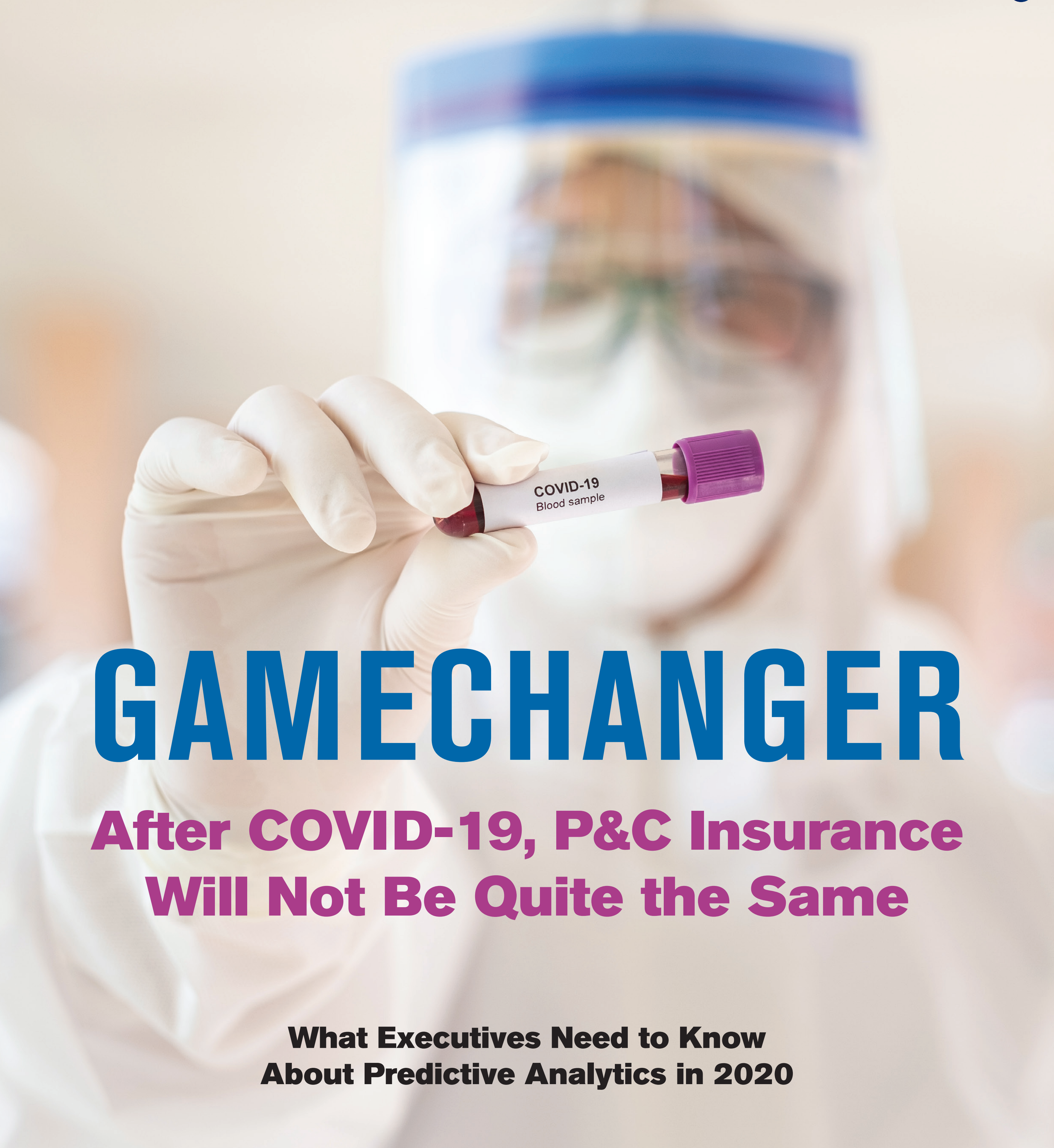
actuarial REVIEW

VOL 47 / NO 3 / MAY-JUNE 2020

PUBLISHED BY THE **CASUALTY ACTUARIAL SOCIETY**



GAMECHANGER

After COVID-19, P&C Insurance Will Not Be Quite the Same

What Executives Need to Know About Predictive Analytics in 2020

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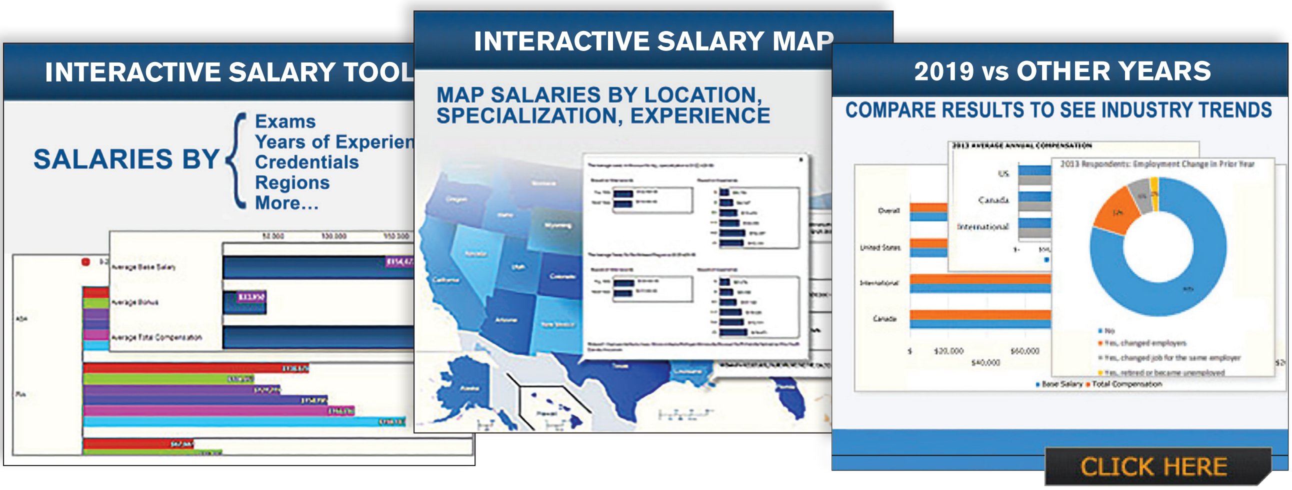
There are a few samples below, but you must go to our website http://www.actuarialcareers.com/ and click on the Salary Survey tab to find the 2019 results. You can also see and query past year's results too!



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actuarialREVIEW

May-June 2020

departments

This issue is dedicated to Vincent Lamar Edwards

CAS Professional Education Manager

1979-2020

FSC LOGO

Actuarial Review (ISSN 10465081) is published bimonthly by the Casualty Actuarial Society, 4350 North Fairfax Drive, Suite 250, Arlington, VA 22203. Telephone: (703) 276-3100; Fax: (703) 276-3108; Email: ar@casact.org. Presorted standard postage is paid in Lutherville, MD. Publications Mail Agreement No. 40035891. Return Undeliverable Canadian Addresses to PO Box 503, RPO West Beaver Creek, Richmond Hill, ON L4B 4R6.

The amount of dues applied toward each subscription of *Actuarial Review* is $10. Subscriptions to nonmembers are $10 per year. Postmaster: Send address changes to *Actuarial Review*, 4350 North Fairfax Drive, Suite 250, Arlington, Virginia 22203.

actuarialREVIEW

The magazine of the Casualty Actuarial Society

editor's NOTE By ELIZABETH A. SMITH, *AR* MANAGING EDITOR

Rock Chalk, Jayhawk!

The Editor's Note column is usually the last thing done for *AR*. With all the things that have to get done with the issue, it comes in very last on the list of priorities.

With the CAS office shut down beginning March 16, we had to make some adjustments in our work. Our CEO, Victor Carter-Bey, began weekly staff meetings through Microsoft Teams to keep us up to date and, I think, to lift our spirits as we adjusted to telework and the anxiety brought on by the pandemic. Those weekly meetings were supplemented with virtual coffee klatches and happy hours before and after work. These virtual get-togethers were a salve during trying times. You hope that your worries will be assuaged — but hopes are not promises.

That is why this column is especially hard to write this time.

On April 3, the CAS staff received news that our colleague, Vince Edwards, had died the night before. Vince was our manager of professional education in charge of the RPM, Reinsurance and Casualty Loss Reserves Seminars. In what was no doubt a very hard thing to do, Victor called for a virtual staff meeting that same morning we learned about Vince. The meeting became an impromptu memorial with several staffers bravely speaking of our beloved coworker and others silently listening, trying to process their shock and sorrow.

