Mathematical Modeling of Infectious Disease Transmission and Dynamics

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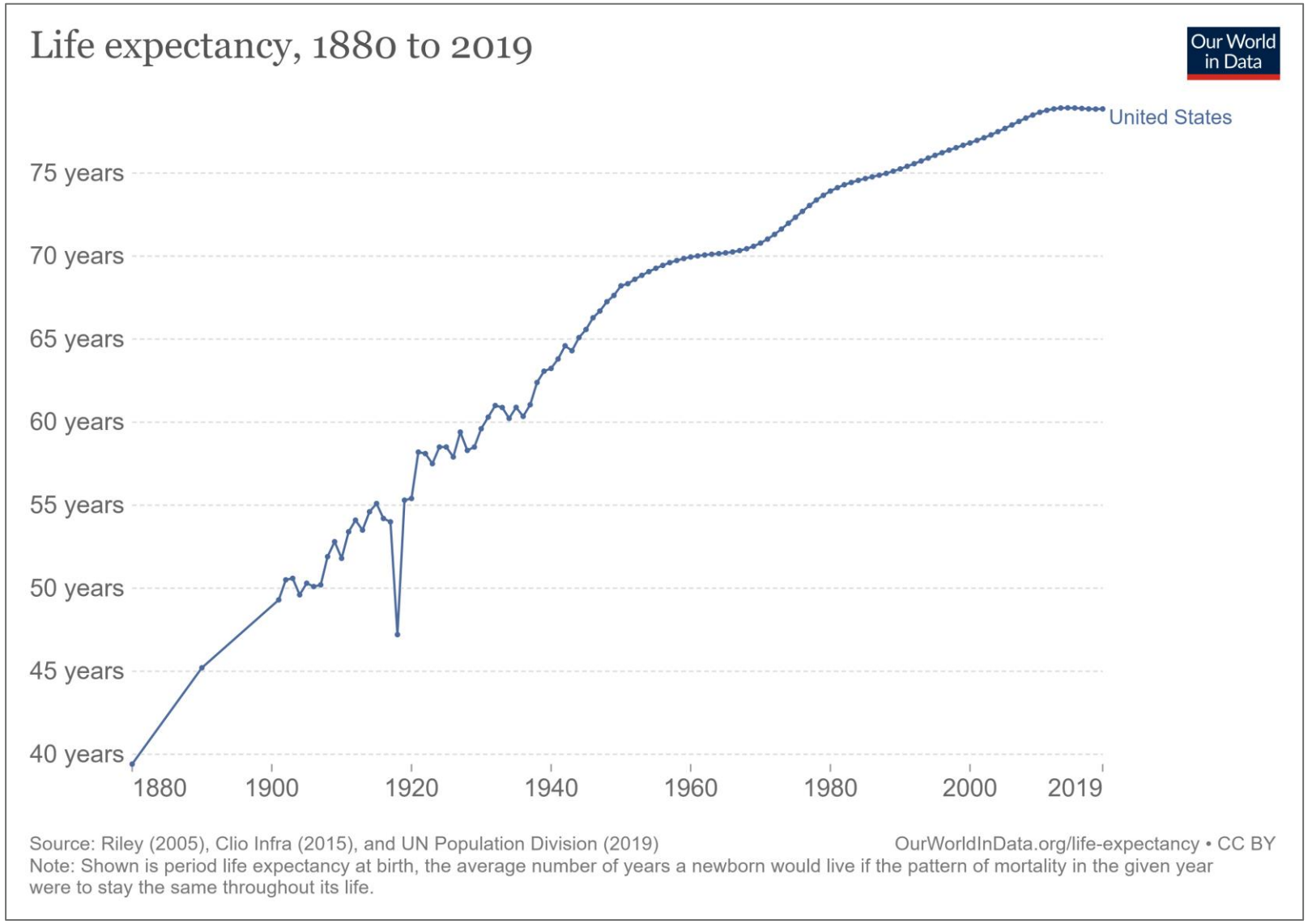
Life Expectancy Estimation at Birth Since 1840 – United States

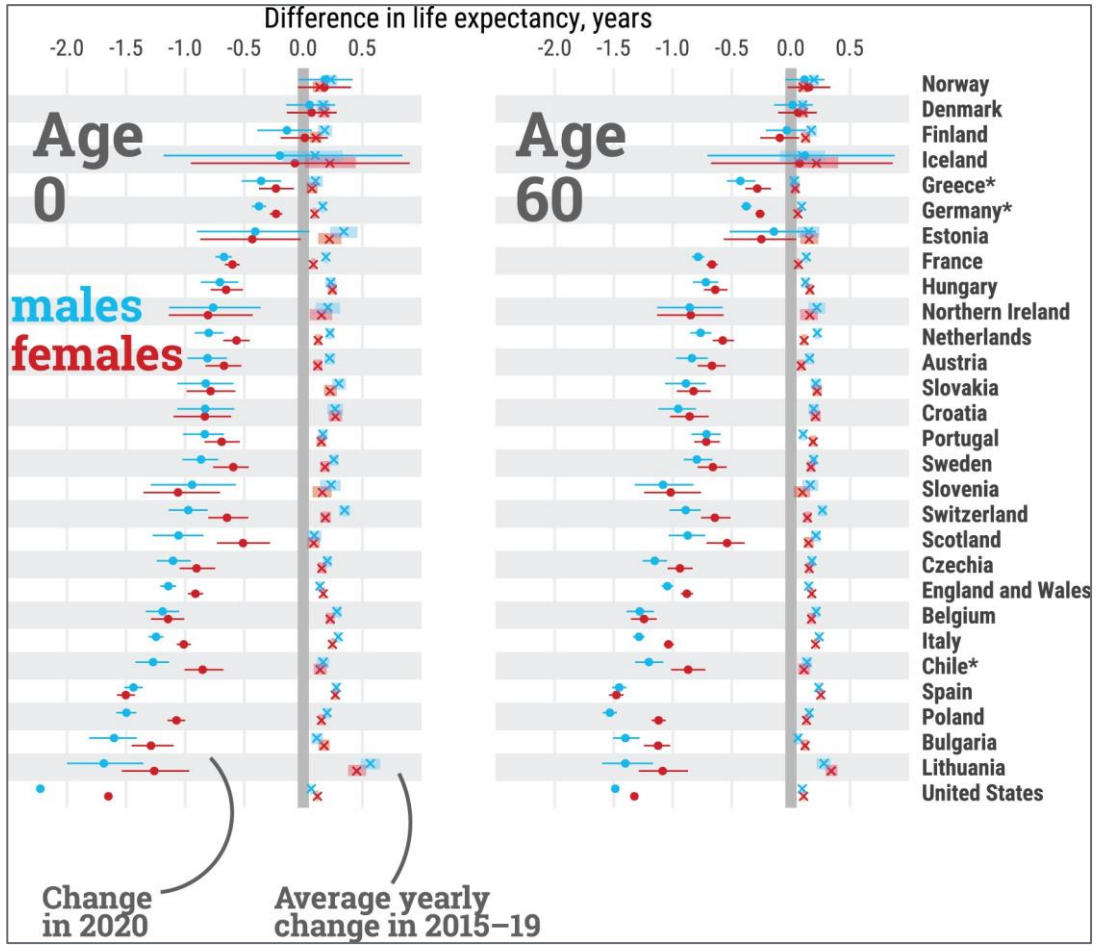


COVID-19 Impact on Life Expectancy

Males in the USA and Lithuania experienced the largest losses in life expectancy at birth during 2020 (2.2 and 1.7 years, respectively)

