2012 SCOR Pandemic Risk Conference Highlights
Pandemic risk is one of the most important tail risks for life (re)insurers and to a lesser degree, for non-life (re)insurers. Estimated losses from a 1-in-200 year pandemic event could be equal to or even greater than major property and casualty events such as a major earthquake or major tropical storm.

Being one of the global leaders in life reinsurance, SCOR has a vested interest in the management of biometric risk. As part of its commitment to providing leadership in the understanding and management of pandemic risk, and in an effort to promote knowledge exchange in this field, SCOR hosted a two-day Pandemic Risk Conference in Paris in July 2012. Experts from a wide variety of fields from industry and academia presented recent studies and perspectives on pandemics.
The following distinguished speakers shared their perspectives at the conference:

- Dr. Vittoria Colizza, INSERM & Université Pierre et Marie Curie, France
- Prof. Dr. Martin Eichner, Epimos GmbH & Co. KG, Germany
- Dr. Jeanne M. Fair, Los Alamos National Laboratory, United States
- Dr. Pierre-Yves Geoffard, Paris School of Economics, France
- Dr. Jean-François Guégan, Institut de recherche pour le développement (IRD), France
- Dale Hagstrom, FSA, MAAA, Milliman, Inc., United States
- Dr. Deirdre Hollingsworth, Imperial College, Great Britain
- Dr. Brian Ivanovic, Swiss Re America Holding Company, United States
- Stephen Kramer, Swiss Re Services Ltd (London), Great Britain
- Dr. Seyed Moghadas, York University, Canada
- Dr. Alessandro Vespignani, College of Computer and Information Sciences & Bouvé College of Health Sciences, Northeastern University, United States

The emergence of a pandemic pathogen is affected by a number of biological factors, including the evolution of the pathogen, by more man-made factors such as surveillance, travel patterns, population density, containment and mitigation strategies, and by their interaction. The biological characteristics of the pathogen will influence the effectiveness of control strategies. Some novel epidemics are caused by transmission of a pathogen which is circulating in an animal population from its natural host to the human population. The zoonoses may not be transmissible from human to human initially, but if there are multiple episodes of cross-species transmission a strain may emerge which is transmissible amongst the human population. Once the pathogen is transmitted amongst the human population there are a number of characteristics which will determine whether it will become a severe global pandemic.

The basic reproductive number, $R_0$, is a measure of the mean number of new infections which a newly infected individual produces in a wholly susceptible population. It needs to be greater than one for an epidemic to take off. If it is close to one, then there may be clusters of cases in localized areas. These cases are more likely to be identified by routine surveillance if the cases are severe, giving opportunities for intervention and control planning. An example of this is influenza H5N1, in which clusters of severe cases were identified several years ago and so preparations are being made for a possible future pandemic. If cases are less severe, the transmission rate is high and transmission is rapid, then local, national or even international spread prior to global awareness becomes more likely. This was true of the influenza H1N1 pandemic in 2009. However, there are opportunities for containing or mitigating potential pandemics either at source or at an international level, although these will depend on the characteristics of the pathogen.
This paper highlights key messages from the conference and reviews research and modeling advances underway today that further our understanding of pandemic risk and how we can manage it.

- Emerging diseases and neglected tropical diseases are widespread, occurring most commonly in the poorest communities, causing adverse impact to human health and worker productivity. This results in a poverty cycle whereby the poorest people are unable to escape poverty.

- There are several approaches to modeling pandemic risk. The approach taken by any stakeholder should be appropriate to the intended use and the available resources. There is some agreement on the basic understanding of infectious diseases and how they spread. Scientists continue to share knowledge, even allowing public (free) online access to certain tools in order to foster understanding and encourage more research on the mitigation and possible eradication of infectious disease.

- Scenario analysis and sensitivity testing are useful tools in understanding the most relevant parameters for pandemics. This allows a modeler to use a model more efficiently by reducing the model size as needed, while focusing on the most relevant parameters for creating probability distributions and other numerical needs. In addition, they help various stakeholders understand the range of outcomes and design appropriate mitigating actions.

