The AIR Pandemic Model

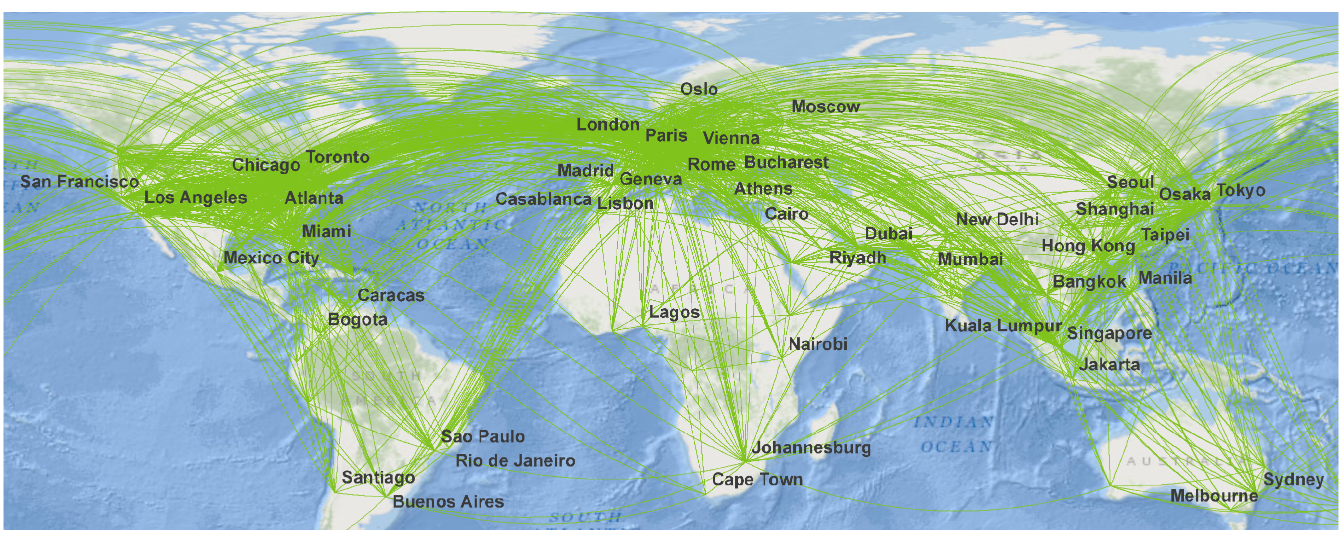
The 1918 "Spanish Flu" pandemic was one of the greatest public health catastrophes in modern history. Caused by a readily transmissible and highly virulent strain of influenza, the pandemic killed between 20 million and 100 million people worldwide, at a time when the global population totaled just 1.8 billion. If a similar virus were to emerge today, the global life insurance industry could be faced with losses exceeding USD 50 billion.

With its limited historical record and potentially catastrophic effects, pandemic risk can be exceptionally difficult to assess. Moreover, in today's highly interconnected world, pandemic disease could spread extremely quickly and cause unprecedented loss of life. To address these challenges, the AIR Pandemic Model goes beyond traditional epidemiological modeling to explicitly capture population movement, temporal dynamics of pandemics, varying availability of medical interventions across the globe, and differences in the efficacy of antivirals and vaccines due to patient age. Accounting for these various sources of uncertainty results in a probabilistic solution for modeling pandemics that gives risk managers a robust and comprehensive understanding of potential mortality and life and health insurance losses.