Vince Edwards

Vince was not just our coworker. He was our friend. I forged a bond with Vince over where we grew up — he was a Kansas Jayhawk and I an Oklahoma Sooner. We had our disagreements, but we resolved them and were better friends for doing so. Vince was there for a party celebrating my newly remodeled kitchen, and over the years we talked at length about many things. (A notable topic was Whitney Houston).

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Actuarial Review welcomes story ideas from our readers. Please specify which department you intend for your item: Member News, Solve This, Professional Insight, Actuarial Expertise, etc.

Send your comments and suggestions to:
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Or email us at AR@casact.org

Follow the CAS

Making a Stronger Community

There is no doubt that COVID-19 is affecting each of us both personally and professionally. At this point, we likely all know someone whose health has been impacted by the virus or someone who has lost their job as a result of the changing economic environment. We all know (or we may be those people) who are struggling with the uncertainty of at-home education and when schools may open. Needless to say, things are tough, and uncertainty abounds.

The staff and volunteer leaders of the Casualty Actuarial Society continuously put our members' and candidates' well-being as our number one priority. The CAS canceled the Ratemaking Product and Modeling Seminar (RPM) in March and has transitioned other major meetings such as the Spring Meeting and the Seminar on Reinsurance to be fully virtual. The CAS provided early clarity on canceling the Spring CAS examinations and has arranged for the full suite of examinations to be offered this fall and in the spring of 2021. The CAS is also providing new virtual education and opportunities to students who may have lost their internships this summer.

The CAS Staff, Board and Executive Council have not lost a beat during these times and are continuing to advance both strategic and operational imperatives that will position us for future success. Despite the curveballs thrown at the CAS from COVID-19, we remain a financially strong and determined organization with an active board of directors refreshing our strategic plan, and our new CEO, Victor Carter-Bey, making internal changes in the office to align the organization to be equipped to handle the challenges and opportunities of the future.

COVID-19 has also brought forward some great innovation and utilization of technology that will benefit both the CAS and the actuarial profession going forward. Disruption certainly forces organizations and individuals to become more resourceful, creative and resilient, and the disruption from COVID-19 is profound. We have all learned the power of empathy and emotional intelligence over the past few months. We have also learned the power of digital transformation (e.g., switching focus from product to customer; implementing new technology and enabling telework; and contending with issues of data security, privacy and ethics). All of these "outputs" from COVID-19 disruption will have lasting impacts on how the Casualty Actuarial Society and the actuarial profession operate going forward.

The CAS Staff, Board and Executive Council … are continuing to advance both strategic and operational imperatives that will position the CAS for future success. Despite the curveballs thrown at the CAS from COVID-19, the CAS remains a financially strong and determined organization….

Another observation during the last few months has been the importance of professional and well-communicated models (in this case, epidemiological-models). The "flatten-the-curve" dialogue alone is a case study in the importance of data visualization and how to take a responsible approach to data and analytics. The parallels to property-casualty risks are obvious and highlight the skill sets that CAS actuaries can bring forward: using data responsibly, conveying highly technical concepts in layman's terms, using a chart that can say more than words ever can. This is powerful storytelling.

In conclusion and as a small call-to-action, I would like to ask all of you reading this to reach out to a CAS member (or future member) that perhaps you have volunteered with on a committee or worked with in a prior job or even someone you don't know at all. Simply call or write to say, "Hi," and check in with them personally and professionally. The CAS is also working to create ways for our members and actuarial professionals to connect, including virtual meetings and seminars, which we hope will prompt many to reach out on their own to connect with colleagues.

The CAS is a small and powerful community, and I am convinced that with a small effort to stay connected, we can be a stronger community after COVID-19 than we were before it.

Be well and be safe.


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Editor's Note

from page 4

But in all the time I knew him, he never mentioned that he was his high school's valedictorian. He was a humble man.

During his far-too-brief life, he helped many people personally and professionally, from volunteering with journalism students to his career at the CAS. Here, he made sure that attendees were getting the most out of their meeting experiences, that speakers were outfitted to give their best presentations and that committee members could focus on developing the best educational programs. He was a consummate professional.

Losing Vince has been a hard blow to his family and his many friends. I can't imagine going back into our office and not seeing him there with his beautiful smile. There is no one like him.

So now, like many people throughout the world, we are left to deal with our losses. Life will not be the same.

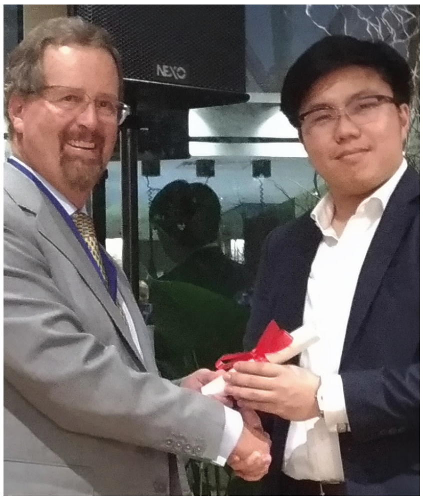
The CAS will recognize our friend and colleague by dedicating two upcoming webinars, Reinsurance and RPM, to his memory. This *AR* is also dedicated to Vince.

ACTUARIAL REVIEW *LETTERS POLICIES*

Letters to the editor may be sent to ar@casact.org or to the CAS Office address. Please include a telephone number with all letters. Actuarial Review *reserves the right to edit all letters for length and clarity and cannot assure the publication of any letter. Please limit letters to 250 words. Under special circumstances, writers may request anonymity, but no letter will be printed if the author's identity is unknown to the editors. Event announcements will not be printed.*

Corrections

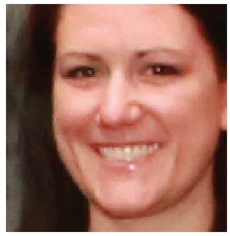
The 2020 January/February *Actuarial Review* contains two errors. In the story "New CAS Members Honored in Singapore," new Associates Ji Hyun (John) Kim and William Naftali were misidentified in photo captions. The correct captions appear below and are corrected online. *Actuarial Review* regrets the error.



New Associate William Naftali (right) with CAS President Jim Christie.

New Associate Ji Hyun (John) Kim (right) with CAS President Jim Christie.

In the print edition of March/April 2020 *Actuarial Review*, a photo of CAS Fellow Debdatta Bose was incorrectly used for Laura Cremerius, FCAS, one of the recipients of CAS New Members Awards. Cremerius is featured in the story "The 2019 CAS Volunteer Awardees: In Their Own Words" and is pictured above. *Actuarial Review* regrets the error.



Laura Cremerius, FCAS

COMINGS AND GOINGS

Mark Desrochers, FCAS, has been appointed to head of Horace Mann's property-casualty insurance business. Desrochers has been with Horace Mann for five years.

Nick Pastor, FCAS, has joined Tokio Marine as senior vice president and chief actuary. Pastor has more than 25 years of actuarial experience.

Transatlantic Reinsurance Company announced the appointment of **Stephanie Russell, FCAS,** to chief agent for the Canadian branch. Russell joined TransRe in 2015.

CAS President **Steve Armstrong, FCAS**, received the University of Illinois at Urbana-Champaign's 2020 Actuarial Science Alumnus of the Year Award. The award is presented by Illinois' Department of Mathematics.

EMAIL "COMINGS AND GOINGS" ITEMS TO AR@CASACT.ORG.

Hayne and Shi Named New Editors of *Variance*

Roger Hayne

Peng Shi

Roger Hayne, FCAS, MAAA, will become the editor in chief of *Variance*, taking over from Richard Gorvett, FCAS, who has held the position through a period of tremendous growth since 2013. Peng Shi, ACAS, FSA, has been named assistant editor in chief, a new position for *Variance*.

Hayne has been principal and consulting actuary at Milliman, Inc., since 1977. He is also an associate adjunct professor in statistics and applied probability at the University of California, Santa Barbara. He holds a doctorate in mathematics from the University of California, Riverside.

"My relationship with *Variance* goes back to its beginnings," said Hayne. "I participated in the CAS task force that decided on many of the features of *Variance*, not the least of which was its name."

An active CAS volunteer, Hayne served as president and most recently completed his term as vice president-international. He has published numerous papers in the CAS *Forum* and *E-Forum*, the *Proceedings of the Casualty Actuarial Society* and *Variance*. He is the 1995 recipient of the CAS Dorweiler Prize for his paper "Extended Service Contracts."

