

November 13, 2020

**Information Paper  
for  
CAS Board of Directors  
December 1, 2020**

**Subject: Annual Research Report**

**Responsible Officer: Jim Weiss, Vice President – Research and Development**

1. Background

The Board of Directors receives an annual report on CAS research activities at its November meeting.

2. Information

The 2020 Report is attached. The report consists of two components:

- A. Overview and Status of 2019-2020 CAS Research Activities  
Details on CAS research projects are provided in this attachment, organized by topic.
- B. CAS Research Commitments and Expenditures (2003-2020)  
Annual funding commitments to research projects and call paper programs are summarized in a spreadsheet.

## CAS Research: 2020 Overview

During the 2019 – 2020 year the CAS Research Department completed a number of significant projects, including

- 2020 Reserves Call for Papers generated 5 completed papers.
- The Data Visualization working party concluded their work with one paper in the E-Forum and 3 presentations at CAS seminars.
- The Actuaries Climate Index – which launched in November 2016 – continues to be updated with new data.
- The auto loss costs project – jointly sponsored by PCI, the SOA and the CAS was updated in November 2020.
- Papers sponsored through the Individual Grants Competition
- Added 15 repositories to GitHub, including one for scraping COVID-19 data. The largest project on the platform - chainladder-python – has seen over 100 commits from 9 contributors.
- [Individual Claims Forecasting with Bayesian Mixture Density Networks](#)
- [Exposure Measures for Pricing and Analyzing the Risks in Cyber Insurance](#)
- [Hierarchical Compartmental Reserving Models](#)
- [A User's Guide to Economic Scenario Generation in Property/Casualty Insurance](#)

Notable work currently in progress includes

- Research on the demand for microinsurance in North American being conducted by Ed Furman at York University 2020 Ratemaking Call for Papers (two papers still in progress for the two-year track to be published early 2020)
- COVID-19 and uninsurable risk
- Individual claim reserving techniques
- Several projects jointly sponsored with the SOA (Individual Grants Competition)
- Research on flood modeling using public data, being conducted by Rob Erhardt at Wake Forest University
- Issued an RFP from the reinsurance committee to solicit research on wildfires.

The CAS has also continued to pursue cooperation with other actuarial organizations. We are a key partner and funder of ERM-related research through the Joint Risk Management Section, which is jointly sponsored by the CIA, SOA and the CAS (several JRMS projects are listed below). The CAS also partners with the SOA and the CIA on other research projects (some relevant projects listed below). The research actuary and director of research have monthly calls with their counterparts at the CIA, IFoA, Australia Institute, and SOA.

We continue to work with organizers of the Actuarial Research Conference to offer P&C-related sessions. Additionally, the research actuary participated on a panel discussion related to COVID-19.

CAS Research continues to work with Professional Education to disseminate the results of research projects to the membership and to sponsor projects that will advance the technical skills of the CAS members.

I am confident that I, together with the CAS Research staff and Research chairs and

November 13, 2020

volunteers, will make continued progress during the 2020-2021 year. I thank my predecessor, Avi Adler, for the work he contributed over the last three years and this report reflects his active involvement. I also thank you for the opportunity to serve you in this capacity for the next three years.

Sincerely,  
Jim Weiss  
VP – Research & Development

## Status of 2020 CAS Research Activities

### Research Projects by Topic

#### 1. Climate Change

- **Project: Actuarial Climate Volatility Index**  
**Project Oversight Group:** Climate Change Committee  
**Contact:** Doug Collins  
**Purpose/Topic:** This project continues the work started in Phase 1 of the project by working to build both an Actuaries Climate Index and an Actuaries Climate Risk Index. The Actuaries Climate Index will be a global index, and will educate the general public about how Climate is changing, while the Actuaries Climate Risk Index (ACRI) will be an Index that measures economic or insured risk in Canada and the U.S.  
**Funding Approved:** \$25,000. Total funding of \$63,000 will come from all three sponsoring organizations (SOA, CAS, and CIA). Additional funding of \$15,000 approved in September 2014 for Web site development.  
**Status:** The project began in August 2013 by Solterra Solutions, who completed Phase 1 of the project as well. The Actuaries Climate Index was launched in November, 2016. It is intended to provide a useful monitoring tool—an objective indicator of the frequency of extreme weather and the extent of sea level change. ACI and ACRI data is updated quarterly on the website, based on data for each meteorological season (3 months ending February, May, August, and November). Since its launch, more than 22,000 visitor sessions from 134 countries have been tracked, and more than 1,600 data downloads have been made. Three updates in 2020 were made to the database.

#### 2. Enterprise Risk Management (also including JRMS research projects)

- **Project: Annual Emerging Risk Survey (since 2007)**  
**Date Announced:** Yearly.  
**Project Oversight Group:** Joint Risk Management Section  
**Purpose/Topic:** This annual survey attempts to track the thoughts of risk managers about emerging risks across time.  
**Funding:** \$20,000 from JRMS.  
**Seminar/Meeting Presentations:** At various CAS events.  
**Publication:** Available on CAS website. Last report: 2018 published in August 2019.  
**Status:** Annual. Recurring. Report printed the following year.
- **Project: Application of ERM to Long Term Care at the Country/Government Levels**  
**Date Announced:** May 2017  
**Project Oversight Group:** Joint Risk Management Section  
**Purpose/Topic:** The research should provide a framework that other countries can use to advance their own LTC risk management and focus on LTC in Canada and the application of ERM within it, showing how ERM can be used as a method to help in future decision-making.