AIR's Innovative and Probabilistic Model for Quantifying Disease Spread

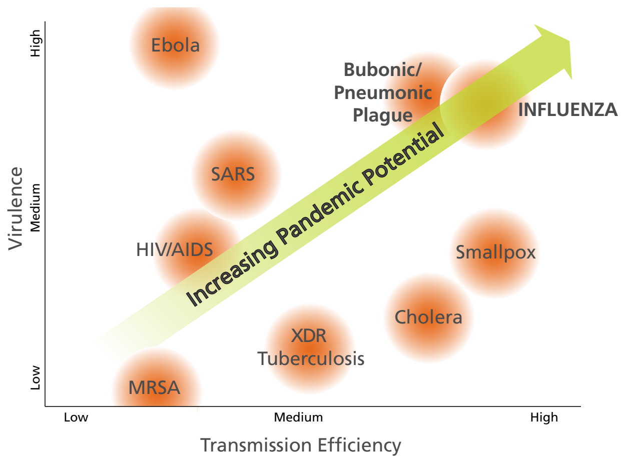
Using the latest scientific research on infectious disease characteristics, the AIR Pandemic Model estimates morbidity, mortality, and life and health insurance losses by sex and age cohort. The product features a 500,000-year stochastic catalog containing nearly 1 million simulated events caused by influenza, coronaviruses, and filoviruses, as well as cholera, Crimean-Congo hemorrhagic fever, Lassa fever, Meningococcal meningitis, plague, and Rift Valley fever. The catalogs capture the full range of pathogen characteristics—including virulence and transmissibility—exhibited by major historical outbreaks, as well as characteristics of pathogens that pose a threat to cause major loss but have not yet had a widespread impact on the human population.

To estimate the spread of disease, AIR researchers developed a novel metapopulation Susceptible-Exposed-Infectious-Removed (SEIR) epidemiological model that explicitly accounts for both long-range and short-range population movement—for example, air travel and work commute, respectively. Each simulated outbreak in the AIR catalog generates an "event footprint" that reveals how many people are infected broken down by when they were infected and where, as well as by age and sex. The model also explicitly accounts for mitigation efforts during the event, such as the development and administration of vaccines and antivirals, and travel restrictions, resulting in an accurate and probabilistic view of disease spread among all segments of the human population.



AIR's metapopulation SEIR model includes explicit modeling of population movement that drives disease spread.

Potential Impact of Infectious Diseases



The pandemic potential of an infectious disease increases with its efficiency of transmission between humans and its ability to cause fatal outcomes.

Many pathogens inflict a significant disease burden on the human population. To cause a large-scale outbreak, a pathogen must be easily spread (transmissible) and cause serious illness (virulent). With its capabilities for efficient transmission and elevated virulence, influenza is believed to have the greatest pandemic potential of known infectious diseases.

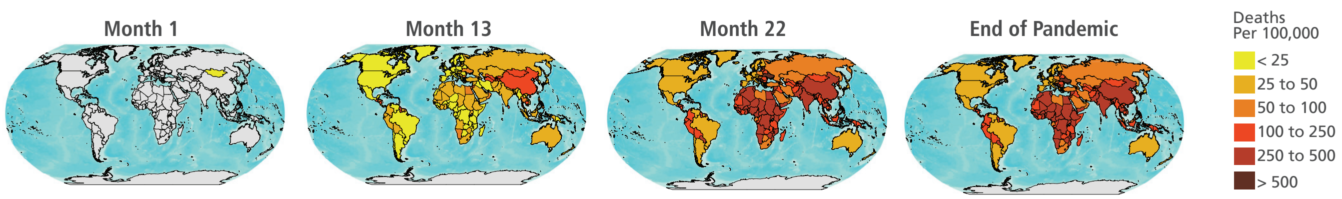
Although multiple influenza variants circulate in the human population today, causing the relatively mild "seasonal flu," novel influenza strains—including H5N1 avian flu and H1N2 swine flu—pose a marked public health threat. While these flu variants do not readily spread between humans yet, influenza's highly mutable genetic code may permit these strains to cause a deadly pandemic in the future.

A group of coronaviruses circulates in the human population and causes a large portion of the common cold each year. The 2003 SARS outbreak and the ongoing MERS event, which started in 2012, are two examples of novel coronaviruses able to cause severe outcomes in humans after emergence from animal populations. The Ebola virus causes frequent, local outbreaks with high mortality rates. The 2014 West African Ebola outbreak raised awareness of the potential international spread of this disease.

Pathogens with traditionally less global spread potential are capable of causing large-scale loss. Following the 2010 earthquake in Haiti, a cholera outbreak in the region claimed nearly 10,000 lives as of December 2015. The 1997-1998 Meningococcal meningitis outbreaks in Africa resulted in 25,000 deaths and immense economic loss. These events and others illustrate the potential hazard of such pathogens.

