LLOYD'S

LLOYD'S SCIENCE OF RISK

2011 CONFERENCE AND WINNERS

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1 FOREWORD

2011 has shown quite clearly the impact of the complex, and often interconnected, risks facing the world. From the effects of climate change and natural hazards to developments in technology and how businesses and governments tackle problems, science plays a vital role in helping us understand the nature of risk.

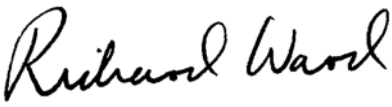
So I was extremely encouraged by the diversity of the audience who attended our Science of Risk conference in November. For the second year running, insurers, brokers, academics, consultants, and lawyers came together to share their knowledge and insight.

The Science of Risk prize, awarded at the conference, aims to increase insurers' knowledge of risk and encourage further research into emerging risks. As we seek new ways to tackle existing and developing challenges, it is vital that the insurance industry and academia work together to share expertise and create solutions. I am delighted we are working with the Technology Strategy Board and Research Councils to support that aim.

The prize itself is presented in five risk categories with one overall winning research paper. Once again, the entries were of the highest standard. Over 60 papers covered topics including, the use of stratospheric data in climate modelling, how the brain learns from managing risks, the underappreciated risk of travelling fires and how to improve satellite damage mapping. This year, we introduced the additional category of insurance operations and markets, which was won with a unifying framework for capital allocation.

The quality of entries meant the judges faced a difficult choice both in shortlisting and in selecting the final winners. I would like to thank all those who entered and personally congratulate the winners, runners up and shortlisted entrants.

During 2012, Lloyd's will be examining many of the topics covered and issues raised by the research. I hope you find the papers from the shortlisted entrants and final winners as fascinating as I do. They show more clearly than ever the practical links that exist between the academic community and the insurance industry.



Dr Richard Ward
Lloyd's Chief Executive

2 SCIENCE OF RISK CONFERENCE 2011

The Science of Risk prize winners and runners up were announced by Lloyd's CEO Dr Richard Ward at a conference held in the Lloyd's building on 24 November 2011. The conference was held in partnership with the Financial Services Knowledge Transfer Network and the Lighthill Research Network, and gave the five category winners the chance to present their work to an audience of insurers, brokers, academics, catastrophe modellers, consultants and lawyers. Speaking at the conference, Dr Ward commented: "Yet again, the entrants into the Science of Risk prize have provided fascinating and thought provoking insights to a range of issues of importance to the insurance industry. The record catastrophe losses facing the industry this year are a reminder of the importance of understanding risk, be it an earthquake, climate change or cyber crime."

Klaus Wunderlich and his team at UCL Wellcome Trust Centre for Neuroimaging (right) was awarded the £5,000 prize for Best Overall Paper, as well as the Science of Risk prize for the Behavioural Risk category.

Wunderlich and his team used brain-scanning technology to reveal how the human brain makes risk-taking decisions. Wunderlich found that the brain learns correlations between risk and reward, and uses this in decision making.

"The paper gives insight into how the brain is capable of learning from prior experience, and how this influences the decisions we make," said Trevor Maynard, Head of Lloyd's Exposure Management and a member of the judging panel. "The entry stood out as behavioural risk is such an important topic for insurance and because the paper is stimulating research into this key topic."

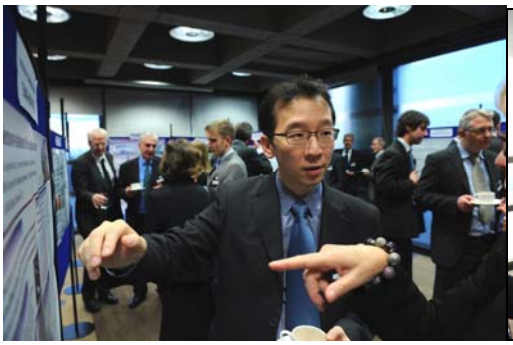
In the Climate Change category, the winning study from Adam Scaife from the Met Office looked at improved projections of major European climate hazards warning that warning that current models of climate change underestimate future rainfall by omitting the impact of the stratosphere.

Angus Law won the Technological/ Biological risk category with his paper on the influence of travelling fires on a concrete frame. Angus' paper uses science to look at ways to improve engineering guidelines/building design and reduce the risk of travelling fires.

In the Natural Hazards category, Norman Kerle's paper titled 'Satellite-based damage mapping following the 2006 Indonesia earthquake - How accurate was it?' took first prize.

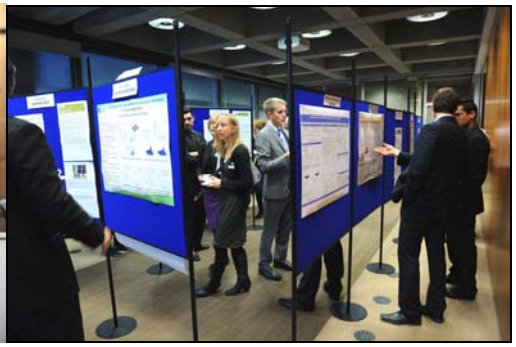
The final winning paper, was Andreas Tsanakas' paper on optimal capital allocation principles in the insurance operations and markets including financial mathematics category, a new category for 2011.

Each Category winner was presented with a winning certificate and a cheque for £2,000. Klaus Wunderlich, the Best Overall Paper winner, collected a cheque for £5,000.




During an extended coffee break, attendees had a further opportunity to explore the work of shortlisted entrants in more detail by viewing academic posters explaining the ideas behind their papers. This interactive session allowed conference attendees to network whilst discovering new areas of potential interest.



SCIENCE OF RISK 2011 FINALISTS

From left to right: Sung-Han Koo (Technological/Biological risk category runner up); Andreas Tsanakas (Insurance Operations winner); Stéphane Loisel (Insurance Operations category runner up); Klaus Wunderlich (Behavioural risk category winner and overall winner); Alexa Spence (Behavioural risk category runner up); Angus Law (Biological/Technological risk category winner); Adam Scaife (Climate Change category winner).

3 THE JUDGING PANEL

Applications for Lloyd's Science of Risk prize were reviewed by a panel of expert judges, which included representatives from research bodies, regulators and Lloyd's.

They considered the quality and relevance of the research to the insurance industry, its financial significance and the originality of the paper.

JUDGING PANEL

Judge	Title	Organisation/Body/Regulator
Dorian Blake	Head of Underwriting Review	QBE
Dougal Goodman	Chief Executive Officer	The Foundation for Science and Technology
Trevor Maynard	Head	Lloyd's, Exposure Management
Jerome Kirk	Head	Lloyd's, Actuarial Services
James Orr	Chief Actuary, Insurance	Financial Services Authority
Simon Pollard	Head of Department	Environmental Science and Technology, Cranfield University
Steven Wilson	Chief Executive	Natural Environment Research Council

4 2012 SCIENCE OF RISK PRIZE

If this booklet inspires you to apply for the 2012 Science of Risk Prize, we would be delighted to receive your application. Equally please feel free to encourage colleagues or friends to submit an application.

For further information about the prize or if you have any questions on the application process, please email scienceofrisk@lloyds.com.

5 BEHAVIOURAL RISKS

5.1 WINNER

Klaus Wunderlich
Klaus also won the Science of Risk best overall paper prize, 2011.

Hedging your bets by learning reward correlations in the human brain

Risk minimization is a key concept in insurance and financial markets. A common risk management strategy in these contexts is hedging, the process of combining multiple positions in different assets to reduce the total risk in a portfolio. However, these choices involving multiple interdependent factors entail rather complex computational processes.

How we make sense of these factors has until now been unclear. We show here that our brains do this naturally by learning the correlation between events. This intricate capability has a defined benefit for our choices by allowing us to observe the outcome of just one action and then infer the outcomes of other actions without having to sample them individually. Our study also identifies the regions of the brain involved in tracking this correlation, which include the insula and the anterior cingulate cortex.

To get to the heart of the question we scanned the brains of 16 subjects using functional magnetic resonance imaging (fMRI), which measures activity in the brain, while the subjects played a game of resource management. The task was similar to a simple portfolio problem in finance: subjects were instructed to adjust the proportion of energy coming from two renewable power sources, a solar plant and a wind farm, in an effort to create the most stable energy output possible. Importantly, the probabilistic outcomes of the two resources co-varied with each other. For example, when they were positively correlated, the wind blew while the sun was shining and each source generated power. We changed the correlation between the two sources throughout the experiment, thus requiring subjects to continuously revise their predictions of how correlated the outcomes were in order to perform well.

We found that the subjects changed their behaviours to reflect new correlations far better than they could have had they been relying on simple trial and error. Instead, they were estimating the correlation between the sources, tracking mistakes in their estimations, and adjusting their estimates of the correlation on the fly. The neuroimaging measurements provide insight into how the brain might perform these computations, highlighting neural activity in two parts of the brain, both of which have previously been associated with decision-making and awareness. Insular cortex represented information about how much the two resources were correlated with each other and the anterior cingulate cortex tracked how accurate the prediction was in order to update this information each time new information becomes available.

We believe there is an evolutionary importance to being sensitive to correlations in the environment. Risks are ubiquitous in nature with predation, starvation, or adverse environmental change acting as constant background variables that shape our behaviour. Imagine our ancestors foraging for food in the woods. They could spend their time either collecting berries or hunting deer. Now imagine they have previously observed that deer eat berries. So, as they are foraging, if they notice a lack of fresh berries, they can infer that there are lots of deer around and instead focus on hunting.

The majority of the research into learning and decision-making over the past decade has focused on direct relationships between actions and rewards. The scientific understanding was hitherto that we separately learn about each of a number of action-reward associations and use that information to make choices.

In the above example, this would mean that the hunter could only predict the success of hunting deer after having tried it and observed the actual outcome. In an ever-changing natural environment it is likely the case that the key correlations are more stable than the relationship between individual actions and reward. In other words, the fact that deer eat berries is always true, but the success at hunting deer can vary from year to year. Learning about the correlations therefore has immediate benefits for efficient choices.

In the financial world, when investing in more than one asset, it is important that one does so with the right mix, which is determined by the correlation between the returns on the assets. In contrast, we are often presented with rough rules of thumb depending on our risk aversion – the more risk averse, the more bonds we should invest in. In fact, from the point of view of financial returns, the mix between stocks and bonds should not depend on risk aversion at all, but on how correlated the two are. And, as we show in this research, we do in fact naturally combine sources in an optimal way, taking into account explicitly how the outputs are correlated.

Importantly, subjects learned those correlations in our experiment through continuous outcome observations. An evolved mechanism in the brain might in fact work best if information is provided in such a sequence of observations, rather than in form of summary statistics from tables or charts (in which case humans often utterly fail at making financial decisions that are based on understanding correlations). These findings may from a basis to promote better decision-making strategies in everyday life and complex financial situations, whereby decision makers are encouraged to observe information sequentially in order to best utilize their inherent neural problem solving mechanism.

You can read this paper at: http://dx.doi.org/10.1016/j.neuron.2011.07.025 (open access)

5.2 RUNNER UP

Alexa Spence

Perceptions of climate change and willingness to save energy related to flood experience

People in places like Uganda and the Maldives apparently don't question climate change. Given the Maldives gradual disappearance due to sea level rise and increasing risks experienced from storm surges, perhaps this is unsurprising; indeed the Maldives were the first to sign the Kyoto protocol and they are aiming to go carbon neutral by 2020. In Uganda, with 80% of the population living off the land, the climate and changes being experienced are vitally important. In the UK, we don't have such dramatic, close relationships with our environment however we do experience weather extremes. In particular, flooding incidents have increased over the past 40-60 years in the UK - but how are people affected by these experiences? Do those who have experienced flooding feel differently about climate change and, similarly to Ugandans or Maldivians, accept climate change more readily? This is actually a question that has long been debated within numerous circles, including policy making, and activist networks, as well as within the academic community, and actually has important implications for the insurance industry as well. Until now evidence has been mixed.

Our study, published in the first issue of the new Nature journal Nature Climate Change, examined this question in a more in-depth rigorous manner than previous research and provides the first solid evidence that people's local experience of floods has an impact on their wider perceptions of climate change and associated behavioural tendencies. This data provides a very useful insight into the consumer. Flood insurance is a large and growing market in the UK and beyond this, our research points to broader perceptions and concerns that have implications for acceptance and demand for new products, services and initiatives as well as the ways that these are communicated.

Our research used data from a national survey collected from 1,822 individuals across the UK in 2010 in order to examine the links between direct flooding experience, perceptions of climate change and preparedness to act on climate change. Findings demonstrate that those who report experiences of flooding express more concern over climate change, see it as less uncertain, feel more vulnerable to the impacts of climate change and feel more confident that their actions can have an impact on climate change. Furthermore these perceptual differences translate into a greater preparedness to reduce energy use in order to help tackle climate change. Importantly, without including these perceptual differences in the analysis, flooding appears to have only a minor impact on behavioural intentions, which may help to explain why previous studies have found mixed and null results. The perceptual factors included in our analyses (concern, uncertainty, perceived vulnerability, confidence in having an impact) appear to be key in driving differences in behavioural tendencies.