Shi is an actuarial science professor at University of Wisconsin-Madison and has extensive experience in education, research and editorial services in the casualty actuarial field. His journal management experience includes serving as an associate editor for *Insurance: Mathematics and Economics* and as a member of the editorial board for *Dependence Modeling*.

"Being in the leadership of the journal is the best way for me to contribute and further move forward our profession," Dr. Shi said. "As an academic actuary, I can bring another perspective to the journal and the CAS members. I hope to help connect and bridge the practical and academic research, and thus create synergy between the two sides of the knowledge."

Shi's research focus is nonlife actuarial science, and he has published extensively in actuarial journals. He has also been a speaker at CAS meetings, including the Annual Meeting and the RPM Seminar.

The *Variance* editors are responsible for directing the peer review of papers, setting high standards for the integrity of the journal's content, soliciting high quality manuscripts on topics of relevance, developing guidelines and processes to ensure effective peer review of papers and regularly engaging with the *Variance* Editorial Board and the actuarial community. They also manage the judging and awarding of the *Variance* Prize.

See real-time news on our social media channels. Follow us on Twitter, Facebook, Instagram and LinkedIn to stay in the know!

CALENDAR OF EVENTS

July 28-29, 2020
Ratemaking, Product, and Modeling Virtual Seminar

September 14-16, 2020
Casualty Loss Reserve Seminar (CLRS) & Workshops
Hilton Orlando Bonnet Creek
Orlando, FL

October 6-7, 2020
Crash Course in Vehicle Technology and Driverless Cars
Insurance Institute for Highway Safety — Vehicle Research Center
Charlottesville, VA

October 20-22, 2020
In Focus Virtual Seminar

November 8-11, 2020
Annual Meeting
Washington Marriott Wardman Park
Washington, D.C.

May 25-28, 2021
2021 Actuarial Colloquia (hosted by the CAS)
Disney's Coronado Springs Resort
Orlando, FL

May 23-26, 2021
Spring Meeting
Disney's Coronado Springs Resort
Orlando, FL

CAS Hires Chief Learning Officer, Announces Staff Promotions

ARLINGTON, Va., May 5, 2020 — The Casualty Actuarial Society today announced that Jennifer Naughton, MEd, CAE, SPHR, an association executive with over 25 years' experience in workforce certification, training and competency modeling, will become the organization's first chief learning officer (CLO). The CLO will plan, direct, develop and execute strategies in the credentialing and professional development business areas, working with CAS staff and volunteers to build learning and assessment vehicles that are cutting edge and innovative and that leverage the most highly regarded cognitive and advanced learning and competency tools in today's market.

Jennifer Naughton, MEd, CAE, SPHR

Naughton recently served as a consultant focused on strategic learning solutions for associations and non-profits in the financial, health care, information technology and training sectors. Prior to consulting, she was the senior director for competencies and credentialing at the Association for Talent Development (ATD), where she launched two international certification programs: Certified Professional in Learning and Performance (CPLP), now the Certified Professional in Talent Development (CPTD), and Associate Professional in Talent Development (APTD). She also directed and published two industry studies defining trainer competencies and helped to design the first stacked career development framework to enable personalized learning pathways for the training profession.

Prior to ATD, Naughton was an associate at Booz Allen Hamilton and a research scientist at the Human Resources Research Organization focused on human capital projects. She has also served as director of professional development at the National Association of Housing and Redevelopment Officials.

Naughton holds a master's degree in education from The George Washington University in Washington, D.C., and a bachelor's degree in psychology from James Madison University in Harrisonburg, Virginia. She is a Certified Association Executive (CAE) and a Senior Professional in Human Resources (SPHR). She has published over a dozen books and articles on the topic of learning and credentialing.

"The addition of Jennifer to our team signals a new level of commitment towards our world-class standard of professional education and credentialing," said Victor Carter-Bey, CAS CEO. "Jennifer's impressive background is a perfect fit to advance our rigorous programs and provide insights into how the CAS can serve as a valued partner to our current and future members in every stage of their careers. For over 100 years the CAS has successfully differentiated itself in the property and casualty actuarial space, and we will continue to invest in resources that help us strengthen that legacy and meet the demands of a growing profession."

In addition to Naughton's hire, the CAS also announced promotions to existing office staff:

- Tamar Gertner will now serve in the newly created role of director of engagement.
- Elizabeth Murray will now serve as director of human resources.
- Kate Niswander will now serve as director of marketing and communications.
- Wesley Ross will now serve as director of information technology.
- Elizabeth Smith will now serve as director of publications.

Tamar Gertner

Elizabeth Murray

Kate Niswander

Wesley Ross

Elizabeth Smith

September 14-16, 2020

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CAS STAFF SPOTLIGHT

Meet Wes Griffiths, FCAS

Welcome to the CAS Staff Spotlight, a column featuring members of the CAS staff. For this spotlight, we are proud to introduce you to CAS Admissions Staff Actuary Wes Griffiths.

- **What do you do at the CAS?**
  I'm serving as the first Admissions Staff Actuary. My role touches all things admissions and education. I've only been on the job since October 2019, but I've already experienced a wide variety of endeavors in the role — from working with authors on syllabus content and engaging with vendors on computer-based testing efforts, to partnering with CAS Leadership on a multiyear admissions roadmap and digging into data underlying our examination process to understand areas for improvement. It's all focused on making sure our education system meets the needs of our candidates and their employers both today and into the future.

- **What do you enjoy most about your job?**
  I enjoy working with individuals with such different backgrounds on a daily basis — my fellow CAS staff members, CAS leaders, candidates, university students, volunteers, actuaries from other organizations, academics and vendors. I cherish every relationship that I've built and take something from each conversation I have.
- **Where's your hometown?**
  I grew up in Hibbing, a small iron-mining town in northern Minnesota. For those trivia buffs, Hibbing is the childhood home of singer/songwriter/poet Bob Dylan and basketball great Kevin McHale. It's the birthplace of the Greyhound Bus Line, and it has a high school on the National Register of Historic Places.
- **Where'd you go to college and what's your degree?**
  I attended college in Duluth at the University of Minnesota-Duluth and double majored in math/statistics and economics.
- **What was your first job out of college?**
  I started my career at St. Paul Companies (now Travelers) as an actuarial student. I had an amazing 19 years at Travelers in various commercial lines roles until joining the CAS last fall.

Wes Griffiths

- **Describe yourself in three words.**
  Positive. Helpful. Curious.
- **What's your favorite weekend activity?**
  I have a boat on the St. Croix River, which borders Minnesota and Wisconsin. I like to spend my summers on the water with my friends and my two dogs Lucy and Riggins.
- **Where's your favorite travel destination?**
  I enjoy beach vacations, where I can read a good book, listen to the sound of the waves and truly disconnect from everyday stressors. For our 40th birthdays, my friends and I traveled to French Polynesia and stayed on the islands of Bora Bora and Moorea. It was an amazing experience and will be hard to top!
- **Name one interesting or fun fact about you.**
  In college I worked at a cemetery during the summer months, mowing the lawn and tending the grounds. I've heard all the cemetery jokes in the book!
- **Favorite Quote.**
  Clear Eyes, Full Hearts, Can't Lose.

GAMECHANGER

By ANNMARIE GEDDES BARIBEAU

After COVID-19, P&C Insurance Will Not Be Quite the Same

On the surface, the assumption was a no-brainer. Since the property-casualty insurance industry does not offer coverage for infectious diseases, with some exceptions or purchased inclusions, COVID-19's financial impact would be minor (*AR*, March-April 2020).

It would have been a reasonable presumption if the outbreak had not led to a full-fledged pandemic. COVID-19, however, is a virus on steroids. It has a similar blueprint to other zoonotic viruses, such as severe acute respiratory syndrome (SARS) and Middle East respiratory syndrome (MERS), with the pandemic power of the Spanish flu that ravaged the world's population in successive waves from 1918 to 1921.

Quelling the virus has been economically devastating worldwide. The International Monetary Fund sees the global economy suffering its worst downturn since the Great Depression.[1] Nearly 15% of the U.S. working population is now unemployed. Experts predict that figure could rise to an eye-popping 30%, eclipsing the estimated 25% unemployment rate during the Great Depression.