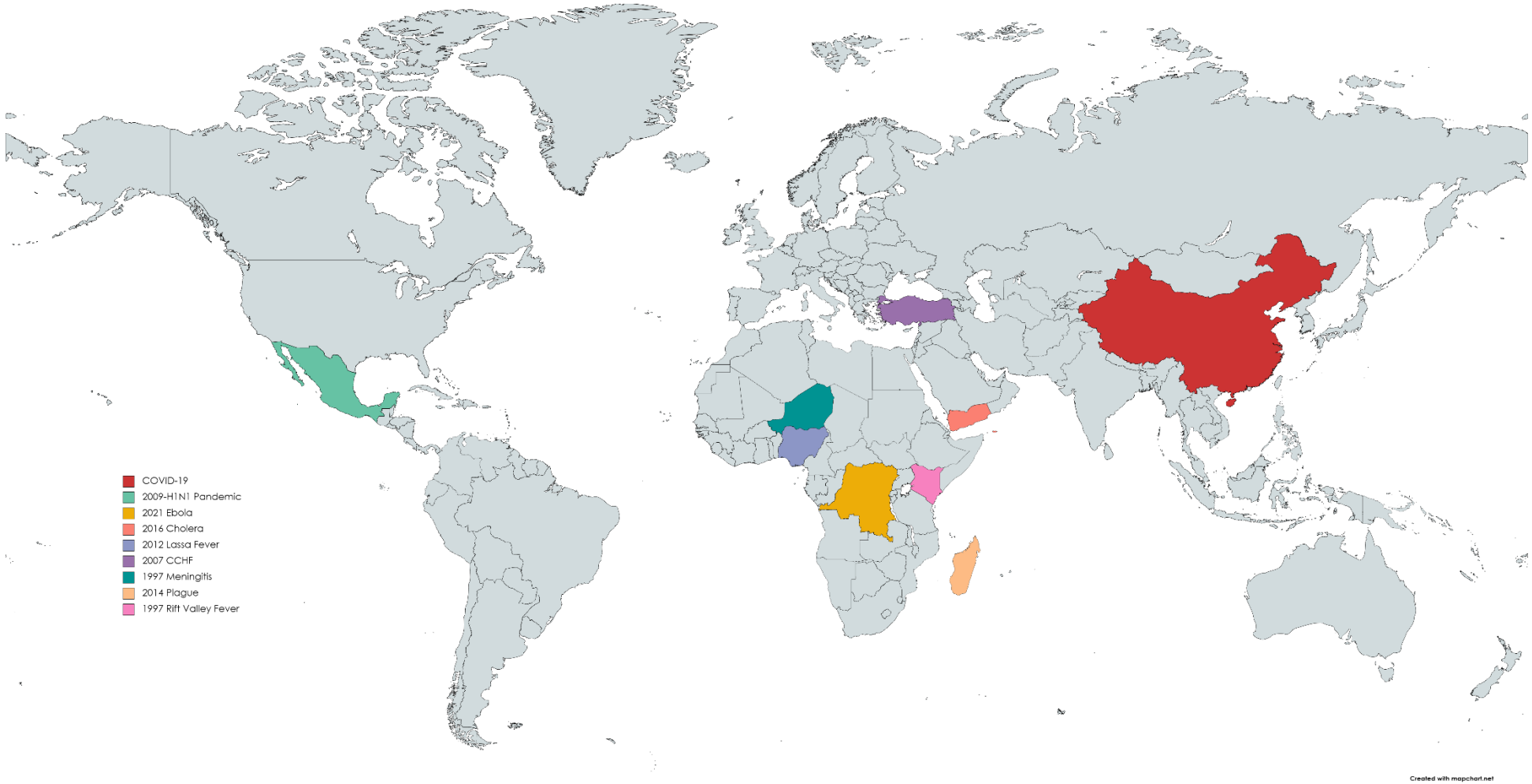
Reductions of more than an entire year in life expectancy were documented in 11 countries for males and 8 among females.

The COVID-19 pandemic triggered significant mortality increases in 2020 of a magnitude not witnessed since World War II in Western Europe or the breakup of the Soviet Union in Eastern Europe.

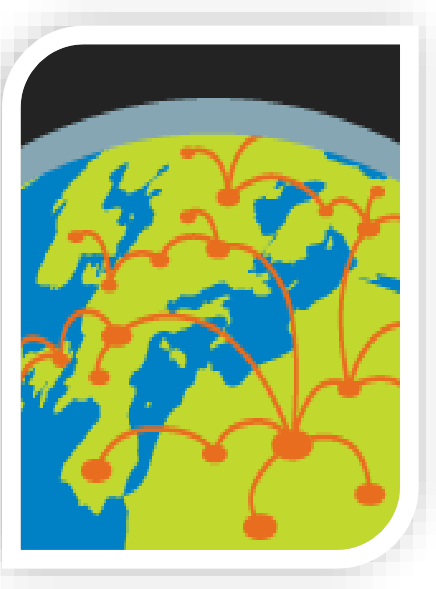


Source: Jose Manuel Aburto, et al. International Journal of Epidemiology, 2021, https://doi.org/10.1093/ije/dyab207

Start Location of the Selected Recent Pandemics



Outbreak Risk Factors Change Over Time

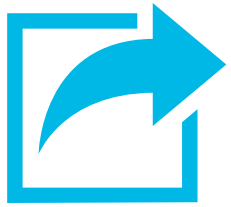


1. Biological Factors
   - Host immunity
   - Pathogen adaptation of transmissibility/virulence
2. Human Behavior
   - Political – prioritization, corruption
   - Social – contact networks
   - Economic – resources, international funding
3. Ecologic Factors
   - Climate change alters geographical range of animal reservoirs
   - Deforestation, urbanization, and land use impact connection between man and environment

Major Variables for Mathematical Model of Infectious Disease Transmission

Start location

The location of the first case, based on past outbreaks and exposure to zoonotic reservoirs

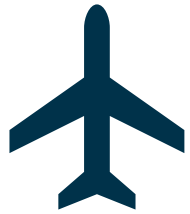


Transmission rate

Expected rate of new cases per case at time t=0. Modeled using a binomial distribution and varies based on seasonality and country latitude.

Case fatality rate

Provides the estimated rate of death per case. CFR is event- and country-specific (ex. industrialized vs. non industrialized)



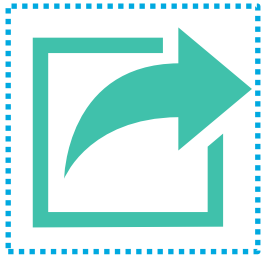
Travel patterns

Modeled using the travel patterns between cities. Verisk incorporates international air travel data, border crossing data (non-air), commuter flow data (where available), and gravity flow model (where commuter flow is not available)

Major Variables for Mathematical Model of Infectious Disease Transmission

Time until active containment

Represents the number of days it takes for active containment by national and international health organizations to take effect.



Transmission rate following active containment

Expected rate of new secondary cases per infectious person following active containment.