- Characteristics of a susceptible population may impact the spread and severity of a pandemic outbreak in that population. Underlying health condition and socioeconomic status may drive pandemic-relevant factors such as (1) access to or availability of high quality medical facilities and personnel; (2) ability to isolate persons, even temporarily, from exposure to the general population; and (3) individual ability to withstand or survive an infection. It is important for any stakeholder to be able to understand pandemics and their impact on various relevant groups. This ability will help in designing public health measures, risk mitigation programs and capital planning processes.

- Issuing mortality index-linked securities is one approach used by (re)insurers in the managing of pandemic risk. In order to succeed, it will require robust models that reflect the nature and magnitude of the risk appropriately.

- The governmental authorities’ goals in respect of pandemic prevention and containment can be diverse: reduce economic cost, prevent deaths at all cost, reduce the incidence of disease and therefore reduce hospital admissions. These can be quite conflicting objectives.

A wealth of research from various fields of expertise is available for companies to use in deepening their understanding of pandemics and ways in which they can manage risk exposure.

- Virologists and biologists continue to uncover the workings of viruses, bacteria and other pathogens that cause infectious diseases. Along with other medical professionals, they help design and develop interventions such as vaccines, antiviral and antibiotic medications.

- Epidemiologists study the speed and pattern of the spread of diseases including those caused by non-biological agents.

- Public health experts conduct research on public behavior and characteristics in order to design effective monitoring, intervention and mitigation tools.

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“One might hope that the changes in market interest spreads on mortality catastrophe bonds could be used to track perceptions of the risk of pandemic mortality. However, the variance in spreads on such bonds appears to be driven primarily by risks other than the pandemic mortality risk. The spread demanded on such bonds in the marketplace has been much larger than the pure mortality risk component for reasons suggested in the paper. The variation over time of the cat bond spreads demanded in the marketplace has been related much more to general credit market conditions than to emerging pandemic risks.

Mortality Catastrophe Bonds: What the Financial Markets Think of Pandemic Risk

Dale Hagstrom, Milliman
Security experts study how individuals or groups could spread disease with malicious intent and design various methods to thwart these attempts.

Mathematicians and statisticians use modeling tools to incorporate various research findings in order to produce models that aid in understanding the implications of pandemics across the spectrum from relatively mild to very severe.

The nature of pandemics today

Pandemics have been recorded throughout history with varying characteristics and patterns of spread and severity. Scientists have developed vaccines and other medications for a number of diseases that caused pandemics in the past, reducing the mortality impact of those diseases.

For influenza, the battle is not over, as for the time being, the versatility of the influenza virus presents a constant challenge as new strains of the influenza virus continue to emerge. In addition, there is the more abstract threat from diseases yet unknown, often referred to as emerging diseases.

The following are examples of emerging and re-emerging infectious diseases as provided by the National Institute for Allergy and Infectious Diseases (NIAID), an agency of the National Institutes of Health (NIH) in the US.

Cyclosporiasis
E. coli 0157:H7
Hantavirus pulmonary syndrome
Dengue hemorrhagic fever
Vancomycin-resistant Staphylococcus aureus
v-CJD
Lyme disease
West Nile virus
Hepatitis C
Lassa fever
E. coli 0157:H7
Multidrug-resistant tuberculosis
Vancomycin-resistant Staphylococcus aureus
H5N1: avian influenza
Diphtheria
Typhoid fever
Drug-resistant malaria
Drug-resistant tuberculosis
Hepatitis B
Multidrug-resistant tuberculosis
HIV
Plague
Marburg virus
Nipah virus
Cryptosporidiosis
Typhoid fever
Drug-resistant tuberculosis
Hepatitis C
Multidrug-resistant tuberculosis
Drug-resistant tuberculosis

Figure 1: Global emerging and re-emerging infectious diseases

Source: http://www.niaid.nih.gov/about/whoWeAre/planningPriorities/strategicplan/Pages/ermerge.aspx
In recent decades, most pandemic threats resulted from influenza or influenza-related outbreaks originating from East Asia. Population density as well as climatic and economic conditions likely contributed to this phenomenon.

While influenza has been the source of most of the pandemics observed in more recent history, and therefore has received the most attention, other emerging infectious diseases have also caused pandemic mortality. Historically, the frequency of non-influenza pandemics has been lower but the diseases tended to be more severe. Emerging infectious diseases and neglected tropical diseases are prevalent in many tropical regions and in areas with extreme poverty. In addition, the prevalence of disease results in conditions that contribute to a continuous cycle of poverty. In other words, the speed and success of pharmaceutical development and production are difficult to predict.

