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Incorporating Queueing Theory into a Spatial Optimization Framework to Improve Mass Vaccination Programs

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Mass vaccination is a cornerstone of public health emergency preparedness and response. However, injudicious placement of vaccination sites can lead to the formation of long waiting lines or queues, which discourage individuals from waiting to be vaccinated and thus jeopardize the achievement of public health targets. Queueing theory offers a framework for modeling queue formation at vaccination sites and its effect on vaccine uptake. We developed an algorithm that integrates queueing theory with a spatial optimization framework to optimize the placement of mass vaccination sites. The algorithm was built and tested using data from a mass canine rabies vaccination campaign in Arequipa, Peru. We compared expected vaccination coverage and losses from queueing (i.e., attrition) for sites optimized with our queue-conscious algorithm to those obtained from a queue-naive version of the same algorithm. Sites placed by the queue-conscious algorithm resulted in 9-19% less attrition and 1-2% higher vaccination coverage compared to sites placed by the queue-naïve algorithm. Although modest, these estimated gains do not capture the future negative effects of excessive wait times and attrition. Our results remained robust to varying queueing model parameters and arrival rates, highlighting the importance of accounting for queueing attrition in mass vaccination site placement.

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