**Funding:** \$10,000 from JRMS in partnership with the CIA Research Executive Committee.

**Status:** This project was managed by the CIA and was published by the sponsoring organizations in May 2020.

- **Project: Negative Interest Rates and the Insurance Agency**  
**Date Announced:** Nov. 2016  
**Project Oversight Group:** Joint Risk Management Section  
**Purpose/Topic:** The project is intended to provide insurance company actuaries and risk managers with information on the range of attitudes and risk management practices across the insurance industry with respect to negative interest rates, both inside and outside of jurisdictions that have experienced negative interest rates.  
**Funding:** \$25,000 from JRMS  
**Status:** This project was managed by the JRMS Research Committee. The survey was posted on the CAS website in February 2019 and the final report was published by the sponsoring organizations in March 2020.

### 3. Ratemaking

- **Project: 2020 Ratemaking Call for Papers**  
**Date Announced:** Announced in July 2018  
**Project Oversight Group:** Ratemaking Committee  
**Contact:** Sandra Callanan  
**Purpose/Topic:** Papers on Ratemaking topics are accepted.  
**Funding Approved:** \$2,500, for the best papers.  
**Seminar/Meeting Presentations:** Ratemaking & Product Management Seminar, March 2019, March 2020  
**Publication:** Papers will be peer-reviewed with the intention of publishing them in *Eforum*.  
**Status:** The call for papers is complete, with one paper submitted to *Eforum* for publication.
- **Project: Ratemaking Call for Essays**  
**Date Announced:** November, 2020  
**Project Oversight Group:** Ratemaking Committee  
**Contact:** Ron Lettovsky  
**Purpose/Topic:** After a lackluster response to a new call for papers, the committee thought it might be a good change of pace to issue a call for essays. Authors will be given a few months to submit three-page essays on a variety of topics related to Ratemaking, with the goal of publication and presenting at the 2021 RPM.

### 4. Reinsurance

- **Project: 2021 Reinsurance Call for Papers**  
**Date Announced:** October 8, 2020  
**Project Oversight Group:** Committee on Reinsurance Research  
**Contact:** Neb Bojer  
**Purpose/Topic:** The Committee welcomes papers on any reinsurance-related topic, including but not limited to Cyber risk, the impact of COVID-19, climate change, predictive analytics in a reinsurance context, catastrophe modeling

**Funding Approved:** \$5,000

**Funding Expended:** \$0

**Presentation:** Paper is expected to be presented at the 2021 Seminar on Reinsurance

**Publication:** Paper is expected to be published in an upcoming e-Forum

**Status:** Proposals may be submitted until December 18, 2020

## 5. Reserves

- **Project: 2020 Reserves Call for Papers**  
**Contact:** Chandu Patel  
**Purpose/Topic:** Papers requested on any reserving topics of relevance and interest.  
**Funding Approved:** \$5,000 for the best papers and \$1,000 for the best practical tool).  
**Funding Expended:** No paper was deemed prize worthy  
**Presentations:** Authors of winning papers were invited to speak at the 2018 CLRS  
**Publication:** Accepted papers published electronically in the Summer 2020 issue of *CAS E-Forum*.  
**Status:** Completed.
- **Project: Exploring the Use of Machine Learning Techniques for P&C Loss Reserving**  
**Date Announced:** September 6, 2018  
**Project Oversight Group:** Committee on Reserves  
**Contact:** Julie Lederer  
**Purpose/Topic:** CASCOR wishes to explore the predictive analytics and machine learning techniques that have proliferated in recent years with the upsurge in computing power and data availability. We are specifically interested in how these processes may be applied to reserving.  
**Funding Approved:** \$30,000  
**Status:** This has been published
- **Project: Compartmental Reserving Models**  
**Date Announced:** September 6, 2018  
**Project Oversight Group:** Committee on Reserves  
**Contact:** Julie Lederer  
**Purpose/Topic:** The Reserves Committee is requesting research that expands upon previous work related to compartmental reserving models.  
**Funding Approved:** \$30,000  
**Status:** This has been published

## 6. Risk

- **Project: Economic Scenario Generators**  
**Date Announced:** October 16, 2018  
**Project Oversight Group:** Risk Committee  
**Contact:** Lawrence McTaggart  
**Purpose/Topic:** The Society of Actuaries released a practical guide to ESGs in 2016. COTOR and DRMC, now the Risk Committee, feel it would be useful to have

something similar which takes a deeper dive in the considerations and techniques that are relevant for P&C actuaries.