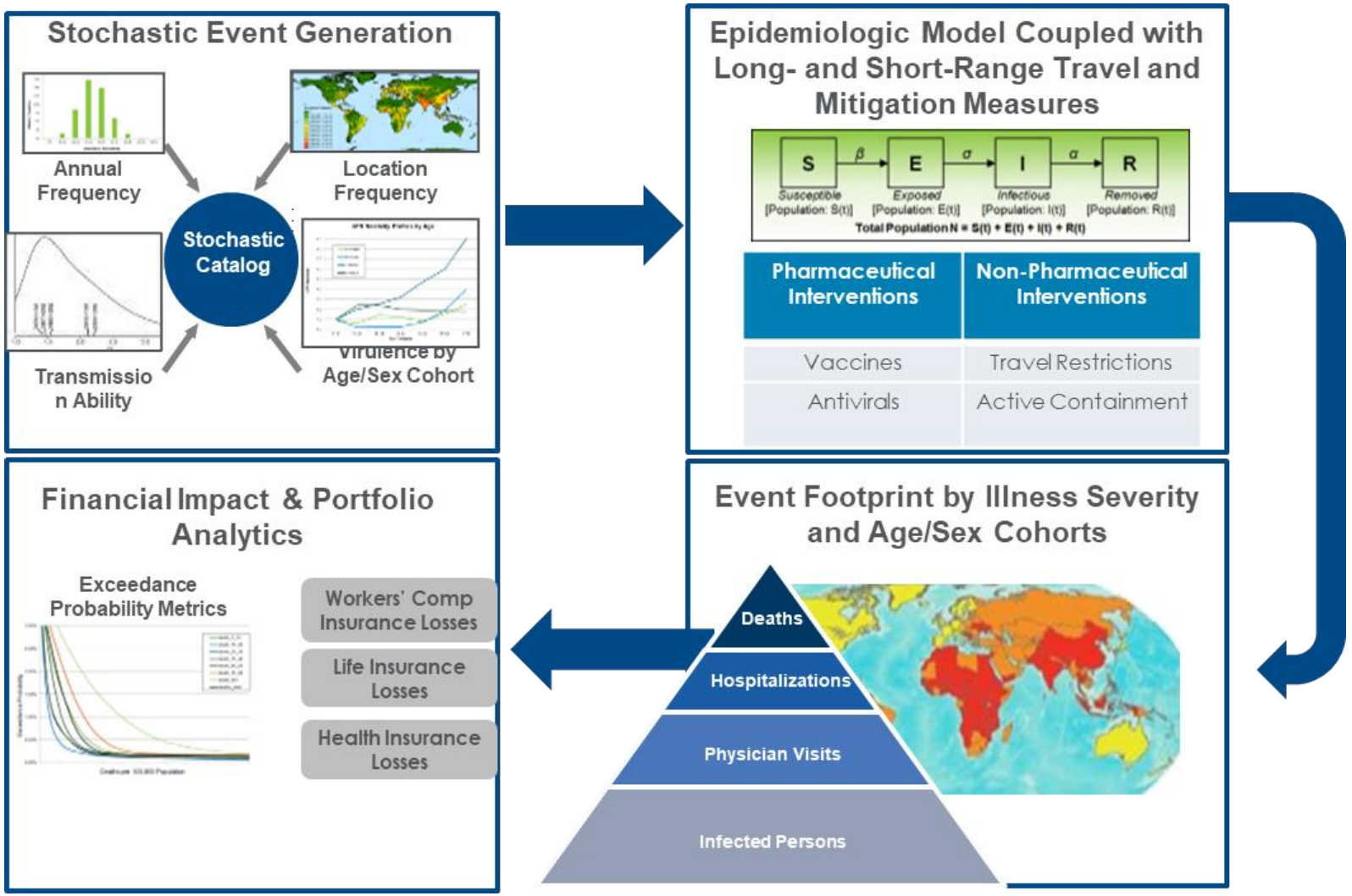
Vaccine production

Represents the number of days it takes for vaccine production to begin.

Country- specific variables

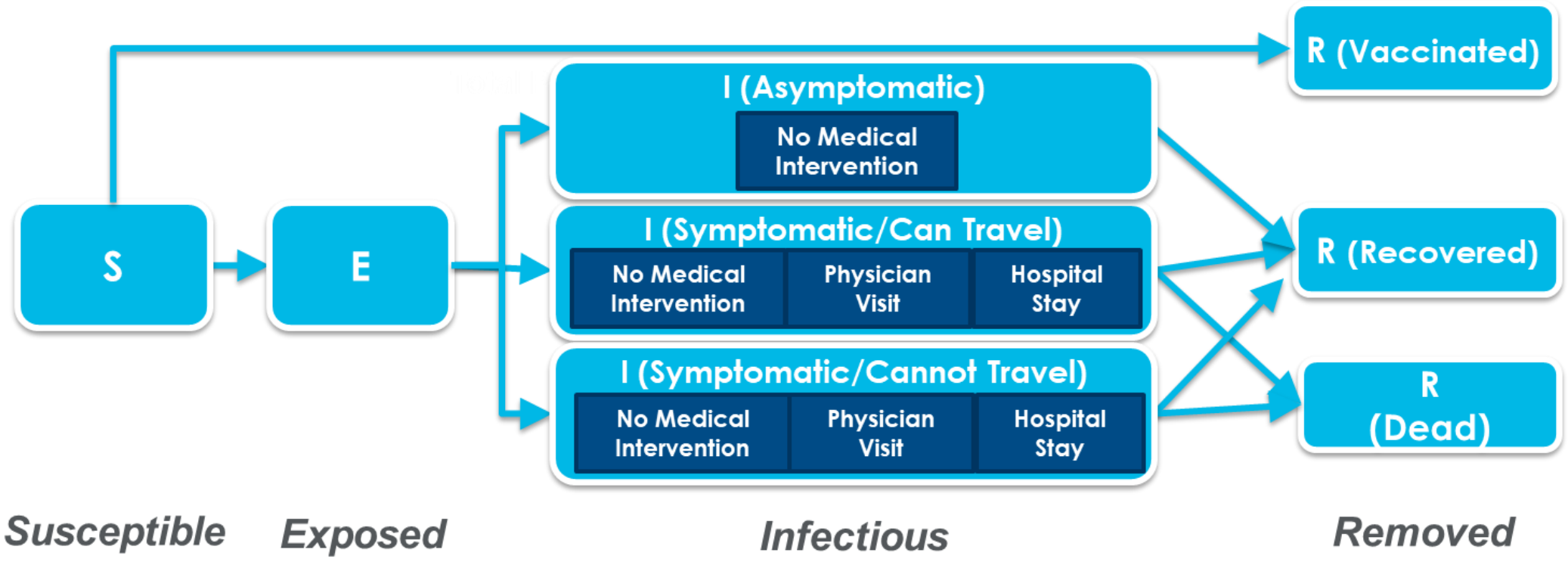
Economic development (ex. GDP per capita), health metrics (ex. hospital beds per capita), cultural practices, etc.

