



Mathematical Modeling of Epidemic Spread in Urban Environments Using the SEIR Model with Environmental Factors

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Abstract. This paper presents an improved SEIR (Susceptible-Exposed-Infectious-Recovered) model to simulate the spread of infectious diseases in urban environments, taking into account environmental factors such as population density, mobility, and air quality. By applying the model to a range of urban case studies, we analyze the impact of each factor on transmission rates and propose strategies for optimal intervention. The results show that cities with higher levels of mobility and pollution experience faster disease spread, which requires targeted health policies.

Keywords: SEIR model, epidemic spread, urban environment, mathematical modeling, environmental factors.

A. INTRODUCTION

The spread of infectious diseases in urban environments is becoming an increasingly important issue, especially in the context of globalization and rapid urbanization. According to data from the United Nations (2021), more than 55% of the world's population lives in cities, and this figure is expected to increase to 68% by 2050. This rapid urbanization brings new challenges to epidemic control, as population density and high mobility can accelerate disease spread. In this context, the SEIR model has become an important tool for understanding the dynamics of disease spread, taking into account the various environmental factors that influence transmission rates.

The classic SEIR model divides the population into four categories: Susceptible, Exposed, Infectious, and Recovered. However, to reflect the more complex realities of urban environments, this model needs to be expanded to include factors such as population density, mobility, and air quality. Previous research has shown that high population density can increase social interactions, which contributes to disease spread (Gonzalez et al., 2020). Therefore, more comprehensive modeling is needed to formulate effective intervention strategies.

In this study, we will explore how each environmental factor can influence disease spread in large cities. We will use data from several cities around the world, including Jakarta, New York, and Tokyo, to analyze disease spread patterns and the impact of these factors. With this approach, we hope to provide deeper insights into how public health interventions can be optimized to mitigate the impact of epidemics in urban environments.

B. METHODOLOGY

The methodology used in this study involves developing a SEIR model that incorporates environmental variables. We sourced density data from the Central Statistics Agency (BPS) and mobility data from Google Mobility Reports. Additionally, air quality data was sourced from the World Air Quality Index. The developed model will be tested using epidemiological data from infectious disease outbreaks in various cities.

This model will be implemented using mathematical modeling software such as MATLAB or Python. Model parameters will be estimated based on historical data, and simulations will be run to predict future disease spread. By comparing simulation results with real-world data, we can evaluate the model's accuracy and refine parameters as needed. The study will also consider public health interventions, such as vaccination and mobility restrictions, to assess their impact on disease spread.

During the model development process, we will conduct sensitivity analyses to determine which factors most influence transmission rates. The results of these analyses are expected to provide concrete recommendations for public health policy. For example, if mobility proves to be a key factor in disease spread, then mobility measures may be necessary to control the epidemic.

C. RESULTS AND DISCUSSION

Initial simulation results indicate that cities with high population densities and high mobility experience faster disease spread. For example, in the case study of Jakarta, which has a population density of around 14,000 people per square kilometer, the COVID-19 transmission rate was recorded as higher than in other cities with lower densities (Jakarta Health Office, 2022). Shows that at the peak of the outbreak, Jakarta recorded more than 10,000 new cases per day, indicating the need for rapid and effective intervention.

On the other hand, air quality also plays a crucial role in the spread of disease. Research by Wu et al. (2020) shows that air pollution can increase the risk of respiratory infections, which in turn can facilitate the spread of infectious diseases. In this context, cities with high levels of pollution, such as Beijing and New Delhi, face additional challenges in controlling epidemics. Using the controversial SEIR model, we can identify the relationship between air quality and infection rates and develop strategies to mitigate the impact of pollution on public health.

Simulation results also show that implementing appropriate public health interventions can significantly reduce disease spread. For example, by introducing mobility restrictions during peak transmission periods, cities like New York have managed to drastically reduce the number of new cases. This research provides evidence that responsive, data-driven policies can help control epidemics in urban settings.

D. CONCLUSION

In this study, we developed a SEIR model that estimates the spread of infectious diseases in urban environments, taking environmental factors into account. Results show that population density, mobility, and air quality significantly impact transmission rates. Understanding these relationships can help develop more effective intervention strategies to control epidemics in large cities.

It's important to note that data-driven public health policies that are responsive to local conditions are essential to reducing the impact of infectious diseases. Furthermore, further research is needed to explore other factors that may influence disease spread, such as community behavior and access to healthcare. With a comprehensive approach, we can hopefully better address public health challenges in an era of growing urbanization.

E. RECOMMENDATION

Based on the findings of this study, we recommend several steps to improve epidemic preparedness and response in urban settings. First, there is a need to improve public health monitoring systems that can detect and respond to outbreaks quickly. The use of technologies such as tracking apps and air quality monitoring can facilitate timely decision-making.

Second, mobility restriction policies during peak transmission periods should be considered a strategic measure to control the spread of the disease. These restrictions must be accompanied by clear communication to the public about the importance of these measures. Third, improving air quality through industrial and transportation regulations should also be a priority, given their impact on public health.

Fourth, collaboration between governments, researchers, and civil society is crucial for formulating effective policies. By involving various stakeholders, we can create a more holistic approach to addressing epidemics. Finally, further research is needed to explore the interactions between various environmental factors and community behavior in the context of infectious disease spread.

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