**Funding:** \$30,000

**Presentations:** TBD

**Publication:** TBD

**Status:** More than half of the chapters have been received and are currently under review.

## 7. Automated Vehicles Task Force

## 8. Cyber Risk

- **Project: Cyber Risk Management: Identification and Quantification of Unreported Healthcare Data Breaches**  
**Date Announced:** Contracted April, 2016  
**Project Oversight Group:** Cyber Risk Task Force  
**Contact:** Dave Cummings  
**Purpose/Topic:** A researcher from Drexel University was contracted to provide an article describing the research involving quantitative analysis of healthcare data breaches and its conclusions (the “Article”) performed as part of the research described in Appendix A.  
**Funding:** \$30,000  
**Presentations/Publications:** TBD  
**Status:** The paper was submitted to *Variance* in early 2020 and is awaiting publication.
- **Project: Exposure Bases in Pricing Cyber Insurance**  
**Date Announced:** July, 2018  
**Project Oversight Group:** Cyber Risk Task Force  
**Contact:** Brian Turner  
**Purpose/Topic:** RFP announced with the ultimate aim to provide actuaries with practical advice which speaks to what exposure bases and rating elements are most useful in pricing cyber risk.  
**Funding:** \$30,000  
**Status:** Published by the CAS as a Research Paper in June 2020.
- **Project: Quantification of Cyber Risk**  
**Date Announced:** April, 2019  
**Project Oversight Group:** Cyber Risk Task Force  
**Contact:** Dale Hall, SOA  
**Purpose/Topic:** The SoA has reached an agreement with SUNY Albany for research into the assessment and quantification of cyber risk. They reached out to the CAS and CIA to inquire whether we wanted to partner with them on the research. In exchange for a financial commitment, we could jointly publish the research and have a CAS member on the project oversight group.  
**Funding:** \$55,000 (CAS \$15,000; CIA \$15,000; SOA \$25,000)  
**Presentations/Publications:** TBD  
**Status:** Published by the sponsoring organizations in May 2020.

## 9. Other Topics

- **Project: Reinsurance, Dividends and Capital Optimisation in General Insurance Companies**  
**Date Announced/Completed:** Funding was awarded in June 2014  
**Researcher(s):** Corina Constantinescu, PhD, Joseph Lo, PhD, and David Siska, PhD  
**Topic:** The aim of the project is to investigate the optimal level of reinsurance versus capital reserve an insurance company should have, given its current risks and historical claim data.  
**Funding Sources:** \$20,800 (CAS)  
**Status:** The paper was submitted to *Variance* but rejected for publication. As the project surpassed the five-year sunset clause in Dec. 2019 with no acceptable revisions, it was terminated.
- **Project: Enhanced Predictive Modeling for Usage-Based Auto Insurance**  
**Date Announced/Completed:** Funding was awarded in March 2016  
**Researcher(s):** Jennifer, Chan, PhD; Boris Choy, PhD; and Udi E. Makov, PhD  
**Topic:** In this research project, the researchers explore the plausibility and benefits of machine learning procedures in enhancing UBI-based predictive models. In particular, the aim is to explore how machine learning algorithms can boost the classical GLM, resulting in new methodologies which retain a modeling context familiar to actuaries and DOI's, while relieving the GLM of inadequacies in rooted in telematics data.  
**Funding Sources:** \$7,000 (CAS), \$7,000 (SOA)  
**Status:** Work completed and was submitted to the NAAJ. Under review.
- **Project: Nonparametric Estimation for Data Modified by Truncation and Censoring**  
**Date Announced/Completed:** Funding was awarded in March 2016  
**Researcher(s):** Sam Efromovich, PhD; Wenui Lu, FSA; and Jerome Tuttle, FCAS, CPCU; Pankaj K. Choudhary, PhD  
**Topic:** Intellectual Merit of the proposal is defined by the following three objectives. (1) To advance knowledge and understanding of nonparametric (that is assuming no parametric formula/shape) estimation of the hazard rate and related distribution functions, develop the theory of sharp minimax nonparametric estimation of the hazard rate with left truncated and right censored data. This theory will allow actuaries and data-analysts to know how the truncation and censoring affect the constant of the MISE convergence. Furthermore, the theory should shed light on choosing the interval of estimation. Developing this theory is based on the recent result Efromovich (2015a) on estimation of the hazard rate for direct data. (2) Expand the asymptotic theory of optimal estimation to statistical inference including confidence bands and hypotheses testing. (3) Based on the asymptotic theory, suggest feasible data-driven statistical estimators, together with inference procedures, for "small" samples.  
**Funding Sources:** \$20,000 (CAS)  
**Status:** Paper completed and accepted for publication in *Variance*. It is awaiting publication in vol. 14 no. 2 next year.
- **Project: Exploring Cyber Risk Contagion - A Boundless Threat**  
**Date Announced/Completed:** Funding was awarded in June 2017



**Researcher(s):** Jing Ai, Ph.D.; and Tianyang Wang, Ph.D., ASA, FRM

**Topic:** The threat of cyber risk is ubiquitous and increasing. FBI notifies over 3,000 U.S. companies each year, from financial institutions to defense contractors to mega retailers, that they were victims of cyber security breaches (Segal, 2016). Most recently, in a public statement on December 14, 2016, Yahoo's Chief Information Security Officer reported a security breach that are "associated with more than one billion user accounts," subsequent to a separate security breach report back in September 2016, in which 500 million accounts were affected. According to PwC's 2014 *Global Economic Crime Survey*, an astounding 19% of U.S. organizations have claimed losses between \$50,000 and \$1 million, and 7% of U.S. organizations lost over \$1 million due to cybercrime in the previous year. The Center for Strategic and International Studies has estimated the annual cost of cybercrime and economic espionage to the world economy at more than \$445 billion, or almost 1 percent of the global GDP.