Other than the highly probable and far-reaching economic impact on P&C industry financial statements, the pandemic also affects the industry's product lines in other ways. The coronavirus is changing how people live and work, while revealing systemic frailties in things like government preparedness, health care delivery, major global manufacturing and supply chains. By rapidly forcing a large-scale experiment on previously limited practices, such as mobile work, telemedicine and virtual meetings, and massively ramping up e-commerce, COVID-19 is introducing both risk and opportunity.

By rapidly forcing a large-scale experiment in previously limited practices, such as mobile work, telemedicine and virtual meetings, and massively ramping up e-commerce, COVID-19 is introducing both risk and opportunity.

As the nation responds, there is so little known about the pathogen. Models and data that are guiding government responses differ and continually change. In Wuhan, China, where the disease first took root, cases are on the rise after a period of reported reprieve. South Korea, which provides a great example of quelling the pathogen's spread, is also experiencing more cases, as are other Asian countries. Meanwhile, predictive models that forecasted a variety of quantitative outcomes are showing significant variability and are demonstrating the adage

[1] https://www.bloomberg.com/news/articles/2020-04-09/imf-sees-world-economy-in-worst-recession-since-great-depression

by statistician George Box that "all models are wrong, but some are useful."

How much the P&C insurance industry is impacted by COVID-19 will depend largely on how long the pandemic lasts. Diagnostic testing kits have been scarce in the United States. Although test availability has been building rapidly for certain circumstances, for most of the population it is currently not clear who is negative, who is positive but asymptomatic, or who is positive and had symptoms but didn't require treatment. As the race for an effective vaccine ramps up, the development period will be followed by a series of necessary clinical trials, and it is quite possible that the coronavirus may be around for a while, like the Spanish flu.

The commercial P&C market was already hardening in most lines before COVID-19 … Liability insurance coverages … were especially hard hit, with claim payments accelerating partly due to increases in litigation defense and settlement costs — also called social inflation.

The Financials

"Systems across our economy will be stressed by the pandemic and subsequent economic fallout — in ways that were often not anticipated by risk management frameworks," predicts Rade Musulin, principal of Finity Consulting, an independent actuarial and analytics consulting firm in Sydney, Australia. "[This] will likely expose unexpected sources of risk."

Fitch Ratings, which downgraded credit ratings to negative for all insurance and reinsurance company sectors and all regions globally, changed its assumptions due to COVID-19's economic impact. The company predicts the pandemic will have a negative impact on the P&C industry-level accident year loss ratios; Fitch is adjusting the aggregate value by 3.5 percentage points, which is offset by 1.5 percentage points due to the favorability of personal auto insurance, according to an April 7, 2020, news release.

Additionally, Fitch makes several assumptions concerning COVID-19's impact, such as a decline in key stock market indices by 35% relative to January 1, 2020, valuations, an infection rate of 5% and a mortality rate of 1%.[2,3]

Personal P&C lines are experiencing generally modest rate increases compared to the commercial side. For the first quarter of 2020, personal lines prices — composed of personal automobile and homeowners insurance — were up 3.5%, a reduction from a 4.5% increase in the fourth quarter of 2019, MarketScout reported on April 6, 2020.

The commercial P&C market was already hardening in most lines before COVID-19 made its appearance. Liability insurance coverages were especially hard hit, with claim payments accelerating partly due to increases in litigation defense and settlement costs —also called social inflation. When comparing first quarter 2020 with fourth quarter 2019 rates, increases were 7.5% in directors & officers (D&O) coverage, 6.25% in professional liability, 4.25% in general liability and 4.5% in employment practices liability, according to another MarketScout release dated April 6, 2020.

Commercial auto continued its decade-long premium ascent, rising 7%, as commercial property rose by 4.5%, and umbrella/excess rose by 4.25%. The only line with a declining premium was workers' compensation at -1.25%. Commercial auto rates have been rising for several reasons, including distracted driving and vehicle repair cost increases (*AR*, May-June 2019). Commercial property costs have also risen for the past three years in large part from major catastrophe losses. Premiums for business interruption coverage and business owners policies increased 4% each as well.

"If history is a guide, as the economy slows, there will be an intensification of competition for market share," explains Robert P. Hartwig, clinical associate professor at the finance department and director for the Center for Risk and Uncertainty Management at the University of South Carolina. "I don't expect a degeneration into a soft market, but it will take the edge off of pricing." Hartwig also says insurers will "take

[2] https://www.lifehealth.com/fitch-ratings-defines-assumptions-coronavirus-reviews-insurance-companies/
[3] https://www.propertycasualty360.com/2020/03/31/fitch-ratings-outlook-negative-for-pc-global-reinsurance-due-to-covid-19/

What Experts are Saying About COVID-19

“Many insurtechs will fail as market opportunities dry up with agents’ and carriers’ focus turned on staying afloat and keeping their operations going during this time. Insurtechs that offer compelling value propositions for a social-distanced world will thrive, and those that do make it through the down period will likely be household names in 10 years, much as startups that made it through the Great Financial Crisis of 2008 have done well over the past decade.” — *Rob Galbraith, author,* The End of Insurance As We Know It

“COVID-19 will be a tipping point for remote work. Traditionally approached as a tactical solution to the problem de jour — attracting and retaining talent, saving money, disaster preparedness, etc. — it will be now be a strategic imperative.” — *Kate Lister, president, Global Workplace Analytics*

“I believe COVID-19 will force insurers to reevaluate how commercial insurance policies are composed and communicated. Yes, property insurance policies that include business interruption coverage also require physical damage and exclude viruses. However, businesses across the country are just now learning about these requirements and exclusions. The inevitable confusion that is created by the current forms and endorsements setup in the United States is archaic and due for a modernization effort that takes advantage of digital technologies and artificial intelligence now available in the marketplace. This will also require a shift in how insurance polici*es are regulated.” — Chris Cheatham, CEO, RiskGenius*

“The pandemic may serve as a wake-up call on climate risk. They share similarities. Both involve clear scientific warnings that have not been fully heeded, neither respects a country’s borders, both demonstrate the importance of multinational cooperation, and both require trillions of dollars in adaptation or stimulus funding. Perhaps a good use for some of the stimulus funding could be investment in infrastructure that will also reduce climate risk.” — *Rade Musulin, principal, Finity Consulting, Sydney, Australia*

“Insurance companies are affected by the increased cyber and other risks in ways not limited to potential increases in some types of insured losses. Their own cyberrisk has also grown; vulnerabilities of their systems and information have on average increased, leading to a greater chance of cybersecurity compromises and exploits. The growth in the cyber component of insurance company operational risk should be taken into account in the overall enterprise risk management.” — *Alex Krutov, president, Navigation Advisor*

a revenue hit as the economy slows,” because exposures are down due to COVID-19 and also due to temporary refunds and discounts currently being offered by most personal auto insurers.

Coverage Expansion

Politicians are pressuring insurers that write certain P&C lines to cover losses outside the written bounds of the policies. Most starkly, both federal and state legislators have been attempting to pass bills that would require business interruption coverage to include losses related to COVID-19. “There is more politics than substance here,” says Hartwig, pointing out that the National Association of Insurance Commissioners and the National Council of Insurance Legislators have positions against retroactive creation of liability for insurers.

“If P&C insurers provided all the coverage and services being proposed by legislatures,” he estimates, “the entire industry would be bankrupt by the Fourth of July.”

Small business continuity losses for businesses with 100 or fewer employees would cost an estimated $255 billion to $431 billion per month when the entire P&C industry’s average monthly spend is about $6 billion, said David A. Sampson, president and CEO of the American Property Casualty Insurance Association, in an April 6, 2020 news release.

Meanwhile, plaintiffs' attorneys are pushing insurers to cover COVID-19 losses in various products and forms. The pandemic coverage is costly, but it is available to businesses willing to buy it. The irony, Hartwig says, is that it is difficult enough to persuade people to purchase flood coverage when the risk is right before their eyes.

However, John Lucker, an insurance industry executive consultant and a retired principal of Deloitte, said the sector could do a much better job providing risk management education for customers and the general public and be clearer about what is and is not covered. "Don't expect customers to read a thick policy document of arcane and vague terms and conditions," he says, suggesting that insurers outline common scenarios in an FAQ type document.

Workers' compensation is also expanding in response to the COVID-19 emergency, but there are concerns that the impact will not be short-term but precedent-setting. Traditionally, workers' compensation covers occupation-related injuries, illnesses and fatalities. Since communicable diseases can be caught anywhere, they are generally, with narrow exceptions, not covered.