It is perhaps fairly intuitive that flood victims are more likely to take insurance of their property more seriously than others; this is something that has been known for some time. Adding to this, our research demonstrates that those who have experienced flooding specifically feel more vulnerable to the impacts of climate change and are more concerned about climate change. For this reason, flood victims may be more likely to be interested in insurance products and services geared specifically towards climate change impacts, including flood risks of course but potentially also others, e.g. other natural disasters, health related products.

Interestingly, those who have experienced flooding, rather than feeling helpless, are actually found to feel greater levels of instrumentality over climate change. As people are better able to relate to the potential consequences of climate change impacts, given their recent experiences, they are also more likely to be able to imagine the real benefits of taking actions to mitigate future related risks. Our study finds that key perceptual differences observed in flood victims mean that they are particularly prepared to save energy in order to mitigate climate change. These individuals are also likely to prefer products, services and company practices that are viewed as being sustainable and which contribute to energy saving in other ways, e.g. in pay-as-you-drive insurance or credits for low emission vehicles. Those that have experienced flooding may also be more likely to increase personal investment in measures designed to protect themselves from future related risks. Beyond insurance, this could also include energy saving products and devices that make houses and lives more sustainable. These individuals are therefore likely to be a key market for new initiatives around insuring 'green buildings' and related equipment.

Importantly, for both the insurance industry and beyond, our findings have implications for public communications about the weather, related hazards like flooding, and climate change. Previously, people have been reticent to discuss individual events in relation to climate change because attributing the cause of a single event to climate change is highly complex and uncertain. However, recent climate modelling has started to do this with more certainty and clearly seasonal events and weather are the primary means by which individuals can experience and observe the climate. Our data indicates that people in the UK are now starting to associate flood events with climate change. These personal experiences are significant useful opportunities to engage people with climate change and encourage action. Similarly, it makes more sense to now discuss flood risks in conjunction with the very real and increasing threat of changes to our climate.

For the first time, we have real evidence that experiences of flooding impacts the way that people think about climate change and actions that they are prepared to undertake. It is beneficial for the insurance industry to take note of these findings in terms of identifying current and potential new markets, in terms of developing new products and services and in the way that these are communicated to the consumer.

You can read this paper at http://www.nature.com/nclimate/journal/v1/n1/full/nclimate1059.html (open access)

5.3 SHORTLISTED ENTRIES

Andreas Milidonis

Do U.S. insurance firms offer the 'wrong' incentives to their executives?

We examine the relation between compensation-based incentives given to insurance executives and market implied firm risk for all publicly traded insurance firms for the period 1992-2007. Firm risk is captured using distance to default, DD: a holistic, default risk measure which combines market and book variables previously used in isolation by the literature in order to capture investors' understanding of default risk.

The insurance literature has mostly focused on book variables to capture firm risk. Executives manipulate book variables such as reserves when their compensation is tied to the firm's stock price (Browne, Ma and Wang, 2008) and bonuses (Halek and Eckles, 2010). Insurance ratings would be an apparent proxy for a firm's default risk. However, periodic changes in rating standards, differences in regulatory status and compensation structure among rating agencies, as well as changes in the competitiveness and the extensive scrutiny of the market for insurance ratings, reduces their applicability. In contrast to the traditional equity risk measures used in the literature, DD allows us to measure directly the investors' perceptions with regard to the survivability of the firm. We provide strong causal evidence that the structure of executive compensation affects the distance away from default, hence the survival of the firm.

Three measures of the structure of compensation package are constructed to capture the different types of incentives given to managers. We include a pay-performance sensitivity measure which captures the overall equity portfolio of an executive; an option-based measure which shows the proportion of total current pay that comes from newly granted executive stock options, and a long-term incentives measure which only captures the grants of restricted shares over the year (again as a ratio of total current compensation).

Our results with regard to the relation between incentives and firm risk mainly support the trade-off prediction of the agency theory framework. Only for option-based incentives do we find a positive relation with firm risk. As we argue, this could be due to self-selection, where risk-loving managers who agree to work for risky firms, tie a large proportion of their pay to risky compensation schemes. In addition, we predict and find a positive relation between stock option-based incentives and the one-year ahead default risk of an insurance firm. On the other hand, other equity-based incentives do not affect the future risk profile of the firm.

The implication of this result is significant in the current climate. Executives who have much to gain from an increase in equity volatility will do so, thus enhancing their firm's default risk. In times of turmoil in the financial markets, where both underwriting and investment risk increase for an insurance company, the increased default risk could lead to catastrophic consequences for the viability of the firm. Shareholders are encouraged to provide pay contracts to their executives that are performance-related, but have linear payoff structures, e.g., based on ordinary or restricted shares. This, as our results suggest, will result in more prudent behaviour on the part of the company executives, since they now have more downside risk, i.e., more "skin in the game" (Jensen and Murphy, 2004). It appears that the reliance of shareholders on stock options to achieve optimal risk-sharing within an insurance firm not only leads to sub-optimal solutions, but also risks the actual existence of the firm.

You can read the paper at http://onlinelibrary.wiley.com/doi/10.1111/j.1539-6975.2011.01418.x/full (open access)

David M. Schultz

Decision making by Austin, Texas, residents in hypothetical tornado scenarios

The decisions that people make during short-fuse weather situations like tornadoes and flash floods could determine whether they live or die. Yet, there are several steps that must happen between the time that a forecaster issues a weather warning and people respond properly to that warning.

- Once the warning has been created, it must be distributed and received by those who need to hear it. Through what means do people receive weather warnings?
- Once the information is received, do people understand it and do they know what to do with it?
- How quickly do they act on that information? Do they need to take the time to collect additional information before making a decision?
- And finally, with that information in hand, do they make smart decisions?

This article is one of a series of papers that originated from the Warning Project, a National Science Foundation–funded project to look at these questions with the goal of providing guidance to the U.S. National Weather Service and other providers about how to improve the dissemination and uptake of their warnings. Our method was to survey floodplain residents in Denver, Colorado, and Austin, Texas, about their perceptions of flash floods. In addition, the Austin residents were surveyed about their perceptions of tornadoes. This portion of the survey is the focus of this particular article.

There are two approaches to determining how people will behave in a given situation: survey them in a hypothetical situation to find out what they might do or survey them after an event to find out what they did. Neither approach is perfect. Hypothetical-situation surveys are imperfect because people may report one behaviour on a survey and do something different when faced with that same situation in reality. Post-event surveys are imperfect because the dead are unable to recount their thought processes.

In this study, we opted for the hypothetical-situation survey and posed two scenarios. One was for the respondent to face a tornado threat at home, and the other was for the respondent to face a tornado threat while driving. The principal results from this article include the following.

1. Previous studies have debated whether a cry-wolf effect exists (i.e. too many false-alarm warnings lead to complacency and inaction among the warned). Our results found that 86–90% of respondents did not feel that they were being overwarned (as a result of too many warnings, a perception that officials were too sensitive to tornadoes, or one or two false alarms or close calls having reduced their confidence in future warnings). Our previous work on flash floods suggests that this result holds for more than just Austin and more than just tornadoes: In an environment that is frequented by short-fuse weather events (7 days per decade have one or more tornadoes within 25 miles of Austin), respondents were not overly concerned about receiving too many warnings.
2. It was satisfying to find that most respondents reported that they would make relatively safe decisions in the two tornado scenarios: at home and while driving.
3. For the tornado-at-home scenario, we found that many respondents did not have a shelter in their home (60%) or did not have a plan to keep themselves and their family safe (37%). But, if they did have a shelter, then they were nearly five times more likely to have a plan and be better educated about the real threat of tornadoes.
4. A disappointing result was that nearly half of the respondents would shelter from a tornado under a highway overpass, likely a result of a highly publicized tornado video and a similar scene in the movie Twister. The reality is that highway overpasses are not safe places to be in case of a tornado. Unfortunately, many of those who would choose the overpass as shelter are doing so confidently, incorrectly believing this to be a safe place. In contrast, those who would not choose the overpass do not have confidence in their abilities to keep themselves and their family safe. These respondents make the right decision, despite being uninformed about the right decisions to make. Thus, both groups need to be educated about proper severe storm safety.

Our results indicate a potential role for insurance companies to engage with their clients in severe-weather preparedness education. Because of the potential harm that residents in the central United States face and the potential losses that the insurance industry faces, insurance companies can build upon their policies of providing discounts for homes with storm shelters or families who have safety plans, further incentivising good practices. As our results show, families that have a shelter are more likely to have a plan, and hence are better prepared in case of severe weather. We speculate that targeted mailings on severe storm preparedness to customers as part of their billing statements or as separate mailings to their clients would provide the opportunity to educate their clients.

One of the most important conclusions to come from this work is the message that overpasses are deadly places in severe weather needs to be conveyed more strongly. Given the extent to which this misperception exists or the extent to which best practices are lacking among the populace, change will not come easily. We suggest that a national educational effort in conjunction with the National Weather Service and Red Cross is needed to effect change on this scale.

You can view the paper at http://journals.ametsoc.org/doi/abs/10.1175/2010WCAS1067.1 (subscription only)

6 CLIMATE CHANGE

6.1 WINNER

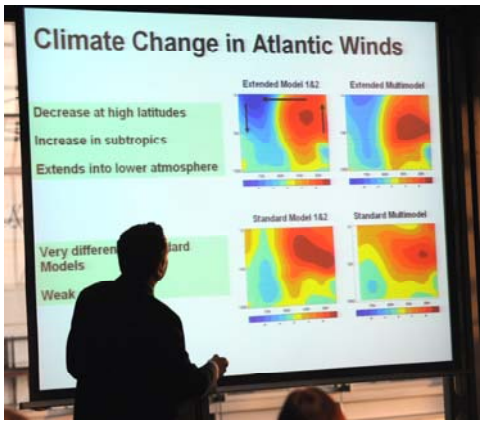
Adam A. Scaife

Improved projections of major European climate hazards. Climate change projections and stratosphere–troposphere interaction.

Flooding and windstorms are a major source of insured risk for Europe. Windstorms alone caused economic damage of almost €2 billion per year, and insurance losses exceeding €1 billion per year across Europe in the 1990s, with much higher values in individual years such as 1999. Similarly, increased flooding in the past decade in the UK alone has cost the insurance industry around £4.5 billion in claims. These perils cause the highest global natural catastrophe insurance losses after U.S. hurricanes.

Climate change could radically alter both flooding and windstorms in the coming years. Current projections suggest that winter rainfall and flooding will increase across extratropical regions of Europe, Asia and North America as evaporation and precipitation rates increase, windstorms become more intense and storm tracks move polewards. Previous studies emphasized that many climate model projections show these changes and results from these studies underpin the quantification of future changes in winter flooding and windstorms.

In this study, Dr Adam Scaife and a group of international colleagues show that regional climate projections for Europe and the rest of the northern hemisphere omit an important component of climate change due to limited climate model resolution. The study shows that increasing the vertical resolution of climate models allows additional changes in atmospheric circulation to take place. The changes affect high altitude stratospheric winds and alter the growth rate of windstorms in the lower atmosphere. The result is a large change in surface winter climate projections for Europe and other densely populated regions. Seasonal mean rainfall and winds are systematically altered by an amount comparable to the original climate change signal. For example, in some parts of Europe these new signals are large enough to completely counter the original climate change signal in rainfall. These effects therefore represent a first order change to our current picture of regional winter climate change and provide a radically altered estimate of future changes in rainfall even on the scale of whole countries. Using world leading climate models with enhanced resolution and bringing together data from a number of international modelling groups, the paper provides important supporting evidence that these results are robust to differences in climate model formulation.



In addition to the effects on mean winter winds and mean winter rainfall which are crucial in underpinning future estimates of water availability and the capacity for wind energy; corresponding changes in perils relevant to the insurance industry are also quantified in this study. Changes in winter mean circulation are mirrored by changes in winter windstorms, with a large increase in storminess in western Europe. Similarly, changes in winter mean rainfall are mirrored by large changes in the frequency of extreme daily rainfall events which are associated with winter flooding. Using the Atlantic storm track as an example, this new effect doubles the predicted increase in the frequency of extreme winter rainfall over large regions of Western Europe compared to other current climate projections.

The quality of this research results from its use of multiple leading climate models and the lead author's personal effort to test his ideas using data collected through international collaboration between world leading climate scientists. It provides both statistical analysis and quantification of results and gives a simple physical explanation of this new mechanism for regional winter climate change. The effect is particularly prominent in Europe and North America but also impacts other highly populated regions which are strongly affected by the extratropical storm tracks. The paper also clearly defines the technical developments needed to reproduce these signals in the next generation of climate models - thereby providing a clear pathway for improving predictions of European winter climate and allowing the insurance industry to be better prepared to buffer the effects of climate change on society. The study has already been highlighted in the journal Nature* and The Times newspaper earlier this year and we hope it is a worthy nomination for the Lloyds Science of Risk Prize.
You can read this paper at http://nldr.library.ucar.edu/repository/assets/osgc/OSGC-000-000-002-080.pdf (open access)

6.2 RUNNER UP

Nicola Ranger

Summary: An assessment of the potential impact of climate change on flood risk in Mumbai

Understanding current and future risks from extreme weather events is the foundation of preparedness for natural hazards and climate change. In this study, we develop and apply new techniques for assessing weather catastrophe risks in a non-stationary climate. The approaches aim to help support and inform decision making related to disaster risk reduction, insurance and adaptation planning. We demonstrate the approaches with an application to fluvial flood risk and adaptation assessment at the city-scale, in Mumbai, India.