**Funding Sources:** \$40,000 (CAS)

**Status:** Submitted to *Variance*. This was accepted by *Variance* and will be published in vol. 14 no. 2 in 2021.

- **Project: Pricing Cyber Insurance for a Large-scale Network**  
**Date Announced/Completed:** Funding was awarded in August 2017  
**Researcher(s):** L. Hua, Ph.D./Northern Illinois University  
**Topic:** This project aims to develop a novel frequency-severity model for modeling and assessing cyber risks for a large-scale network based a reasonably small set of underwriting information, while accounting for the heterogeneity of the network nodes and their interdependence. The proposed methodology is able to account for the unique features of cyber risks and is expected to have an immediate impact on the actuarial practice for modeling cyber risks. Moreover, the theory and innovative models proposed will contribute fundamentally to the literature for risk modeling of general scale-free networks that widely exist in the real world (see many examples of scale-free networks in [2]).  
**Funding Sources:** \$20,000 (SOA/CAS)  
**Status:** Submitted to and accepted by *Variance* and will be published in vol. 14 no. 2 in 2021.
- **Project: Text Mining and Sentiment Analysis in Insurance**  
**Date Announced/Completed:** Funding was awarded in April 2017  
**Researcher(s):** Diego Zappa,; M. Borrelli; G.P. Clemente, Ph.D.; N. Savelli, Ph.D.; and G. Spedicato Ph.D.  
**Topic:** This proposal fits into the big data paradigm [1], which nowadays is more and more frequent both in applications and in scientific research. A strict definition of what it refers to does not yet exist. Generally speaking, big data may be depicted as an unstructured, large, heterogeneous and unstable dataset that often hides latent relevant information not measurable through a standard sampling process. Big data may be documents, the flow of tweets on the web, any social network, sentiment about the health of the economy, the status of either a country or a company, or the flow of documents produced during daily work (e.g. reports, recipes, phone calls, mails) and so on.  
**Funding Sources:** \$10,000 (CAS)  
**Status:** Accepted for publication in *Variance* Jan. 9, 2018. Tentatively scheduled for volume 14 no. 1.

- **Project: A Parsimonious Stochastic Model for Catastrophe Modelling with Climate Change Residuals**  
**Date Announced/Completed:** Funding was awarded in April 2018  
**Researcher(s):** Titus K. Rotich, Ph.D.; and Joseph Kyalo Mung'atu, Ph.D.  
**Topic:** The purpose of the proposed project is twofold: Firstly, is to lay down a theoretical framework for the development of a stochastic Catastrophe model (Cat Model) that incorporates climate change residuals. Secondly, is to develop a package within the R statistical software to implement the developed Cat Model, which shall be available within the R repository.  
**Funding Sources:** \$21,703 (CAS)  
**Status:** Agreement signed. Work in progress.
- **Project: Gaussian Process Models in Actuarial Science: A Guided Tour**  
**Date Announced/Completed:** Funding was awarded in June 2018  
**Researcher(s):** Michael Ludkovski, Ph.D.; and Howard Zail  
**Topic:** Our vision is to promote the GP framework to both academics and practitioners, thereby complementing other machine learning concepts that are rapidly gaining currency in Actuarial Science [3,6,11,21]. To do so, we will develop several case studies as well as offer a guided overview. The case studies will demonstrate and expand the practical use of GPs as part of the actuarial toolbox and bridge latest theoretical advances with targeted adaptations for key actuarial contexts.  
**Funding Sources:** \$35,000 (CAS)  
**Status:** Submitted to and accepted by *Variance*. Not yet published.
- **Project: Credibility theory under a general dependency structure of risk profile between frequency and severity of loss**  
**Date Announced/Completed:** Funding was awarded in June 2018  
**Researcher(s):** Jae Kyung Woo, Ph.D. and Eric Cheung, Ph.D.  
**Topic:** Its goal is to set a premium for a policy (of unknown risk profile) based on the policy's past claim history as well as information from the collective that contains similar policies possibly of different (and unknown) risk profiles. For property and casualty insurers, it is important to estimate the future claim costs accurately which can be used to set up an appropriate level of predictive premium. Underestimation of the premium results in failure of achieving the target profit of the company, whereas overestimation could make the insurer less competitive in the market. We propose a Bayesian approach allowing for dependent prior information for the frequency and severity of claim. Incorporating individual's characteristic variables leads us to construct more accurate Bonus-Malus System (BMS) compared to the traditional approach.  
**Funding Sources:** \$20,000 (CAS)  
**Status:** Submitted to and accepted by *Variance*. Not yet published.
- **Project: Maximum likelihood inference of predictive models for misrepresentation risk in GLM ratemaking**  
**Date Announced/Completed:** Funding was awarded in April 2018  
**Researcher(s):** Michelle Xia, Ph.D.  
**Topic:** We seek funding for extensions of our completed work [10] on predictive analysis of misrepresentation risk in ratemaking under the framework of generalized linear models (GLM): Theoretically, we propose to derive new algorithms for maximum likelihood estimation (MLE) that is commonly used for GLM ratemaking;

Computationally, we propose to develop a package in the statistical software R to facilitate the application of the new methods by the insurance industry.