Probabilistic Pandemic Model Estimates Morbidity and Mortality Risk

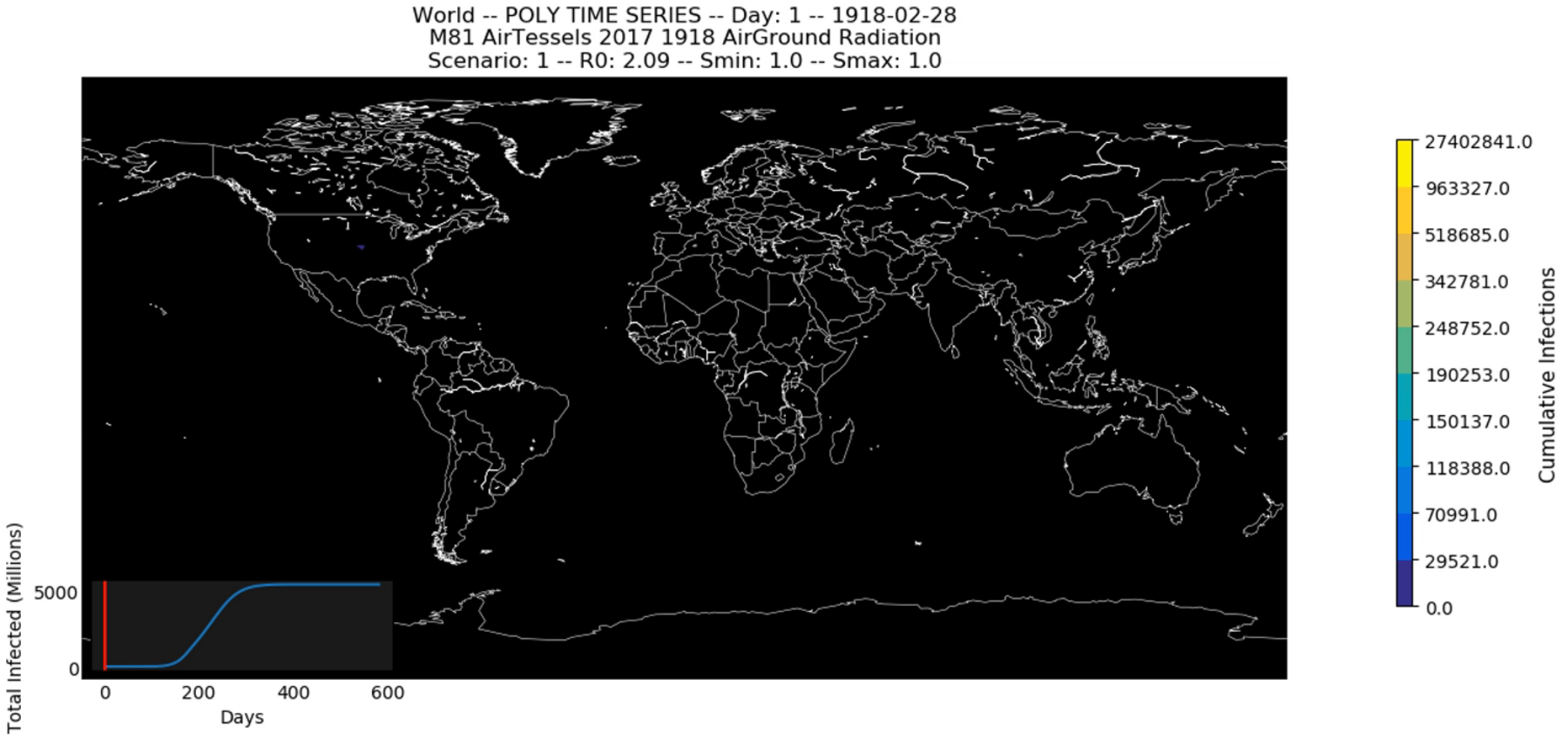


Epidemiologic Components Captured with Susceptible-Exposed-Infectious-Removed (SEIR) Model

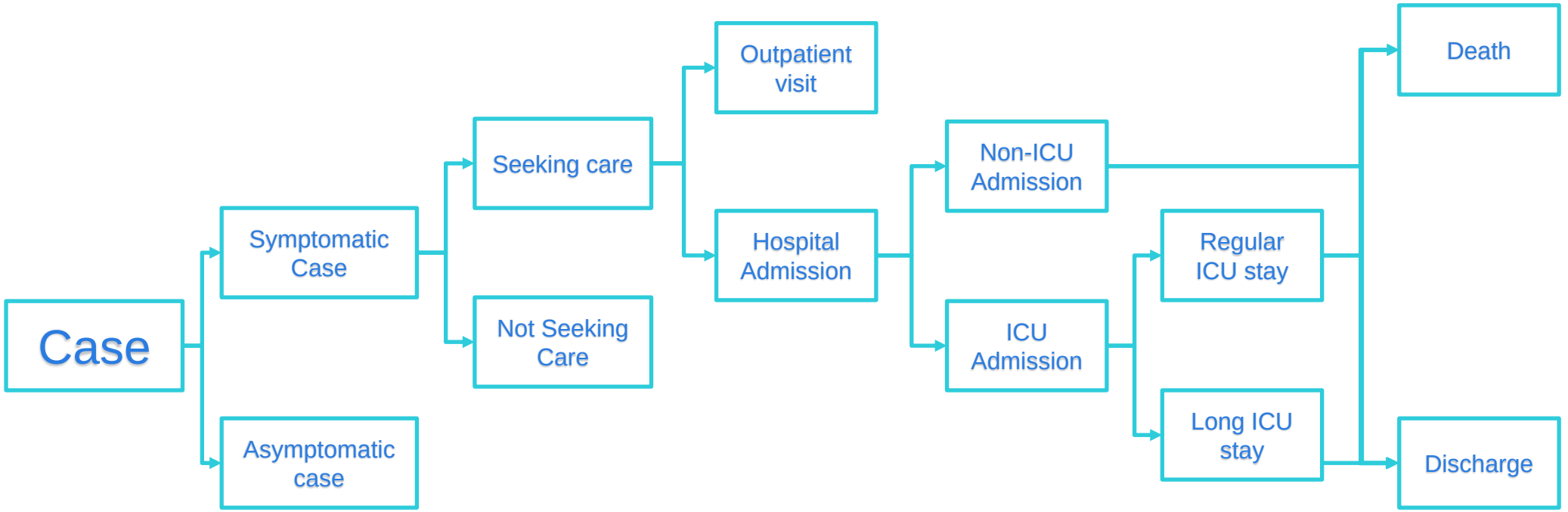
SEIR model operates at a daily time step with seven age bands and two gender groupings.