Capturing Temporal Dynamics of Pandemics

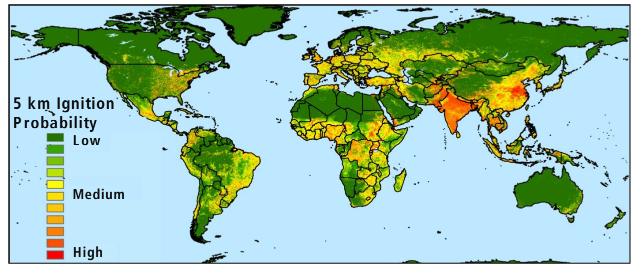
Pandemics can last from months to years and manifest multiple waves of infection. These temporal characteristics are explicitly addressed in the AIR Pandemic Model. The model's stochastic catalogs include events up to six years in duration. Based on pathogen characteristics, such as transmissibility, and environmental factors, such as seasonality, the number of waves of infection varies for each simulation. The catalogs include some events that have only one wave, while other events develop multiple waves of infection. Users of AIR's CATRADER® application can leverage this information with three different stochastic catalogs covering different stages in the progression of a pandemic (Year 1, Year 1+2, and Event Total).



Cumulative death rates by country during the progression of a single pandemic event.

WHERE MIGHT THE NEXT PANDEMIC EMERGE?

The AIR stochastic catalogs, each with nearly 1 million pandemic events, accurately captures where pandemics are most likely to emerge. Spatial data, such as human population density and the density of domestic pigs and poultry, are used to model the probability of pandemic emergence across the globe. Although a pandemic may be sparked anywhere in the world, the likelihood of ignition is highest in parts of Africa, India, and Southeast Asia.



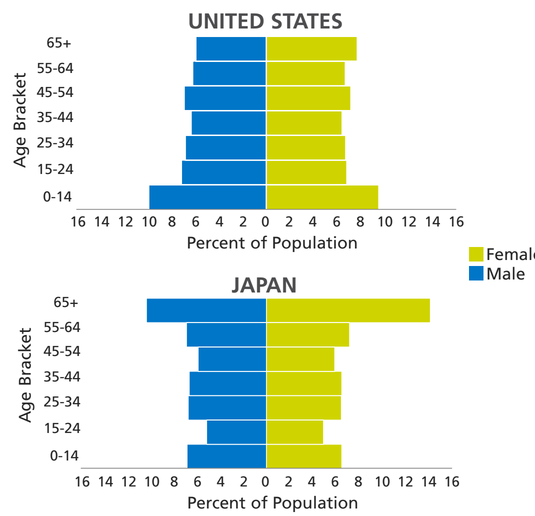
Modeled spatial distribution of the likelihood of influenza pandemic emergence.

Assessing the Impact of Pandemics

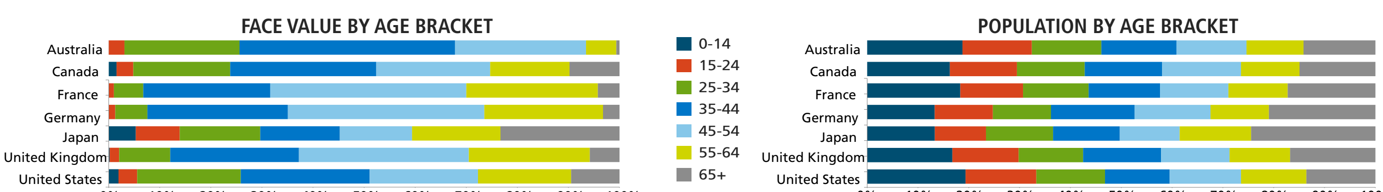
Vulnerability to disease varies by age and pathogen. Infants and the elderly are often the most vulnerable age groups. In some locations, medical care may not be available for all who are stricken, increasing the likelihood that people will suffer serious outcomes.

To address factors that influence people's vulnerability to infectious diseases AIR has developed a unique, high-resolution industry exposure database of worldwide population data, age distributions, and sex ratios based on data obtained from the World Bank and local census offices.

Using the pandemic footprint as a starting point, the AIR model assesses morbidity and mortality by age and sex using severity functions that estimate the probability of various outcomes, such as hospitalization or death. Country-specific factors are taken into account, such as the general health of the local population, economic resources, and the availability of physicians, hospitals, antivirals, and vaccines. Each factor is informed by data obtained from the World Health Organization, the United States Centers for Disease Control and Prevention (CDC), the European Centre for Disease Prevention and Control (ECDC), and other national and local health agencies.