**Funding Sources:** \$15,500 (CAS)

**Status:** Submitted to *Variance* and under review.

- **Project: Recommender Systems in Insurance Business**  
**Date Announced/Completed:** Funding was awarded in April 2018  
**Researcher(s):** Giorgio Spedicato, Ph.D., FCAS, FSA, CSPA, C.Stat  
**Topic:** The research aims to review and apply most relevant RS techniques on a representative insurance portfolio data set in order: 1) To provide a general overview of RS methods with a focus on Insurance Industry. 2) To present an application of key methodologies like Apriori (Agrawal & Srikant, 1994), collaborative filtering (Hahsler, 2011) and binary matrix factorization (Nenova, Ignatov, & Konstantinov, 2013; Udell, Horn, Zadeh, & Boy, 2016) on a real insurance dataset comparing: a. their predictive performance; b. the ease of their usage and their interpretability. 3) To explore the use of one or more advanced approach on the same data, like Deep Neural Networks and Gradient Boosted Models.  
**Funding Sources:** \$8,000 (CAS)  
**Status:** Submitted to and accepted by *Variance*. Not yet published.
- **Project: Model Risk Assessment on Tails of Portfolio of Insurance Policies**  
**Date Announced/Completed:** Funding was awarded in April 2019  
**Researcher(s):** Carole Bernard, Rodrigue Kazzi, and Steven Vanduffel  
**Topic:** Insurance companies use models to assess the risk of their portfolios. No model, however, is perfect and model-based decisions might be highly sensitive to underlying model deviations. In our research, we develop a methodology that allows measuring the error one can make by using misspecified portfolio models. Our starting point is a given model of which we trust some characteristics such as the mean, the variance, the unimodality, the non-negativity, and the probabilities on certain (but not all) outcomes. We then provide the worst case, the best case, and the most plausible distribution for the portfolio loss such that it complies with the trusted characteristics. We provide analytical and numerical solutions and implement them in an R-package that we will make publicly available.  
**Funding Sources:** \$21,000 (CAS)  
**Status:** Submitted to *Variance*. Under review.
- **Project: Assessing Systemic Risk in the Insurance Sector Via Network Theory**  
**Date Announced/Completed:** Funding was awarded in April 2019  
**Researcher(s):** Alessandra Cornaro, Ph.D; Gian Paolo Clemente, Ph.D. and Edoardo Glauco Luini.  
**Topic:** In this framework, our aim is to provide a peculiar approach based on network theory to analyse the downside risk of insurance sector and its behaviour in times of financial crisis. A variety of empirical studies and different techniques have been proposed in finance, undertaken through the prism of the graph theory, in order to catch interconnections between firms and to assess systemic risk. At the best of our knowledge, these methods have not yet been investigated in the insurance sector. A brief overview of the existing methodologies provided in the literature to assess systemic risk and a description of the methodological details of our proposal are reported in next sections.

**Funding Sources:** \$12,000 (CAS)

**Status:** Agreement signed. Work in progress.

- **Project: Multiple Peril Maps and Uncertainty Quantification for Climate Induced Risks in Agricultural Insurance with Deep Learning and Climate Model Ensembles**

**Date Announced/Completed:** Funding was awarded in July 2019

**Researcher(s):** April 2019

**Topic:** We propose to develop novel machine learning approaches, based on a combination of the deep learning framework with copula methodology, targeting to deliver not only more robust and data driven agricultural risk assessment and space-time prediction of crop production losses but more importantly to yield systematic uncertainty quantification in agricultural insurance under limited data availability. The proposed methodology further advances the results on nonparametric modeling of atmospheric risks in home insurance [9] and on deep Bayesian networks in agricultural insurance.

**Funding Sources:** \$20,000 (CAS)

**Status:** Submitted to *Variance*. Under review.

- **Project: Anonymizing Private Property/Casualty Ratemaking Datasets using Generative Adversarial Networks**

**Date Announced/Completed:** Funding was awarded in April 2019

**Researcher(s):** Marie-Pier Côté

**Topic:** We will base the synthetic dataset on the French Motor Third Party Liability datasets, publicly available in the R package “CASdatasets.” These two datasets contain individual policy characteristics, claim number and claim severity for 413,169 and 678,013 policies, respectively, observed over at most one year. After synthesizing the datasets and showing some simple summary statistics, we will run many models on the synthetic and original datasets. This will allow the reader to compare the datasets and resulting models and become convinced that the synthetic dataset is both free from private information and valuable for research.

