

**Information Paper
for
CAS Board of Directors**

Subject: Annual Research Report

Responsible Officer: Avraham Adler, 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 2019 Report is attached. The report consists of two components:

- A. Overview and Status of 2018-2019 CAS Research Activities
Details on CAS research projects are provided in this attachment, organized by topic.
- B. CAS Research Commitments and Expenditures (2003-2019)
Annual funding commitments to research projects and call paper programs are summarized in a spreadsheet.

CAS Research: 2019 Overview

During the 2018 – 2019 year the CAS Research Department completed a number of significant projects, including

- 2019 Non-Technical Reserves Call for Papers generated 3 completed papers. “Relative Unpaid Claims Loss Reserving” by Bertram Horowitz was given a cash prize at the CLRS.
- 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 September
- Papers sponsored through the Individual Grants Competition
- COTOR Call for Essays
- Ratemaking Predictive Modeling RFP by Brian Hartman and Alisa Walch
- Created an organizational account on the cloud collaboration platform GitHub.

Notable work currently in progress includes

- Cyber Risk Task Force: Exposure Bases in Pricing Cyber Insurance paper written by Michael Bean is undergoing final revisions
- 2020 Ratemaking Call for Papers (two papers still in progress for the two-year track to be published early 2020)
- Compartmental Reserving Models RFP
- Exploring the Use of Machine Learning Techniques for P&C Loss Reserving
- 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
- Research on the demand for microinsurance in North American being conducted by Ed Furman at York University

In 2019, two working parties concluded their work. Three working parties are currently under way.

In an effort to streamline research and keep things current, the Dynamic Risk Modeling Committee and the Theory of Risk Committee joined forces and are now collectively the Risk Committee.

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 and SOA. We have ongoing dialogue with staff at the Institute and Faculty of Actuaries to explore sensible partnerships on general insurance research.

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 with representatives from the SOA, the CIA, AAA and IFOA at this year’s event.

November 10, 2019

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 volunteers, will make continued progress during the 2019-2020 year. I thank you for the opportunity to serve you in this capacity since 2017.

Sincerely,

Avraham Adler
VP – Research & Development

Status of 2019 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 2019 were made to the database.
- **Project: Developing Adaptive Climate Indices for Evaluation of the Impact of Climate Change on Insurance Risks**
Project Oversight Group: Climate Change Committee
Contact: Doug Collins
Purpose/Topic: This project has two purposes: 1.) To perform a statistical analysis of a number of claims due to floods, heavy rain and storms with respect to varying frequencies and magnitudes of climatic events; and 2.) to develop a new data-driven adaptive climate risk index that links future climate projections with insurance risks.
Funding Approved: \$31,500
Status: Complete. Published in *Variance* (vol. 12, iss. 2) as “Where Home Insurance Meets Climate Change: Making Sense of Climate Risk, Data Uncertainty, and Projections”

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: Joint CAS/CIA/SOA Risk Management Section Award for Practical Risk Management Applications**
Date Announced: Yearly. (No call for papers planned for 2020.)
Project Oversight Group: Joint Risk Management Section
Purpose/Topic: Every year the JRMS selects a research paper submitted to the ERM Call for Papers for best practical application.
Funding: \$5,000 from JRMS.
Seminar/Meeting Presentations: At the ERM Symposium.
Publication: Published annually in August on the SOA website in a monograph of ERM Calls for Papers.
Status: The 2019 award was presented to Dariush Akhtari for his paper, “A Novel Approach to Valuing an Insurance Company’s Economic Surplus.”
- **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 is managed by CIA and is finishing up.
- **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 is managed by the JRMS Research Committee. The survey was posted on the CAS website in February 2019 and the research is finishing up.

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: Three papers were accepted into the two-year cycle, with the intention of publishing them in 2020. One paper dropped out, but two are still in progress.