India is an important emerging market for insurance. In 2010, the total non-life premium volume for India was $10.6 billions USD and over the past five years, this has grown at a rate of more than 9% per annum. Mumbai was selected as a case study as it is a city with a high exposure to heavy precipitation events and where rapid population growth and urbanisation are increasing flood risks year-on-year. Mumbai is also of relevance to the insurance industry, being the main commercial and financial centre of India.

Mumbai experiences severe disruptions from flooding almost annually. In July 2005, the city experienced the worst flooding in its recorded history, resulting in damages estimated at around $1.7 billions USD and around 500 fatalities. Across Northwest India, the flooding crippled an area of over 35,500 km2, affecting 20 million people and causing economic damages of around $3–5 billions USD.

The study evaluates the current and future risk of pluvial flooding in Mumbai and provides quantitative estimates of the benefits of a range of risk management options, including insurance.

The research was conducted through collaboration between public and private sector organisations across three countries. The research was led by Dr Nicola Ranger, of the Grantham Research Institute on Climate Change and the Environment, at the London School of Economics and Political Science (and a researcher at Risk Management Solutions Inc. during the first phase of the project in 2008), Dr Stéphane Hallegatte, of the Centre International de Recherche sur l'Environnement et le Développement and Météo-France, and Dr. Jan Corfee-Morlot of the OECD. Insurance industry data and risk modelling expertise, provided by Risk Management Solutions in London and RMSI in India, were important inputs the study. Local knowledge and data, contributed by our collaborators in India (RMSI, NATCOM and the National Council of Applied Economic Research) also formed a crucial foundation to the research. The research was supported by the OECD Cities and Climate Change programme.

Approach

The research develops several innovative approaches of relevance to the insurance industry:

- The use of climate model projections alongside statistical downscaling approaches, hydrological modelling and GIS to model flood hazard.
- The development of new approaches to assess vulnerability and exposure in data sparse areas, using both industry and public data sources.
- The use of economic input-output models to assess the indirect damages from flooding at the sectoral level.
- Assessment of the benefits of increasing flood insurance penetration for city-wide resilience using an economic input-output model.
- Each of the tools and data inputs for the hazard assessment is either publicly available or accessible to insurers and academic researchers; suggesting a strong transferability of approaches.

Findings

The study demonstrates the significant current vulnerability of Mumbai to heavy precipitation, as well as the high potential sensitivity to climate change and the strong need for effective and integrated climate change adaptation. Key findings include:

- By the 2080s, for a medium-high emissions scenario, an 'upper bound' climate scenario could see the likelihood of a 2005-like event more than double. Continued rapid urbanisation will further increase future risks.
- We estimate that total losses (direct plus indirect) associated with a 1-in-100 year event could triple compared with current situation (to $690–$1,890 million USD), due to climate change alone.

- Disaster risk management and adaptation can have significant benefits both today and in the future, for example, our estimates suggest that by upgrading the drainage systems in Mumbai, losses associated with a 1-in-100 year flood event today could be reduced by as much as 70%.
- By extending insurance to 100% penetration, the indirect effects of flooding could be almost halved, speeding recovery significantly.

The research article discusses how the approaches developed could be used as part of risk management and adaptation planning. We conclude that, while this study explores only the upper-bound climate scenario, the risk-assessment core demonstrated in this study could form an important quantitative tool in developing city-scale strategies both in the public and private sector. The approaches developed are designed to operate within the data limitations typically found in an emerging economy, but could also be applied more broadly. We provide a discussion of sources of uncertainty and discuss how risk-based tools could be linked with decision-making approaches to inform long-term risk management plans that are robust to climate change.

The article also considers priorities for future research. We highlight the benefits of focussing research and monitoring towards the more 'reducible' uncertainties associated with managing extreme events, in particular related to understanding levels of current hazard, exposure and vulnerability; such investments would have significant benefits for both climate change adaptation and present-day disaster risk management.

Impact for the insurance industry

The study demonstrates the application of a series of innovative tools aimed at quantifying risk and the benefits of adaptation and insurance that have relevance to risk managers and strategic planners in both the public and private sector. We consider the research to have strong relevance to the insurance industry. Firstly, the estimates of current and future risks from flooding in Mumbai have direct relevance to risk managers and long-term business planning for one of the world's most important emerging insurance markets. Secondly, the tools introduced are readily applicable within the insurance industry as well as being resource light and designed for use in relatively data sparse regions, such as the emerging markets. Finally, the research demonstrates the value of insurance for enhancing resilience at city-scale in an emerging market.

You can read this paper at http://www.springerlink.com/content/p6524722514x5663/ (open access)

6.3 SHORTLISTED ENTRIES

Simon Gosling

The benefits of quantifying climate model uncertainty in climate change impacts assessment: an example with heat-related mortality change estimates

The European heat wave of 2003 had a devastating effect on human health. The extremely high temperatures have been estimated to have caused over 35,000 deaths across the continent. Climate change predictions indicate that events such as this heat wave could occur more often in the future and that future heat waves could be even more extreme. Moreover, there is evidence that towards the end of this century, every summer in Europe could be as hot as the summer of 2003. Given the scale of the effects of the 2003 heat wave, and the predictions of more frequent and intense heat waves due to climate change, there is a need to understand how these kinds of events may affect human health in the future.

One way of understanding how heat-related mortality risk will change in the future is through the application of numerical models that simulate the effects of climate change on human health. Up until recently, such models have typically produced projections of climate change impacts based upon only one or two possible future climates. However, great uncertainty is associated with the numerical models that simulate future climate, due in part, to the limited understanding of the physical climate system. This means that this climate modelling uncertainty is often considerably under-estimated. A more complete treatment of this uncertainty is important for better informing risk-based decision-making in the insurance industry.

The study presented here provides the most complete treatment of climate modelling uncertainty in climate change-health impacts assessment to date. By considering the different patterns of climate change projected by 17 climate models, the paper gives an indication of the current level of scientific confidence in projected changes in heat-related mortality for six cities; Boston, Budapest, Dallas, Lisbon, London and Sydney. The cities were selected based upon data availability and to represent a range of different climates.

The research demonstrates that relying on a single climate model for estimating future health impacts is not appropriate. Moreover, by considering the possible range of impacts across 17 different climate models, it is possible to assess the probability of different magnitudes of impact. Heat-related mortality is projected to increase in all cities. However, the results show that for some cities, the most probable estimate for future mortality is substantially lower than the estimates derived from applying just a single climate model (e.g. Budapest), or in some cases mortality estimates are higher (e.g. Boston), when applying 17 models.

The study shows that climate modelling uncertainty is the greatest source of uncertainty, compared with uncertainty on how greenhouse gas emissions might change in the future, or whether global-scale or regional-scale climate models are used. This has important implications for future studies, given that previous studies have considerably underestimated climate modelling uncertainty. The approach described in this study facilitates the risk-based decision-making process and is advantageous over a determinist approach, which essentially presents a single impact estimate that can not be placed within a risk-management framework.

For a number of reasons it is beneficial to the insurance industry to understand and attain knowledge on how mortality due to heat waves will change in the future:

1. Such knowledge and understanding can be used to inform which regions are likely to experience the greatest changes in risk. For instance, in some cities in warm climates (e.g. Dallas), people are more acclimatised to higher temperatures and so these populations present a lower vulnerability to mortality from future heat waves than populations that live in cooler climates (e.g. London). Understanding this can facilitate the appropriate proportioning of resources to deal with the changing spatial structure and magnitudes of the risk.
2. Within the insurance market place, such knowledge can be considered as a considerable competitive advantage.
3. An understanding of the projected changes in risk can allow for insurers to prepare for the demands on the insurance industry that will be evident in a future world impacted by climate change. A key component of the insurance industry that could benefit from an understanding of how heat-related mortality might change in the future is the actuarial profession. Actuaries have long been involved in financial planning for the UK National Health Service (NHS), for instance.
4. The research presented here gives an indication of the probability of the impact of future heat waves on mortality because it considers the role of climate uncertainty in a comprehensive manner, which previous studies have not. Such risk-based estimates are useful to actuaries, given that they are often required to advise on strategic risk measurement in areas including life insurance and healthcare.
5. The number of actuaries in health and care is still relatively small, but growing. Research such as that presented here can provide evidence and information to help foster further growth in the sector.

Moreover, research on the confidence and uncertainties associated with future mortality risk from heat waves, should be of particular interest to the insurance industry, especially in terms of informing the risk-based decision making process.

You can read this paper at http://www.springerlink.com/content/60120mg13721j222/ (open access)

Pardeep Pall

Anthropogenic greenhouse gas contribution to flood risk in England and Wales in Autumn 2000.

The occurrence of a damaging weather-related event often prompts debate as to whether anthropogenic climate change is to blame. Yet apparently conflicting expert statements often appear quickly in the aftermath, along the lines that 'one might expect more intense and frequent extreme events under climate change' whilst at the same time 'one cannot attribute any individual event directly to climate change'. Of course the better-posed question, familiar to the insurance industry, is to ask: what is the change in risk of that type of event due to anthropogenic drivers, such as increased greenhouse gas emissions?

To address this question inevitably requires modelling of the climate that might have existed at the time of the event in the absence of greenhouse gas emissions – since we cannot observe such a climate directly. However, the state-of-the-art climate models used to study this attribution problem typically do not resolve the weather systems associated with damaging events (particularly hydrological ones) yet, at the same time, the insurance industry desires information at the postcode level.

In this paper we present a physically-based multi-step 'probabilistic event attribution' (PEA) framework for providing a more objective assessment of changing weather-related risk less prone to subjective expert judgement, and at scales resolving the impact of interest. We apply it to the pilot case of the UK floods of October and November 2000 that occurred during the wettest autumn in England and Wales since records began in 1766. These floods damaged nearly 10,000 properties across the region, disrupted services severely, and resulted in insured losses estimated at £1.3 billion.

Although the floods were deemed even by the Deputy Prime Minister as a 'wake-up call' to the impacts of climate change at the time, such claims were again typically supported only by broad – in this case thermodynamic – arguments that suggest general increases in extreme UK precipitation under global warming but fail to account fully for the complex hydrometeorology associated with UK floods. Instead, our multi-step PEA framework models the change in such floods more directly using a novel approach.

Firstly, we harness the publicly volunteered distributed computing power of the climateprediction.net project to generate several thousand seasonal-forecast-resolution (~95 km) climate model simulations of autumn 2000 weather – both under realistic conditions, and under conditions as they might have existed had twentieth-century greenhouse gas emissions and the resulting large-scale warming never occurred. In this way we can explicitly simulate the change in probability of what was considered a relatively unpredictable rare weather event rather than relying on, for example, the application of statistical extrapolation techniques such as Extreme Value Theory to generate our event sets.

Secondly, we feed all these global weather simulations into a precipitation-runoff model that originates from one used to assess flood risk in the re-insurance industry by Risk Management Solutions Ltd, thus allowing us to account for the hydrometeorology of autumn 2000. The model simulates daily river runoff events in England and Wales, and we count severe runoff events as proxy indicators of autumn 2000 floods.

Although the precise magnitude of the anthropogenic contribution remains uncertain, our PEA framework shows it is very likely that twentieth-century global anthropogenic greenhouse gas emissions substantially increased the risk of flood occurrence in England and Wales in autumn 2000: in nine out of ten cases by more than 20%, and in two out of three cases by more than 90%.

Even though a study such as this examines only a short 'time-slice' of climate (in this case the year 2000), it generates a wealth of global data. Indeed, follow up studies have further exploited our database of simulations and examined change in weather-related risk for other regions. For example, colleagues at the University of Oregon found that winter 2000-01 drought risk in the Northwest US appears to decrease, which perhaps indicates a peril that will be of less future concern to water mangers in this sensitive region.

The major challenge this study has now posed, however, is not to examine mere time slices of climate but to assess long-term year-on-year and decade-on-decade trends in the attributable risk of damaging weather-related events, both for several past decades, and into the near future – an endeavour that is of much interest to our colleagues in the re-insurance industry who are keen to examine, for example, attributable trends in European-wide flood losses using their latest flood models. The recently launched climateprediction.net 'weatheathome' experiment aims to make exactly this long-term assessment, now employing an even higher resolution (~25/50 km) regional climate model (and follow up

studies to ours by the Centre for Ecology and Hydrology, again exploiting our year 2000 database, suggest such an increase in resolution may be beneficial for more precise estimates of attributable England and Wales flood risk).

A related challenge is to develop a near-real time 'operational' attribution system to forecast the attributable risk of extreme weather events for, for example, the coming season, in order to issue timely attribution statements for such events when they occur. Such work is being pioneered at the University of Cape Town by the Climate Systems Analysis Group's Weather Risk Attribution Forecast (http://web.csag.uct.ac.za/~daithi/forecast/), and much exiting work remains to be done.