However, COVID-19 is quickly becoming an exception, said Mark Walls, vice president of communications and strategic analysis for Safety National, a specialty insurance and reinsurance provider. "We are changing the rules about what compensable claims are," he adds.

In most states, the concept has also expanded to essential workers, however those are defined. With a couple of exceptions, states have been expanding workers' compensation eligibility by directive without consulting industry advocates, Walls says.

The cost of covering COVID-19 through workers' compensation losses could be severe. In New York, the costs for workers' compensation losses could jump to $31 billion compared to annual losses of $8.7 billion for insurers and self-insured companies, according to a legislative analysis by the New York Compensation Insurance Rating Board, dated March 27, 2020.

What remains to be seen, however, is the degree to which people will choose to file workers' compensation for COVID-19, Walls said. The federal government has passed a law expanding leave of absence that provides a full salary, which means higher payments than offered through workers' compensation. This would incentivize workers to file claims under group health, he says. Many private insurers are offering to pay first-dollar coverage for COVID-19 treatment, including Aetna, CIGNA, the Blues and Humana.

With this said, however, Lucker also wonders whether on-the-job COVID-19 experiences could trigger additional workers' compensation claims for mental health-related PTSD-type ailments for certain front-line health care workers such as ICU nurses or respiratory therapists.

According to the Kaiser Family Foundation, which based estimates on 2018 data reflecting 22% of 82 million patients in the IBM Health Analytics MarketScan Commercial Claims and Encounters Database, the average total cost of hospital stays for pneumonia, the primary illness that can ultimately kill COVID-19 patients, was $21,000 in 2018 for patients with major complications or comorbidities; for those without health complications, the cost was $9,763.

In personal auto, carriers are generally respecting requests from state insurance commissioners to allow customers a reprieve from premium payments if they are not currently able to pay their bills. Cancellation rules have also been relaxed for a number of months. If these contractual concessions continue in the longer term, it could impact whether premiums are ultimately paid in arrears and could introduce retention issues, says Roosevelt C. Mosley, principal with Pinnacle Actuarial Resources.

Due to the reduction in accident or claim frequency, many insurers are offering relief to insureds. State Farm is offering credits on future policy terms. Allstate announced plans to pay more than $600 million to its customers during April and May 2020 as part of its "Shelter-in-Place Payback." American Family will be returning $50 per vehicle. "They are getting a head start on the next rate revisions," says Mosley, adding that personal auto insurers will be either returning money or reflecting lower losses in future rates.

The decline in accident frequency in Ohio demonstrates the impact of social distancing. For example, when Governor Mike DeWine (R) declared a state of emergency on March 9, 2020, the vehicular crash rate began to subside. From March 14 to March 31, 2020, when the governor restricted bars and restaurants to take-out orders only and later implemented an executive order to stay at home, claims frequency dropped 57% compared to the same period in 2019, according to TNEDICCA, which offers comprehensive location-based traffic accident data. As reports of COVID-19 cases increased, crash rates declined even more to reach a year-over-year 76% reduction from April 1 to 5, 2020. (See Chart 1.)

Homeowners insurance losses could come out as a wash. Non-weather residential losses are mostly due to factors that could be exacerbated by lockdowns, explains John Rollins, principal and consulting actuary with Milliman. “With more people in homes more hours per day, and perhaps some who are unfamiliar with the home, it stands to reason that the effective exposure to loss per measured house-day would go up,” he says. This could lead to, for example, an increase in fire-related losses, which have the highest severity per claim. In contrast, homeowners insurers could also see fewer losses because more people are home to mitigate losses. “[I]t's often surprising how many large homeowners claims are due to ‘inside jobs’ where a domestic worker or even a relation steals property,” Rollins observes.

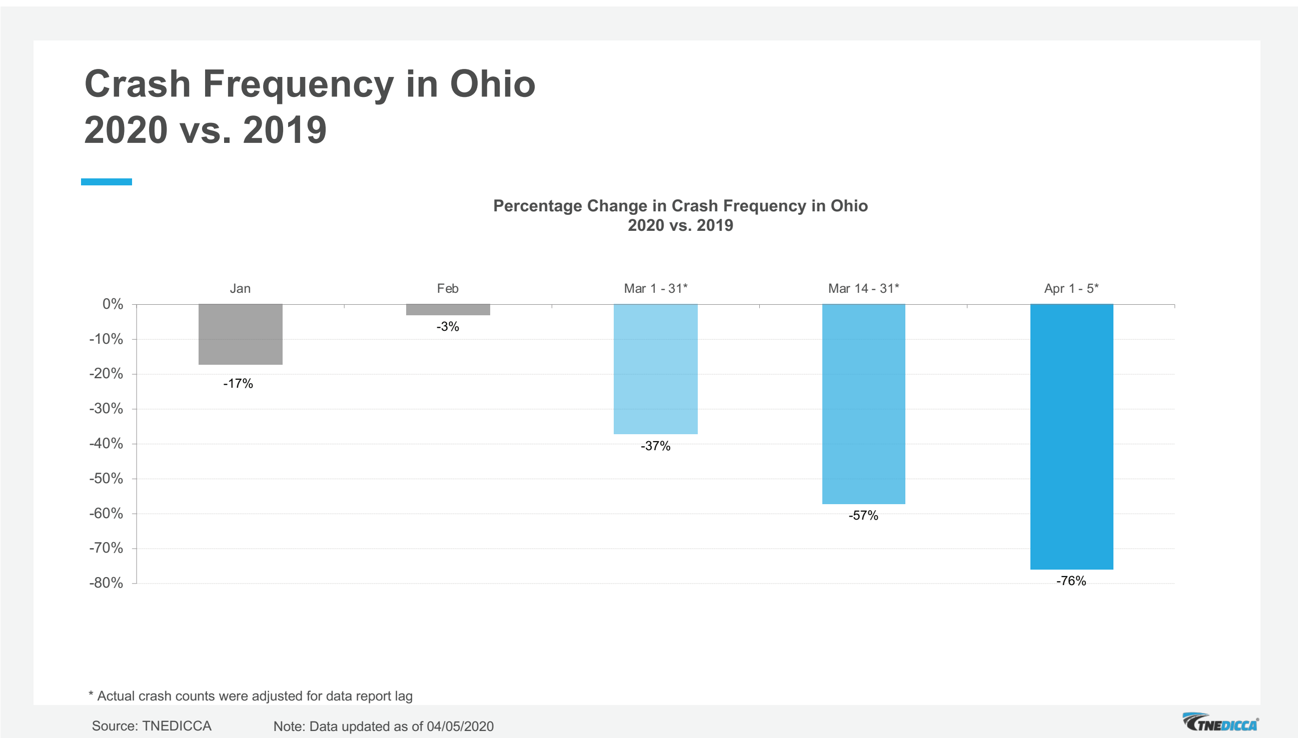
> **“If P&C insurers provided all the coverage and services being proposed by legislatures,” [Hartwig] estimates, “the entire industry would be bankrupt by the Fourth of July.”**

Teleworking can also introduce numerous cyber vulnerabilities, Lucker explains, including cyber threats not previously known or seen in a work context, due to inadequately secured home networks or routers, Wi-Fi hitchhiking, unencrypted communications, phishing schemes, etc. “Many companies have not demonstrated that they have robust business continuity plans with regards to having large portions of their workforce working remotely,” he observes. “So inevitably there could be some significant cyberrisk exposure not contemplated by their policies.”

Alex Krutov, president of Navigation Advisors, a firm specializing in quantitative analysis of cyberrisk, says cyberrisk has grown in a short period of time, and some of the increased risk will persist in the long term. “This has also led many to identify gross inadequacies in their cyber insurance coverages. It will ultimately lead to coverage changes and additional demand for certain types of cyber insurance,” he adds.

Liability coverages lawsuits are also expected to rise due

Chart 1



to COVID-19, says Cathine Lam, a senior data scientist and associate actuary for Metabiota's data science team. "There is a rise of COVID-19-related BI and D&O insurance coverage lawsuits from restaurants, cruise lines, hospitality and service groups," she observes. Metabiota supports and develops products and services that help track and anticipate the social and economic repercussions of pathogenic microbial agents.

The cases, she says, "are largely related to the interpretation of whether civil authority coverage could be triggered by shelter-in-place orders, [whether] 'contamination' has occurred on premises or [related to] actions considered to be 'wrongful acts,' especially when 'communicable disease' is not specifically excluded." Lam explains that this means insurers could potentially see a rise in commercial general liability claims.

