The Impact of Supply Chain Performance on Seasonal Influenza: An Exploratory Analysis

Nabeela Mumtaz, School of Computer Science, NUI Galway.

Abstract
An ability to optimize policy to mitigate infectious disease helps ensure significant health and economic benefits. This novel approach integrates SEIR with a vaccine supply chain model to explore the impact of vaccination supplies on the progression of seasonal influenza infectious disease.

Flu / Vaccine Supply Line
“Seasonal influenza is an acute viral infection that occurs worldwide causing an estimated 3-5 million severe cases and up to 500000 deaths every year” (WHO, 2014). The vaccine recommended coverage is 75% before the onset of each influenza season. Vaccination programs aim to achieve a coverage which is above the Herd Immunity Threshold, outbreaks are unlikely to occur (Vynnycky and G White, 2019). A. Vaccine dispense process with minimum delay can protect maximum susceptible population. B. Vaccine coverage equal to HIT percentage before the onset of each influenza season is a cost-effective solution. C. Fluctuation in vaccine production capacity and actual disease’s potential Ro affect on the system behaviour. Optimize policy ensures significant health and economic benefits.

SEIR / Supply Chain Model
The integrated SEIR/Vaccine Supply Chain model evaluates the disease’s potential Ro Ratio, HIT, Vaccine Order and Capacity to improve decision-making process. Uncertainty in the determination of vaccine ordering and capacity leads to a significant risk of insufficient vaccine supplies during the epidemic. The model has the following sectors:
1. SEIR Sector
2. Vaccine Supply Chain Sector

Fig 1.1: Seasonal Influenza Vaccine Supply Timeline

Fig 1.8: SEIR / Vaccine Supply Chain Model

Fig 2.2: Avg Dispensive Delay= 4
Fig 2.3: Avg Dispensive Delay = 8
Fig 2.4: Avg Dispensive Delay= 12

A. Vaccine Dispense scenarios

B. Vaccine Dependent Parameter Cases

C. Sensitivity Analysis

Fig 2.5: Vaccine Order Cases (1-3)
Fig 2.6: Vaccine Order Cases (4-6)
Fig 2.7: Vaccine Order Cases (7-9)

Fig 2.9, 2.10, 2.11, 2.12: SA Runs
Fig 2.13, 2.14, 2.15, 2.16: SA Plots

Key Findings / Conclusion
“Vaccination programs aim to achieve a coverage which is above the Herd Immunity Threshold, outbreaks are unlikely to occur” (Vynnycky and G White, 2019).
A. Vaccine dispense process with minimum delay can protect maximum susceptible population. B. Vaccine coverage equal to HIT percentage before the onset of each influenza season is a cost-effective solution. C. Fluctuation in vaccine production capacity and actual disease’s potential Ro affect on the system behaviour. Optimize policy ensures significant health and economic benefits.

Discussion / Future Work
The epidemic response always remains critical due to uncertainty of influenza attack rate, vaccine order and capacity.
- The SEIR model of infectious disease continue research on population group (age cohorts) and add other preventive methods (PPE, antivirals, etc.).
- The Vaccine Supply Chain structure continue research on adjustment stocks to overcome the unfulfilled and unexpected vaccine demand during the epidemic.

Acknowledgments
This work is funded by research scholarship from the College of Science & Engineering, National University of Ireland Galway.