A pandemic would affect the world differently today than in the past. Over the past 100 years, global travel has become much more accessible, faster and affordable, allowing infectious disease to spread more rapidly often before any symptoms of infection have occurred. The emergence of drug-resistant strains of bacteria has added to the potential increase in mortality due to a pandemic.

On the other hand, other developments are positive: modern communication tools such as radio, television, internet and mobile telephones accelerate the sharing of information, aid in better surveillance, and result in earlier and speedier deployment of public health measures including quarantines and vaccine production/distribution. Improvements in virology have led to better detection of viruses and the subsequent vaccine development. Vaccines and antibiotics were not available during the 1918 pandemic; these, combined with antivirals and other medications, serve to reduce the incidence and severity of an infection, and have helped reduce mortality in a pandemic.

The impact of these developments may vary across different countries or among different ages and socioeconomic classes. For example, travel within Western Europe easily crosses country boundaries, increasing the potential for rapid spread of a pandemic in that region. However, these countries are considered to have some of the best health care facilities in the world, and are considered to be among the most prepared in the event of a pandemic. These situations are not met, or are highly deficient, in many countries of the South and especially in sub-saharan African countries. New scientific and global health challenges, and funding supports should then focus on this part of the world where risk of new epidemics is huge. Figure 2 below illustrates the ability of various countries to contain an influenza pandemic.

**Figure 2: 2012 Global capacity to contain pandemic influenza risks**

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<th>Rank</th>
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<tr>
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<td>2</td>
<td>Guinea-Bissau</td>
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While at first thought (re)insurers might focus on pandemics transmitted from human to human, there are other potential causes of fatal diseases. These include vector-borne or rodent-borne diseases that are caused by microbes transmitted by insects, arachnids or rodents to humans. Others are transmitted by contaminated water, food or air. While large numbers of people could be exposed in any such event, these outbreaks tend to be more local. However, they still have the potential to cause increased mortality and should not be ignored.

Characteristics of pandemics

Two drivers used to describe the impact of a pathogen on a population are incidence and prevalence. Prevalence measures the presence of a pathogen within the population, roughly equivalent to the proportion of infected individuals at a particular point in time. Incidence is the measure of the rate at which new infections occur.

One widely used measure of transmissibility is the Basic Reproduction Number ($R_0$). It is the mean number of secondary infections caused by a primary infection in a totally susceptible population without intervention. This parameter varies over time. When $R_0>1$, then the infection is highly likely to spread if there is no intervention. When $R_0<1$, the infection will phase out and would not spread into a pandemic. Travel, human interaction and the time span of infectiousness will impact $R_0$.

Over the course of an outbreak, the rate of subsequent infections may be altered. The Effective Reproduction Rate, $R_e$, is the number of new infections caused by each new case occurring at time $t$. Over the lifetime of an outbreak, as the infection makes its way through the population, $R_e$ is expected to decline to the point where the outbreak is considered to be over. If a disease continues to spread at a stable level over a period of several years, it is considered endemic to that population. While it may still represent a public health threat, it has no longer the same dynamics as a pandemic, but is rather an ongoing public health concern.

The identification of the disease at a sufficiently early stage is key to implementing containment measures that could reduce or prevent the spread of a pandemic. The likelihood of detection is higher when symptoms are more severe and/or manifest early in the stage of a disease.
A rise in reported influenza-like symptoms generally raises some flags. In the case of HIV/AIDS, symptoms did not appear for many years, allowing the virus to spread undetected. Once symptoms appeared, they were very serious and often fatal. This long latency in symptoms made it difficult for scientists to identify and isolate the virus and understand its emergence. Severity of an infection is measured by the Case Fatality Ratio (CFR), the proportion of infections that result in death. There are several problems associated with determining CFR, among them:

- Reporting delays for both infections and deaths; and
- Misreporting or underreporting of the cause of infection and the cause of death.

A more severe case tends to get reported when it results in death. However, in cases where the disease is new but has similar symptoms to an existing one, the cause of death may be misreported. On the other hand, a case that does not result in death or does not initiate professional medical care may remain under the radar and may not get reported as an infection, a critical issue in analyzing the severity of diseases. This often distorts the CFR.