General liability already has a material legal cost element, accounting for 10% of total loss and loss adjustment expenses, according to "COVID-19: The Property-Casualty Perspective," a Casualty Actuarial Society research brief posted on March 27, 2020.[4] The brief also looks at the impact COVID-19 has had on travelers, event cancellation and major coverages.

Another area of concern is medical malpractice coverage, which is likely to see a rise in claims of treatment errors at overwhelmed hospitals and potentially from the growing use of telemedicine. "There's no question that increased mortality at overwhelmed hospitals will increase the potential for litigation," Hartwig says. That said, most hospitals in the U.S. have seen reduced patient loads as elective surgeries and other procedures are postponed or canceled. "With many non-COVID patients unwilling or unable to visit their health care providers in person, an increased reliance on telemedicine — a technology still in its infancy — is a concern," he adds.

Systemic Vulnerabilities

Besides the ravages of death, lost employment and changed lives that COVID-19 is leaving behind, the coronavirus's emergence has also revealed systemic frailties. "One key lesson from the current crisis involves how complex and fragile our 'just-in-time' supply chains have become," Musulin observes.

The COVID-19 crisis also reveals that many firms do not fully understand their supply chains, and few actively manage them, he adds. "One way this could affect personal lines insurance is a shortage of certain repair parts that could lead to either delays in claim settlement or higher costs," he says.

"Globalization is a powerful economic force, but it fails to build resilience when just-in-time inventory appears as if by magic," says Max Rudolph, a life and enterprise risk management actuary. Just-in-time supply systems are not sustainable when medical supplies like ventilators and personal protective equipment become scarce. In the future, he adds, medical and food supplies need to be sourced closer to the final user to build redundancy into the supply chain. In the crisis, the U.S. closed down all but essential services because there were not enough COVID-19 testing kits and reporting delays made it difficult to track and manage the disease's spread.

Actuaries, risk managers and insurance executives answering the 13th Annual Survey of Emerging Risks[5] believed that the undervalued risks deserving of more attention in the next 20 years include climate change, demographic shifts, and a tie between cyber/networks and pandemics/infectious diseases, according to the key findings of the survey released in March 2020. Climate change was ranked as the top emerging risk, followed by disruptive technology, risk from cyber/networks, financial volatility and asset price collapse.

[4] https://www.casact.org/research/COVID-19_The_PC_Perspective_3-27-2020.pdf
[5] https://www.soa.org/globalassets/assets/files/resources/research-report/2020/13th-emerging-risk-survey-key.pdf

Participants answered the survey in November 2019. But since risk is perception-based, says Rudolph, who compiles and analyzes the data each year, he believes the results would have been quite different had the survey been conducted in March 2020.

How the insurance sector engages with decision-makers now and in the future will also dramatically impact the sector's future.

New Risks, Opportunities

The pandemic has changed how people live, work and visit their health care providers, which can introduce greater risks and new coverage offerings. In the longer term, says Lucker, "some of the unique issues that may emerge from the pandemic could serve as catalysts for innovation or foster the evolution of products like pandemic coverage, enhanced supply chain disruption coverage, and greater adoption of Pay-As-You-Drive policies."

Consider telecommuting, also known as remote work. Global Workplace Analytics estimates that more than 75 million employees could be working from home by the end of the crisis.

The organization predicts that, within two years, 25-30 million U.S. employees will regularly work from home on either a full-time or part-time basis. In comparison, before COVID-19, five million employees — 3.6% of the workforce — telecommuted on a full-time or part-time basis. "Before COVID, we were predicting annual growth continuing at about 10-15% per year," says Global Workplace Analytics President Kate Lister.

"Companies that accommodated remote work as a 'nice to have' for employee retention are quickly attempting to figure out how to run their entire business with a remote workforce as a 'must have,'" observes Rob Galbraith, author of *The End of Insurance As We Know It*.

Of course, at-home work exposure is nothing new for workers' compensation. But that doesn't eliminate challenges. "It's very difficult to monitor the environment from a loss control standpoint," Walls says. "There is also very little case law out there defining to what degree an employer can be held responsible for a work injury sustained in the worker's home," he observes. Companies might also demand cyber policies that better cover at-home employees.

Personal auto insurance is currently picking up losses typically assigned to commercial auto due to the use of personal vehicles for essential deliveries. Covering these exposures "is not a significant amount of additional exposure when fewer cars on the road reduces accidents," Mosley explains, and some insurers were offering such coverage before the COVID-19 pandemic. Grocery delivery service is nothing new, but it is possible that in the post-COVID-19 world, a greater population will adopt deliveries rather than visit a store.

It is also likely that people will prefer telemedicine when possible, offering risk and opportunities for insurers.

Lucker, an advisor to the parametric contract company Machine Cover, expects greater demand for parametric contracts,[6] warranties and similarly structured insurance products for risks like cyber at home, internet outages, website downtime and home and business power outages/failures. "Such parametric product categories could offer advantages over traditional insurance as they eliminate complex claim handling and simplify purchase, payments and claims," he adds.

Conclusion

COVID-19 hit the world suddenly and unexpectedly. The response has revealed sobering realities about the health of Americans, the health care delivery system and the health of the economy.

The response to COVID-19, however, largely falls in the hands of public officials, policymakers, regulators and, potentially, the courts, whose decisions can affect P&C coverage. How the insurance sector engages with decision makers will also dramatically impact the sector's future. Future-forward insurance companies will develop new products in the "new normal" of COVID-19 and its aftermath.

Annmarie Geddes Baribeau has been covering insurance and actuarial topics for nearly 30 years. Find her blog at www.insurancecommunicators.com.

[6] From the NAIC website: The term parametric insurance describes a type of insurance contract that insures a policyholder against the occurrence of a specific event by paying a set amount based on the magnitude of the event, as opposed to the magnitude of the losses in a traditional indemnity policy.

What Executives Need to Know About Predictive Analytics in 2020

By CLAUDINE MODLIN AND ROOSEVELT MOSLEY

Analytics is an issue of leadership. It needs champions who have overarching business strategies in mind — minimizing the prospect of multiple uncoordinated efforts and unshared insights across the enterprise.

Editor's Note: *The following article was first published by Carrier Management on January 8, 2020.*

By this time, most leaders in the insurance industry have heard of using predictive analytics to study previous patterns that can help businesses understand what could happen in the future. However, the amount of noise being made about predictive analytics can be deafening. Ultimately, this can lead a company to jump into a flurry of activity that may or not be useful, or inactivity due to confusion about where to begin.

Predictive analytics is an effective tool that can lead to significant benefits when applied correctly, and we have identified six key themes that executives should focus on in 2020 to help ensure these benefits are achieved.

1. Analytics is mostly a leadership issue.

We often think of analytics as the purview of statisticians, actuaries or data scientists because that's often who performs the work. We assert that it's a leadership issue because executives define what questions to answer, what problems to solve and what opportunities to pursue. These questions need to relate to the company's overall business strategy — thus beginning with the end in mind.

Additionally, executives should champion an overall analytics strategy versus the pursuit of multiple uncoordinated efforts. Consider how many business units or functional teams are relying on similar data to chase the same questions (What drives the cost of claims? What drives customer satisfaction?) or leveraging different technologies (data science platforms, chatbots) and not coordinating efforts or sharing insights across the enterprise.

2. Predictive analytics has little value if it's not generating favorable business outcomes.

Predicting which policies are likely to lapse is very interesting and often generates a lot of discussion, but if that prediction is not being leveraged to refine existing processes, behaviors or decisions, it has not delivered much business value. It's critical for executives to understand the intended application and success criteria of analytics initiatives and set expectations to measure return on investment after implementation.

The allure of insurtech offerings, especially, can lead insurers to chase solutions that may not generate favorable business outcomes. Insurance companies often approach the insurtech space backwards. Insurers act as surveyors, identifying what solutions are out there and ultimately deciding to incorporate technologies that demonstrate (or promise) results that are impressive.

Unfortunately, an impressive application that is not related to a company's mission will generally not result in favorable business outcomes. It would be better for companies to approach the insurtech landscape as miners, identifying the business needs of the company and searching for solutions that address the business need.

Insurance companies often approach the insurtech space backwards. Insurers act as surveyors, identifying what solutions are out there and ultimately deciding to incorporate technologies that demonstrate (or promise) results that are impressive.

