Award Winner

Catastrophe Modeling for Life and Health Insurance: How It Can Be Similar and Different to Property and Casualty Insurance

Rajeshwari VS, FIA

INTRODUCTION

In 2005 any single natural or manmade disaster causing losses of $5 million or more was termed a catastrophe by the insurance industry. By 2020 this number had been revised to $25 million to accommodate inflation and increasing residential and commercial development of disaster-prone areas. Not only are there more people and construction in harm's way now, but the number and severity of the incidents (floods, wildfires, and storms) is also increasing. Traditionally, catastrophe modeling used in property insurance refers to a probabilistic simulation-based approach to estimate losses from catastrophes—natural disasters such as earthquakes, hurricanes, wildfires, etc., and manmade acts of terrorism. Sophisticated catastrophe models have the ability to forecast hazards from weather, seismic activity, other geographic and atmospheric data, and generate more accurate risk scenarios. Along with properties—buildings and contents—there is also a human cost of disasters, with people living in these areas suffering injuries, losing lives and livelihoods. However, catastrophe modeling is still in experimental stages across the life and health insurance industry—even in developed insurance markets—due to inherent differences in the nature of damages, interactions of risks and, the greater complexity of modeling the impacts of a catastrophic event on mortality and morbidity compared to damage to buildings. The rest of this essay explores some of these challenges, including aspects of property catastrophe modeling that can be applied to and potentially form the basic elements of a framework to assess catastrophe risks for life and health insurance.

IS IT WORTHWHILE EXTRAPOLATING THE 4-BOX PROPERTY CATASTROPHE MODEL FOR LIFE AND HEALTH?

There are fundamental differences in catastrophe modeling for life and health insurance versus property beginning with the definition of a catastrophe. While its mostly natural perils and manmade acts such as terrorism that cause property damage, there could be a wider range of events that can have catastrophic consequences for life and health of a local population, causing death, injury, or illness to a large number of people. Most events can be classified into the following:

- Natural perils—earthquakes, hurricanes, tornadoes, floods, wildfires, etc.
- Manmade perils—terrorism (chemical, biological, nuclear, and other Weapons of Mass Destruction (WMD))
- Infectious diseases—epidemics/pandemics

- Mental health impacts—social isolation, anxiety/other mental health impacts from lockdowns, overuse of technology, etc.
- Climate change—more abnormal weather-related illnesses, vector borne diseases, mortality from excess heat and cold
- Emerging risks—PFAS, micro and nano plastics, artificial intelligence (AI), and other emerging technologies

The most common 4-box models consider hazard rate, exposure, vulnerability, and financial aspects to generate estimates of losses from natural perils, i.e., these models simulate events (based on frequency of occurrence of the peril), use the distribution of assets in peril-prone areas (exposure), and assess damage based on the characteristics of the properties (age, building type, construction material, etc.). A basic extrapolation of this approach to a potential catastrophe model for mortality and morbidity is shown in Table 1.

Table 1

EXTENDING A TYPICAL 4-BOX APPROACH FROM PROPERTY TO LIFE AND HEALTH

Modules	Property	Morbidity	Mortality
Event/Hazard	Quite similar to natural perils, infectious diseases, and other emerging risks (tech/AI, PFAS etc.) need to be considered for mortality and morbidity		
Exposure	Assets at risk, such as buildings, infrastructure, and contents, by their location and value	Number of people at risk, insureds especially, along with demographics, location, and health details	
Vulnerability	Extent of damage based on factors like construction type, age, and local building codes	Extent of damage to health based on age, location, pre-existing conditions, lifestyle/living conditions	
Financial	Transforming the expected damage into monetary terms using deductibles, limits, and other (re)insurance conditions		

However, this approach will have limited usefulness in the context of life and health insurance in quantifying exposure, vulnerability, and financial aspects in ways similar to property models owing to challenges in data collection, grouping, and analysis. But the major differences would be due to the nature of the business itself and the possibility of both short- and long-term impacts on human health.