Containment is the elimination of the virus or pathogen before the source can become widespread. Some options for containment include:

- Treatment of infected individuals;
- Prophylaxis of household members, or of schools or workplaces of those infected;
- Blanket prophylaxis of affected areas;
- Closure of schools/workplaces; and
- Reduction in travel in and out of affected zones.

Treatment and prophylaxis would include antiviral and antibiotic medication and vaccines for non-infected individuals. The effectiveness of containment measures depends on various factors, including:

- Effectiveness of surveillance mechanisms and pathogen characteristics that impact surveillance;
- Infectiousness in the pre-symptomatic stage of a disease;
- Transmissibility, or $R_0$; and
- Ease of travel to or from the physical location site of the initial infection.

The investigation of deaths due to 2009 pandemic influenza included an assessment of the prior health status of victims. In the United States, over 70% of individuals dying of pandemic influenza between April and July of 2009 had a pre-existing medical condition, suggesting that chronic prevalent disease was a risk factor for adverse pandemic influenza outcomes. Investigations of several other pandemic influenza outbreaks have also suggested that the probability of death could be influenced by underlying health status. Individuals applying for life insurance are underwritten; a process that often includes a screening for diseases of mortality significance. As a result, the prevalence of disease in underwritten populations can be lower than the prevalence of disease in the general population.

Through actuarial studies this “selection effect” has been noted to have a favorable and persistent impact on mortality. Based on the findings of epidemiologic investigations linking chronic disease to adverse influenza outcomes and the lower prevalence of disease in underwritten insured policyholder populations it could be expected that the mortality experience of insured groups during pandemics could be more favorable than the experience observed in the general population.

This conference session will therefore explore any differentials in pandemic influenza mortality observed between insured and general population groups. The discussion include a review of historic literature on this subject and the results of an actuarial analysis of life insured data that detailed the mortality experience of US insured populations during influenza pandemics of the 20th century. Risk selection practices and the magnitude of the selection effect have differed from country to country over time so the pandemic mortality differentials observed in the United States between insured and population groups should be similarly investigated in other regions.
New advances in science and medicine help us gain ground against certain infectious diseases, yet new infections continue to emerge that spread rapidly into the population and may reach pandemic proportions causing significant human and economic costs. The global scientific and public health communities face a perpetual challenge against the capacity of new pathogens to lead to emerging epidemics, potentially greatly magnifying the global burden on the population.

Computational models can help in confronting this reality by offering new tools as important as medical, clinical, genetic or molecular diagnosis tools. Massive datasets describing human activities become increasingly available, thanks to pervasive new technologies leaving behind digital traces of individual behaviors. Increasingly powerful CPU capabilities allow us to store and rationalize these data, and solve sophisticated intensive algorithms to describe complex spreading processes.

The Information Communication Technologies and “Big Data” revolution have recently led to the development of realistic computational models for the simulation of infectious disease spread, providing a synthetic framework to conduct experiments not feasible in the real world. The possibility to integrate data at different levels allows the simulation of a variety of intervention strategies in response to a pandemic, to study their efficacy and also the potential systemic risk resulting from the interlinkages and interdependencies among the various facets of reality.

By introducing a large-scale data-driven computational model at the global level, I will present travel-related and pharmaceutical response strategies against a pandemic, discussing feasibility, availability, sustainability and management issues, and the resulting associated risks.

In some cases, severity of an illness may also impact containment. If symptoms are severe enough that infected individuals are forced to stay home or require hospital admission, then the rest of the community has less exposure to the infection.

In 2003, the SARS outbreak was rapidly brought under control. A study of the first ten weeks of the 2003 outbreak found that after the initial outbreaks, which were aggravated by hospital transmissions, transmission rates fell primarily due to reduction in population contact rates, improved hospital infection control and faster hospitalization admission of symptomatic cases. These interventions were effective due to certain characteristics of the SARS virus, particularly transmissibility and the infectiousness in the pre-symptomatic stage. The same approaches may not necessarily be as effective for diseases with different profiles.\(^2\),\(^3\).

Numerous studies have focused on the effects of an outbreak on subsets of the population. (Re)insurers are interested in age, time since policy issuance, health condition and socio-economic status and their impact on pandemic mortality since these factors may distinguish an insured block from the general population.

