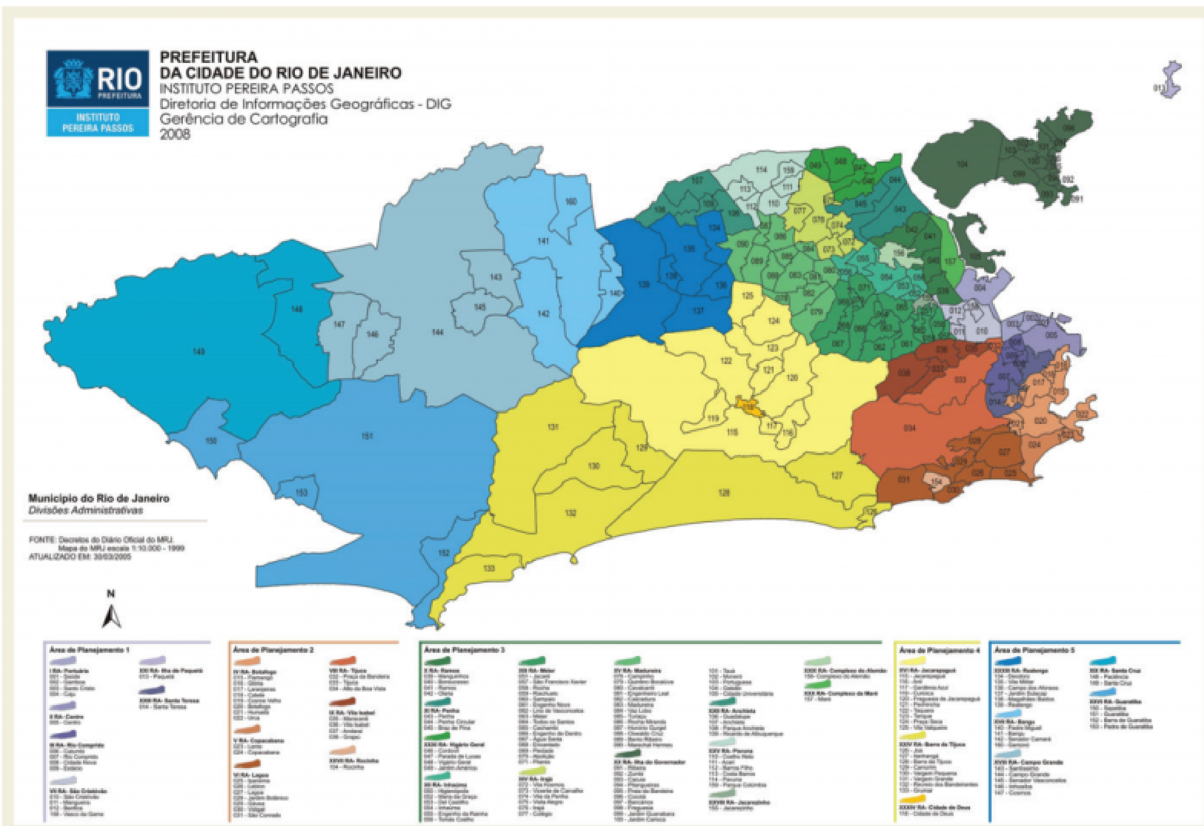
New SIR-Network Model helps predict dengue fever epidemic in urban areas

December 23 2015



Rio de Janeiro divided into neighborhoods (numbered) and administrative regions (colored).

Mathematics is often implemented in healthcare and medical research. From health management to the bio-pharmaceutical fields, math modeling can be used to predict the spread of diseases, how to prevent epidemics and so much more. An article 'SIR-Network Model And its Application to Dengue Fever,' authored by Lucas M. Stolerman, Daniel Coombs and Stefanella Boatto, published recently in the *SIAM Journal on Applied Mathematics* introduces a new mathematical model which offers a simplified approach to studying the spread of the infectious virus, Dengue fever, in urban areas, specifically breaking down the epidemic dynamics across a city and its varying neighborhoods and populations.

The model is important for studying how varying neighborhood conditions affect the spread of Dengue fever and how to contain it. For example, some neighborhoods have standing water allowing large mosquito populations to develop. Since mosquitoes fly, on average, only a few hundred meters from their birthplace, a human infected with the disease who commutes long distances could spread the disease. This new SIR-Network model will allow researchers to understand how these conditions affect epidemic dynamics across an entire city and beyond.

"The SIR-Network model can be used to predict whether local interventions—like cleaning up standing water in containers—in one or two neighborhoods could affect the prevalence of Dengue across the city," says coauthor Daniel Coombs. "We give formulae that describe whether an epidemic is possible, in terms of human travel patterns among neighborhoods, mosquito populations and biting rates in each neighborhood."

The model uses a Susceptible- Infected- Recovered (SIR) approach to disease spread and the network consists of the city's neighborhoods where local populations are assumed to be well-mixed. The fraction of people traveling from residential neighborhoods to active ones are represented by directed edges in the network. The article also presents fundamental properties of the basic reproduction number (Ro) for their specific model. Ro is the expected number of secondary cases due to a single infection. The group focuses on how Ro depends upon geometry and heterogeneity—different infection rates in each vertex—of the complex network.

In the second part of the article, the authors applied the SIR-Network model to Dengue fever data, which had been updated several times, including as recent as 2014, from the epidemic outbreak of 2007-2008 in various neighborhoods of Rio de Janeiro, Brazil, and soon discovered several interesting features of the epidemic.

First, they needed to include a transmission rate that varied over the months of the Dengue season to match the available data. The authors predict that the transmission rate peaks 6-8 weeks before the peak incidence of Dengue.

Secondly, they predict that the city center, where large populations from various neighborhoods go to work each day, is the most important neighborhood to spreading the fever. Ultimately, the researchers found that results were improved most when a time-infection parameter was introduced to model seasonal climate changes.

"We feel that our results highlight the need for countermeasures before the peak of an epidemic, and also point to the importance of central neighborhoods as hubs of Dengue transmission," says coauthor Stefanella Boatto.

The coauthors admit establishing a comprehensive picture of Dengue would be very challenging because there are so many varying pieces to the puzzle. For example, some of the factors to be considered include the impact of environmental variables on mosquito populations, changes in weather, human behavior like mosquito avoidance or control and travel on the network.

"In the case of Rio de Janeiro, for example, there is a major influx of tourists every year for Carnival, but the date of Carnival, the weather patterns in the preceding months, and the numbers of tourists that show up vary from year to year," says coauthor Lucas M. Stolerman. "The benefit of simple models is that we can average out some of this complexity and try to understand the big picture...our model will be useful as a conceptual tool for modeling the impact of interventions aiming to control Dengue in urban areas."

The SIR-Network Model offers researchers a simplified and clearer image of the bigger picture of Dengue fever, and has the potential to help quell the disease (as well as be applied to other disease spread issues), saving lives, time and money.

More information: Lucas M. Stolerman et al. SIR-Network Model and Its Application to Dengue Fever, *SIAM Journal on Applied Mathematics* (2015). DOI: 10.1137/140996148

Provided by Society for Industrial and Applied Mathematics