**Funding Sources:** \$27,000 (CAS)

**Status:** Submitted to *Variance*. Under review.

- **Project: Explaining Machine Learning Models for Insurance Rating**

**Date Announced/Completed:** Funding was awarded in April 2019

**Researcher(s):** Kevin Kuo and Daniel Lupton

**Topic:** Risk classification for insurance rating has traditionally been done with one-way, or univariate, analysis techniques. In recent years, many insurers have moved towards using generalized linear models (GLM), a multivariate predictive modeling technique, which addresses many shortcomings of univariate approaches, and is currently considered the state of the art in insurance risk classification. At the same time, machine learning (ML) techniques such as random forests and deep neural networks have gained popularity in many industries due to their superior predictive performance over linear models. However, these ML techniques, often considered to be completely “black box”, have been less successful in gaining adoption in insurance pricing, which is a regulated discipline and requires a certain amount of transparency in models. While recent efforts in ML research have attempted to provide mechanisms for explaining or interpreting these complex models, to the best of our knowledge none has focused on the insurance pricing use case, which we plan

to address in this project. We envision that this work will be a step-in enabling insurers to use and file more accurate predictive models, which lead to fairer prices. In addition, it is our intent that this work will assist practitioners in complying with relevant Actuarial Standards of Practice related to ratemaking, modeling, and clear communication of relevant assumptions. This will have additional benefits to regulators and other stakeholders tasked with reviewing actuarial work products.

**Funding Sources:** \$30,000 (CAS)

**Status:** Submitted to and accepted by *Variance*. Not yet published.

- **Project: Developing Advanced Actuarial Compensation Tables for Injury and Death: A Reconciliation of Actuarial Models and the Law**  
**Date Announced/Completed:** Funding was awarded in April 2019  
**Researcher(s):** Şule Şahin; and Gary Venter,  
**Topic:** The aim of our research is to introduce advanced actuarial Markov models for compensation benefits for the loss of future income, as indicated by mortality, work life expectancy and stochastic discount rates. Our models will reconcile with legal requirements by reflecting the regulations in the mathematical formulas in order to address conflicts between jurists/lawyers and actuarial expert witnesses about the calculation. We will categorise the main legal issues that affect the calculation, develop actuarial approaches for each issue by using some of the emerging methodologies, and illustrate the problem of mis-implementation by courts as well as ways to avoid this. We will use our model to construct standard compensation tables for different jurisdictions. Once we develop a theoretical model, we will use mortality, labour force participation, and other socio-economic data to estimate the parameters. We will construct an advanced compensation table for illustrative US state requirements, and then extend our research to requirements in countries such as UK and Spain.  
**Funding Sources:** \$20,000 (CAS)  
**Status:** Agreement signed. Work in progress.
- **Project: Spatial modelling of driver crash risk using georeferenced data**  
**Date Announced/Completed:** Funding was awarded in April 2019  
**Researcher(s):** Diego Zappa, Ph.D. (Project leader); A. Amico; M. Borrelli; G.P. Clemente, Ph.D.; and N. Savelli, Ph.D.  
**Topic:** Modern technology and sophisticated algorithms are progressively changing the traditional approach to the estimation of pure premiums. In non-life lines of business, the widely used generalized linear models are nowadays increasingly connected with machine/statistical learning methods capable of efficiently grasping the nonlinear and/or heteroscedastic risk components often present in insurance datasets [1][2][3]. How to exploit to the maximum the capability of these new algorithms is a new challenge for the future. One strategy is to enrich the traditional database with “exogenous” variables (at the minimum cost whenever possible) able to capture additional portions of standard GLM model residuals and consequently to improve the precision of the risk estimate.  
**Funding Sources:** \$14,000 (CAS)  
**Status:** Agreement signed. Work in progress.
- **Project: Research on Machine Learning Applications to Actuarial Science**  
**Date Announced/Completed:** Funding was awarded in April 2019

**Researcher(s):** Rick Gorvett, PhD; Alicia Lamere, PhD; Son Nguyen, PhD; and Gao Niu PhD

**Topic:** Predictive modeling and data science are increasingly widespread and important in actuarial science. New basic education requirements and continuing education opportunities in these areas have recently been introduced by both the CAS and SOA, and researchers and practitioners alike are becoming more and more interested in utilizing the relevant methods. Among the most promising of these methods is machine learning, which involves a system that creates and improves models through pattern recognition and learning from data. The objective of this research is to explore the potential for applications of machine learning to actuarial science. In particular, our goals are to (1) develop a framework and written guide for the application of machine learning to problems in actuarial science, risk management, and insurance; (2) undertake at least two specific machine learning research projects of relevance to the actuarial community; and (3) provide students with opportunities for undergraduate research, and experience working with machine learning methods and data procurement, in this important area.

**Funding Sources:** \$ 9,430 (CAS)

**Status:** Agreement signed. Work in progress.

- **Project: "Adjusting Manual Rates to Own Experience: Comparing the Credibility Approach to Machine Learning"**

**Date Announced/Completed:** Funding was awarded in April 2020

**Researcher(s):** Christophe Dutang, Giorgio Alfredo Spedicato, Ph.D., Quentin Guibert

**Topic:** The project subject of funding aims to investigate to what extent machine learning methodologies may help to add market data information to individual portfolio experience as well as to make a fair comparison with traditional credibility methods. After reviewing machine learning algorithms and traditional credibility regression models, we will develop a practical application of such techniques on an anonymized dataset related to crop insurance in Europe.