With the costs of more recent UK floods such as in summer 2007 being even higher than in autumn 2000 (£3.2 billion), and with billions of dollars being pledged by the United Nations Green Climate Fund for climate adaptation activities in developing countries over the coming years, there is clearly an urgent need for objective, timely, and robust assessments of the attributable risk of weather-related events: so as to distinguish legitimate cases for cover against anthropogenic climate change from cases of mere bad luck with the weather. By demonstrating the contribution of anthropogenic climate change to the risk of a damaging event, the approach used in this study and its successors could prove a useful tool for addressing this need.

You can read this paper at http://www.nature.com/nature/journal/v470/n7334/full/nature09762.html (subscription required)

Leonard Smith

Uncertainty in science and its role in climate policy

Uncertainty in science plays a direct role in the insurance sector as it provides an idea of the likelihood of events, sometimes. At other times it can lay bare the fact that there is no coherent scientific story upon which to base probabilities, or at least no probabilities which are thought sufficiently robust to be of use to the sector, what we call "decision-relevant probabilities". Climate Policy also plays a direct role in the insurance sector, as it drives current and future adaptation, impacting the insured losses of events which occur directly; ideally decreasing them. Policy also impacts the sector and the economy more generally through its effects on long-term large-scale infrastructure projects in flood and coastal defence, in energy and transport, and in water resources; effects that touch both on capacity and vulnerability of that infrastructure and thus all those dependent on it. Finally clarifying the role of scientific uncertainty within the formation of climate policy can lead to a better informed policy. The main focus of our paper is this last point, while relevant to all the points above our main goal is to clarify different types of uncertainty within science, and how the confusion of these with one another leads to poor decision making. This links the content of our paper to the insurance sector firmly.

The paper notes four varieties of uncertainty: imprecision, ambiguity, intractability and indeterminacy. They are not mutually exclusive, but confusing one for another can lead to badly mis-pricing risks. The paper aims to inform the discussion of both the "new risks out there that we as insurers need to be aware of, as well as new ways of thinking about old risks" to quote Richard Ward in his forward to the Science of Risk booklet. Our paper traces uncertainty through the causal chain from current actions by people to future impacts on people. We attempt to clarify the case that rational action can be taken even when we do not have precise probabilities that reflect real-world uncertainties, actions which shift future events toward more acceptable outcomes. For concrete examples, take flooding under current climate conditions and the range of sector relevant impacts in the UK's 2012 Climate Change Risk Assessment (CCRA), to be laid in front of Parliament in January. We have a much firmer grasp on the uncertainties surrounding UK flood risk in 2012 than we do in the 2080's. Probability forecasts for flood losses next year are much better grounded, and believed more robust, than those of the 2080's. One aim of our paper is to disentangle the reasons why, and stress the importance of using different risk management tools when the available probability distributions are thought NOT to be robust. If we misinterpret the kind of uncertainty represented by "probabilities" for 2012 flooding, we can learn from our mistakes and do better in 2013, and we have good physical grounds for thinking that costly losses would be similar to those of an "extreme event" year. On the other hand, if the CCRA was to cloth ambiguity as imprecision, and present probability distributions that are not robust as if they were, then the costs of mal-adaptation could be tremendous, not only financially but also in terms of the credibility of science based policy more generally. By noting the varieties of uncertainty and how they might be handled, our paper aims to clarify the pitfalls policy makers, scientists and decision makers must chance.

In terms of the judging criteria, the improved communication of risk is of fundamental relevance to the insurance sector. In terms of the financial significance of climate: policy, impacts and regulation each play nontrivial financial roles in the sector. While the ideas in our paper are focused on climate policy, they apply to the handling of all scientific uncertainties, and thus broadly relevant to the insurance sector. We would hope you find the quality of the research high, and the writing style clear and accessible. The authors have attempted to use their rather different backgrounds to make the paper accessible both to the scientist and to the policy maker, explaining nuances of the definitions of climate and of weather which are vital in terms of risk management, while discussing how scientists can better understand and aid the needs of decision makers.

We echo the Lloyd's booklet call "Please do speculate!" Indeed the paper calls explicitly for scientists to speculate on things they cannot currently model realistically. While it is critical that all scientific speculation is clearly labelled as such, it is also critical that it be made clear when we have run our simulation models well beyond their likely range of reliability. To present flimsy, model-based probabilities that are NOT believed to be robust as if they were decision-relevant probabilities for use in risk management is to confuse a quantified imprecision with which we can see the future with a fundamental ambiguity in what the future holds. We often know there are things we do not know, and to fail to make this clear will lead to poor risk management and to negative impacts on society, the insurance sector, and the value of science based policy more generally. Our paper is relevant to the insurance sector in that it attempts to constructively clarify these distinctions and improve the communication about risk between scientists and decision makers.

You can read this paper at http://www.lorentzcenter.nl/lc/web/2011/460/presentations/Smith.pdf (open access)

7 INSURANCE OPERATIONS AND MARKETS INCLUDING FINANCIAL MATHEMATICS

7.1 WINNER

Andreas Tsanakas

Joint co-authors for this paper include:

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Optimal capital allocation principles

Financial firms, such as insurance companies or banks, need to hold a level of safely invested risk capital to protect themselves against unexpected losses. It is common practice to allocate the total required capital for the portfolio to its constituent parts, e.g. lines of insurance business. Capital allocation, often linked to return-on-equity arguments, provides a useful method for assessing and comparing the performance of different sub-portfolios. Allocating capital may also help to identify areas of risk consumption and support decision-making concerning business expansions, reductions or even eliminations.

Because of portfolio diversification effects, there is no single way in which to carry out such a capital allocation exercise. Some of the methods used in practice or proposed in the literature are underpinned by very different arguments, while others are remain quite arbitrary. In an insurance world dominated by Solvency II, linking capital allocation to internal processes, such as performance measurement, pricing, and portfolio optimisation, is an emerging tough requirement. It is hard to envisage such exercises being successful, when the methods used are not explicitly linked to management's thinking and formulated risk appetite.

Our own contribution to that debate is to, first, provide a unifying framework for capital allocation methods, which covers most known approaches; and, second, give a business-driven interpretation of these methods, thus enabling the formulation of an explicit link between risk appetite and decision-making.

Our approach follows two fundamental principles. First, we claim that the aggregate capital that needs to be held for the portfolio should be derived from specific adverse scenarios that may materialise in the future. Different firms, and for different applications, may require focus on different ranges of such scenarios; for example these may be scenarios under which financial markets perform poorly, or scenarios where the firm's own idiosyncratic loss is high. Scenarios may be formulated, at either the level of the portfolio or at that of a business line, reflecting the diverging ways in which diversification may be considered. Depending on what the risk management priorities are in the context of a given exercise, scenarios are assigned individual weights, and the total capital is calculated as the weighted average of losses arising from these scenarios.

Once the adverse scenarios of interest and their weights have been fixed, we apply the second principle in our approach, that is, for each line of business, the allocated capital should be as close as possible to the potential loss. Of course "closeness" has to be formally defined, and we do this by using mathematical notions of distance, in particular the quadratic and absolute deviations. What is crucial is that the distance between capital on the one side and risk on the other, is calculated again by weighting adverse scenarios, in the same way as is done in the calculation of aggregate capital. Thereby, capital allocation is derived consistently with the management preferences that underlie the aggregate capital levels.

The optimisation problems from which capital allocations derive are solved in their general form. Explicit allocation formulas are obtained, which, by their scenario-based structure, can be easily implemented via Monte-Carlo simulation. When focusing on specific cases, we find that nearly every capital allocation method encountered in the literature can be seen as a special case of our approach. That includes methods as diverse as marginal/Euler-type allocations; allocations based on the value of the default option; allocations driven by market-consistently calculated solvency ratios; and VaR-

based allocations, where diversification is recognised by requiring a lower confidence level for business lines than for the portfolio.
In the case that the aggregate capital is exogenously given and not set as part of the allocation exercise, capital can still be optimally allocated according to the above arguments and similar allocations emerge; it turns out the difference between the theoretical and the actually available level of capital is allocated on a weighted proportional basis.
The generality of our approach allows easy derivation of new capital allocation methods, given appropriate formulations of scenario weights. Nonetheless, we believe that it is less important to add more methods to an already crowded landscape, than to explore what given methods mean and on which implicit assumptions they rest. If each allocation method is an answer to a specific business question, our approach allows risk managers to clearly formulate that question and then allocate capital in a consistent way.

You can read this paper at http://papers.ssrn.com/sol3/papers.cfm?abstract_id=1332264 (open access)

7.2 RUNNER UP

Stéphane Loisel

From deterministic to stochastic surrender risk models: Impact of correlation crises on economic capital

Runs occurred recently in the banking industry: customers lined up to withdraw their money from Northern Rock Bank as soon as its reputation was hit. In the mortgage business in the United Kingdom, we have observed herd behaviour: customers seem to be widely influenced by recommendations of specialized newspaper pages.

Surrender risk is very important for life insurance companies. It corresponds to the risk that many policyholders surrender their contract earlier than expected and choose to reinvest their money in another product or in some project. Because fees are charged throughout the duration of the contract, the insurer may not have enough time to charge the fees in the case of early surrenders. Massive early surrenders might also cause important liquidity issues and of course a loss of market share. Many policyholders surrender their life insurance contract every year, mainly to finance a project (building a new house, purchasing a new car, ...) or because the tax relief delay or penalty relief delay has been reached. Insurers were used to forecasting lapse rates using explanatory variables and extrapolating historical data far away from past observations. In Solvency II, internal or partially internal models are being developed by many companies. They have to go from a deterministic model, often based on a so-called S-shaped lapse rate curve to a stochastic model. The S-shaped curve corresponds to the lapse rate expressed as a function of the difference between the interest rate given by the contract and the one that the policyholder could obtain somewhere else in the market. The idea that practitioners have followed is that even if this difference is very small, some policyholders are going to surrender their contract for tax reasons or to fund a personal project, that the lapse rate is increasing in this spread, and that even if the spread is very large, some policyholders are going to stay in the portfolio because they do not really pay attention to the market evolution. The problem with this S-shaped curve is that one has not observed policyholders' behaviour in the extreme situation where the spread is very large. It may be tempting for internal model designers to use a Gaussian distribution around the value of the lapse rate in the S-shaped, deterministic curve to describe stochastic surrender risk.

A sudden increase of interest rates or reputation risk could breed massive surrenders. Due to the size of the market, and to the sophistication of recent contracts like variable annuities, it may happen in the near future that some specialized analysts provide some advice to customers about how to optimize their strategy. If this happened, decisions of policyholders would not be independent anymore, but strongly influenced by the analysts recommendations : we can expect correlation crises between decisions of policyholders if things go bad, in analogy to correlation crises observed on credit derivatives markets during the credit crunch. Events that are considered to be almost independent in the classical regime can suddenly become extremely correlated if things go wrong. As data do not exist, to design relevant stress scenarios about customer behaviour, one should learn from observed runs in the banking industry and rather rely on thought experiments than on statistical analysis.

We propose a simple surrender model that takes correlation crises into account: as the spread between offered and available interest rate increases, correlation between policyholders' decisions increases. In extreme or unusual scenarios, the central limit theorem does not hold anymore, and the conditional surrender rate distribution becomes bi-modal. This leads to anticipate policyholders' behaviour more like a $0-1$ law than according to a bell-shaped unimodal distribution. This means in particular that the best estimate of the surrender rate is in between the two remote ranges of most likely values. On contrary to the Gaussian world, if some event occurs, then it is very likely that the observed value is going to be far from the best estimate and that the quality of the model is going to be questioned. This already happened in the variable annuity market: surrender rates were recently much lower than expected by several companies since the last crisis.

We explain how to compute surrender rate distributions in the proposed model, with closed formulas and with simulations. We make use of stochastic orderings in order to study the impact of correlation on the surrender rate distribution from a qualitative point of view. We also quantify this impact on a real-life portfolio for a global risk management strategy based on a Solvency II partial internal model. Of course, subjectivity is there and we do not claim to be able to calibrate such a model. Nevertheless our methodology enables risk managers who already chose some internal model to incorporate potential correlation crises and to better design stress scenarios.

For further research, it would be interesting to explore the path-dependent aspect or memory properties of surrender rates, as well as other types of customer behaviour like movements from Unit-Linked to Euro products, or partial withdrawals in Guaranteed Minimum Withdrawal Benefit contracts.

Good risk management starts by trying to manage behavioural risk at the creation of the contract. But outside of behavioural risk, the lesson of this work is more general: uncertainty about some parameter of a model, about the future progress of medical science, about future regulation and legal changes or whatsoever does not only breed uncertainty on the profitability of individual contracts, but also generates correlations of extremes or correlation crises at the portfolio level.

You can read this paper at http://www.sciencedirect.com/science/article/pii/S0377221711003821 (subscription required)

7.3 SHORTLISTED ENTRIES

Mario V. Wüthrich

An academic view on the illiquidity premium and market-consistent valuation in insurance

The insurance industry currently has a very controversy discussion about the appropriate discount rate for insurance liabilities in Solvency II. Concepts such as the illiquidity premium and the matching premium are proposed in order to value long-term insurance liabilities.

The present paper studies this question from an actuarial perspective that is based on market-consistent valuation. We conclude that mathematical theory does not allow for discounting insurance liabilities with an illiquidity or a similar spread. The crucial point is that market-consistent valuation with a one-year solvency requirement does not allow to account for expected financial returns beyond the solvency time horizon. This would either contradict market-consistent valuation or the no-arbitrage concept.