- **Project: Predictive Modeling RFP**
Date Announced: February 2018
Project Oversight Group: Ratemaking Committee
Contact: Sandra Callanan
Purpose/Topic: To put forth an RFP related to Predictive Modeling in which the CAS will provide data for researchers to use.
Funding Approved: \$25,000
Seminar/Meeting Presentations: RPM 2020
Publication: *Eforum*
Status: The work has been completed and submitted to *Variance* for publication.
- **Predictive Models: A Practical Guide for Practitioners and Regulators**
Date Announced: April 2019
Project Oversight Group: Ratemaking Committee, WP on Best Practices for Predictive Model Documentation
Contact: Don Closter
Purpose/Topic: This white paper provides both practitioners and model reviewers (i.e. product managers and regulators) with recommendations for analysis and review of predictive models (in particular GLMs), including guidance with respect to the creation, testing, documentation, and evaluation of models. This information is meant to assist both practitioners and reviewers in their efforts to be comfortable with final model results.
Funding Approved: n/a
Seminar/Meeting Presentations: TBD
Publication: CAS Website
Status: Work began in 2017. The work has been completed and published.

4. Reinsurance

- **Project: 2019 Reinsurance Call for Papers**
Date Announced: July 9, 2018
Project Oversight Group: Committee on Reinsurance Research
Contact: Neb Bojer
Purpose/Topic: The Committee seeks papers on any reinsurance-related topic, including but not limited to: reinsurance pricing or reserving considerations and methodologies for cyber risk, mortgage risk, alternative capital vehicles, multi-year deals, enhancements, or challenges, to traditional reinsurance methodologies & techniques; credibility methods for combining exposure and experience estimates of loss cost; the impact of rising interest rates on reinsurers and reinsurance pricing catastrophe modeling; predictive analytics in a reinsurance context; backtesting of actual results vs. expected results from pricing algorithm
Funding Approved: \$5,000
Funding Expended: \$0

Presentation: Paper is expected to be presented at the 2019 Seminar on Reinsurance

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

Status: Cancelled due to lack of participation

5. Reserves

- **Project: 2018 Reserves Call for Papers**
Date Announced: November 2017
Project Oversight Group: Committee on Reserves
Contact: Denise Ambrogio
Purpose/Topic: Papers requested on the topics of: opinion issues; best estimates, variability, and ranges; methodologies; unique or changing exposures; and other matters affecting reserving. Committee is trying the non-technical twist again to see if more papers will be published.
Funding Approved: \$6,000 (\$5,000 for the best papers and \$1,000 for the best practical tool).
Funding Expended: The chair of the committee experienced some health issues during the summer, which had some bearing on the committee not having evaluated the papers for the purpose of awarding cash prizes. The committee will assess the papers and make an award determination soon.
Presentations: Authors of winning papers were invited to speak at the 2018 CLRS
Publication: Accepted papers published electronically in the Winter 2019 issue of *CAS E-Forum*.
Status: Completed.
- **Project: 2019 Non-technical reserving call paper program**
Date Announced: Announced October 17, 2018
Project Oversight Group: Committee on Reserves
Contact: Julie Lederer
Purpose/Topic: The goal of the paper program is to encourage and develop more practical and less technical paper. As well, we seek to foster the sharing of practical ideas between actuaries which can be used on a day-to-day basis and readily explained to others. Authors are encouraged to focus on presenting ideas in a logical manner accessible to other actuaries and professionals with experience in reserving.
Funding Approved: \$5,000
Presentations: Authors of accepted papers were invited to speak at the 2019 CLRS.
Publication: Accepted papers will be published electronically in the *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
Presentations: TBD

Publication: TBD
Status: Final edits are underway

- **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
Presentations: TBD
Publication: TBD
Status: Final edits are underway

6. Risk

- **Project: Call for Essays**
Date: September, 2018
Project Oversight Group: Theory of Risk Committee
Contact: Lawrence McTaggart
Purpose/Topic: Call for Essays on the topic of Communications to Senior Management. Essays should describe and discuss practical approaches to communicate technical results to senior management.
Funding: \$2,000
Presentations:
Publication: TBD
Status: Three papers were completed by Feb. 2019 and are awaiting publication in *Eforum*.
- **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: Fundamental Approach to Cyber Risk**
Date Announced: February 2015

Project Oversight Group: Cyber Risk Task Force

Contact: Dave Cummings

Purpose/Topic: A researcher from Innsbruck University in Austria was contracted to produce a research document discussing an overview of the existing research most relevant to the analysis of cyber risk for cyber insurance and proposing a general approach and methodology for cyber insurance modeling, building on the previous research by the professor and the latest developments in cyber insurance and cyber risk modeling research, as specified in the research proposal, the terms of which are incorporated herein by reference.

Funding: \$30,000

Presentations/Publications: A final report was submitted to the task force in May 2016; they are working with the researcher to have it submitted for publication to *Variance*. Published in *Variance* (vol. 12, iss. 2).

