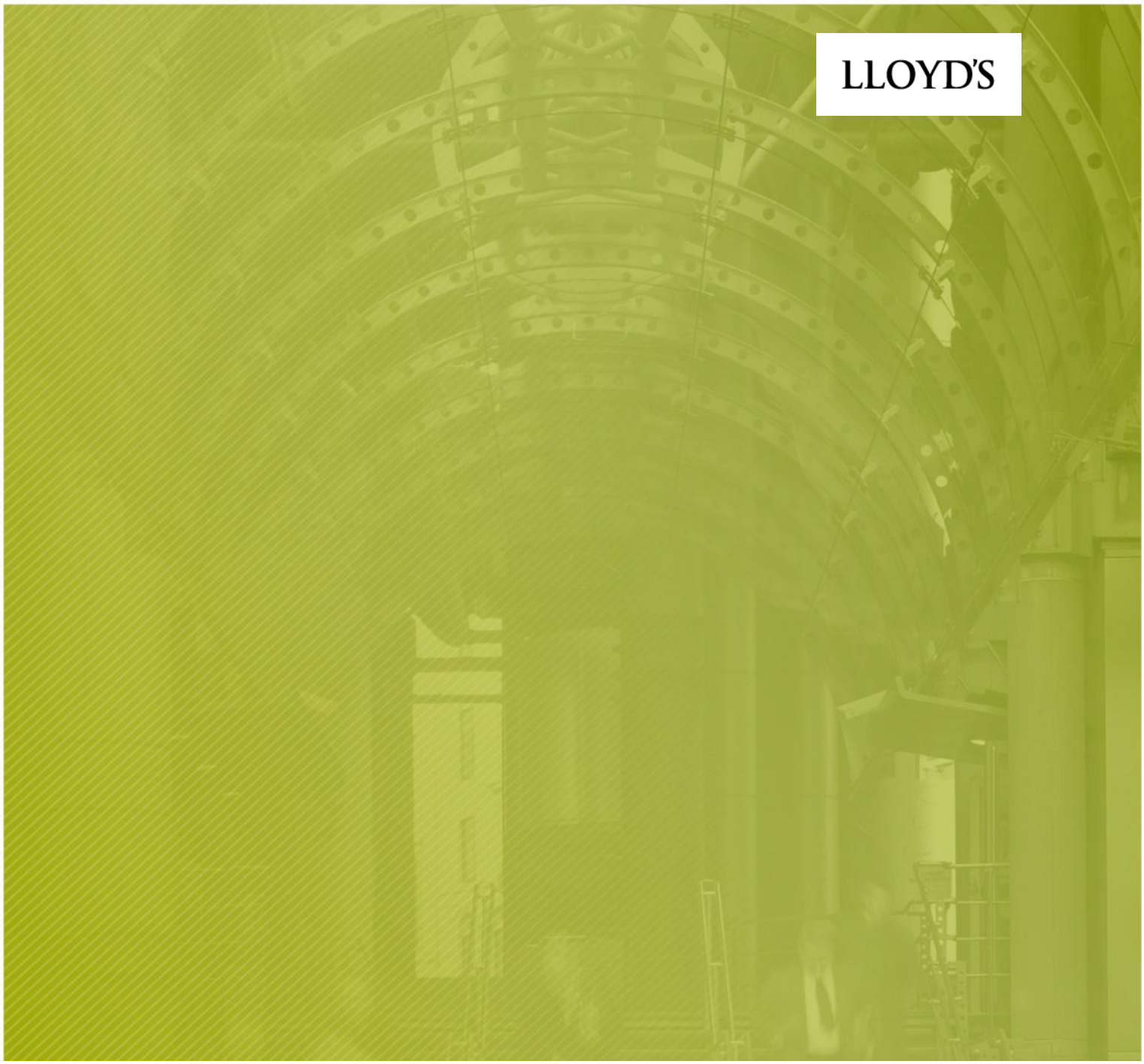

LLOYD'S

# LLOYD'S SCIENCE OF RISK

## 2013 CONFERENCE

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# CONTENTS

# 1 FOREWORD

I often hear insurance described as a 'promise to pay', and it's a very fitting description. But of course insurance goes much further, it's about managing risk, it's about giving insurers and policyholders the tools to prevent or mitigate disaster before it happens.

The Science of Risk Prize is a real celebration of the close relationship between insurance and research. This year we had three categories for the Science of Risk prize: behavioural, geopolitical and societal, and biological and technological. The high calibre as well as the volume of entries gave the judges a very difficult decision.