In order to account for long-term returns one either needs to change the accounting framework (for example from market-consistent valuation to statutory valuation) or one needs to change the solvency time horizon.

The present paper was discussed very lively with several parties and is currently one of the most downloaded papers at the European Actuarial Journal. I hope that it brings some light into these discussions about market-consistent valuation.

You can read this paper at http://www.math.ethz.ch/~wueth/Positions/2011_Illiquidity_Wuthrich.pdf (open access)

Nan Zhu

Applications of forward mortality factor models in life insurance practice

Two of the most important challenges for the application of stochastic mortality models in life insurance practice are the apparent incompatibility of most stochastic methods with classical life contingencies theory, which presents the backbone of insurers' Electronic Data Processing (EDP) systems, and the complexity of many of the proposed approaches. These obstacles have not only led to an increasing discrepancy between life insurance research and actuarial practice and education in some parts of the world, but the reluctance of practitioners to rely on stochastic mortality models may also be a primary reason for the sluggish development of the mortality-linked capital market. Specifically, stochastic methods are necessary to assess a company's capital relief when hedging part of its mortality risk exposure, which should be one of the key drivers of the demand for mortality-linked securities.

One model class that overcomes these problems are so-called forward mortality models, which infer dynamics on the entire age/term-structure of mortality. As already pointed out by previous researchers, the "traditional rates used by actuaries" really are forward rates so that the forward approach can be viewed as the natural extension of traditional actuarial theory. In particular, the actuarial present values for traditional insurance products such as term-life insurance, endowment insurance, or life annuity contracts are of the same form as in classical actuarial theory, where the "survival probabilities" now are to be interpreted as expected values of realized survival probabilities. Hence, the inclusion of such models in the operations of a life insurer or a pension fund will not require alterations in the management of traditional product lines, but nonetheless present a coherent way to take mortality risk into account when necessary. Examples of such situations include the calculation of economic capital based on internal models or the pricing and risk management of mortality-linked guarantees in life insurance or pension products.

However, only few forward mortality models have been proposed so far, and most authors have relied on 'qualitative' insights and/or modelling convenience for determining suitable specifications. Moreover, some of the presented models entail a high degree of complexity, which may lead to problems in their calibration.

In a companion paper, we present an alternative, data-driven approach by relying on forward mortality factor models with Normal-distributed transition factors, the (necessary) explicit functional form for which has been identified in the financial mathematics literature. More specifically, we use principal component analyses of time series of mortality forecasts generated based on rolling windows of annual mortality data to derive a suitable number of stochastic factors and their functional forms. The resulting specifications are then (re)calibrated based on maximum likelihood estimation. In this paper, we demonstrate the technical advantages of this model class by discussing and implementing several important example applications. Furthermore, our numerical results based on a simple model version calibrated to British population mortality data illustrate the economic significance of systematic mortality risk.

The first application concerns the calculation of economic capital for life insurance companies. After providing a framework for this problem, we explicitly demonstrate how to derive the economic capital for a stylized life insurance company offering traditional life insurance products in our setting. Our implementation highlights the tractability of forward mortality factor models as well as the important advantage of this model class in that it avoids the necessity of nested simulations. Furthermore, our numerical results display that in addition to financial risk, (systematic) mortality risk has a considerable impact on the results and thus plays an important role for a life insurance company's solvency.

In the second application, we discuss the valuation of different mortality-contingent embedded options within life insurance contracts. Specifically, we derive a closed-form valuation formula for simple Guaranteed Annuity Options (GAOs) within traditional endowment policies in the considered forward mortality model framework. Moreover, we demonstrate how to derive the fair option fee for Guaranteed Minimum Income Benefits (GMIBs) within Variable Annuity contracts based on Monte Carlo simulations; here, akin to the first application, forward mortality models bear the profound advantage that no nested simulations are necessary. Our numerical results again emphasize the economic significance of systematic mortality risk.

You can read this paper at
http://www.willisresearchnetwork.com/Lists/Publications/Attachments/76/BauerZhu_ForwMort_Application.pdf (open access)

Enrico Biffis

Securitizing and tranching longevity exposures

We consider the problem of optimally designing longevity risk transfers under asymmetric information. We focus on holders of longevity exposures that have superior knowledge of the underlying demographic risks, in the sense that they have access to better experience data or forecasting technologies developed by monitoring the exposures. This assumption is realistic for life insurers, reinsurers and other intermediaries (such as pension buyout firms and investment banks) that have developed considerable expertise in managing longevity-linked cashflows. The incentive to enter a transaction is given by an exogenously specified retention cost resulting from capital requirements or alternative investment opportunities. Knowledge of this cost is available to all agents, as it can be quantified from international regulatory rules and accounting standards.

As a practical example, we consider the securitization of a book of annuity-like cashflows and their backing assets, but our analysis carries over to cashflows exposed to the risk of systematic mortality increases (as in mortality bonds). The presence of asymmetric information means that the holder or originator of the longevity exposure faces a `lemons' problem, in the sense that investors' demand for the new security may be downward sloping and expose the issuer to a liquidity problem. As is common in reinsurance and securitization, retention of part of the exposure can be used to `prove' the quality of the cashflows to the market and alleviate the impact of asymmetric information. We use a signalling model of Walrasian market equilibrium to determine optimal retention levels and securitization payoffs. The resulting separating equilibrium allows us to determine the issuer's retention costs and to examine how risk premia would emerge if there were departures from the optimal securitization level.

We then allow the holder of the book of liabilities and backing assets to issue a security that is contingent on the net exposure to longevity (i.e., the surplus on the assets in excess of the exposure) and examine conditions under which the optimal contract results in tranching of the net exposure. By tranching, we mean slicing the net exposure so that, in exchange for a lump sum paid to the originator, investors who buy the tranche are entitled to a specific portion of the net exposure's cashflows. The optimal tranching level minimizes the sensitivity of these cashflows to both asymmetric information and the impact of systematic risk, which is material to risk-neutral agents when payoffs are nonlinear. Since we wish to minimize the cost to the originator of issuing the tranche, the optimal tranche is the one that is least risky from the investors' viewpoint.

We also address the issue of securitizing pools of exposures, and show how diversification benefits can be traded off against the detrimental effect of information loss from pooling together low-longevity- and high-longevity-risk cashflows. We obtain the result that pooling and then tranching can reduce the negative impact of unsystematic risk at high ages and in small portfolios. Also, the benefits from pooling and tranching are magnified when private information is highly correlated across exposures, while residual risk is not. This occurs, for example, when issuers of securities pool different cohorts of individuals belonging to the same geographic area or social class, or pool several small portfolios with comparable demographic characteristics. When considering securities written on publicly available demographic indices, the model shows that `age-bucketing' (i.e., writing derivatives on the mortality experience of an entire age range in a given population) can reduce asymmetric information costs, in addition to mitigating basis risk.

The work contributes to the existing literature and industry practice in at least three ways:

6. We use an equilibrium model to endogenise the market price of longevity risk, showing how capital requirements and asymmetric information might shape longevity risk premia. Our approach has the advantage of focusing on standard market frictions in an otherwise risk-neutral setting, without having to rely on calibration to (illiquid) secondary market prices or ad-hoc assumptions on approximate hedging methods.
7. We not only determine optimal retention levels for direct transfers of insurance liabilities, but explicitly study optimal contracts, showing when it is optimal to issue a security with option-like payoffs. Our results provide a robust framework for defining tranching levels in securitized products and introducing caps/floors in the floating leg of longevity swaps.
8. We explicitly allow for securities written on multiple exposures, resolving the trade-off between two opposing effects of risk pooling: the loss of information to the privately informed originator and the diversification gains (reduction in unsystematic risk) resulting from pooling together several exposures.

You can read this paper at http://papers.ssrn.com/sol3/papers.cfm?abstract_id=1261264 (open access)

John Quigley

Estimating the probability of rare events: Addressing zero failure data

Estimating the probability of an event that has yet to be observed is an important challenge in risk analysis generally and to the insurance industry specifically, because such estimates contribute to safety, financial and legal assessments. A novel data driven approach to inference has been developed to estimate the probability of an anticipated event being realised. This new method is particularly well suited for rare events, common in risk analysis and it also outperforms traditional estimation procedures for moderate sample sizes. Our research shows that existing methods overestimate low frequency events by a factor of 2.5 to 7.5. This implies that using the traditional, pessimistic, inference methods can lead to, for example, uncompetitive insurance pricing and unnecessary costs incurred for accident prevention. By using the proposed new methods, more accurate estimates of events should be obtained leading to more effective and efficient pricing decisions.

Traditional statistical procedures, such as the Maximum Likelihood Estimate (MLE) for estimating the probability of an event (i.e. the ratio of the number of observations to sample size $\frac{x}{n}$), provides an estimate of zero if the event has not occurred. Consequently, current practice in such situations is to augment the general form of the estimator with an ad hoc estimate. These augmentations can result in inference that is conservative and, more importantly, incoherent. That is, the probability of an event decreasing with additional realisations which does not make sense.

We have derived a coherent framework for estimating the probability of an event being realised based on sound methodological principles. Our method will provide a non zero estimate if no events are realised and closely approximates the standard MLE when events have been realised. We concern ourselves with estimating the probability of events, which although are rare, could reasonably have occurred given the number of opportunities in the data (i.e. a sample size of n). As such, we are not attempting to estimate the probability of extremely low probabilities, such as a one in a million based on relatively small sample such as ten.

There are a few standard approaches to estimate the probability of an event being realised in a sample of n given it has not been realised. Some approaches consider the problem through a Bayesian framework, where a uniform prior distribution is used for the prior probability of the event and this is updated in light of no events being realised. Such an approach is based on a dubious foundation of a uniform prior given its application to low probability events and results in inference that closely approximates the estimate where one event has been realised in the sample, i.e. $\frac{1}{n+2}$. The most popular method is the Rule of 3, which assigns an estimate that corresponds to the 5th percentile of the Cumulative Distribution Function (CDF) to obtain an estimate of approximately $\frac{3}{n}$. Clearly, by the nature of its construction it will be conservative, but flawed if comparisons are made with events that have been realised if more natural estimates are used. For example, in comparing two risks both based on a sample of 100, one that has had two occurrences might sensibly be estimated at probability 0.02 and another which has had none would be estimated at 0.03. We need a coherent framework to provide a sensible estimate and support a comparison between risks.

Since the motivation for this research concerns low frequency events, the CDF was the initial focus of attention however, rather than assigning an overly conservative percentile to the CDF such as the 5th as in the Rule of 3, we pursue accuracy.

For our framework to be of use in the case of zero observed events, we must model the count data rather than the time to events. That is, we build our inference for the discrete probability distribution representation of the data. While the distribution of the CDF evaluated at a randomly selected point is well understood to be uniformly distributed if we are working with continuous distributions, this has led to deriving estimates in some cases from matching 0.5 to the CDF. However, these distributional properties do not apply in the discrete case; in the paper we develop the necessary theory for the case of the Binomial distribution.

Rather than obtaining an extreme bound such as with the Rule of 3, we consider a Minimax criterion for inference which seeks an estimate that will minimise the maximum expected error. In our case the mean squared error. Such an approach has been applied directly to infer the probability of an event from a random sample, resulting in $\frac{x}{n}\frac{\sqrt{n}}{1+\sqrt{n}}+\frac{1}{2}\frac{1}{1+\sqrt{n}}$ which provides an overly pessimistic estimate when there are zero events realised as it pulls the estimator towards $\frac{1}{2}$. We apply this criterion to estimating the CDF. Solving the estimate of the CDF for the corresponding probability of an event being realised resulted in an estimate that is easily approximated by the following.

$$\hat{p} \approx \begin{cases} \frac{1}{2.5n}, x = 0 \\ \frac{x}{n}, x \geq 1 \end{cases}$$

We see from the expression that the estimate closely approximates the MLE when we have non zero data. In the paper we show that this procedure for estimating the probability of an event has a smaller mean squared error than the MLE for a larger proportion of the parameter space for moderate sample sizes, i.e. fewer than 60.

You can read this paper at http://onlinelibrary.wiley.com/doi/10.1111/j.1539-6924.2010.01568.x/abstract (subscription required)

8 NATURAL HAZARDS

8.1 WINNER

Norman Kerle

Satellite-based damage mapping following the 2006 Indonesia earthquake - How accurate was it?

Risk assessment, central to the insurance business, is a function of two fundamental parameters: hazard, and the vulnerability and value of elements at risk. There have been changes in risk conceptualization and calculation over the years, such as a more detailed assessment of different vulnerability types, better modeling of multiple hazards, or incorporation of delayed effects caused by a given hazard event, leading to risk assessment that is substantially more sophisticated and meaningful than in the past.

However, any risk calculation can only be as good as the data on hazard and vulnerability used. While both parameters are frequently determined by modeling, remote sensing has become a commonly used tool, allowing both model validation and acquisition of information on the actual consequences of a hazard event. Such damage mapping, which allows the assessment of specific site effects, as well as vulnerability, has been operational for significant disasters worldwide for more than 10 years already (in the framework of the International Charter "Space and Major Disasters").