**Funding Sources:** \$13,000 (CAS)

**Status:** Agreement signed. Work in progress.

- **Project: "A Realistic Risk Dependence via General Additive Models: Effects of Heavy-Tailedness and Dependence on Loss Reserving"**

**Date Announced/Completed:** Funding was awarded in April 2020

**Researcher(s):** Edward Furman, Ph.D., Yang Shen, Ph.D., Andrew Fleck

**Topic:** In the research, we put forward and study a general ABRM. This allows for considerable freedom in the choice of the distributions of the idiosyncratic and systematic RFs, thus reflecting the fact that the risks due to distinct lines of business (LoBs) are often very heterogeneous in nature, as well as that the systematic risk - which may be frequently heavy-tailed - deserves special attention. We propose to drop Assumptions (A2) and (A3) above, but retain the much-desired tractability of the simple ABRM. The potential applications of a dependence structure of the kind we explore are vast and cut across virtually all sub-domains of actuarial science. In the proposed research we have decided to examine the effect of the general ABRM dependence on the notion of stochastic loss reserving. Our preliminary message to practitioners is this: while it is very hard to detect in data, systematic heavy-tailedness - even if merely at the incremental payments level - drives the variability inherent in the aggregate outstanding loss liability.

**Funding Sources:** \$24,000 (CAS)

**Status:** Agreement signed. Work in progress.

- **Project: "Categorical Predictor Embeddings in Actuarial Modeling"**  
**Date Announced/Completed:** Funding was awarded in April 2020  
**Researcher(s):** Kevin Kuo, Ronald Richman  
**Topic:** While several studies have shown that applying this technique leads to high predictive accuracy, nonetheless, several open questions remain: - How do embedding relate to classical actuarial techniques for modelling categorical data? - What guidance can be given for choosing the hyperparameters of embedding layers? - How can embedding layers be used in GLM models? - Can insights from credibility theory lead to enhanced embeddings? - Can the modelling of numerical variables benefit from the application of embedding layers? In this research, we will examine these questions and look to provide the theoretical underpinnings of and practical guidance to actuaries on a new technique that can be used for everyday modelling problems.  
**Funding Sources:** \$30,000 (CAS)  
**Status:** Agreement signed. Work in progress.
- **Project: "Regression shrinkage and selection for actuarial models"**  
**Date Announced/Completed:** Funding was awarded in April 2020  
**Researcher(s):** Gee Lee, Ph.D.  
**Topic:** The purpose of this project is to extend the use of loss models to problems requiring variable shrinkage and selection. Parametric loss models are essential to the work of an actuary, and recent advancements in the statistical learning literature illustrates that it is possible to construct regression models with automatic variable selection using penalized likelihoods. Variable selection and shrinkage allow a modeler to avoid overfitting in problems where a large number of explanatory variables are available. This project will attempt to build loss models with automatic variable selection capability.  
**Funding Sources:** \$10,000(CAS)  
**Status:** Agreement signed. Work in progress.
- **Project: "Statistical Models and Algorithms for Assessing Robustness and Reliability of Networks with Applications in Cyber Insurance"**  
**Date Announced/Completed:** Funding was awarded in April 2020  
**Researcher(s):** Hon Keung Tony Ng, Ph.D.  
**Topic:** The main objective is to develop dependable and flexible statistical algorithms to assess the robustness and reliability of complex networks and to provide measures of similarity between networks. We also aim to apply the proposed methodologies to evaluate risks and price insurance related to both cyber and physical networks such as cyber space, Internet, power grids, and water line systems.  
**Funding Sources:** \$20,000 (CAS)  
**Status:** Agreement signed. Work in progress.
- **Project: "Determining Vehicle Symbols Using Machine Learning Techniques"**  
**Date Announced/Completed:** Funding was awarded in April 2020  
**Researcher(s):** Giorgio Alfredo Spedicato, Ph.D, Marco De Virgilis  
**Topic:** Our objective is to provide a theoretical background and review current uses and implementations. We will also show a worked example presenting how open and easily accessible tools could be used in the VS estimation framework. Several

algorithms will be implemented and the performance achieved will be evaluated and compared. Such comparisons will focus on the model performance, and also the practical issues that a practitioner could encounter.

**Funding Sources:** \$14,000 (CAS)

**Status:** Agreement signed. Work in progress.

- **Project: "Auto Insurance Pricing Using Telematics Data: Application of a Hidden Markov Model"**  
**Date Announced/Completed:** Funding was awarded in April 2020  
**Researcher(s):** Qiao Jiang, Tianxiang Shi, Ph.D.  
**Topic:** This project aims to explore new data analytic techniques for auto insurance risk classification and pricing, using a proprietary dataset provided by Verisk Analytics, Inc. Recently, a new type of data, namely telematics data, has been widely used in auto insurance risk classification and pricing. The telematics data collects various driving information, such as GPS coordinates, time period, acceleration at each direction, and speed, etc. Compared to traditional rating variables, telematics data directly captures policyholders' driving behavior, and allows insurers to detect the so-called auto insurance premium leakage (due to omitted or misstated underwriting information) at an individual level. Following this effort, we develop a Hidden-Markov based predictive model, which can powerfully identify the dynamics of driving behavior by time and provides new insights to both actuarial researchers and practitioners on utilizing telematics data for auto insurance pricing. The proposed methodology may also be applied in other actuarial fields that involve high frequency data (i.e., time series data with updates occur in every second).  
**Funding Sources:** \$7,500 (CAS), \$7,500 (SOA)  
**Status:** Agreement signed. Work in progress.
- **Project: "Extended ECM Algorithm for Fitting Mixture of Experts Models to Censored and Truncated Regression Data"**  
**Date Announced/Completed:** Funding was awarded in April 2020  
**Researcher(s):** X. Sheldon Lin, Ph.D., Andrei Badescu, Ph.D., Tsz Chai (Samson) Fung  
**Topic:** The objectives of our project are summarized as follows: • To extend the ECM algorithm to randomly censored and truncated regression data. • To demonstrate the importance and effectiveness of the proposed algorithm empirically through a simulation study. • To investigate into two actuarial applications using real automobile insurance datasets: Individual claim reserving and deductible ratemaking.  
**Funding Sources:** \$7,000 (CAS), \$7,000 (SOA)  
**Status:** Agreement signed. Work in progress.
- **Project: "Pricing and Reserving Wildfire Insurance in North America"**  
**Date Announced/Completed:** Funding was awarded in April 2020  
**Researcher(s):** Méлина Mailhot, PhD, Mathieu Boudreault, Ph.D  
**Topic:** The main objective of this research project is to create an actuarial spatial model for wildfire occurrence and size to assess the loss distribution at the individual and portfolio levels. An important purpose of this project is to provide a transparent and simple, yet powerful model that can be used by actuaries to price, reserve or manage the financial risk from wildfires.  
**Funding Sources:** \$13,500 (CAS)  
**Status:** Agreement signed. Work in progress.