This year's overall winning entry really chimed with Lloyd's international ambitions, and demonstrated an innovative approach by trying to understand the behaviours of those vulnerable to natural catastrophe. By analysing the cultural attitudes to insurance of those living in different earthquake zones the research raised questions that have a direct application to how the industry works.

In addition to the winning entry there were many fascinating contributions on subjects ranging from the technology to cool jet engines in aviation, to the human skill involved in detecting insurance fraud, which I know will give the industry valuable new insights.

As someone who has spent 12 years working in research I know personally how challenging, as well as rewarding, a career in academia can be. I'd like to offer my personal congratulations to the winners, runners up and those shortlisted and to thank everyone who made an entry to this year's prize.

The Science of Risk Prize is just one part of the work Lloyd's does to increase insurers' knowledge of new and emerging risks, and as this will be the last time the prize is awarded during my tenure as CEO, I would like to thank the Emerging Risks team for their hard work and dedication to this initiative.

Dr Richard Ward
Lloyd's Chief Executive

# 2 SCIENCE OF RISK CONFERENCE 2013

Members of the academic, insurance and broader research and business communities joined together on 28 November 2013 for the fourth presentation of the Lloyd's Science of Risk Prize. The awards were presented by Lloyd's Performance Management Director, Tom Bolt, before the six winners and runners-up delivered presentations about their work, followed by questions from the audience. This year there were three categories for the prize: behavioural, biological and technological, and geopolitical and societal risk. The conference was held in partnership with the Lighthill Research Network.

Professor Helene Joffe was awarded the top £5,000 prize for her paper submitted in the Behavioural risk category. Professor Joffe's paper, "Social Representations of Earthquakes: A Study of People Living in Three Highly Seismic Areas", observes that action to reduce earthquake risk is undermined by feelings of anxiety and fatalism. From looking at three different but all highly earthquake-prone cities, Seattle (USA), Izmir (Turkey) and Osaka (Japan), Professor Joffe demonstrated that the measures people take to prepare against risk are influenced by emotional and cultural factors.

While an earthquake is a peril that is well-established on the insurance radar, the judges were impressed by how Professor Joffe's paper looked at this topic in a light that was novel for insurers, but also practical in its scope of understanding why people who live in risky areas might not buy earthquake insurance. The multi-cultural outlook of the paper was also felt to be relevant to Lloyd's Vision 2025 goal to develop a broader understanding of both established and emerging markets.

The winner of the Biological and Technological category was Dr Rosemary Waring, who delivered a thought-provoking talk on efficient and pragmatic ways to assess the risks posed by potential endocrine disruptors. Dr Waring has devised a method of rating responses from tests on human cells *in vitro* in order to more rapidly and accurately understand how many chemicals used in everyday life could be affecting the human body.

Professor Tim Bedford was the winner of Geopolitical and Societal risk with his paper "Decision making for group risk reduction: dealing with epistemic uncertainty". This looked at the statistical methods used in modelling group risks, and proposed a new approach to doing so which better acknowledges the amount of uncertainty in representations of the size of these risks. The judges felt that Professor Bedford's entry was highly useful in the way it can be broadly applied to insurance modelling in order for the industry to have a sharper understanding of the risks it faces.

As well as winners, each category had a runner-up award. In the Behavioural category, Professor Tom Ormerod's paper on the behaviours of claims fraud investigators won the runner-up prize. This paper had a clear relevance to insurers, and was informative about how to combat claims-fraud, thus creating great savings for insurers.

The Biological and Technological runner-up, Dr Francesco Montomoli, spoke about his paper on improving the design of aeroplane jet engines. Dr Montomoli specifically looked at the cooling system of engines, and at how taking into account microscopic manufacturing variations could improve an engine's reliability and lifespan.

To finish up the day the Geopolitical and Societal runner-up, Professor Neil Adger, talked about his paper "Renegotiating social contracts that shape the balance between public and private risk". Specifically looking at the examples of the 2009 floods in England and Ireland, Professor Adger examined how certain events can reshape people's expectations of how much risk should be borne by governments.


In addition to the Overall Winner's prize of £2,000, the other category winners were presented with winning certificates and a cheque for £2000. The runners up in each category also received certificates and cheques for £500.

As well the series of presentations from the winning entrants, the attendees were able to view posters of the work of all shortlisted entrants during a long coffee break. This provided an opportunity for networking and idea-sharing between members of the business and research communities, highlighting the cross-professional collaboration which the Science of Risk prize aims to foster.