Using Mathematical Models to Simulate a Modern 1918 Flu Pandemic



Feasible Outcome for Infected Individuals



COVID-19 Pandemic

Verisk
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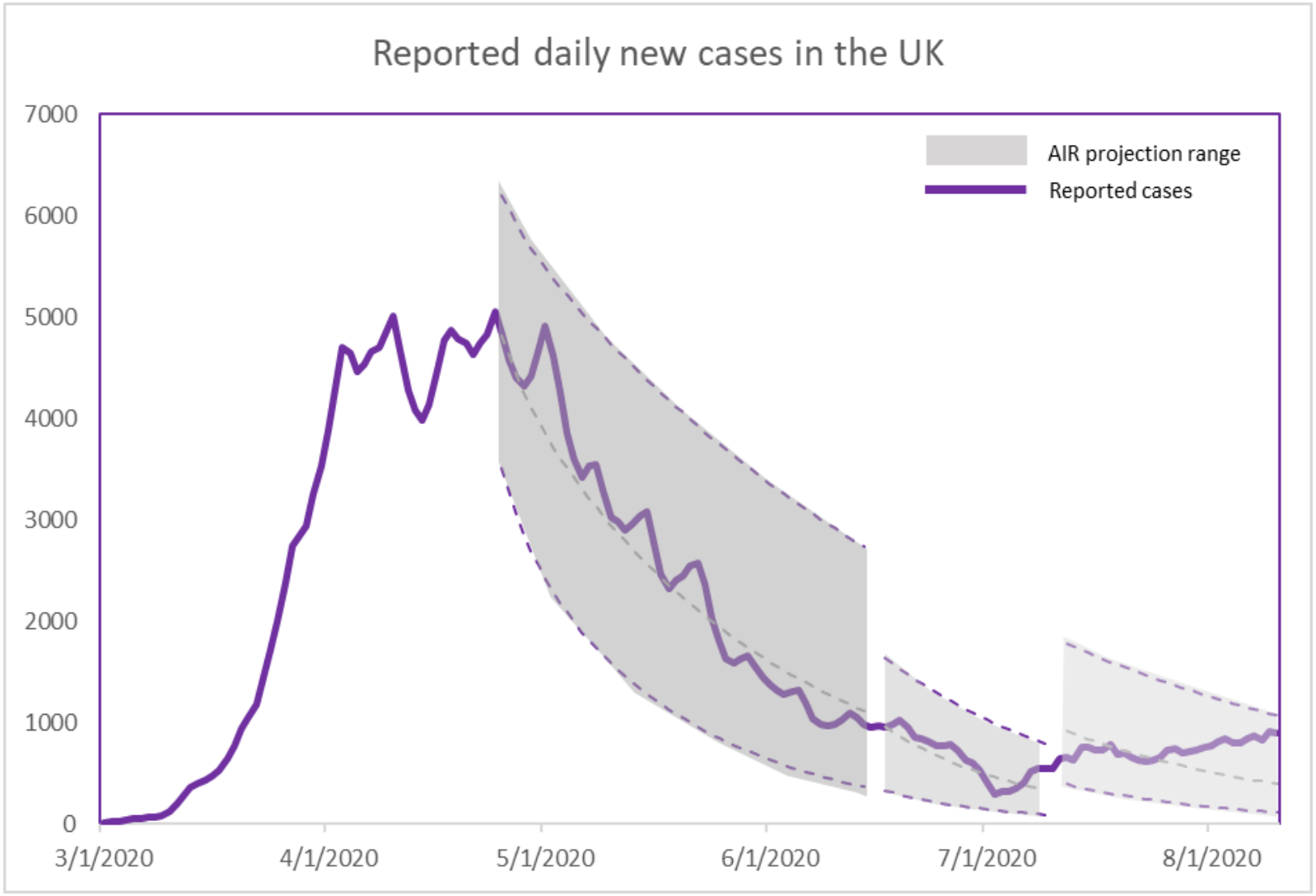
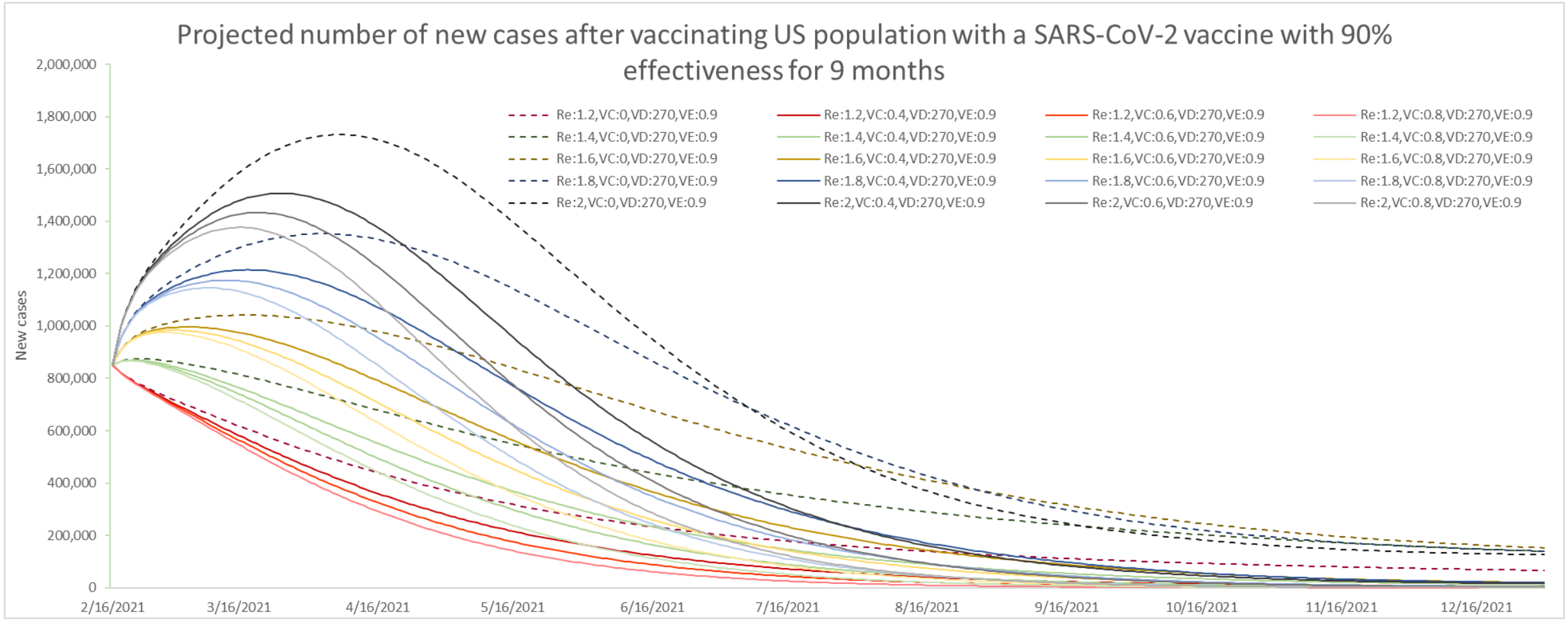
Short-Term Projection of Cases and Deaths



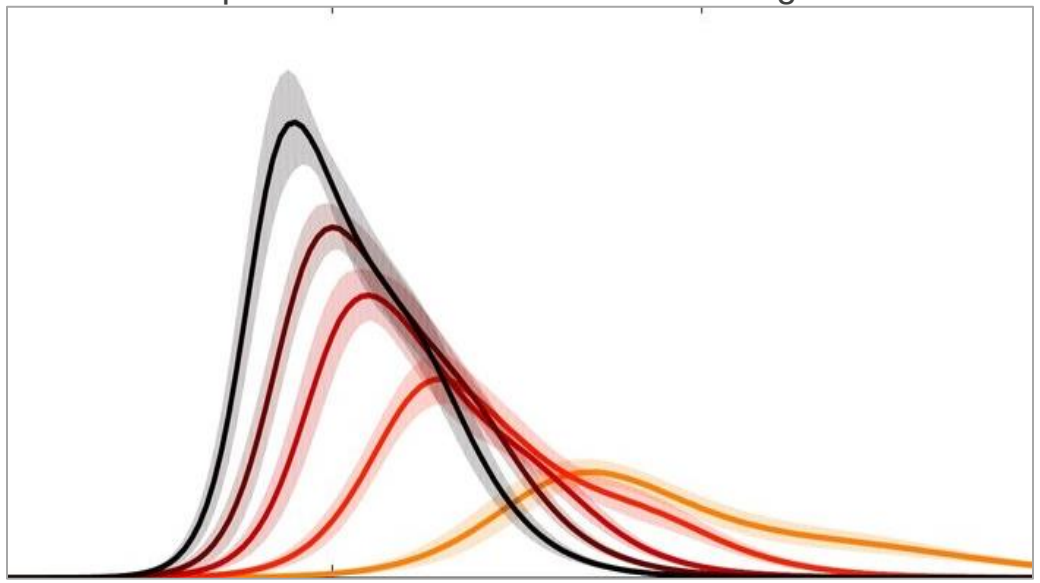
Medium-Term Projection of Mass Vaccination Impact



