Resource Distribution Strategies for Mitigation of Cross-Regional Influenza Pandemics

Andres Uribe-Sanchez, University of South Florida, USA
Alex Savachkin, University of South Florida, USA

ABSTRACT
As recently acknowledged by the Institute of Medicine, the existing pandemic mitigation models lack dynamic decision support capabilities. This paper develops a simulation optimization model for generating dynamic resource distribution strategies over a network of regions exposed to a pandemic. While the underlying simulation mimics the disease and population dynamics of the affected regions, the optimization model generates progressive allocations of mitigation resources, including vaccines, antivirals, healthcare capacities, and social distancing enforcement measures. The model strives to minimize the impact of ongoing outbreaks and the expected impact of the potential outbreaks, considering measures of morbidity, mortality, and social distancing, translated into the cost of lost productivity and medical expenses. The model was implemented on a simulated outbreak involving four million inhabitants. The strategy was compared to pro-rata and myopic strategies. The model is intended to assist public health policy makers in developing effective distribution policies during influenza pandemics.

Keywords: Allocation, Antiviral, Dynamic, Mitigation, Pandemic, Social Distancing, Vaccine

INTRODUCTION AND MOTIVATION
The history of influenza pandemics is a history of enormous societal calamities aggravated by staggering economic forfeitures. In the U.S. alone, the Spanish flu (1918, virus serotype H1N1), the Asian flu (1957, serotype H2N2), and the Hong Kong flu (1968, serotype H3N2) resulted in the death toll of more than 500,000, 70,000 and 34,000 cases, respectively (Longini, Halloran, Nizam, & Yang, 2004). In recent years, a series of scattered outbreaks of the avian-to-human transmittable H5N1 virus has been mapping its way through Asia, the Pacific region, Africa, the Near East, and Europe (Centers for Disease Control and Prevention - CDC, 2008). As of March 2010, WHO has reported 287 deaths in 486 worldwide cases (World Health Organization, 2010a). In Spring 2009, a...
mutation of the human-to-human transmissible H1N1 serotype resurfaced and propagated to an ongoing global outbreak; as of March 2010, 213 countries have been affected with a total reported number of infections and mortalities of 419,289 and 16,455, respectively (World Health Organization, 2010b). Nowadays, most experts have an ominous expectation that the next pandemic will be triggered by an emerging pathogenic virus, to which there is little or no pre-existing immunity (Schoenstadt, 2010).

The nation's ability to mitigate influenza pandemics depends on available emergency response infrastructure and resources, and at present, challenges abound. Prediction of the exact virus subtype remains a difficult task, and even when identified, reaching an adequate vaccine supply can take between six and nine months (Aunins, Lee, & Volkin, 1995; Fedson, 2003). Even if the emerged virus has a known epidemiology, the existing stockpiles will be limited due to high manufacturing and inventory costs (WHO Global Influenza Programme, 2009; World Health Organization, 2009). The supply of antiviral drugs, healthcare providers, hospital beds, medical supplies, and logistics will also be significantly constrained. Hence, pandemic mitigation will have to be done amidst a limited knowledge of the virus nature, constrained infrastructure, and limited resource availability. This ongoing challenge has been acknowledged by WHO (2009) and echoed by the HHS and CDC (Centers for Disease Control and Prevention, 2009; U.S. Department of Health & Human Services, 2007).

The existing literature on pandemic influenza (PI) modeling aims to address various complex aspects of the pandemic evolution process including: (1) the underlying spatio-temporal structure, (2) contact dynamics and disease transmission, (3) disease natural history, and (4) analysis and development of mitigation strategies. A comprehensive decision support model for PI containment and mitigation has to invariably consider all of the above aspects: it must incorporate the mechanism of disease progression, from the initial infection, to the asymptomatic phase, manifestation of symptoms, and the final health outcome (Atkinson & Wein, 2008; Handel, Longini, & Antia, 2010; Pourbohloul et al., 2009); it must also consider the population dynamics, including individual susceptibility (Pitzer, Leung, & Lipsitch, 2007; Pitzer, Olsen, Bergstrom, Dowell, & Lipsitch, 2007) and transmissibility (Cauchemez, Carrat, Viboud, Valleron, & Boelle, 2004; Handel et al., 2010; Yang, Halloran, Sugimoto, & Longini, 2007; Yang et al., 2009), and behavioral factors affecting infection generation and disease progression (Colizza, Barrat, Barthélemy, & Vespignani, 2006; Epstein, Parker, Cummings, & Hammond, 2008; Halloran, 2006); finally, it must incorporate the impact of pharmaceutical and non-pharmaceutical measures, including vaccination (Ball & Lyne, 2002; Becker & Starczak, 1997; Carrat, Lavenu, Cauchemez, & Deleger, 2006), antiviral therapy (Ferguson, Mallett, Jackson, Roberts, & Ward, 2003; Lee et al., 2002; Lipsitch, Cohen, Murray, & Levin, 2007), social distancing (Halder, Kelso, & Milne, 2010; Kelso, Milne, & Kelly, 2009; Miller, Randolph, & Patterson, 2008; Milne, Kelso, Kelly, Huband, & McVernon, 2008; Yasuda & Suzuki, 2009) and travel restrictions, and the use of low-cost measures, such as face masks and hand washing (Glass, Glass, Beyeler, & Min, 2006; Lipsitch et al., 2007; Nigmatulina & Larson, 2009; Scharfstein, Halloran, Chu, & Daniels, 2006).

In recent years, the models for PI containment and mitigation have focused on integration of pharmaceutical and non-pharmaceutical measures in search for synergistic strategies, aimed at better resource utilization. Most of these approaches aim to implement a scheme of social distancing to reduce infection exposure, followed by application of pharmaceutical means. Significant contributions in this challenging area include (Chao, Halloran, Obenchain, & Longini, 2010; Colizza, Barrat, Barthélemy, Valleron, & Vespignani, 2007; Cooley et al., 2008; Glass et al., 2006; Longini et al., 2004; Mills, Robins, & Lipsitch, 2004; Patel & Longini, 2005; Wu, Riley, Fraser, & Leung, 2006). One of the most notable among the recent efforts is a 2006-07 initiative by MIDAS (National Institute
A New Approach to Pattern Recognition in Fractal Ferns
Mamta Rani and Saurabh Goel (2010). *International Journal of Artificial Life Research* (pp. 21-28).
www.igi-global.com/article/new-approach-pattern-recognition-fractal/44668?camid=4v1a