- **Project: " Multivariate Mixtures of Gamma Distributions: A Joyful Toolkit for Modeling Dependent Insurance Data"**  
**Date Announced/Completed:** Funding was awarded in April 2020  
**Researcher(s):** Qifan Song, PhD, Jianxi Su, PhD  
**Topic:** Multivariate loss distributions have been a staple of actuarial work for many years. This proposal aims to put forth a versatile class of multivariate mixtures of gamma distributions tailored for actuarial applications. Particularly, the proposed models enjoy the merits: a.) admitting meaningful and relevant interpretations; b.) allowing for an adequate fit to a wide range of multivariate data, be it in the marginal distribution and in the dependence; c.) possessing desirable distributional properties for insurance valuation and risk management; and d.) can be readily implemented.  
**Funding Sources:** \$14,000 (CAS)  
**Status:** Agreement signed. Work in progress.
- **Project: Flood Risk and Spatial Diversification**  
**Date Announced:** May 2019  
**Contact:** Brian Fannin  
**Purpose/Topic:** This project has three research objectives: (1) to provide an introduction to flood risk modeling for actuaries, (2) to extend the research literature on ratemaking and reserving for flood risk, and (3) to research the connection between spatial dependence in flood risk and diversification.  
**Funding:** \$33,551  
**Presentations/Publications:** TBD  
**Status:** Research is underway
- **Project: Demand for Microinsurance**  
**Date Announced:** May 2019  
**Contact:** Brian Fannin  
**Purpose/Topic:** Researchers will look to determine the factors that drive the demand of microinsurance in developing countries of varying level of development as well as in a developed country. In the latter context, the researchers think of microinsurance as a form of accessible insurance for low-income individuals. Research funds will be used to conduct a pilot study, in which researchers will test the conjecture that microinsurance (or accessible insurance) is in fact not realized in a developed country like Canada. Funds will be used towards covering the expenses of data collection.  
**Funding:** \$21,000  
**Presentations/Publications:** Forecast early 2021  
**Status:** An initial draft has been reviewed and comments are being shared with the author
- **Project: On Insurability and Transfer of Pandemic Business Interruption Risk**  
**Purpose:** The CAS would like to generate content which speaks to the pressing issue of COVID-19, but which may remain relevant for some time in the future  
**Funding:** \$0  
**Status:** A POG is reviewing the first draft
- **Project: Introduction to Data Visualization**  
**Purpose:** The CAS wanted to establish some common awareness, language and principles about data visualization for actuaries  
**Funding:** \$0

- **Project:** Cannabis and auto frequency  
**Purpose:** The CAS and CIA have had discussions about joint research projects which would be relevant for actuaries in the US and Canada. Given the different legal treatment of cannabis in recent years, this forms a natural experiment to gauge impact on auto accident frequency.  
**Funding:** ~~\$420~~ \$33,000  
**Status:** This project is being announced, with submissions through the end of the year
- **Project:** Peer-to-Peer Insurance  
**Approved:** February 2020  
**Researcher:** Runhuan Feng, University of Illinois  
**Purpose:** An overview of business models with the most influential players in the mutual aid/P2P insurance industry. A review of the current state of development for the new industry. A technical assessment of these business models. A discussion of areas in which actuaries can be involved for the development in this new industry.
- **Project:** Auto Loss Costs Trends  
**Date Announced:** 2016  
**Researcher:** Brian Hartman  
**Purpose/Topic:** The CAS, the SOA and the American Property Casualty Insurance Association banded together to analyze auto loss cost trends reflecting an uptick in property damage liability and collision frequency. Using publicly available data from the Federal Highway Administration, Bureau of Labor Statistics, the Census Bureau, and other sources, an analysis group is searching for explanatory variables. Over two dozen variables were considered within the Lower 48 States and Alaska but excluding the District of Columbia.  
**Funding:** \$16,000 (CAS share)  
**Status:** Four reports published between January 2018 and November 2020. Work ongoing.