Mortality adjustments should be applied in the pandemic models of (re)insurers. Findings from research focused on the general population should be evaluated with care when applied to (re)insurers’ books of business.


During the 2009 H1N1 influenza pandemic, Canadian First (CN) populations experienced disproportionate rates of infection and hospitalization, often necessitating intensive care unit admission. We sought to evaluate the relative risks of infection and hospitalization among FN populations and compare their distributions with those estimated for non-FN populations in the province of Manitoba, Canada.

We extended the analysis to compare such risks between FN populations residing on-reserve and off-reserve. Incidence and hospitalization risks in FN populations were significantly higher than those in non-FN populations throughout the 2009 pandemic.

Major factors for the differential risk among these vulnerable communities include the availability and effectiveness of disease control programs, prevalence of low quality housing and predisposing health conditions, exposure to indoor air pollutants, lack of access to clean water and critical infrastructure, and differences in demographic characteristics, crowding, and mixing patterns.

Our findings support the need for the development of targeted prevention and control strategies specifically for vulnerable FN and remote communities.

Infectious diseases have been found to have varying impacts on different age groups. Typically, seasonal influenza causes the worst impact on the youngest and the oldest age groups. However, during the 1918 influenza pandemic, the younger working ages suffered severe mortality, just as much or even more than the youngest and oldest age groups. Figure 3 below shows the “U-” and “W-” shaped combined influenza and pneumonia (P&I) mortality, by age at death, per 100,000 persons in each age group for the USA, 1911–1918.

Figure 3: Age impact of seasonal vs. pandemic influenza

Despite the progress of modern medicine, humanity is far from being safe from being afflicted by devastating infectious diseases. Recent examples are given by several influenza pandemics (the worst of which was the Spanish flu which killed millions), by the ongoing AIDS pandemic and by the increasing prevalence of many drug-resistant bacteria and parasites. New infections like SARS spread over several continents and were on the verge of getting completely out of control.

Many others like Ebola, Marburg and Lassa fever could be contained locally. Discussions on bioterrorism have fuelled our imagination of what may happen if rogue states or groups got hold on the remaining reserves of smallpox virus or of genetically modified pathogens.

Although it cannot be predicted when and where new pandemics start, the course of such outbreaks and their effects on the population at large and its economy can be described by dynamic mathematical models and computer simulations; the most important parameters used in these models are summarized by the basic reproduction number and by the generation time. As practically all people may be non-immune against a new pandemic pathogen, the number of cases initially grows exponentially, such that local epidemics may develop at an astounding speed once an infection is introduced. The development, production and delivery of a new vaccine will most likely be too slow to arrive in time. Targeted measures like case isolation, contact tracing, social distancing and improved hygiene can reduce the rate of exponential growth. Novel strategies of identifying and removing super-spreaders may further slow the overall transmission rate. These interventions delay and lower the pandemic peak; i.e., fewer people will be sick at the same time. This does not only relieve hospitals, it also prevents private companies from collapse and from causing domino effects.

The age profile of an insured block is generally different from that of the general population and may also vary significantly among different markets and insurers. It is important for a (re)insurer to have the ability to properly reflect the pandemic impact by age or age group in order to determine the true impact on its block of business.

There continues to be many studies on the relationship of underlying health condition to the mortality risk in a pandemic. Scientists have studied the 1918 pandemic and the 2009 H1N1 pandemic and have found that certain pre-existing conditions sharply increased the risk of death from a severe infectious disease.

These conditions include: respiratory and cardiovascular diseases, liver diseases, diabetes, kidney diseases, neurological diseases, immune system deficiency and obesity. Other studies have analyzed the risk of infectious disease for people with different pre-existing conditions such as those listed. Underlying health condition for an insured group is driven to a large degree by the selection or underwriting process. In the United States, various preferred, standard and substandard risk classes are widely used to segment the applicants. Most of the conditions that increase the mortality risk during a pandemic are screened out by many preferred underwriting programs.

Thus a portfolio that is heavily weighted towards preferred risks is likely to have a different pandemic risk profile from the general population or even from other insured blocks with a less preferred risk profile.

The ability of a (re)insurer to understand its own book of business and how a pandemic might affect it would provide excellent tools for risk and return optimization as well as aid in the most efficient use of capital.

