify and validate the models using real-world data to improve their applicability and reliability.

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