Executives also play an important role in translating the company's strategy to help data teams prioritize efforts. This means striking the right balance between continuous improvement efforts in core data assets and innovative efforts to create new data assets based on novel combinations of disparate data. For example, if you want to study how shortcomings in your digital self-service capabilities drive contacts to your service center, you have to build a data platform that can stitch together the customer's experience across digital and service center transactions. If resources are limited, should more resources be deployed to undertake this or to pursue defects in core data assets (e.g., policy and claims data)? Which aligns more closely with strategic objectives?

3. Ensure data strategies align with analytics applications.

Have you ever asked a question that your data could not answer, either because you did not collect the right information, you were not confident in the quality of the information or the information was not easily accessible? Not only will a well-defined data strategy help alleviate these issues but exposing the desired business outcomes to those involved in executing the data strategy will help underscore the importance.

4. Push beyond the hype to attain a working knowledge of machine learning and artificial intelligence.

We're inundated with sound bites around machine learning and AI, and it's easy for executives to proliferate the hype without a solid understanding of what these terms mean. This is exacerbated by the fact that the business world does not have consistent definitions. Executives may choose to become conversant through books or classes aimed at business leaders, but it's equally important to push your own teams for business-relevant definitions, an understanding of advantages and shortcomings, as well as knowledge in what methods can and can't do, likely applications, etc. In particular, leaders will be well-served to better understand the balance between complexity and understandability (e.g., the most complex model may not be well-suited to changing agent behaviors). It's also prudent for leaders to ask about potential unintended consequences of a model.

5. Keep the "last mile" in mind.

What technology will be used to deploy the predictive model in operation?

Many legacy systems were set up to handle if/then/else rules or simple algorithms but not complex models. Modern systems can often call models via application program interfaces. What are the downstream and upstream implications of introducing a model into a broader process? What is the change management plan to ensure people who are part of the broader process have "bought in" and are working with the model and not fighting against it?

It is also important to remember that the "last mile" of the journey leads to the starting line of the next journey. This is for two reasons. First, no model is perfect, so part of the ongoing maintenance of the predictive model application will be to identify situations where the results are unusual or unexpected. Second, no model is implemented in a scientific laboratory. Once the results are implemented, customers, competitors and even company employees may adjust behaviors. This will result in an underlying shift to the process being modeled.

Consistent monitoring of results and incorporation of updated data in the modeling process will constitute the continuous future journey.

6. Promote and inspire multidimensional teams.

No matter how much science advances, it will not displace the need for business context. In fact, one might argue that as science advances to the point of training machines to learn on their own, the business context becomes even more important. Executives establish the business climate that enables diverse competencies (e.g., quants, domain experts, technologists) to row in the same direction.

If business executives keep these six things in mind in 2020, they can help improve the likelihood of predictive modeling applications driving improved business outcomes and achieving the desired strategy.

Roosevelt Mosley, FCAS, MAAA, CSPA, is a principal and consulting actuary with Pinnacle Actuarial Resources, Inc. and has 25 years of property-casualty actuarial experience. His skill set includes predictive analytics applications for all insurance functions, ratemaking and product development, competitive analysis and litigation support.

Claudine Modlin, FCAS, MAAA, is an insurance executive and actuary with more than 25 years' experience in the industry. She is currently the head of personal lines product for the Western zone at Farmers Insurance Group.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IN MY OPINION By GROVER EDIE, *AR* EDITOR IN CHIEF

An Actuary looks at COVID-19

In the second month of my state's shelter-in-place order, I began to think about applying some actuarial concepts to the subject. I offer the following observations.

Concurrent events

In addition to this mess, a spat broke out between Russia and Saudi Arabia over oil, as evidenced by a March 9, 2020, headline mentioning a "squabble" over oil production limits. Oil prices had been at about $47 a barrel at that time and closed just above $20 on March 18 of this year. Fuel prices are really low, but with shelter-in-place edicts and many offices and factories shuttering, people aren't driving to work. So, our oil stocks have dropped precipitously. Which has the greater impact on oil prices: the production limits or the reduction in driving brought about by the coronavirus? Someone will likely do some analysis.

Information (data quality)

When I was young, we got our news from one TV channel, a few radio stations, newspapers and news magazines. News was very limited, and the sources controlled what we read or heard.

Today there are multiple news sources. Now my problem is to determine what to believe and what not to. Anyone with access to the web can "publish," and many do. Those who don't create original news can often forward misinformation along to others that can be fatal. For example, one hot "news" item falsely claimed that drinking a sip of water every 15 minutes would keep you from getting the coronavirus.

How do we recognize the noise and separate it from the signal? How much of the news is broadcast to further a political or social agenda, rather than provide facts? We need to inspect our data (news) in our personal lives as well as for our work purposes.

How do we recognize the noise and separate it from the signal? … We need to inspect our data (news) in our personal lives as well as for our work purposes.

Severity of the event

In the pre-pandemic era, when deciding what to eat at a restaurant, I realized that the likely worst-case result that could happen was that I'd get a meal that I didn't like. (The worst thing would be to get poisoned and die, but that is not very likely.) The severity of my decision then was small. Under today's virus conditions, however, deciding whether to be in a public place with a lot of people can have a different outcome: I could get a life-threatening virus. Regardless of the frequency, the severity deters me from getting out of the house unless it is absolutely necessary.

Frequency

I am monitoring how many people get the virus in my state using multiple sources. It is a proxy for what I would really like, that is, some means of finding out if people with whom I come into contact have the virus. Absent contact tracing, I simply am working from home and severely limiting any interaction with outsiders. I am limiting my frequency of exposure by avoiding all but the most essential contact.

Modeling

We are experiencing a plethora of models, with widely varying results. I am reminded of all of the models that predicted that Hillary Clinton would handily win the election over Donald Trump. Are the same model errors present in the COVID-19 models? Are any of the modelers biased one way or the other? Are our leaders and press selecting models based on the model outcomes rather than their accuracy? I would like to know.

Contagion of exposures

It seems that the more chaotic things become, the greater the likelihood for more chaos. Stress in one segment adds to the stress in others, even areas not previously deemed connected or correlated. I started a list of all of them; here is a start:

Some homeowners and businesses face a fine if they do not keep their grass mowed. Many in my neighborhood hire professionals to cut their grass, but since commercial mowers are not considered "essential" in Michigan, the grass can't be mowed. They can be ticketed if they don't mow, but the commercial mowers can't come out to mow.

The grocery stores that used to be open 24 hours now close at night so they can clean and disinfect. That means second shift essential workers, who used to shop on their way home in the early hours of the morning, can no longer do so. And no one can do the "emergency run" to get diapers or whatever at 2 am.

The grocery stores that used to be open 24 hours now close at night so they can clean and disinfect. That means second-shift essential workers, who used to shop on their way home in the early hours of the morning, can no longer do so.

I work from home, but now that the entire state is staying home, the load on my internet provider has increased immensely. This causes my internet speed to suffer.

Reserve development

Another observation is how specialists and others are analyzing the progression of the cases — looks to me a bit like a loss reserve estimation. And while we recognize that different lines of business have different development factors, different countries and even different regions within a country are exhibiting different "development factors." I wonder if any of the big producers of such data employ an actuary.

Truncated and other "dirty data"

I am fascinated with headlines and the order in which the information is presented. Since many people don't read past the headline, writers can print a shocking (or biased) headline and leave the real facts to the end of the article.

You probably have your own favorite examples of conflicting information. What is the real death rate from the virus? What is the rate of underreporting? Who is at the greatest risk? And how much of what we hear is fearmongering for the sake of gaining publicity or notoriety for the speaker/writer/producer?

Some writers are not beyond quoting only a portion of a speech or article, leaving out parts that finish the thought. Some publications are worse than others, and once I find a publication that does so, I cross it off my list of acceptable sources.

Qualifications

We actuaries must meet certain experience and educational requirements in order to express an opinion in our area of expertise. What makes a sports star, an entertainer or a politician an expert on COVID-19 and projections of future contagion and death? Why does the news media continue to quote these nonexperts? Is it to raise viewership or push their own agenda? Governor Cuomo was asking for 30,000 additional ventilators, stating "I operate on the data and on the numbers and on the science. And every projection I have, from multiple sources, and these are worldwide health experts, say that we have to be prepared for an apex of 140,000 hospital beds and 40,000 ICU beds with ventilators." Fortunately, his modelers overstated the need.[1]

Emergency preparedness

My local warehouse store was out of toilet paper for weeks. This "not-in-stock" situation followed by the "too-much-to-put-onto-the-shelves" scenario will likely continue in the upcoming weeks for other products, such as hand sanitizers, masks or nitrile (examination) gloves.