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A number of studies have focused on the relationship of socioeconomic status and pandemic morbidity and mortality. One can theorize that more affluent individuals, communities or countries would have overall better underlying health, or better access to medical care or the means to remove themselves at least temporarily from the general population to avoid exposure in a pandemic. Edgar Sydenstricker studied the relationship of socioeconomic status and the incidence and severity of influenza during the 1918 epidemic and found that the attack rate was higher for persons of lower economic status.

Prof. C. J. Murray et al used vital registration data to compare pandemic impact among several countries and found that per-head income explained a large fraction of the variation in excess mortality.

The chart below from a study of the US Centers for Disease Control demonstrates the relationship of education, an indicator of socioeconomic status, and mortality for different causes of death in a non-pandemic year. It shows that post-secondary education is related to a lower overall mortality due to all causes, and particularly communicable diseases.

**Figure 4: Age-adjusted death rates for selected causes for adults 25-64 by education level and gender, selected states, 1995**
The End of AIDS? Insights from Economic Epidemiology

Pierre-Yves Geoffard and Marlène Guillon, Paris School of Economics

In recent years, many clinical trials have provided strong evidence that some preventive actions were effective in reducing HIV transmission rates. Even in the absence of a vaccine, pre-exposure prophylaxis (PrEP), treatment as prevention (TasP), or circumcision have been identified as potential health interventions. A thought provoking paper (Granich et al., 2009) has proposed a mathematical model to identify conditions under which such interventions could lead to the eradication of AIDS. However, important implementation challenges remain:

1. Costs may be substantial, especially in low income countries;
2. Testing must be performed on a very large scale, and repeatedly;
3. Compliance rates must be high. Standard economic analysis may illustrate the first issue, and identify the most cost efficient strategies in various economic and epidemiological contexts.

Our analysis draws upon “economic epidemiology” models (Geoffard and Philipson, 1997). The analysis shows that behavioral responses to health policy interventions may increase the costs of such interventions and raise additional challenges.

Measuring pandemic risk

Various epidemiological models are used to understand the dynamics of the spread of a pandemic, and can help design support and intervention measures in the event of a pandemic. Pandemic models tend to be very complex with uncertainty in numerous inputs, assumptions and outputs. Some of the sources of uncertainty are:

Nature of pathogen
- Disease R0, CFR, duration of disease stages;
- Infectiousness prior to symptoms; and
- Number and relative infectiousness of asymptomatic individuals;

Pandemic preparedness and efficiency of medical response
- Vaccine and antiviral effectiveness;
- Initial stockpiles of antivirals and pre-pandemic vaccine;

- Quality and timeliness of surveillance; and
- Public health policy for capacity-limited healthcare operations.

Behavioral factors
- Fraction of people seeking healthcare;
- Absenteeism response to the disease; and
- Degree of social distancing;

By analyzing the range of potential outcomes and the use of sensitivity analysis, it may be possible to identify the most important factors in a pandemic outbreak. In general, the transmissions that occur prior to the manifestation of symptoms (R0), the length of each stage of a disease and the ability to identify symptoms tend to have the most impact. Containment measures such as quarantine, travel restrictions and social distancing have been found to have varying degrees of impact on the timing of the spread and on the severity of an outbreak.

Two characteristics of pandemic modeling need to be pointed out. First, pandemics are rare events, and thus intrinsically difficult to predict. Modeling will help us understand pandemics, but models have to be used wisely. Second, using solely historical pandemics to infer future pandemic risk is not sufficient since the frequency of pandemics is quite small (much less than earthquakes or tropical storms). Furthermore, significant advancements and developments in society and medicine have come about since these past events have occurred, which have to be taken into account when evaluating historic data.

Many epidemic models are based on an epidemiological approach called an SEIR model, for Susceptible, Exposed, Infected and Recovered. This approach describes the numbers of individuals in the population in susceptible, exposed, infected and recovered state at any point in time, with the dynamics defined by differential equations.

The parameters of these equations capture the characteristics of the pathogen (e.g. R0, CFR), assumptions about population density, travel, interaction within the population and medical and other interventions. Additional states can be included to the model (e.g., vaccinated or hospitalized), at the expense of steeply increasing complexity of the system of differential equations. Advantages of a deterministic epidemiologic approach such as the SEIR include:

- Ability to add different interventions and to compare the impact of various interventions;
- Insight provided on the dynamics of transmission; and
- Ability to start with a simple model with minimal parameters and no interventions and to add parameters to determine incremental impacts of various parameters.