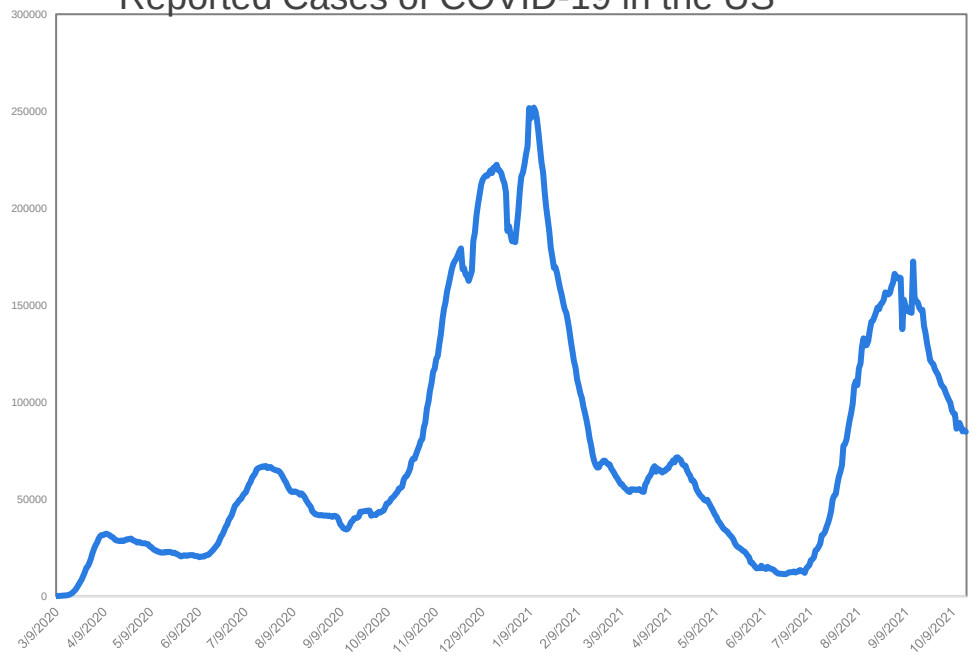
Uncertainty Associated with Human Behavior

- Human response to containment is not necessarily what we expect to observe in a short- and long-term.
- There is a need to better understand and model changes in human compliance to containment measures.

Modeled Impact of Interventions on Controlling Pandemics



Reported Cases of COVID-19 in the US



What Happens Next?

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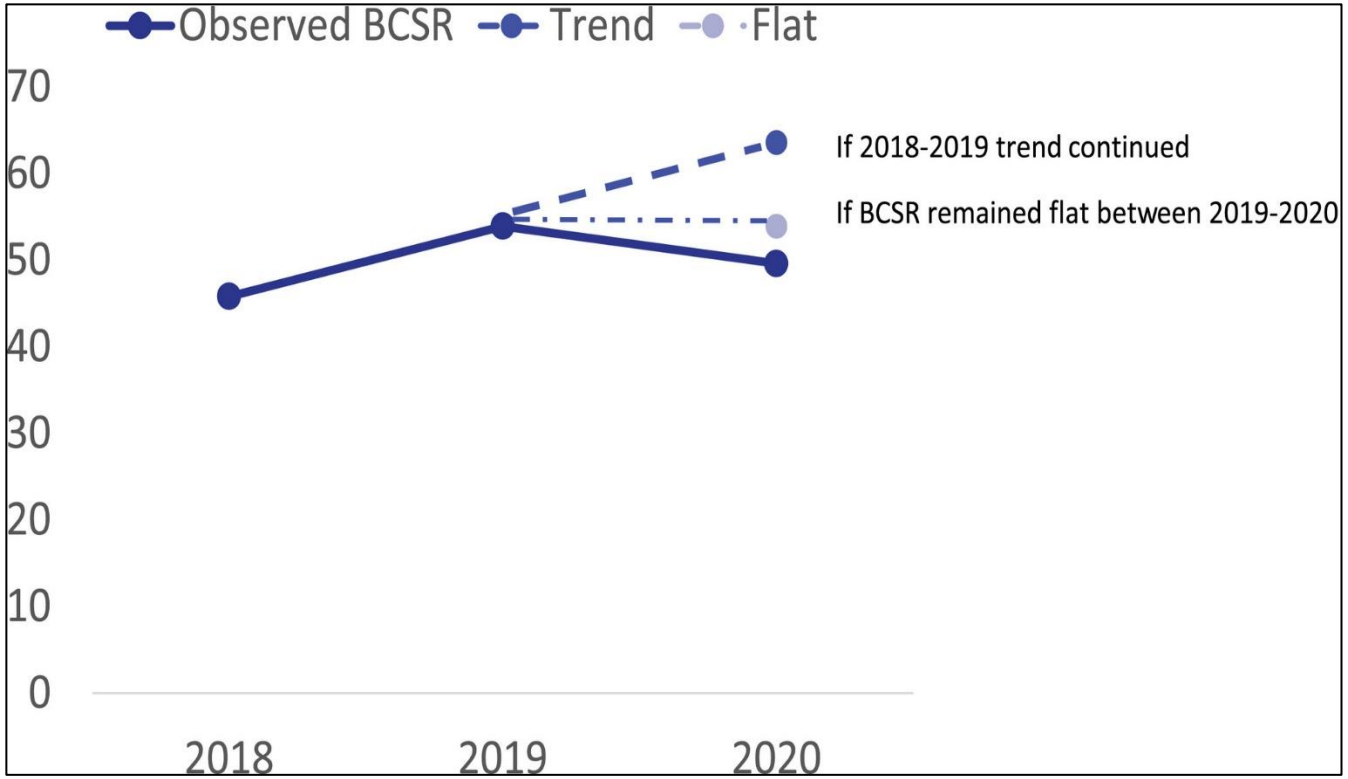
Indirect Impacts of Pandemics

Potential Mid- to Long-Term impacts of COVID-19 on Chronic Conditions

Chronic conditions, such as cancer, may experience a decline in the number of diagnoses.

As a result, we may observe an increase in the cancer diagnosis at later stages, which may lead to a decrease in the survival rate over the medium-term.



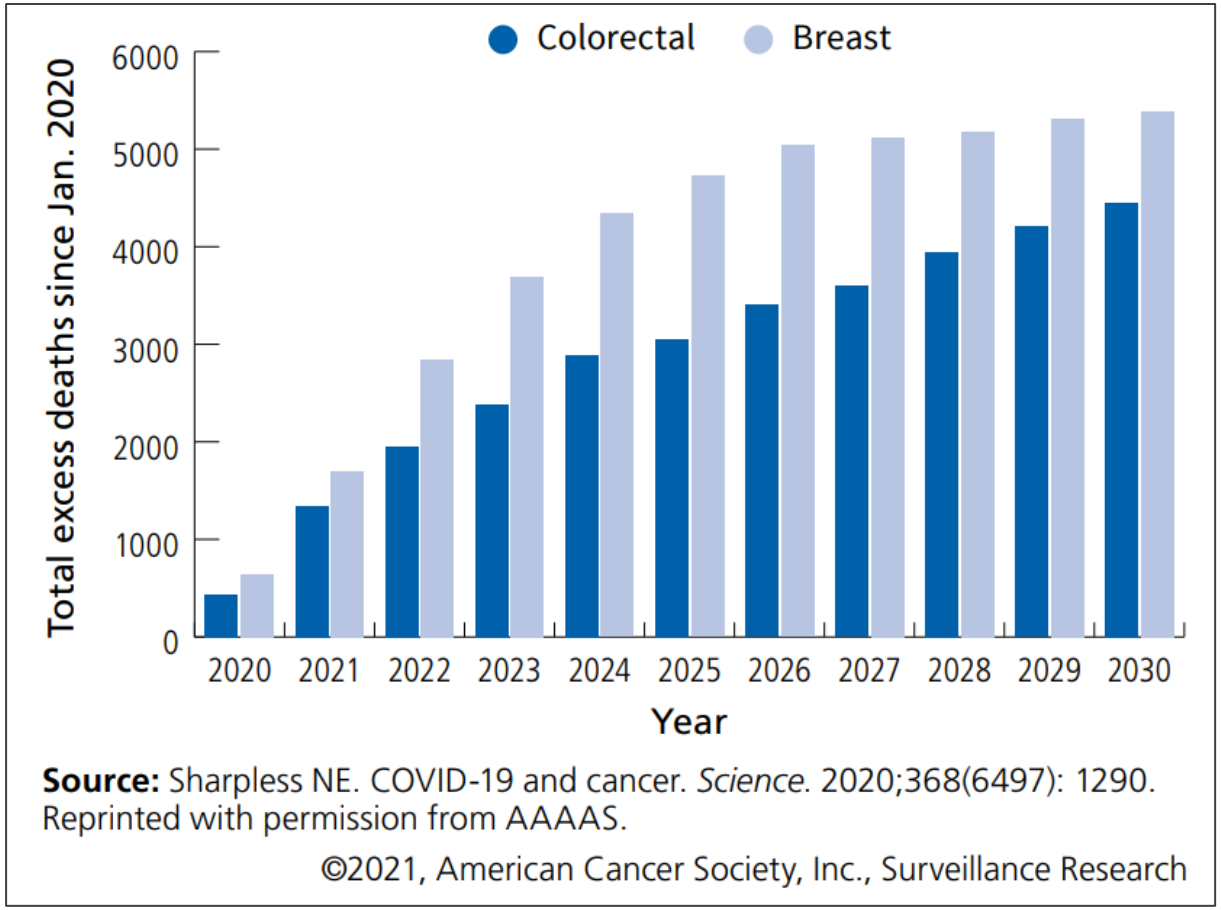
Observed breast cancer screening rate among 32 community health centers: 2018, 2019, and 2020. Source: Fedewa, Stacey A., Megan M. Cotter, Kristen A. Wehling, Karla Wysocki, Richard Killewald, and Laura Makaroff. "Changes in Breast Cancer Screening Rates among 32 Community Health Centers during the COVID-19 Pandemic." Cancer https://doi.org/10.1002/cncr.33859.