I have experienced several periods when I could not go to the grocery store, such as the Midwest power outage of 2003 and the New York City/Northeast blackout of 1977. You may have experienced a hurricane that kept you in place for days. I have learned to keep at hand several weeks' worth (or more) of certain supplies like toilet paper. We also keep about a month's stock of foods that don't require refrigeration and have a long shelf life — canned meats, nut butters, etc.

Business continuity

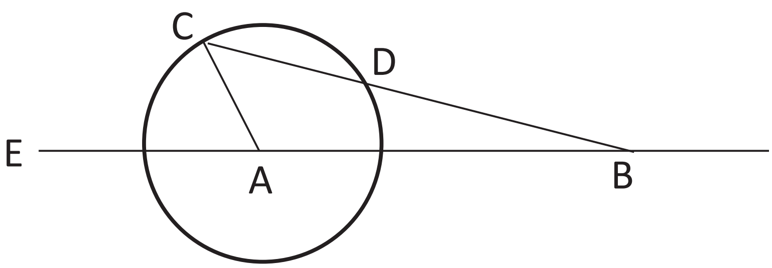
I believe this crisis will accelerate the work-from-home option for many employers. I haven't worked in a formal office setting since I started my current job five years ago — and the firm for which I work didn't miss a beat.

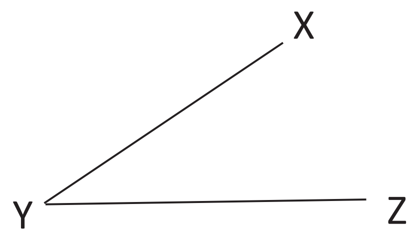
There is no doubt in my mind that this current situation will change the way we live and work in the future. Some of the changes will be for good; some of them will not be good. The best we can do is to learn from what has happened and be prepared if something like it happens in the future.

[1] nbcnews.com/politics/donald-trump/i-operate-data-numbers-cuomo-responds-trump-ventilator-claims-n1170636

IT'S A PUZZLEMENT By JON EVANS

Straightedge and Compass Geometry





The figures above are not necessarily drawn in accurate proportion. In the figure on the left, *CB* intersects the circle, centered at *A* and containing *C* at *D*. *EB* contains *A*. The length of *DB* is equal to the length of *AC*. What is the ratio, *r*, of angle *ABC* to angle *EAC*?

The angle on the right, *XYZ*, is given separately with no specified relationship to the figure on the left. Your only tools allowed are a straightedge to construct the line containing two points and a compass to draw a circle centered at one point and containing another point. You are allowed to use these tools only in the traditionally accepted ways of Euclidean geometry. For example, you can pick an *arbitrary* point on the plane or on an already constructed item to use for further construction. Can you describe a finite number of allowed constructive steps to construct a new angle Θ whose ratio to angle *XYZ* is *r*? It is not mandatory that the complete resulting construction resembles the figure on the left and the fewer steps the better.

Just Multiplying Some Positive Integers

Once again, the mighty Bob Conger comes to our rescue with an industrial strength solution. Since $A(n)$, $B(n)$ and $C(n)$ are defined as positive integers, k must be positive, since $A(k)$ would not be an integer for integer values of $k<1$.

Solutions for Each of the Given Conditions

1. Does not exist.
2. $k = 6$.
3. Does not exist.

CONDITIONS 1 and 3

Condition 1 or 3 would require that $B(k) < A(k)$ for some positive value of k, since $GP!$ and $C(k)$ are positive integers. However, we can demonstrate that $B(k) > A(k)$ for all integers $k > 1$, as shown below. Thus, Conditions 1 and 3 will never be satisfied.

For $k = 1, 2, 3$, $B(k) > A(k)$ is easily seen by inspection. $B(3) = 720 > A(3) = 256$ and, furthermore, $B(3) > 2 \times A(3)$.

We also can show that if $B(k) > 2 \times A(k)$, then $B(k + 1) > 2 \times A(k + 1)$ and, by induction, $B(k) > 2 \times A(k)$ for $k > 2$.

By definition, $(2 \times A(k))! = (2 \times A(k)) \times (2 \times A(k) - 1) \times \ldots \times 1$.

There are easily $A(k)$ terms in this product that are greater than $A(k)$ and many other terms greater than 2. So, $B(k + 1) = B(k)! > (2 \times A(k))! > 2 \times A(k)^{A(k)} = 2 \times A(k + 1)$.

CONDITION 2

We are able to find the smallest positive integer value of k such that $A(k) \geq GP! \times C(k)$, or equivalently, since all are positive integers, we are to find the smallest positive integer k such that $A(k) / C(k) \geq GP!$.

The numbers quickly spiral out of control as k grows. To keep a handle on them we can work with base-10 logarithms:

$\mathrm{Log}_{10}(G) = 100$

$\mathrm{Log}_{10}(GP) = G = 10^{100}$

$\mathrm{Log}_{10}(GP!) = \mathrm{Log}_{10}(GP) + \mathrm{Log}_{10}(GP\text{-}1) + \ldots + 0.$

This sum has $GP = 10^G$ terms, with an average value >1, since all terms but the final term are ≥ 1, and most of the terms are a lot bigger. The average value of a term is $< \mathrm{Log}_{10}(GP) = 10^{100}$, since only the largest (first) term is 10^{100}. So:

$(10^G) \times (1) < \mathrm{Log}_{10}(GP!) < (10^G) \times (10^{100})$

$(10^G) < \mathrm{Log}(GP!) < (10^G + 100)$.

For the first few values of k, we can handle the problem easily with arithmetic:

$A(1) = 2 \qquad C(1) = 1$

$A(1)/C(1) = 2 < GP!$

$A(2) = 2^2 = 4 \qquad C(2) = 2^1 = 2$

$A(2)/C(2) = 2 < GP!$

$A(3) = 4^4 = 256 \qquad C(3) = 2^2 = 4$

$A(3)/C(3) = 64 < GP!$

$A(3) = 4^4 = 256 \qquad C(3) = 2^2 = 4$

$A(3)/C(3) = 64 < GP!$.

By $k = 4$ we have to deploy logarithms:

$A(4) = 256^{256} \qquad C(4) = 2^4 = 16$

$\mathrm{Log10}(A(4)) = 256 \times \mathrm{Log10}(256) \approx 616.5$

$\mathrm{Log}_{10}(C(4)) \approx 1.2$

$\mathrm{Log}_{10}(A(4)/C(4)) = \mathrm{Log}_{10}(A(4))$ - $\mathrm{Log}_{10}(C(4)) \approx 615.3 < 10^{100} = \mathrm{Log}_{10}(GP)$

$(A(4)/(C(4) < GP$

For $k = 5$:

$A(5) = A(4)^{A(4)}$

$\mathrm{Log}_{10}(A(5)) = A(4) \times \mathrm{Log}_{10}(A(4) \approx 10^{616.5} \times 616.5 \approx 10^{616.5} \times 10^{2.8} = 10^{619.3} > \mathrm{Log}_{10}(GP)$.

$A(5) >> GP + 1$ and $A(5) >> GP$

$C(5) = 2^{16} = 65{,}536$

$\mathrm{Log}_{10}(C(5)) \approx 4.8 \approx 10^{0.7}$

$\mathrm{Log}_{10}(A(5)/C(5)) \approx 10^{619.3} - 10^{0.7} = 10^{619.3} << 10^G < \mathrm{Log}_{10}(GP!)$

$A(5)/C(5) << GP!$.

For $k = 6$:

$A(6) = A(5)^{A(5)}$ and from above we know $A(5) >> GP$.

Each term of this product is $A(5) >> GP$; but $GP \geq$ each term in $GP!$.

The number of these terms in $A(6)$ is $A(5) >> GP + 1$, which is the number of terms in $GP! + 1$.

Therefore, $A(6) >> GP^{GP+1} >> GP!$.

$C(6) = 2^{C(5)} = 2^{65{,}536}$

$\mathrm{Log}_{10}(C(6)) = 65{,}536 \times \mathrm{Log}_{10}(2) \approx 19{,}728 \approx 10^{4.3} < 10^{619.3} \approx \mathrm{Log}_{10}(A(5))$.

Thus:

$C(6) < A(5)$.

Thus:

$A(6)/C(6) > A(5)^{A(5)}/A(5) = A(5)^{A(5)-1} > GP^{GP} > GP!$.

Therefore, Condition 2 is met with $k = 6$.

Know the answer? Send your solution to ar@casact.org.

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