Deterministic models do not readily provide insight into probabilities and uncertainty; however they can be used as a framework for combining with simulation approaches. Such combined models can provide insight into probabilities which in turn aid in understanding the behavior in the tail. Various stochastic versions of the SEIR-type models have been developed.

The computational cost is driven by the number of stochastic simulations performed, allowing stochastic models to more easily introduce complexity without exponentially increasing computing power demands. More complex patterns of social

interaction can be captured by network-based simulators that assign each individual to a node in a network graph and simulate social contacts and their consequences on the spread of the pandemic.

In place of adding complexity to models by increasing the number of parameters, sensitivity testing may be used to improve understanding of pandemic risk. This approach may be helpful in limiting the parameters to those that have the most impact and relevance to a (re)insurer. Some global scale complex models also provide scenario analysis capability 10.

Stochastic models are used in public health applications whereby various interventions are modeled and tested in order to design appropriate disaster-preparedness plans. Insurers and reinsurers make use of stochastic models in order to determine their capital requirements or define risk limits 9.

Modeling and measuring pandemic risk are necessary in order for a (re)insurer to be able to manage its risks and determine its capital needs. Approaches in managing pandemic risk include:

- Reducing the exposure by limiting the inforce below a given risk limit;
- Purchasing tail stop loss coverage;
- Selling mortality catastrophe bonds;
- Arranging mortality swaps;
- Selling the risk by utilizing non-recourse embedded value securitization;
- Diversifying the risk, for example, by writing longevity business; or
- A combination of any of the above.

Pandemic flu poses the risk of a mortality shock as it has through many centuries. The context in which pandemic flu emerges, spreads and is treated has however changed over time, making comparison of past pandemic meaningless unless these factors are dealt with. We have built a specialist epidemiological model to imitate the spread of a flu globally, taking into account factors such as the age structure of countries, travel, medical technology and preparedness, scientific understanding of viruses and other societal factors. Simulations are run using randomly generated variables which reflect the ability of a virus to spread (R0), the lethality of viruses, and other factors such as the age profile of susceptibility and whether antivirals are effective or not. Factors such as the age profile of lethality are subsequently generated, based on the two initial variables. Doing these simulations many times, using variables which reflect historical distributions, allows an understanding to emerge of the sort of risk posed by pandemics in various countries and to certain age groups. Together these allow an understanding of how exposure to certain countries and age groups could impact an insurer.
Measuring the Uncertainties of Pandemic Influenza

Jeanne M. Fair, Los Alamos National Laboratory, Biosecurity & Public Health

It has become critical to assess the potential range of consequences of a pandemic influenza outbreak given the uncertainty about its disease characteristics while investigating risks and mitigation strategies of vaccines, antivirals, and social distancing measures. We used a simulation model and rigorous experimental design with sensitivity analysis that incorporates uncertainty in the pathogen behavior and epidemic response to show the extreme variation in the consequences of a potential pandemic outbreak in the United States. Using sensitivity analysis we found the most important disease characteristics are the fraction of the transmission that occur prior to symptoms, the reproductive number, and the length of each disease stage. Using data from the historical pandemics and for potential viral evolution, we show that response planning may underestimate the pandemic consequences by a factor of two or more. Investigating the range of outcomes that incorporates the uncertainty in influenza evolution, disease characteristics, mitigation possibilities, sociological responses, and public health policies can lead to a better understanding of overall probabilities for the development of pandemic preparedness plans.

Summary

We will continue to see the emergence or re-emergence of pandemics. It is not a question of if, but of when. There is a wealth of general knowledge and awareness of this risk, and there are experts in various fields interested in furthering knowledge and designing management tools to address the impact of pandemics. SCOR believes that the pandemic risk must continue to be taken seriously by all stakeholders. A tight partnership among academia, government agencies, private industry and the medical community will be key in the understanding and the management of pandemic risk to temper the adverse impact on society and capital markets.

To view the Pandemic Conference presentations, please visit the SCOR Global Risk Centre at http://www.scor.com/en/sgrc/life/pandemic.html