THE PROBLEM WITH THE "BOXES"

The 4-box catastrophe models, although probabilistic, rely on a lot of data—historical and scientific. Even if we argue that the hazard module that produces simulations of events can easily be extended to cover catastrophic events for life/health insurance (including those discussed on the previous section), we may not have reliable historical data or scientific studies to be able to estimate frequency (or return period) for some kinds of events (see the Data Challenges section below).

The exposure module for property uses location or the coordinates of a building to determine if this property gets damaged in the 'event' the hazard module simulated. In a similar life/health insurance situation, the entire local population can provide a suitable estimate of exposure for the entire insurance market and this can be scaled using market share for each insurer. At any given time, this would be an approximation with people traveling for leisure and work, before and after events. While a building's coordinates are static, the distance of a person from a fire or the epicenter of an earthquake is never static, and so no model can predict with much certainty the damage—extent of injury—they may suffer.

The vulnerability module would present the biggest challenges. The equivalent property module assesses how much damage a building would suffer in case the simulated event occurs. For health impacts, it's hard to say how much an average person's health suffers from a disaster. This would depend on age and fitness, distance from the epicenter of the event, previous medical history, lifestyle, smoking habits, education and affordability, any mitigation measures, or precautions they may have taken, and how soon they were evacuated and received medical help.

DATA CHALLENGES

Like all models, catastrophe models are calibrated with historical data. The question of how we use experience and adjust it to model our present reality has no straightforward answer. We live in a very different world now in terms of economic, technological/ medical advancements and demographics, than when some of those historical catastrophes occurred. How the same events might affect populations today could be very different from what we experienced in the past. Although populations are aging; medicine has greatly advanced, while many people may have sedentary lifestyles; there is also a lot more awareness about precautions; there are many more such counteracting trends. We may be able to derive assumptions for natural perils, infectious disease, and even terror attacks from history, but for the emerging risks such as climate, micro or nano plastics, and new technologies, we have virtually no data, only a few very reliable studies that make some predictions into the future.

A more practical difficulty to analyzing claims experience from catastrophic events is determining the distance/geographic boundaries in the case of medical expense claims. Natural perils occur within a defined geographic area and there is usually a 'consecutive hours' clause that reflects the time within which we can expect all property damage to have occurred. In other words, all claims from that catastrophic event would have occurred with a certain boundary of space and time enabling insurers to treat all claims arising in that stipulated zone and timeframe as originating from that event. There is no easy definition for an equivalent in health impacts, and it could be particularly challenging when symptoms appear later or persist until long after the event. For example, people in surrounding areas may inhale particulate matter which settles in airways or enters the bloodstream with symptoms appearing much later, over the course of days, months or years, and can linger. This could be exacerbated in people with long COVID. Health deterioration could also be exacerbated by a general decrease in living standards and wellbeing post a significant catastrophic event due to reduced economic activity and stressed infrastructure. To be able to perform a thorough analysis of the impacts of a catastrophic event on mortality, morbidity, and healthcare costs, we would also need to define for how long, how far, and how wide its impacts are likely to be felt.

Consider the following scenarios in the recent LA wildfires:

- An otherwise healthy, young firefighter develops breathing difficulties after a week. There is a direct causal link to the event.
- An elderly person living 5.5 miles downwind has an asthma attack within a few days of the fires breaking out. How likely would this be from the fire? Would this person report this if they are asthmatic and can self-medicate? If hospitalization occurs, would the hospitals report this as a case of illness from the wildfire, especially when we would not expect a reasonably healthy young adult to get ill from the smoke in the same location?