## SCIENCE OF RISK 2013 FINALISTS


From left to right: Rosemary Waring (Biological and Technological winner), Tom Ormerod (Behavioural runner up), Francesco Montomoli (Biological and Technological runner up), Helene Joffe (Overall winner), Neil Adger (Geopolitical and Societal runner up) and Tim Bedford (Geopolitical and Societal 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 |
|---|---|---|
| Dougal Goodman | Chief Executive Officer | The Foundation for Science and Technology |
| Trevor Maynard | Head | Lloyd's, Exposure Management |
| James Orr | HoD, General Insurance Risk Specialists | Bank of England |
| Mel Goddard | Market Liaison Director | Lloyd's Market Association |
| Adrian Alsop | Director for Research and International Strategy | Economic and Social Response Council |
| Dorian Blake | Head of Underwriting Review | QBE |

# 4 2014 SCIENCE OF RISK PRIZE

If this booklet inspires you to apply for the 2014 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 RISK

## 5.1 WINNER

**Helene Joffe**

**Social Representations of Earthquakes: A Study of People Living in Three Highly Seismic Areas**

This paper was published in 2013 in *Earthquake Spectra*, a leading earthquake engineering journal. The paper presents the findings of a large research project and is the only current, cross-cultural study concerned with how members of the public in highly seismic areas of the world represent and prepare for earthquakes. The focus is on what drives preparatory actions, such as acquiring earthquake insurance.

**Key findings**
Demographically-matched samples of people in three earthquake-prone cities - Seattle, Izmir and Osaka - were studied. The results challenge the conventional assumption that people's action to reduce their risk results from perceiving the risk as likely and severe. Questionnaire data collected alongside interviews indicated that despite universally high awareness of earthquake threat, participants in all three cities did little to prepare for earthquakes or mitigate their risk. Out of a list of nineteen risk-reducing actions - which include possessing earthquake insurance - participants in all locations reported having done (on average) less than half, though the Americans had adopted a significantly greater number of actions than either the Turkish or Japanese participants.

Qualitative analysis of the interview data threw light on people's failure to act to reduce their earthquake risk. Analysis indicated that important contributors towards whether people acted or not lay in their emotional responses to earthquake threat. While the Japanese and particularly the Turkish respondents associated earthquakes with intense panic, fear and anxiety, American respondents displayed a much more moderate level of concern. The Turkish interviews were also notable for the intensity of their anger, blame and distrust of the state and of building construction authorities, whose negligence and corruption were positioned as the cause of earthquake damage. Furthermore, while US and Japanese participants distanced themselves from the earthquake threat by favourably comparing themselves to places that they saw as more seismic, Turkish participants sharply deviated from this pattern: they also compared themselves with other countries, but this resulted in seeing themselves as extremely vulnerable to earthquake damage.

These emotional responses to earthquake threat interacted with a cluster of feelings relating to a sense of agency and control in relation to earthquakes. Almost all participants demonstrated that they were aware that actions to reduce earthquake risk were available. However, alongside this awareness lay a strong trend towards fatalism in all three cities, with respondents asserting that human action is pointless in the face of earthquake threat. These fatalistic tendencies were clearly culturally grounded and were rooted in different belief-systems in the three countries. US and Japanese fatalism largely followed from cultural representations of earthquakes as acts of nature, a sphere immune from human influence. The fatalism present in the Turkish data, on the other hand, drew on a religious framing of earthquakes as acts of divine power, as well as an emphasis on vulnerability caused by institutional corruption.

The data suggest that emotional and socio-cultural variables exert an appreciable influence on people's risk behaviour. The intense emotions experienced by the Turkish and Japanese participants, in combination with cultural currents that represented earthquakes as insurmountable forces, seem to have overwhelmed people and paralysed them from action. The US participants displayed a more muted emotional response to earthquakes and also reported the greatest levels of protective action. A more moderate level of concern, rather than high anxiety, may be more facilitative of earthquake-protective behaviour. Nevertheless, even the US participants performed less than half of the recommended practices. Action is undermined by cultural representations of earthquake threat as impervious to human action, by the long return period of earthquakes and by them being rare but potentially catastrophic risks.

**Relevance to Insurance Industry**
A significant earthquake mitigation measure is the provision of earthquake home insurance in developed countries or of micro-insurance schemes in developing contexts. Within our samples, however, earthquake insurance was amongst the least popular adjustment measures, with under ¼ of the sample across the three contexts stating that they had it.

This research demonstrates that barriers to the adoption of insurance as a mitigation measure are not purely financial. In addition, the barriers do not fit within the traditional cognitive biases, like the optimistic bias, which are touted as reasons for people failing to prepare for rare, high magnitude risks. Indeed the city where least preparation is found – Izmir - is also the one where people have the most pessimistic outlook concerning the deathly effects of earthquakes. Thus Turkish inaction is more likely to be related to distrust of authorities, fatalism and anxiety than to cognitive bias. Emotion rather

than cognition should be foregrounded when endeavouring to understand people's risk-related behaviour. These findings are in line with major shifts in the psychology of risk field, away from pure reliance on cognitive processing to emotive reaction, from biases in the 'perception of risk' to the consequences of the 'feeling of risk'.