Short- and Medium-Term Impact of COVID-19 on Cancer Mortality

The National Cancer Institute estimated a 1% increase in deaths from breast and colorectal cancer over the next 10 years.

Partially due to:

- Reduced access to care
  - Fear of infection
  - Relocation of healthcare resources
  - Unemployment
- Delayed routine care
- Later-stage diagnosis
  - Lower probability of survival
- Delayed/Modified treatment
  - Postponed procedures, …



Source: Sharpless NE. COVID-19 and cancer. *Science*. 2020;368(6497): 1290. Reprinted with permission from AAAAS.

©2021, American Cancer Society, Inc., Surveillance Research

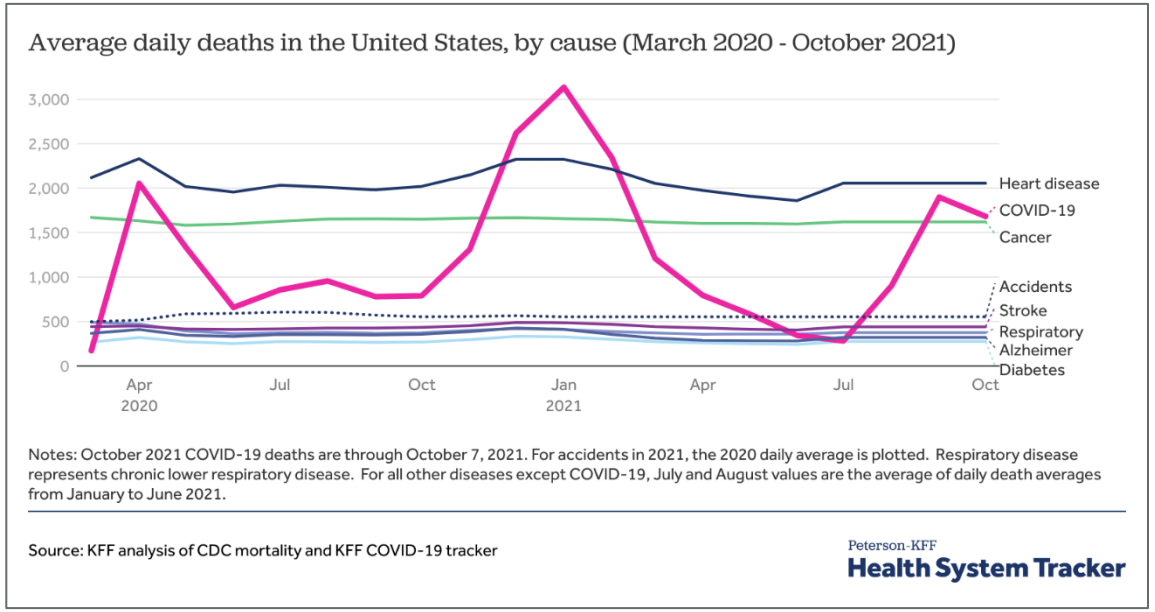
Impact of COVID-19 on Cardiovascular Diseases

According to the CDC and the American Heart Association, it is expected that heart disease remains the leading cause of death in the US, likely due to the long-term impact of the novel coronavirus.

The influence of COVID-19 will directly and indirectly impact rates of cardiovascular disease prevalence and deaths for years to come.

Adoption of unhealthy habits during pandemics may contribute to the expected trend:

- Unhealthy lifestyle behaviors
- Missed medical visits
- Fear of hospitals
- Heart-related risks for COVID-19 patients



COVID-19 Impact on Insurers

Customer-focused products

Dynamic Work Processes

Investment of Accelerated Underwriting

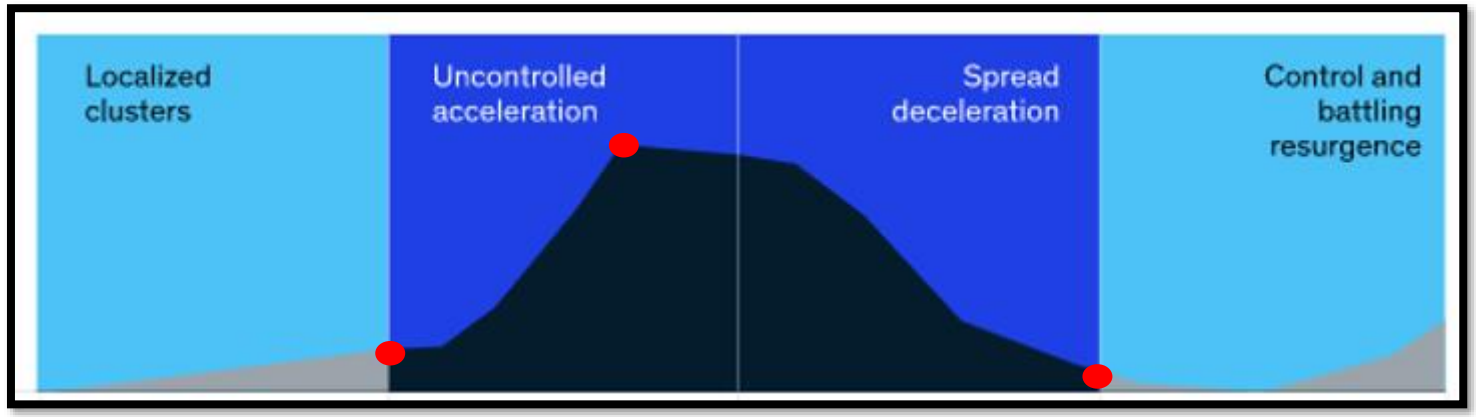
Location-base estimation of risk factors