- Which of these two individuals would recover sooner—the young, fit firefighter with no history of asthma whose exposure was many times greater or the elderly asthmatic living farther away?
- If the elderly person requires frequent hospitalization for breathing difficulties and lung problems in subsequent weeks and finally succumbs a month later, does this add to the death count from the fire and would it be reported as such?
- Consider a more common scenario from asbestosis! The young firefighter retires years later, and experiences illness from PFAS in firefighting foam. How would we apportion costs across years and the various fires he has helped combat?
- People usually are advised to take precautions when they can see or smell smoke. Depending on the intensity of the fire and wind conditions at the time, the number of people who can see and/or smell smoke can vary greatly. So how do we know the number of people potentially exposed to any given event?

It is possible to identify many such grey areas in recording and attributing claims to a specific event, from the healthcare and life insurance perspective.

QUANTIFYING THE ECONOMIC COSTS OF HEALTH IMPACTS FROM CATASTROPHIC EVENTS

In recent years, with more catastrophic events, there has been an increasing number of studies on the human cost of disasters, trying to quantify the economic impacts on health. Floods, earthquakes, and terror attacks are short duration, high impact events. Loss of life is more likely than prolonged illness. These studies could be very useful in the context of wildfires which have a high possibility of longer-term health consequences, although the exposure time is larger, providing the opportunity to save lives and reduce impacts.

Studies in Canada[1], Australia[2], Portugal[3] and the U.S.[4] have attempted to estimate health care costs from particulate matter (PM2.5) exposures during wildfires in terms of premature deaths, heath care costs related to premature deaths, and acute and chronic illnesses. We look at four measures that have been calculated in these studies here.

MORTALITY IMPACTS: VALUE OF STATISTICAL LIFE (VSL)

Value of Statistical Life (VSL) is the per unit cost of premature mortality and is mostly measured as "willingness to pay" for mortality risk reduction, through precautions, purchasing insurance, and any other risk mitigation measures. A higher VSL could represent a lower mortality risk from a given event.

MORTALITY IMPACTS: YEARS OF LIFE LOST (YLL)

Years of Life Lost (YLL) is a common public health measure usually used in the context of diseases. It measures the premature mortality of a population in terms of the number of life-years lost.

$$\begin{aligned} Years\ of\ life\ lost\ (YLL) &\\ &= Number\ of\ lives\ at\ a\ certain\ age\ and\ of\ a\ certain\ sex\ lost\ due\ to\ a\ particular\ cause\\ &* life\ expectancy\ for\ that\ age\ and\ sex \end{aligned}$$

---

[1] Health impact analysis of PM2.5 from wildfire smoke in Canada (2013–2015, 2017–2018) - ScienceDirect

[2] Extreme air pollution events from bushfires and dust storms and their association with mortality in Sydney, Australia 1994–2007 - ScienceDirect

[3] Health and economic burden of wildland fires PM2.5-related pollution in Portugal – A longitudinal study - ScienceDirect

[4] How to measure the economic health cost of wildfires - A systematic review of the literature for northern America

Several studies[5] estimate the costs from premature mortality due to PM2.5 exposure during wildfires using the YLL.

MORBIDITY IMPACTS: COST OF ILLNESS (COI)

Cost of Illness (COI) is a measure that reflects the costs of resources, medical care, the opportunity cost of being sick (lost wages), and the additional stresses from illness. A study based on the 2009 LA Station fire yielded an estimate of 3.3 symptom days on average, 8.7 days among 38% of the people surveyed and an average cost per exposed day of $9.50. The COI doesn't consider lost recreation days, pain or discomfort with no resulting hospitalization, or cost of preventive measures people have adopted.

MORBIDITY IMPACTS: WILLINGNESS TO PAY (WTP)

Like the VSL measure, morbidity impacts can also be measured by the costs people incur to avoid being sick. In the same Station Fire study, the WTP was much higher than COI, at $84.42 per person.