Since the year 2000 satellite-based damage mapping has been done for more than 300 disaster events, with the data processing being done by UNOSAT, the German space agency (DLR) or SERTIT (based in Strasbourg, France). What started out as a small support operation now leads to the creation of hundreds of damage map products after exceptional disasters, such as the 2010 Haiti earthquake (more than 2000 maps were created following the event). However, a number of problems can be identified: (i) all the Charter mapping is done in Europe (typically without incorporation of field data), (ii) no standards exist for the damage mapping process of the types of damage map created, and (iii) validation of the mapping results is not being done. Yet at the same time an ever growing number of stakeholders – including the insurance industry – uses those map results. For example in the aftermath of the Haiti event it is estimated that more than 10,000 organizations (mostly smaller NGOs) were actively involved in the response – those are also all users of the damage map products. This is true for earthquakes but also other hazards of significance for the insurance sector, such as flooding, windstorms, landslides or oil spills. The derived data are critical to assess and quantify the different hazards.

The purpose of the research paper was to assess the post-disaster damage mapping process based on satellite data. After the 2006 earthquake near Yogyakarta (Indonesia), in which nearly 6,000 people died, more than 100 volunteers mapped more than 54,000 buildings on the ground, a post-disaster damage inventory unmatched until the Haiti event. It formed an excellent basis to assess the accuracy of different damage map types, some of which are shown in figure 1. The paper reached a number of conclusions:

- clusters of severe damage can be mapped accurately in high-resolution data, such as the Quickbird data (ca. 70 cm pan-chromatic resolution) used by UNOSAT (see figure 1, C);
- an attempt also by UNOSAT to map smaller units (small groups of buildings, e.g. Figure 1, B) proved too inaccurate;
- a mapping style used by the DLR, based on 250 x 250 m grid cells (figure 1 A), was very inaccurate, in addition to being very difficult to interpret for map users. One of the surprising points is that the DLR has been using this mapping type for years (also after Haiti), despite the potential flaws;
- essentially both satellite-based mapping and damage assessment on the ground have problems: for satellite data we need (i) a suitable data type, (ii) cloud-free conditions, (iii) damage that is visible from a vertical perspective (e.g. substantial roof damage or rubble piles), and (iv) data that cover the entire affected area. Ground-data are very useful but (i) are time-consuming to obtain, (ii) often incomplete because of site access problems, (iii) hard to do consistently when many people are involved, and (iv) error-prone because of needed transcription and compilation;
- it is concluded in the paper that we urgently need: (i) agreement on damage map style and nomenclature, (ii) standardized mapping procedures, (iii) standardized accuracy assessment procedures, (iv) integration of field information in the mapping process (or means to use local knowledge to validate to clarify uncertainties), and (v) better means to visualize damage and the uncertainty associated with the mapping.

It was a critical – and equally disconcerting – realization of this research that after ten years of professional Charter mapping validation and error assessment are still not being included in the process (only after the Haiti event some extensive validation is now being done). Likewise, it is irritating to see many different maps styles being used, a number that continues to grow. When questioned during this research about the use of the grid approach, DLR staff essentially said that no one had complained, leading them to assume that the style was considered useful.

Damage mapping has a very clear influence on our understanding of hazards and the (physical) vulnerability of assets, both of which are central when risk is calculated. It is thus vital that the insurance industry pays attention to the problems and limitations in damage assessment addressed in this paper, and even pressures the mapping agencies to improve their work. This work – the first research paper to address damage map accuracy – has shown that the best-effort basis that underpins Charter-mapping is insufficient to get mappers to assess their methodologies critically, and that improvements in the process, and greater transparency about what can reasonably be mapped, are needed.

You can read this paper at http://www.sciencedirect.com/science/article/pii/S0303243410000942 (subscription required)

8.2 RUNNER UP

Lee Jones

Modelling Volume Change Potential in the London Clay

Many towns, cities, transport routes and buildings in the UK are founded on problematical clay–rich soils and rocks. These clays are a significant hazard for engineering and construction because they shrink or swell with seasonal changes in moisture content. The changes are mainly related to rainfall and the evapo-transpiration from vegetation. However, local site changes also aggravate the situation, including leakage from water supply pipes or drains, changes to surface drainage and landscaping (including paving) or the planting, removal or severe pruning of trees or hedges.

The effects of shrinking and swelling clay soils damaging foundations and buildings were first recognised after the dry summer of 1947. The drought of 1975–76 resulted in UK insurance claims of over £50 million. In 1991, after a preceding drought, claims peaked at over £500 million. The Association of British Insurers has estimated that the average cost of shrink–swell related subsidence to the insurance industry stands at over £400 million a year, and that with climate change by 2050 it could rise to over £600 million. As many as one in five homes in England and Wales are likely to be damaged by ground that swells when it gets wet and shrinks as it dries out.

Predictions are that global warming and climate change will have an increasingly adverse effect on these soils and the damage they cause to homes, buildings and roads. The Government recognises that climate change is one of the biggest challenges that the UK faces; predictions are for hotter, drier summers in the south–east of England and milder, wetter winters, in the rest of the UK. The shrink–swell process is controlled largely by temperature and the amount of rainfall, and their seasonal distribution. It is also dependent on the amount of clay minerals in the soil, the more clay present the higher the soil's shrink–swell potential and the more water it can absorb or lose. It is predicted that climate change will lead to a significant increase in the damage done by the shrinking and swelling behaviour of these clay soils.

The London Clay Formation, lying beneath much of the Greater London area, is particularly susceptible to this shrink–swell behaviour. It has a long history of foundation damage caused by ground movements and has cost up to £500 million in a single year. The clay is of major engineering importance as it is on and within this formation that the majority of the city's infrastructure, buildings and underground services are constructed. The Volume Change Potential (VCP) of a soil is the relative change in volume to be expected with changes in soil moisture content and the subsequent shrinkage or swelling that can cause major damage to structures above or below ground. Detailed statistical and spatial analyses of data across the London Clay outcrop have revealed a significant geographical trend in the volume change potential of this deposit, confirming an overall increase from west to east, but also showing subtle trends with depth.

The attached paper represents over ten years work by specialist engineering geologists working to British Standards. It describes how the analysis was carried out to determine 3-D Volume Change Potential (VCP) for the London Clay, and discusses how such assessments can yield valuable information about shrink–swell behaviour, not only of the London Clay but of similar shrink–swell prone clay formations elsewhere in the country. The data have been analysed by Geographic Information System (GIS) producing digital 2-D and state-of-the-art 3-D models. For the insurance industry the results are important as they help to define the most shrink-swell prone areas and refine the current hazard scores used for determining subsidence risk and calculating insurance premiums. The results are significant for the construction industry too, informing and providing engineers and builders with technical parameters for effective foundation design and providing planners with maps of potentially hazardous areas, so that problems and insurance claims can be avoided in the future.

You can read this paper at http://nora.nerc.ac.uk/13629/ (open access)

8.3 SHORTLISTED ENTRIES

Katsu Goda

Assessment of Seismic Loss Dependence Using Copula

"How should we cope with low-probability high-consequence risk?" – This is a grand challenge in earthquake disaster mitigation. Our capability to tackle this problem is limited, even with advanced engineering technology and fast-expanding scientific knowledge (e.g. seismic isolation and dampers, early warning system, geodetic GPS monitoring, computer simulation of complex fault systems and etc). This was clearly demonstrated during the recent tragedy in Tohoku, Japan, which was devastated by massive tsunami and the crisis at the Fukushima Daiichi Nuclear Power Plants. The difficulty stems from large uncertainties associated with occurrence of extreme events and their far-reaching negative impact, and inability of human beings to process such (probabilistic) information and to make rational decisions about earthquake risk mitigation. It is thus of paramount importance to imagine "unimaginable situations" in an uncertain and complicated world – this is the art of modern risk management.

From financial viewpoints, extreme seismic loss payout due to a single catastrophic event is a serious concern for insurers and re-insurers, as their reserved fund/surplus may be quickly depleted and compensation from reinsurance contracts and other risk hedge/transfer measures may be insufficient to cover all incurred costs, resulting in bankruptcy as the worst case. It is important to recognize that the catastrophic nature of earthquake risk is attributed to simultaneous effects to numerous stakeholders in a seismic region, causing a surge of seismic loss claims. Therefore, this "physical" nature of catastrophic earthquake disaster must be taken into account, when earthquake risk is modelled and regional economic impact for an insurance portfolio is assessed. Incorrect assumptions/models for describing spatially-correlated ground shaking at different locations could lead to a gross error (a factor of 2 or more) in the estimated seismic loss. (Note: previous studies by Goda are innovative and pioneering works in the area of engineering seismology and earthquake engineering, and have opened a new avenue for estimating catastrophic seismic loss for urban cities.)

Built upon Goda's previous achievements, the Goda-Ren paper tackled a challenging problem "portfolio relocation and aggregation" related to earthquake insurance portfolio management. A simple example will clarify the essence/significance of the problem. Consider that an insurer underwrites earthquake insurance coverage in City A and City B, which are close geographically. Because of the spatial proximity and prevalent common features of building stocks in Cities A and B, seismic losses in the two cities are correlated. Insurer's task is to assess financial risk for the combined portfolio of Cities A and B, and to take adequate risk transfer measures so that ruin probability due to this undertaking is sufficiently low. How can he combine probability distribution of seismic loss in City A with that in City B? (Note: it is well-known that seismic loss has a heavy right tail and a sophisticated loss model is often required.) It is likely that seismic loss in City B would be large given that seismic loss in City A is large (i.e. upper tail dependence). How can he take such nonlinear upper tail dependence into account and make rational decisions?

To tackle the above-mentioned problem, Goda and Ren developed a novel copula-based seismic loss assessment tool to investigate the seismic loss characteristics in the upper tail and their dependence for building portfolios subjected to significant seismic risk. A copula is a statistical technique to model multi-variate random variables flexibly, and has been extensively developed/applied in the field of financial engineering and actuarial sciences, but not in earthquake engineering. It allows the construction of joint probability distribution in two steps: (i) marginal loss distribution modelling and (ii) loss dependence modelling. A great benefit can be obtained, when seismic loss data for multiple portfolios exhibit nonlinear upper tail dependence, which cannot be dealt with by conventional statistical approaches/models (e.g. multivariate normal/log-normal models). The use of copulas facilitates the accurate statistical modelling of nonlinearly correlated seismic loss.

This work offers a new insight for earthquake insurance portfolio management. A link between correlation of physical phenomena (i.e. ground shaking) and copula parameters was established – this greatly facilitates the improvement of consolidating multiple insurance portfolios in a realistic manner. Moreover, practical merits of this new technique are high. For instance, the method can be used to determine an optimal reinsurance arrangement and its pricing by accounting for upper tail dependence of earthquake risks due to different portfolios. The model would also be useful for designing a catastrophe bond product for earthquake risk transfer. Returning to the original question "How should we cope with low-probability high-consequence risk?", this paper certainly provides a first-step cornerstone to answer/solve this problem. A high confidence in catastrophe earthquake risk modelling definitely has a very positive impact to make more rational and informed decisions and will contribute significantly to earthquake risk mitigation through both hard and soft measures (note: soft measures include earthquake insurance and other financial risk transfer instruments). Such an integrated risk management approach is more successful in coping with low-probability high-consequence risks and in reducing global earthquake risk reduction.

You can read this paper at http://onlinelibrary.wiley.com/doi/10.1111/j.1539-6924.2010.01408.x/abstract (subscription required)

Aidan Slingsby

Discovery exhibition: Making hurricane track data accessible

Natural hazard models are increasingly important tools for assessing risk. The outputs of these are usually hidden inside off-the-shelf catastrophe models that model financial impacts of this risk to insurance companies. However, in many cases, the characteristics of individual modelled events or groups of modelled events, provides important information about risk.

This is particularly true of the dynamically simulated storm event-sets generated by scientists at the National Centre of Atmospheric Science. Storm tracks are extracted from hundreds of years of high-resolution General Circulation Model simulations, producing events-sets containing thousands of storms. Each storm track has data points at 6-hourly intervals, each of which has information, such as windspeed and vorticity, at several atmospheric levels. These tracks, in their spatial and temporal, contexts provide useful information about the nature of atmospheric risk. Understanding how storm hazard risk evolves over time and across the globe, and the underlying atmospheric and oceanic conditions that determine the level of risk, is still not fully understood, either by climate scientists or risk managers.

At the giCentre at City University London, we specialise in interactive visualisation for data exploration. We are working with these scientists to design interactive visualisation techniques that enable event-sets to be visually browsed, events of interest identified and captured. These techniques were implemented as a lightweight, cross-platform and easy to use tool that enables thousands of storm tracks to be easily and interactively explored and interrogated. Specific tracks, or periods of interest can be exported as video clips. Tracks are animated over time on a world map where line thickness indicates windspeed. Moving the mouse left/right allows jumping to any arbitrary point in time.