Occupation-based estimation of risk factors

Enhancing Employees Skillsets

Investment on Complimentary Services

Pandemic Impact on Supply Chain



● Control Points

Pandemic Progression by Phase

Indicators:

- ❑ Transmission
- ❑ Magnitude
- ❑ Growth
- ❑ Human Response

Interventions:

- ❑ Physical distancing and quarantine
- ❑ Travel restrictions
- ❑ Testing and tracing
- ❑ Effective use of PPE
- ❑ Healthcare capacity

Impacts:

- ❑ BI
- ❑ CBI
- ❑ Economic Loss
- ❑ Financial Loss

Quantifying the level of COVID-19 community spread

Total new cases per 100,000 persons in the past 7 days

Percentage of positive tests in the past 7 days

ICU bed occupation by COVID-19 patients in the past 7 days

Percentage of Residents age 12+ that are fully vaccinated

Estimated transmission rate

Low	Moderate	Substantial	High

Quantifying the Community Spread of COVID-19 for Operational Purposes

Country_ID	Country_Name	Verisk_Site	WorkForce	Prob.Case.Full.WorkForce	Estimated_R	Prevelance.Per.100k	Pct.Tests.Positive	Pct.Fully.Vax	Overall	Overall_PreviousWeek
84	Germany	Munich, Germany	21	0.024	1.16	113.97	8.3	63.36	12	9
84	Germany	Markdorf, Germany	27	0.030	1.16	113.97	8.3	63.36	12	9
84	Germany	Frankfurt, Germany	8	0.009	1.16	113.97	8.3	63.36	12	9
84	Germany	Siegen, Germany	40	0.045	1.16	113.97	8.3	63.36	12	9
84	Germany	Hamburg, Germany	20	0.023	1.16	113.97	8.3	63.36	12	9
106	India	Hyderabad (Begumpet), India	102	0.008	0.97	7.68	1.2	31.00	8	8
106	India	Mumbai, India	83	0.006	0.97	7.68	1.2	31.00	8	8
106	India	Bangalore, India	319	0.024	0.97	7.68	1.2	31.00	8	8
106	India	Hyderabad (Kondapur), India	226	0.017	0.97	7.68	1.2	31.00	8	8
106	India	Gurugram, India	18	0.001	0.97	7.68	1.2	31.00	8	8
242	United Kingdom	Warwick, UK	16	0.075	1.06	485.82	5.2	65.78	10	10
242	United Kingdom	Glasgow, UK	12	0.057	1.06	485.82	5.2	65.78	10	10
242	United Kingdom	Cow Cross Office, London	53	0.227	1.06	485.82	5.2	65.78	10	10
242	United Kingdom	London, UK (Bishopsgate)	578	0.940	1.06	485.82	5.2	65.78	10	10
242	United Kingdom	Fleet, UK	29	0.132	1.06	485.82	5.2	65.78	10	10
242	United Kingdom	Roskill Office, London	20	0.093	1.06	485.82	5.2	65.78	10	10
242	United Kingdom	Esher, UK	20	0.093	1.06	485.82	5.2	65.78	10	10
242	United Kingdom	Norwich, UK	177	0.578	1.06	485.82	5.2	65.78	10	10
242	United Kingdom	Cambridge, UK	15	0.070	1.06	485.82	5.2	65.78	10	10
242	United Kingdom	Newcastle upon Tyne, UK	15	0.070	1.06	485.82	5.2	65.78	10	10
242	United Kingdom	Edinburgh, UK	432	0.878	1.06	485.82	5.2	65.78	10	10
242	United Kingdom	Bath, UK	40	0.177	1.06	485.82	5.2	65.78	10	10
242	United Kingdom	Sheffield, UK	6	0.029	1.06	485.82	5.2	65.78	10	10

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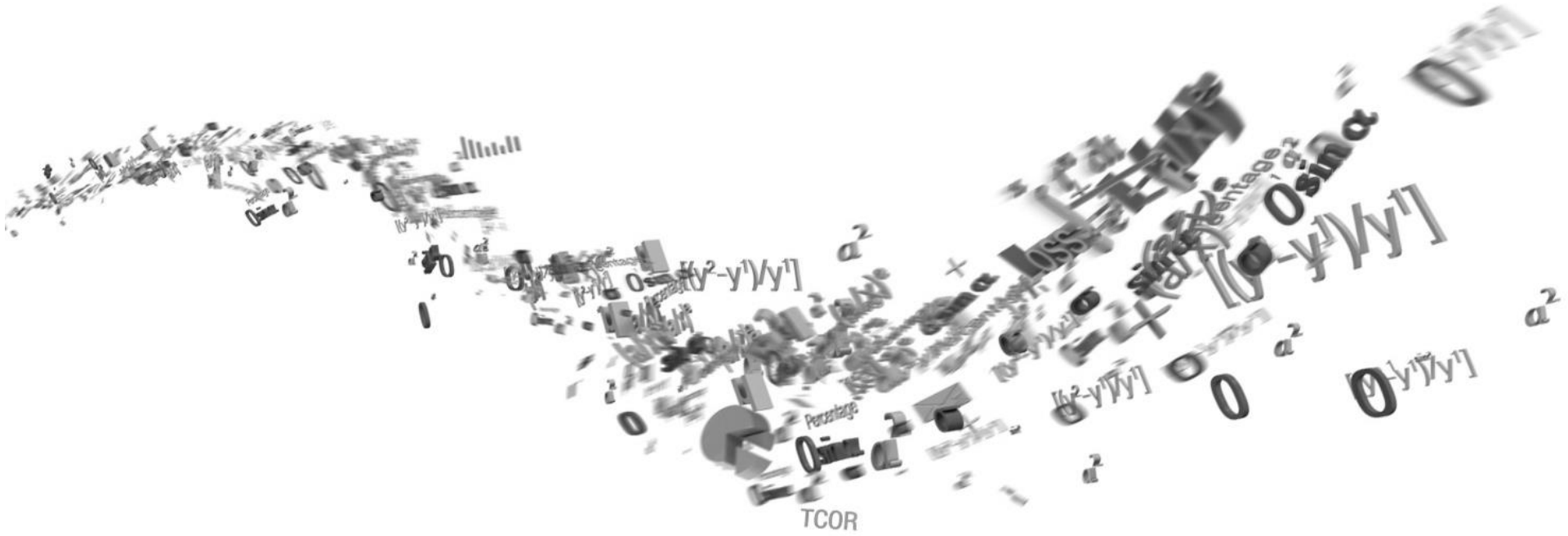

Pandemic Modeling

How Companies are using the models

Jim TeHennepe

Background on Pandemic Models

- Pandemic models have been around since 2014
- Will Covid 19 be the Hurricane Andrew and Northridge EQ for Pandemic Modeling?

How are Life Companies using the Pandemic Model?

- Developing a better understanding of exposure data
  - Breakouts of lives and TSI by age & gender bands
  - Group vs Individual Life
- Researching the peril / asking questions of themselves and the models
- Validating the PML & AAL results
  - Historical pandemic events such as Spanish Flu, SARS, etc.
  - Covid 19 “proxy”
  - Seeking to understand how pandemics start, progress
    - CFR by segment and by country
    - What are the drivers of loss?
    - Want to have informed answers / discussions
      - What is our Covid Loss?
      - What is our loss to other pandemics and how often should we expect them?
      - What is our risk tolerance?
      - Are we charging for the risk?

Other uses for Pandemic models

- Impact on other areas:
  - Travel Interruption & Event Cancelation
  - Workers Compensation
  - Contingent BI
  - Supply Chain, etc.
  - Upticks in other disease (e.g., cancer not caught as early, etc.)
  - Rating Agency Impact?

Contact Information

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