USEFULNESS IN ACTUARIAL WORK

These measures do not easily convert into mortality or morbidity adjustments for actuarial modeling, and would vary by awareness, affluence, age, distance from disaster-prone areas, and attitudes. However, they still provide useful starting points to quantify financial losses from wildfire incidents. In pricing and capital management, they can form the basis for risk margins and catastrophe loadings. They can also be used in risk management, planning interventions, mitigations, and disaster relief. Such measures can help assess the risk a person represents during underwriting. For example, in the case of a wildfire, an individual with a high VSL or WTP could represent a potentially lower risk with respect to mortality, because they have purchased safety measures such as air filters/purifiers, emergency kits, or created a fire-resistant zone around homes. These studies have focused on large groups and estimated VSL for entire populations of cities/fire affected areas. VSL for individuals is likely to vary widely based on age, affluence, and attitudes. For example, older people may be equally more willing to spend more on preventive measures because they may believe they have fewer remaining years, or to spend less for the same reason! COI could help arrive at medical expenses for an average person during a wildfire season.

PIECING TOGETHER A FRAMEWORK FOR CATASTROPHE RISKS TO LIFE AND HEALTH

Catastrophe modeling is a very sophisticated approach that combines inputs from several fields to estimate financial impacts from events. While some existing functionality of property catastrophe models can be easily extended and applied, some others are not so intuitively adaptable to a life/health insurance scenario. The traditional 4-box model for property insurance, though not exactly replicable for life and health insurance, can provide a starting point for a framework to assess the impacts of catastrophes on mortality and morbidity:

- Events can be simulated based on history and scientific research from relevant fields such as epidemiology, climate change, etc.
- Exposures are readily available in population and demographic information. Scaling market wide exposures to individual companies is a common practice in insurance that can be replicated here.

[5] Impacts on Urban VOCs and PM2.5 during a Wildfire Episode

- Companies have health data of their policyholders to assess vulnerability, though this could be challenging. The task then remains to convert all this information into a financial estimate of losses. In this area, some of the measures such as VSL, COI, WTP can be incorporated to assess potential costs, while also providing useful risk assessments for underwriting and pricing. Where such measures are available at regional/city level, they can be used to estimate catastrophe loadings/margins for catastrophic events.

With more frequent events, and more studies happening in this area, more possibilities will open for catastrophe modeling in life and health.

* * * * *

Rajeshwarie VS, FIA is a P&C actuary based in India. She can be reached at r.eshwari.894@gmail.com.

REFERENCES

- California Department of Forestry and Fire Protection | CAL FIRE
- Risky business: Modeling catastrophes
- The long-term health effects of L.A. County wildfire smoke - Los Angeles Times
- Sustainable-Insurance-Strategy-One-pager.pdf
- California wildfires and the future of wildfire risk modeling - WTW
- Los Angeles Wildfire Smoke Adds Billions to Healthcare Costs - Bloomberg
- The hidden cost of wildfires: Economic valuation of health effects of wildfire smoke exposure in southern California
- Economic Impact of the Los Angeles Wildfires | UCLA Anderson School of Management
- Natural Catastrophe Analytics | Marsh
- The hidden cost of wildfires: Economic valuation of health effects of wildfire smoke exposure in southern California
- Spotlight on: Catastrophes - Insurance issues | III
- Catastrophe modeling: A vital tool in the risk management box | III
- Industry insured losses for Los Angeles wildfires
- How to measure the economic health cost of wildfires - A systematic review of the literature for northern America
- (PDF) The economic cost of adverse health effects from wildfire-smoke exposure: a review
- The human cost of disasters: an overview of the last 20 years (2000-2019) | UNDRR
- How the California wildfires are impacting healthcare | Chartis
- Modeling epidemic recovery: An expert elicitation on issues and approaches. - Abstract - Europe PMC
- Mortality Risk Valuation | US EPA
- Health and economic burden of wildland fires PM2.5-related pollution in Portugal – A longitudinal study - ScienceDirect
- Long-term health effects of wildfire exposure: A scoping review - ScienceDirect
- Health impact analysis of PM2.5 from wildfire smoke in Canada (2013–2015, 2017–2018) - ScienceDirect