The original purpose of this tool was for climate modellers to find examples of storm track configurations that illustrated important issues about atmospheric risk of relevance to the insurance industry. This has made a significant impact on the way in which atmospheric risk can be disseminated by climate modellers to general insurance audiences. Examples include:

- **'Sticky tracks'**: storm tracks that cluster in time and space. There is a widely held assumption – built into many CAT models – that rare events are independent of each other. Use of the tool identified multiple examples where this is not the case. Using tangible examples to illustrate this point serves to illustrate that clusters of extreme events are not as rare as commonly assumed and suggests that in some cases, risk is being underestimated. Further collaborative work with statisticians at the University of Exeter is helping to quantify the clustering of storms.
- **Extra-tropical transition**: tropical storms that move into higher latitudes and evolve to become extra-tropical wind storms. Another widely held view is that wind storms and tropical cyclones are different types of perils and modelled independently of each other. Use of the tool identified numerous examples of tropical to extra-tropical transitioning storms. For the same reasons as above, this dependency between perils that are often considered independently by risk managers is of concern in terms of the potential for accumulation of seemingly unconnected risk. Tangible examples that illustrate connected hazards is leading to a more realistic view of connected risk.

An unintended but important application of the tool for climate researchers is for model validation. The tool is a new and convenient way for the climate modellers to explore the output from their model simulations. Since it provides a relatively direct interpretation of the events in the set, details of interest could be discovered without the a priori assumptions necessary with existing analysis and visualisation tools. The climate modellers found that use of their existing analysis and visualisation tools became more efficient and effective when used in conjunction with interactive exploratory visualisation. For example, they were able to identify and observe storms that form together (in the same place and at the same time) and see whether they follow the same path or diverge, examples of both of which were identified. They were then able to look at prevailing atmospheric conditions (using other techniques) to establish whether the observed behaviour was plausible. They were able to observe storm seasons developing in different basins, and simultaneously identify the current state of climate phenomena, such as el nino and la nina conditions, thus were able to assess how well these known phenomena, and related activity were reproduced. Discoveries made by interactively exploring the event set helps to establish how well the model produces expected behaviour; identified unexpected behaviour can then be investigated further.

The tool has also been used to directly disseminate model results, by allowing peers to interactively explore the event sets. Potential for using the tool in education has also been recognised.

The event sets being generated by the National Centre of Atmospheric Science are important means of assisting understanding and quantification atmospheric risk. In particular, the long timescales over which the model is being run is leading to a better understanding of the impact of natural variability on the frequency, intensity and spatial distribution of extreme events, compared to limited information we can derive from the relatively short historical record. The work reported here is important because it demonstrates that interactive visualisation is an important tool for disseminating this knowledge to the insurance industry. It also has a role in improving the science by helping validate and tune the model and opening the results to further academic scrutiny.

The authors of the original work are climate modellers from the National Centre for Atmospheric Science based at the University of Reading and interactive visualization researchers from City University London. Both groups are members of the Willis Research Network funded by Willis, with a remit to apply the latest research to problems faced by the insurance

industry. The general circulation model used to generate the dynamical storm database used in this study was the UK Met Office Hadley Centre Unified Model, ran at various resolutions from approximately 135km to 60km.

This work was the winning entry for the Discovery Exhibition, part of the IEEE InfoVis conference, widely considered as the flagship academic conference for Information Visualisation. The competition showcases visualisation work that has made a tangible impact in another discipline. Entries were peer-reviewed and this entry was the overall winner. The full entry with the paper submission is available from the exhibition page. Further work is planned to establish specific research needs and to design interactive visualisation techniques to help answer these questions.

You can read this paper at
http://www.willisresearchnetwork.com/Lists/Publications/Attachments/117/Discovery%20Exhibition%20slingsby.pdf (open access)

The Discovery Exhibition page is http://discoveryexhibition.org/pmwiki.php/Main/2010

Antje Weisheimer

Assessment of representations of model uncertainty in monthly and seasonal forecast ensembles

To be useful, any prediction of weather or climate must include a reliable assessment of forecast uncertainty. This is especially true for forecasts of severe weather events, of particular importance to the insurance industry, since such weather events are often the most unpredictable, and hence most uncertain, but yet the most damaging. The need for reliable estimates of forecast uncertainties implies that predictions must take explicit account of inherent uncertainties in the prediction process, and therefore be probabilistic in nature.

Although uncertainty arising from the limited accuracy and coverage of global weather observations is an important contributor to weather forecast uncertainty, in recent years it has increasingly become acknowledged that forecast model uncertainty is also a crucial source of prediction error. Indeed, for climate prediction, model uncertainty is the dominant source of forecast error.

Historically, the modelling tools needed to predict climate have been developed, somewhat independently, at a number of weather and climate institutes around the world. Whilst these models are individually deterministic, it is often said that the resulting multi-model diversity provides a useful quantification of uncertainty in global or regional predictions. However, this notion is a very pragmatic ad hoc approach not well founded theoretically. It is known that the corresponding multi-model ensemble estimates of uncertainty can be prone to systemic failure. Furthermore, such ensembles are limited by the number of models available and their assumed independence, and moreover there is no prior guarantee that the available models faithfully represent true model uncertainty.

The problems of limited ensemble size of a multi-model ensemble is mostly solved in the alternative approach of perturbing free sub-grid scale parameters within a single model framework. However, the remaining problem, that of ensuring true model uncertainty is properly represented, is even more acute in the perturbed parameter framework, since uncertainty in the structural form of the physical description of sub-grid scale variability is not addressed.

A new approach to representing model uncertainty has been developed in recent years – the idea of stochastic parameterisation. A key source of uncertainty in the prediction of weather, and even more climate, arises from the inevitable computational approximations needed to solve the underlying equations of motion. Using stochastic mathematics, this approach recognises uncertainty explicitly in the parametrised representation of unresolved weather and climatic processes. Stochastic parametrisation is shown to be more consistent with the underlying equations of motion and can also help reduce long-term biases which have bedevilled numerical simulations of weather and climate from the earliest days to the present.

In our paper entitled "Assessment of representations of model uncertainty in monthly and seasonal forecast ensembles" we evaluated the forecast performance of three different types of representation of model uncertainty in monthly and seasonal prediction mode, namely the multi-model ensemble, the perturbed parameter ensemble and the stochastic parametrisation ensemble. To do so, we analysed a coordinated set of retrospective forecast experiments using IPCC-class global coupled ocean atmosphere models and computed the probabilistic skill of forecasting unusually warm or cold and wet or dry months and seasons ahead. We also compare our results with a default ensemble with no representation of model uncertainty.

The paper shows, for the first time, that, on monthly and seasonal timescales, this stochastic representation of model uncertainty produces overall more reliable forecasts than does a traditional multi-model or perturbed parameter ensemble forecasts, on timescales where verification data exists.

This result has some extremely important implications, not only for improving weather forecast reliability for users in the insurance industry, but also for the way in which future weather and climate models are developed in Europe and elsewhere.

Insurance against adverse weather and climate effects is a core business in the insurance industry. The losses of catastrophic and non-catastrophic weather events have increased dramatically on a global scale over the last 50 years. Thus, major advances in the science of weather and climate prediction could translate directly into financial significance for the insurance industry. The improved representation of model uncertainty through the introduction of stochastic approaches for the un-resolved sub-grid scale physical processes in weather and climate models will mark a big and important step also relevant for the insurance sector.

The representation of model uncertainty in climate change projections is particularly problematic as there is as yet little verification data to assess potential representations. As a result, the concept of seamless prediction has arisen whereby climate models can, and should, be tested in weather and seasonal prediction mode. The notion of seamless prediction suggests that the results presented in our paper may be relevant on longer multi-decadal timescales and that stochastic parameterisations should now be developed for multi-decadal climate predictions using Earth-system models.

Our paper was published in Geophysical Research Letters in August 2011. It was written in collaboration with my institutional co-authors from ECMWF and Oxford but I carried out the majority of the research.

You can read this paper at http://www.agu.org/pubs/crossref/2011/2011GL048123.shtml (subscription required)

9 TECHNOLOGICAL/BIOLOGICAL RISKS

9.1 WINNER

Angus Law

The influence of travelling fires on a concrete frame

FM Global states that fire continues to be the leading cause of property damage worldwide. This paper develops a new approach for designing large buildings to resist fire. The paper advances two key areas of understanding: how large fires can realistically be represented; and how they can be applied to the design process. The paper also fuses the disciplines of structural engineering and fire engineering to give a unique insight into how real fires may affect real buildings.

Structural fire engineers use "design fires" to understand how severe a fire in their building might be. The structure of the building – the beams and columns – are then designed to resist this fire. Typically engineers concentrate most of their efforts on the design of the structure while relatively little attention is paid to the types of fire that may occur in the building. This asymmetry in design focus has left a significant gap in our understanding of the true risk to our infrastructure posed by fire.

Many buildings around the world are now built with large open-plan layouts. This has led to a change in the types of fire that are likely to occur in the building. Fires that move around ("travel") within a building uninhibited by partitions are more likely to occur – for example the Windsor Tower, in Spain; TU Delft, in the Netherlands; and the World Trade Centres, in the USA. These fires produce very different heating from the typical "design fires" currently used by structural engineers; this paper develops the concept of travelling fires for design.

The drive for sustainability is also leading architects and engineers to strive for more efficient forms of construction. This has led to a reduction in the tolerances and less margin for error in the engineering calculations used in the design of structures.

These two factors mean that, simultaneously, our design approaches have become outdated and that the consequence of errors in design has become much more significant. This conclusion has serious consequences for the safety of building occupants, the owners of the building, and buildings' insurers.

This paper proposes a new method for defining the design fires used in structural engineering. It is shown that travelling design fires can be more onerous than static design fires. The impacts of different fire sizes are assessed using the latest structural analysis techniques. This research will lead engineers to ensure that buildings actually deliver the required level of performance. Realistic design fires can be defined and the design of the structure can be modified to ensure that it is sufficiently robust to resist them.

The authors of this work believe that industry adoption of these techniques will allow the fire performance of buildings to be quantified, and ultimately the exact performance (and therefore financial exposure of a building's insurers) to be defined and integrated into the design process.

The concept of travelling fires and their application to structural design is novel. The techniques in this paper recognise that the nature of fire risk in buildings has changed, and should be considered in the design process.

Engineering Structures is a wide ranging and exceptionally highly regarded international journal in the field of structural engineering; in addition to this publication, this work has been presented at a number of international conferences. The thesis of which this work forms part was awarded the "Best Thesis Award, Europe and Africa 2007-2011" by the International Association for Fire Safety Science.

You can read this paper at http://www.era.lib.ed.ac.uk/handle/1842/4907 (open access)

9.2 RUNNER UP

Sung-Han Koo

Sensor-steered fire simulation

The costs of fire are great, commonly estimated in the range of 1-2% of GDP. Despite this, emergency service intervention at fires is often reliant upon very basic information – a fire officer may only know that an alarm has been activated on a certain floor and may have to rely on gut instinct in determining possible fire development based on whatever external visual clues are available, e.g. smoke emerging from a building. Extrapolation of this evidence to consideration of how an incident may evolve, thus how the evacuation should be effectively managed and whether it is safe to send in fire-fighters, is an extremely difficult task even for the most experienced fire chief. A single misjudgement could lead to catastrophe, as tragically illustrated in the 9/11 World Trade Center response when emergency crews continued operations totally oblivious to the impending collapse of the towers. Lack of adequate information on fire conditions is a common factor in other fire disasters of this type and the associated costs, both in terms of life and property, can be very high.

Technology could be harnessed to transform this situation, by linking measurements from modern sensor-rich built environments to advanced fire simulation calculations running on the latest computer hardware, i.e. the "grid", to provide interpretation and prediction of the evolving hazards. Historically, computer simulation has been widely used in fire safety engineering practice, for example in application to smoke movement analysis, assessing sprinkler performance, and modelling structural response to fire. Due to the inherent complexity of fire, however, the capability of models to accurately reproduce the relevant phenomena has often been a subject of debate. A priori definition of necessary input parameters and boundary conditions is extremely challenging. Even if we assume all the requisite information is available and sufficiently well defined, a small change in the fire or other boundary conditions (e.g. wind effects, glazing failure, etc.) can have a drastic impact, leading to the fire developing in a totally different way. Thus, a finite number of computer simulations cannot realistically cover all the relevant fire scenarios, all the more challenging when there are significant numbers of enclosures of potential fire origin, whilst in a single room there are many different combustible items and each may burn in a complex manner. Thus, in most cases, a small number of computer simulations are undertaken, typically using nominal "design fires", and only for a specific, "representative", part of the building, thereby providing information that is only relevant to those highly idealised conditions.

Increasingly, built environments are equipped with sensors which continuously collect data and monitor infrastructures for various purposes such as fire detection, indoor comfort and security. In most cases, however, this information is not provided to fire-fighters or building occupants, beyond the initial stage of warning people that there may be a fire. But even simple fire sensors such as thermocouples can also supply essential details about the fire conditions, which if interpreted can provide an assessment of the hazardous environments in a building. More advanced buildings (with "Intelligent" or "Smart" infrastructures) may be equipped with more sophisticated sensors, e.g. to define the location and movement of the occupants. All this information could potentially supply the critical "unknowns" in an incident simulator, facilitating a novel way of harnessing advanced fire and evacuation models and enabling genuine predictions of possible hazard evolution and the threat to life and property.