Status: Complete.

- **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 authors plan to finish the work by the end of 2019.
- **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
Presentations/Publications: TBD
Status: Final edits are underway
- **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: Work underway

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. Authors plan to edit and resubmit.
- **Project: Risk Measurement Based on Available Information**
Date Announced/Completed: Funding was awarded in April 2015
Researcher(s): Yiqing Chen and Rahul Parsa
Topic: In this project, the researchers will focus on the measurement of a risk variable associated with a few other risk variables, interpreted for example as risk factors, which are exactly or partially known.
Funding Sources: \$6,000 (CAS)
Status: The paper was rejected by *Variance* and the researchers will submit it to another journal.
- **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: Agreement signed. Work in progress.
- **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*.

- **Project: Embedded predictive analysis of misrepresentation risk in GLM ratemaking models**
Date Announced/Completed: Funding was awarded in March 2016
Researcher(s): Michelle Xia, PhD
Topic: For the current project, we aim to develop GLM ratemaking models that embed predictive analyses of misrepresentation risk. The particular objectives include: (1) to confirm whether the proposed model gives valid inference on how various risk factors affect the probability of misrepresentation, when we model the relationship under the GLM framework with regular ratemaking data; (2) to verify whether the ratemaking model can identify the misrepresentation probabilities and risk effects, when there are multiple risk factors subject to misrepresentation; (3) to assess the possible impact from and on other risk factors that do not suffer from misrepresentation; (4) to conduct simulation studies to confirm the theoretical findings, as well performing case studies using the Medical Expenditure Panel Survey (MEPS, [1]) data.
Funding Sources: \$12,500 (CAS)
Status: Paper completed and published in *Variance* (vol. 12, iss. 1) as “Embedded Predictive Analysis of Misrepresentation Risk in GLM Ratemaking Models”
- **Project: Machine Learning and ‘Big Data’ Methodologies for Policyholders’ Retention and Conversion Modeling**
Date Announced/Completed: Funding was awarded in March 2016
Researcher(s): Giorgio Alfredo Spedicato, PhD, ACAS; Luca Lombardi; and Christophe Dutang, PhD
Topic: The project subject of funding proposal aims to investigate to what extent machine learning methodologies improve policyholders’ retention and conversion estimation with respect to classical GLM. The investigation will both review the machine learning algorithms currently used in business application and develop a practical application of such algorithms on a real insurance data set to compare their performance with a standard logistic GLM approach.
Funding Sources: \$6,500 (CAS), \$6,500 (SOA)
Status: Paper completed and published in *Variance* (vol. 12, iss. 1) as “Machine Learning Methods to Perform Pricing Optimization: A Comparison with Standard Generalized Linear Models”
- **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*. The author is revising the manuscript following feedback from peer review.

- **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: Agreement signed. Work in progress.
- **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 *Variance* and under review.
- **Project: Credibility theory under a general dependency structure of risk pro le 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 *Variance* and under review.
- **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 *Variance* and under review.

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

- **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: Agreement signed. Work in progress.

- **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: Agreement signed. Work in progress.

- **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): Kevin Kuo and Daniel Lupton
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: 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: TBD
Status: Research is underway

CAS Research Commitments and Expenditures (2003-2020)

As of October 31, 2019.

FY 2020 (Budgeted to Research Fund: \$)

Sponsor	Project / Researcher	Original Commitment	Expense to Date	Commitment Balance
Ratemaking	2020 Call Paper Prize	7,500.00	-	7,500.00
TOTAL		\$ 7,500.00	\$ -	\$ 7,500.00

FY 2019 (Budgeted to Research Fund: \$340,177)