Age distribution of the population can have a significant impact on morbidity and mortality.



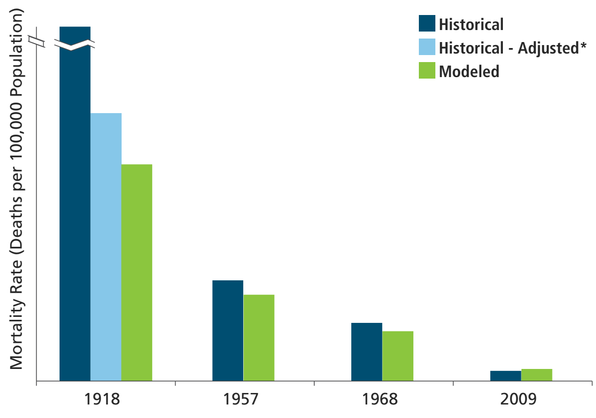
The AIR model includes detailed analysis of financial loss in each age bracket of the human population and accounts for the large variation in insurance coverage across age brackets and countries.

Estimating Financial Losses from Pandemics

Morbidity and mortality are translated into financial loss by applying appropriate policy conditions to the number of people insured in each illness outcome category. AIR's CATRADER application estimates life insurance losses through the application of policy conditions and death benefit levels. Health insurance losses associated with physician visits and hospitalizations, which incorporate data obtained from Verisk Health, are available on a consulting service basis.

Validating Modeled Mortality Rates and Insurance Losses

The estimated mortality rates and insurance losses produced by the AIR Pandemic Model have been validated against loss data from historical pandemics. But to ensure the most robust and scientifically rigorous model possible, each model component has been independently validated against historical data from multiple sources.



AIR's modeled mortality rates for four historical influenza pandemics compare well with reported mortality rates when medical and scientific advances are taken into account. The data shown are pooled results for the United States, Canada, United Kingdom, France, Germany, Japan, and Australia.

*The historical adjusted value for the 1918 pandemic was obtained from Murray et al. (2006). This value represents one published estimate of the mortality rate a 1918-like event would inflict, if it were to occur today.

PEER REVIEW OF AIR'S INFLUENZA MODELING

> "This model is sophisticated and draws on much of the best work available for anticipating the range of outcomes that may occur from a flu pandemic."

Dr. Marc Lipsitch, Professor of Epidemiology & Director of the Center for Communicable Disease Dynamics, Harvard University

> "Overall, the AIR pandemic model is remarkably detailed, based on sound scientific principles, and of genuine utility to the insurance industry."

Dr. Joshua Plotkin, Professor of Biology & Professor of Computer and Information Science, University of Pennsylvania

Users can customize benefit levels in CATRADER to calculate losses to lines of business that include mortality or morbidity loss, such as death, health, personal accident, or workers' compensation. Morbidity and mortality benefit assumptions can be customized by region, book of business, age, and sex.

Model at a Glance

Modeled Perils	Excess morbidity and mortality from an infectious disease pandemic
Model Domain	Pandemic initiation and spread are modeled on a global model domain. AIR's CATRADER software provides healthcare utilization, fatalities, and life and health insurance losses for the U.S., UK, Australia, Canada, France, Germany, and Japan; results for other countries are available on a service basis.
Stochastic Catalogs	The three 500,000-year stochastic catalogs (Year 1, Year 1+2, Event Total) each contain nearly 1 million simulated pandemic events.
Industry Exposure Database (IED)	The IED provides a foundation for all modeled industry loss estimates. The IED includes worldwide population data, age distributions, and sex ratios.

Model Highlights

— Models pandemic initiation and spread across the entire globe
— Captures morbidity, mortality, and insurance losses by sex and age cohort
— Utilizes a cutting edge metapopulation epidemiologic model with explicit modeling of long- and short- range population movement
— Explicitly accounts for mitigation measures such as vaccines, antivirals, and travel restrictions when modeling the spread of infectious disease
— Accounts for temporal aspects of pandemics, including multiple years of duration and multiple waves of infection
— Externally peer-reviewed by leading experts in epidemiology, infectious disease modeling, and disease economics

AIR
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