In our study, a methodology has been developed which could underpin a prototype emergency response system of this nature. Steering the fire model from sensor observations is a major challenge in its own right, particularly in light of the indirect relationship of many measured parameters to the fire definition. An intelligent approach to integration of sensor measurements and model representations is needed. Using a procedure based (in part) on Bayesian inference, our methodology progressively adjusts the parametric space from which new scenarios are generated, thereby identifying fire scenarios which are increasingly accurate matches to the evolving sensor readings. The effectiveness of this data-driven approach for "steering" the model has been proved, with fixed model parameters successfully recovered from simulations of trial fire scenarios. But it is also responsive, with the capability to handle rapid changes in fire conditions, or other external factors, something which is impossible for traditional fire modelling approaches. All of this enables the vital real-time "forecasting" element, i.e. prediction of hazard evolution, with the system providing estimates of the range of possible fire development behaviours, together with advance warning of extreme events such as "flashover" and structural collapse. The model results are expressed in terms of probabilistic information, i.e. the assessed likelihoods of the various scenarios at relevant lead times. These extensive outputs are interpreted and presented in simplified format to the end user via a dedicated fire panel display, which also supports user interaction where more detailed information can be accessed as required.

The demonstration of the methodology has been achieved via live deployment for a full-scale fire test in linked compartments, simulating part of a building, attended by a broad audience including senior fire officers. The complex evolution of the experimental fire, with unforeseen behaviours, was an ideal test of the sensor-linked model, and the system capabilities were effectively proved in the real-time simulation and model predictions. In real-world application, this novel approach could support the decision-making of fire-fighters and building occupants, improving the effectiveness of interventions and facilitating safe egress. Thus it has potential to fundamentally change the way in which fire emergencies

are handled, reducing the impact of poorly managed incidents and mitigating the various direct and indirect costs of fire, spanning life safety and property protection issues. Further development of such systems extends a genuine hope that some of the chronic and long-standing problems associated with the impact of devastating accidental fires might eventually be overcome, with a direct relevance to fire risk concerns of insurers and wide-ranging benefits to all relevant stakeholders.

You can read this paper at http://www.era.lib.ed.ac.uk/handle/1842/3534 (open access)

9.3 SHORTLISTED ENTRIES

Geoffrey Hunt

Building expert consensus on problems of uncertainty and complexity in nanomaterial safety

The rapid development of nanotechnology will bring new benefits and new uncertainties to the insurance industry, and it is vital for the industry to stay a step ahead of this development in its scientific, technological, regulatory and social implications. While nanotechnology will carry with it the benefits of a new market and novel techniques for risk mitigation, it is the uncertainty and complexity of this technology which is of concern to insurance industry strategy. The industry will have to make ongoing step-by-step adjustments if it is not to be caught by the tension between the perceived benefits and the real uncertainties. Insurance strategy requires understandable and manageable risk and this is not currently the situation in nanotechnology, which is a new industrial approach running ahead of scientific knowledge, safety and regulation.

Clearly it is valuable to the insurance industry to have an up-to-date snapshot of expert opinion on the progress made and the remaining work to be done, especially concerning the uncertainties. That is what this piece of research provides.

In 'Building expert consensus on problems of uncertainty and complexity in nanomaterial safety' the authors have asked the important questions, to the right people at the right time. The general answer they have received from those actually working in the field of nanotechnology safety and closely related disciplines is that the level of uncertainty is still very high, and more than one kind of uncertainty is involved. The advances made in the field of nano-safety have not yet answered major questions of uncertainty, but they have begun to answer questions about how to go about reducing this uncertainty. This is a necessary first stage.

This research has achieved two things. Firstly, the experts were able collectively to identify priority areas for research conducive to establishing nano-safety. Secondly, an analysis of their responses to the questionnaire showed up the need for greater theoretical clarity on the kinds and levels of complexity which underlie the uncertainty.

The participants identified the following ten priorities in the development of nano-safety: the need for realistic exposure scenarios, better established dose-response relationships, improved extrapolation from in vitro to in vivo, identification of the most relevant assessment parameters, understanding the dynamic biological interfaces, long-term studies, information about stability and reactivity, understanding the behaviour of the protein corona, having test guidelines adapted to manufactured nanomaterials, and the development of more advanced statistical and computational methods.

The research shows that it is vital to understand the basis of this uncertainty. It is important to distinguish between mere lack of data and the intrinsic uncertainties that are a consequence of the complexity of living systems in their responses to nanoscale entities. The uncertainty may, in some respects be of a special character. That is, it is vital to get a grip on what kind of uncertainty we are dealing with. It is not merely the uncertainty of not having yet collected sufficient data, although this is also a problem. An analysis of the varied responses of the experts shows up a problem of complexity that is currently unmanageable and this complexity can be broken down into specific aspects. These aspects, as they are refined and 'populated' by empirical findings, will be useful to the insurance industry in creating a framework of pre-emptive risk mitigation criteria. In brief, the aspects are: 'Adequacy of data' (e.g. difficulty of translation from in vitro to in vivo; lack of long-term studies); 'Adequacy of methods' (e.g. inadequacy in protocols, definitions, standardisation, reference materials and comparability of experimental outcomes); 'Nanotoxicological Complexity' (e.g. the bio-nano interface, non-linear systems, emergent properties, and the need for computerised mass-data stochastic approaches).

On the whole, those working in occupational and public health or in human and environmental toxicology have the impression that we do not sufficiently understand the impact of manufactured nanomaterials on living systems. This is perceived as a source of concern. There is a substantial need for raising the awareness of the kinds of complexity involved across the life-cycle of nanomaterials, with long-term documentation and traceability of MNMs' application and use.

This paper can be read at http://www.nano-ntp.com/purchase_individual_issues.html (subscription required)

Villie Flari

Expert judgment based multi-criteria decision model to address uncertainties in risk assessment of nanotechnology-enabled food products. Emerging technologies: Friend or foe?

Although innovative emerging technologies are exciting, they still create room for potential risks for which we have so far not been prepared to fully understand and assess. Most recent examples of such emerging technologies include nanotechnology and synthetic biology both of which offer enabling platforms for exciting prospects and potentially an enormous number of benefits for the consumer and the environment. Just to illustrate, more than 1,300 consumer products are currently claimed to be enabled by nanotechnologies; the inventory of manufacturers' identified nanotechnology enabled products has grown by nearly 521% (from 212 to 1317 products) since it was initially released in March 2006. Nevertheless, the new technologies may be accompanied by risks to human health and/or the environment. Currently these are difficult to address due to the lack of knowledge of possible interactions of nanosized materials at the molecular and/or physiological level and their effects on human health either directly or indirectly. In order to ensure that we would continue benefiting from progression in science the question becomes: how precautionary or non-precautionary the approach to risk assessment should be?

Whilst the full knowledge of the properties and effects of nanomaterials may take years to emerge, an interim solution to this problem can be provided by a multi criteria decision making (MDCM) model. By applying the MCDM approach to each situation and/or product, potentially risky products would be identified and distinguished from the ones that are perceived as potentially safe. This would greatly facilitate the identification of risky products which could await more thorough evaluation for safety before being placed on the market. In addition to this, the setting up of insurance premiums would become more accurate and simpler.

We have recently developed a MCDM model that carries unique potential; because the level of uncertainties involved in products based on emerging technologies is extremely high it employs expert judgment. Experts' opinions will vary substantially among experts. The issue in question then also becomes: how to capture all experts' current knowledge and uncertainties in a coherent way and understand how they use their knowledge when thinking about risks of nanotechnology-enabled products?

Our approach captures experts' preferences in terms of scores on 10 key criteria to address the main uncertainties that need to be taken into account for the safe development of such products. Instead of directly assessing weights for criteria our approach requires experts to rank a number of scenarios differing with respect to values on the criteria. The model is based on probabilistic inversion that is used to obtain a distribution over criteria weights which best reproduces the observed distribution of experts' rankings. Thus, it enables us to perform out of sample validation of the model. In our paper we achieved out-of-sample validation in 2 ways: (a) a portion of the rankings was excluded from the model fitting; these rankings were then predicted by the model fitted on the remaining rankings; (b) a partially different set of experts generated new scenarios, using the same criteria and ranked these; their ranks were compared with ranks predicted by the model. Out-of-sample validation is essential as it offers a robust scientific basis for any decision made, and adds predictive power to the MCDM model developed.

Our work has demonstrated that the MCDM model has the potential to both: (a) distinguish among different nano-applications for the food sector in terms of their safety and potential risk, and (b) predict in which category experts in the field would place a newly developed product while the percentage of successful predictions of the preliminary model we developed was 75%.

The MCDM model could serve as a first tier decision making or screening support tool to distinguish products that could be considered as potentially safe from the ones for which a far more detailed risk assessment may be needed. The successful employment of the model is based on the following assumptions: (a) it could be assured that possible misuse or misapplication of the tool would not take place, and (b) its predictive power would be refined regularly (e.g. biannually) by tailoring in the latest knowledge advances in this area of research.

Regarding world-wide recognition, 41 internationally recognised experts in the areas of nanotechnologies and food science participated in our research. Results from our work were presented at the 2010 annual meeting of the Society for Risk Analysis (December 2010, Salt Lake - Utah, USA), and were published in the Journal of Nanoparticle Research (J Nanopart Res (2011) 13: 1813–1831; DOI 10.1007/s11051-011-0335-x). We were invited to present our structured methods to elicit expert judgment and the developed MCDM models in the international conference on "Food Safety and Consumer Protection" organised within the MoniQA European Union network of excellence (http: www.moniqa.eu; Varna – Bulgaria, 27th – 29th Sep 2011). This research also led to acquiring further funding to organise two international experts' workshops to elicit expert judgment on risks, benefits and uncertainties of emerging sciences and technologies: "Health and environment safety of nanotechnology enabled products" and "Prospects and potential pitfalls of Synthetic Biology" at The Food and Environment Research Agency (Fera), York, UK (21-23 September 2011).

This paper can be read at http://www.springerlink.com/content/926307922p336gv6/ (open access)

David I. Blockley

Engineering Safety

A key issue behind all insurance risks is the relationship between technical and human issues. For example in a private communication, about the recent earthquake in Christchurch New Zealand, an engineer friend who lives there said that 'almost everything is on hold because people cannot get insurance for any new building, unless they are shifting from a damaged house where they were existing customers for an insurance company. Also, contractors are finding it difficult to insure buildings as they are building them'. This is a totally unexpected and unintended consequence of the earthquake.

Over many years these two aspects of risk (technical and human) have been treated quite separately by engineering researchers although many studies of case histories have shown that they are intimately related. There are big gaps between what people research, what people do in practice and why things actually go wrong in practice. It is no longer acceptable to treat them as if they are quite separate and independent aspects of a project and there is a desperate need to integrate the different approaches.

Still less research attention has been given to the intimate relationship between technical risks and the law although in practice after any accident the law is always paramount. In practice law is the ultimate arbiter. All engineers know that they have a 'duty of care'. Many engineers are uncomfortable that so often, in practice, the legal processes of ascertaining blame obstruct the technical processes of learning. A consequence is that there has been an increasing interest in developing a discipline of forensic engineering particularly in the USA.

The paper submitted is an invited contribution to the first edition of Forensic Engineering now published by the Institution of Civil Engineers. The major question addressed is 'how is engineering safety best served by forensic science and engineering that pertains to legal processes?' The paper notes that a critical question for a lawyer is 'who is trying to do what to whom?' The primary concern of the court is not an abstract inquiry into the causes of an incident but to establish who is to blame.

Engineers have realised that failure is essential to the growth of knowledge. But failure is exactly what engineers do not want. It is all the more essential therefore that we learn lessons when failure does happen. Technical reports are embedded in human and social systems and so forensic engineers must be sensitive to semantic subtleties regarding error, mistakes, accidents and disasters. Models of how 'latent' hazards, technical and social, are described in the paper but all require engineers to think in an integrated way – to cross disciplinary boundaries between 'hard' physical technical systems and 'soft' managerial ones.

A major message of the paper that an integration of all considerations of risk and safety, including insurance, may be facilitated by systems thinking – a way of looking for commonalities, dealing with dimensionality, multiple perspectives and looking for alignment between fragmented professional and social silos.

The paper concludes that much of the present focus of forensic engineering is on hard system failure. While this is necessary and important, it is not sufficient. When an accident, failure or disaster comes to court it is important to remember that the primary purpose of the court proceedings is to allocate blame – not to find out, in a dispassionate manner, what actually happened. Still less is it concerned with the lessons that can be learned for the future.

The forensic engineer needs to distinguish clearly between how blame can be allocated and what lessons can be learned in order to prevent similar incidents in the future. We all need to recognise that an approach that seeks to name, blame and shame is not helpful for engineering learning. Blame stifles learning by restricting the flow of information. We must work with multiple perspectives about a whole range of issues, from what risks are acceptable/unacceptable to the subtleties of the meanings of words such as error, mistake, accident and disaster. We need to make sure that the purpose of, and responsibilities within, any particular process are well defined. We must recognise that context can make a big difference to what technically may seem similar and see the hard system failure as embedded in a soft system failure so that we can cooperate to seek to understand what happened in the soft system.

Finally the paper urged forensic engineers to submit papers to the new journal that report on new cases of even quite small incidents from which lessons can be drawn. It is also important to draw attention to situations in which legal processes inhibit engineering learning the lessons through creating a genuine dialogue between lawyers and engineers.

This paper can be read at http://www.icevirtuallibrary.com/content/article/10.1680/feng.2011.164.1.7