Sponsor	Project / Researcher	Original Commitment	Expense to Date	Commitment Balance
Reserves	Individual Claims Reserving	30,000.00	-	30,000.00
Reserves	2019 Non Technical Call Papers (<i>Note: not all prize awarded</i>)	5,000.00	2,500.00	-
Reinsurance	2019 Call Paper Prize (<i>cancelled</i>)	5,000.00	-	-
Climate Change	Climate Data Users Guide	25,000.00	-	25,000.00
CAS	Flood Risk and Spatial Diversification	33,551.00	5,000.00	28,551.00
CAS/SOA	Insurance Implications of Cryptocurrency	15,000.00	-	15,000.00
CAS/SOA/PCI	Auto Loss Cost Trends	10,000.00	-	10,000.00
CAS	Microinsurance as Social Innovation	21,000.00	10,500.00	10,500.00
CAS/SOA	Quantification of Cyber Risk	15,000.00	-	15,000.00
CAS	Bernard, et.al., "Model Risk Assessment on Tails of Portfolio of Insurance Policies"	21,000.00	5,250.00	15,750.00
CAS	Cornaro, et.al., "Assessing systemic risk in the insurance sector via network theory"	12,000.00	3,000.00	9,000.00
CAS	Gel, et.al., "Multiple Peril Maps and Uncertainty Quantification for Climate Induced Risks in Agricultural Insurance with Deep Learning and Climate Model Ensembles"	20,000.00	5,000.00	15,000.00
CAS	Hartman, et.al., "Anonymizing Private Property/Casualty Ratemaking Datasets using Generative Adversarial Networks"	20,000.00	5,000.00	15,000.00
CAS	Kuo, Lupton, "Towards Explainability of Machine Learning Models in Insurance Pricing"	20,000.00	7,500.00	12,500.00
CAS	Venter, et.al., "Developing Advanced Actuarial Compensation Tables for Injury and Death: A Reconciliation of Actuarial Models and the Law"	20,000.00	5,000.00	15,000.00
CAS/SOA	Zappa, et.al., "Spatial modelling of driver crash risk using georeferenced data"	14,000.00	3,500.00	10,500.00
CAS/SOA	Gorvett, et.al., "Research on Machine Learning Applications to Actuarial Science"	9,430.00	1,500.00	7,930.00
TOTAL		\$ 295,981.00	\$ 53,750.00	\$ 234,731.00

FY 2018 (Budgeted to Research Fund: \$321,317)

Sponsor	Project / Researcher	Original Commitment	Expense to Date	Commitment Balance
Reserves	2018 Call Paper Prize (<i>not awarded</i>)	6,000.00	-	-
Ratemaking	2018 Call Paper Prize (<i>Note: not all prize awarded</i>)	5,000.00	2,500.00	-
Climate Change	2018 Call Paper Prize	5,000.00	5,000.00	-
COTOR	Call for Essays	5,000.00	-	5,000.00
International	2018 Young Researchers Competition (<i>Note: not all prize awarded</i>)	15,000.00	8,362.32	-
Cyber Risk Task Force	RFP - Cyber exposure	30,000.00	10,000.00	20,000.00

CASCOR	RFP - Compartmental models	30,000.00	7,500.00	22,500.00
CASCOR	RFP - Predictive modeling for reserves	30,000.00	-	30,000.00
COTOR/DRMC	RFP - Economic Scenario Generators	30,000.00	-	30,000.00
Ratemaking	Predictive Modeling RFP	25,000.00	-	25,000.00
CAS	Insurance On-Demand Working Party Sur	5,000.00	5,675.00	-
CAS/SOA/PCI	Auto Loss Cost Trends	6,000.00	6,000.00	-
CAS	Researcher Travel to CLRS	1,400.00	1,394.00	-
CAS	Ludkovski, "Gaussian Process Models in Actuarial Science: A Guided Tour"	35,000.00	17,500.00	17,500.00
CAS	Rotich, "A Parsimonious Stochastic Model for Catastrophe Modelling with Climate Change Residuals"	21,702.50	10,852.00	10,850.50
CAS	Spedicato, "Recommender systems in Insurance Business"	8,000.00	8,000.00	-
CAS	Jae Kyung Woo, "Credibility theory under a general dependency structure of risk pro le between frequency and severity of loss"	20,000.00	10,000.00	10,000.00
CAS	Xia, "Maximum likelihood inference of predictive models for misrepresentation risk in GLM ratemaking"	15,500.00	7,750.00	7,750.00
TOTAL		\$ 293,602.50	\$ 100,533.32	\$ 178,600.50

FY 2017 (Budgeted to Research Fund: \$307,705)

