

Optimizing the Societal Benefits of the Annual Influenza Vaccine: A Stochastic Programming Approach

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Influenza (flu) is a highly contagious, acute, respiratory viral disease. Seasonal epidemics annually impact 5-15% of the world's population, resulting in 3-5 million cases of severe illness and up to 500,000 deaths. Seasonal flu epidemics caused by antigenic drifts and the high rate of influenza transmission require annual updates in the flu shot composition. The World Health Organization recommends which strains of influenza to include in each year's vaccine based on surveillance data and epidemiological analysis.

There are two critical decisions regarding the flu shot. The first is its composition; currently three strains comprise the flu shot, and this decision affects its effectiveness against the upcoming flu epidemic. The second decision is the timing of the composition decision. If the strains are selected too early, there is a greater likelihood that there will be a mismatch. However, delaying the decision may leave a short time for manufacturing, resulting in delays or shortages in the flu shot supply.

Optimization models have not yet made a large impact on public health. Thus far, the design and timing of the flu shot have been made in an ad hoc manner. We propose a multi-stage stochastic mixed-integer program to address the optimal design of the annual flu shot design and calibrate our model with real-life data. Risk evaluation is taken into account by incorporating risk measures in the objective function. Multi-stage stochastic mixed-integer programs are very difficult optimization problems, but have many potential applications. The techniques we have developed are likely to lead to algorithmic enhancements that can be broadly applied.

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