Sponsor	Project / Researcher	Original Commitment	307705 Expense to Date	Commitment Balance
Reinsurance	2017 Call Paper Prize	5,000.00	5,000.00	-
Ratemaking	2017 Call Paper Prize <i>(Note: no prize awarded)</i>	5,000.00	-	-
CAS	Zappa, "Text Mining and Sentiment Analysis in Insurance"	10,000.00	10,000.00	-
CAS	Furman, "An Efficient Algorithm For Approximating Independent And Dependent Sums Of Log-Normally Distributed Losses"	18,000.00	18,000.00	-
CAS	Ai, "Exploring Cyber Risk Contagion - A Boundless Threat"	40,000.00	25,000.00	15,000.00
CAS/SOA	Hua, "Pricing Cyber Insurance For A Large-Scale Network"	10,000.00	2,750.00	7,250.00
DRMC	Simulation Engine for Stochastic Reserving	35,000.00	35,000.00	-
TOTAL		\$ 123,000.00	\$ 95,750.00	\$ 22,250.00

FY 2016 (Budgeted to Research Fund: \$288,230)

Sponsor	Project / Researcher	Original Commitment	288230 Expense to Date	Commitment Balance
Reserves	2016 Call Paper Prize <i>(Note: not all prize awarded)</i>	6,000.00	5,000.00	-
Open Source Software Comm	Acquire Rstudio <i>(project terminated)</i>	3,000.00	-	-
Research Oversight Comm	Webinar funding	5,600.00	6,214.00	-
CAS	Support L. Francis - ASTIN Colloquium	2,500.00	2,097.00	-
CAS	2016 Actuarial Research Conference	2,300.00	2,272.00	-
CAS	Efromovich, "Nonparametric Estimation for Data Modified by Truncation and Censoring"	20,000.00	11,000.00	9,000.00
CAS	Xia, "Embedded predictive analysis of misrepresentation risk in GLM ratemaking models"	12,500.00	12,500.00	-

CAS/SOA	Spedicato, "Machine Learning and 'Big Data' Methodologies for Policyholders' Retention and Conversion Modeling"	6,500.00	6,500.00	-
CAS/SOA	Makov, "Enhanced Predictive Modeling for Usage-Based Auto Insurance"	7,000.00	2,000.00	5,000.00
CAS/SOA	Asimit, "Numerical Optimization for Actuarial Applications"	8,500.00	8,500.00	-
CAS/CIA/SOA	"Actuarial Review of Insurer Impairments/Insolvencies and Future Preventions" (Note: Amount authorized was more than we needed.)	32,000.00	16,548.00	-
CAS/CIA/SOA	"Incorporation of Flood and Other Catastrophe Model Results in Pricing and Underwriting Strategies (Canada)"	25,000.00	21,517.00	-
TOTAL		\$ 130,900.00	\$ 94,148.00	\$ 14,000.00

FY 2015 (Budgeted to Research Fund: \$251,043)

Sponsor	Project / Researcher	Original Commitment	251043 Expense to Date	Commitment Balance
Reinsurance	2015 Call Paper Prize	2,000.00	2,000.00	-
Reserves	Non-Technical Call Paper Prize (Note: not all prize awarded)	5,000.00	2,500.00	-
Rate-making	2015 Call Paper Prize (Note: no prize awarded)	5,000.00	-	-
Climate Change	Developing Adaptive Climate Indices for Evaluation of the Impact of Climate Change on Insurance Risks	31,500.00	31,500.00	-
COTOR	Risk Premium Project Continual Update	10,000.00	10,000.00	-
COTOR	Capital Assets Pricing Model (CAPM) Modifications Appropriate for Insurance Companies	25,000.00	25,000.00	-
Health Care	Effect of Health Insurance Coverage Expansion on P/C Claims	50,000.00	50,000.00	-
Cyber Risk TF	Fundamental Approach to Cyber Risk Analysis and the Research Agenda for Cyber Insurance	40,000.00	30,000.00	-
Cyber Risk TF	Health Care Data Breaches	30,000.00	15,000.00	15,000.00
Cyber Risk TF	Assessment of requirements to create a cyber risk information resource (cancelled)	25,000.00	-	-
CAS/SOA	Hong/Martin, "Flexible Bayesian nonparametric credibility models"	8,750.00	8,750.00	-
CAS	Badescu, et. al., "Erlang Based Methods for estimating IBNyR reserves in general insurance" (project terminated)	13,000.00	3,500.00	-
CAS	Chen/Parsa, "Risk Measurement Based on Available Information"	6,000.00	3,000.00	3,000.00
NAAC	Actuarial Supply and Demand Study	33,152.00	33,152.00	-
CAS	Monograph Editorial Board Prize	50,000.00	50,000.00	-
TOTAL		\$ 334,402.00	\$ 264,402.00	\$ 18,000.00