The study is also relevant to the insurance industry in that it explores people's thoughts, feelings and mitigation behaviours naturalistically. This allows researchers and practitioners to model what drives behaviour without imposing assumptions on the research.

In order to promote the uptake of mitigation measures, the barriers identified need to be counteracted. Once it is recognised that barriers are largely emotive and also socio-culturally variable, campaigns can be tailored accordingly. Such tailoring can only be achieved once the dynamics of each group's complex representation of a particular danger are understood.

**Quality and Impact**

The research method adopted in this paper is both highly rigorous and novel. Demographically-matched samples of individuals were chosen in cities that were themselves matched for seismicity, size and coastal location. None of the cities had experienced a major earthquake in the past fifty years. The quality of the work was also endorsed not only by it being Engineering and Physical Science Research Council (EPSRC) funded, but by the EPSRC giving the researchers a further £2.2 million to intervene to increase preparatory behaviour in Seattle and Izmir.

## 5.2 RUNNER UP

**Tom Ormerod**

### Understanding and supporting the behaviours of expert investigators to combat insurance fraud

The submitted paper describes a project conducted in collaboration with Axa Insurance plc to develop novel methods for detecting and investigating fraudulent insurance claims. Many technological solutions proposed to the problem of insurance fraud (e.g., data mining; voice stress analysis) focus on identifying the behaviours of fraudulent claimants. The novelty of our approach is in capitalising upon identifying the behaviours of fraud investigators. By understanding the strategies of skilled investigators, we can build novel technologies that reflect and support their expertise.

In this project, we set out initially to study the people involved in the fraud investigation process using an 'ethnographic' method, in which we spent long periods alongside staff working in a wide range of UK insurance companies and loss adjustors, documenting their actions, conversations, meetings, and reflections. From data collected in our ethnographic studies, we set out to identify behaviours that inhibit successful handling of fraudulent insurance clams and behaviours that facilitate fraud detection and investigation. We looked at two staffing groups: claims handlers at the front line of fraud detection, receiving calls and letters from claimants; and specialist fraud investigators, following up on unusual or suspicious claims refered to them by claims handlers.

Studies of claims handlers yielded two surprises. First, although typically inexperienced with little training and high staff turnover rates, claims handlers were surprisingly adept at spotting potentially fraudulent claims. They were able to identify anomalies and gaps in the data provided by claimants, evaluate the plausibility of accounts, and notice suspicious language use or other dispositional characteristics among claimants. It turns out that the same methods proposed by some expensive technological solutions are the very skills that humans do best: spotting anomalies and detecting unusual vocal delivery. Second, although they might successfully detect a likely fraud, claims handlers were unlikely to persue their suspicions in an effective way. More often than not, they simply chose to ignore their suspicions and continue to process the claim. We suggest that the emphasis on through-flow (where performance is measured by number of calls handled) combined with a lack of clear reward for acting on fraud suspicions acted as disincentives to effective handling of potential fraud cases.

Studies of experienced investigators also yielded surprises. First, in trying to understand a case, investigators often built up elaborate narrative accounts of how a fraud might have evolved over time, often going way beyond the facts at their disposal. By doing so they were able to expand the range of hypotheses considered and adopt a more critical stance to evaluating their current hypothesis. Second, although laboratory studies of expert reasoning often show biases such as a tendency to select evidence that confirms the current hypothesis rather than the optimal approach of attempting to find evidence that might falsify it, skilled investigators regularly set out to find exceptions and exclusions that might potentially nullify their current line of enquiry. Third, investigators had a range of strategies for managing the amount of information they had to consider at any one time, often delaying the pursuit of relevant evidence until the optimum time to open it up to consideration. However, we found that expert investigators were often hampered by a poor fit between their skills and the technologies meant to support them. Poor design of interfaces to data systems and hypothesis-building tools that did not match the activities that investigators needed to carry out meant that more often than not skilled investigators ignored the support systems provided for their use.

In the next phase of the project, we specified and developed prototypes of computer-based tools to support both claims handlers and expert investigators in detecting and investigating fraudulent claims, focussing on motor policies (though the principles generalise across all insurance types). The first, a Mass Detection tool, acts as a filter to identify high-risk cases. It uses a statistical method called Bayesian Belief Networks to link together the anomalies and concerns identified by claims handlers and subsequently assesses the probability of fraud based on their co-occurrence. To encourage the reporting of suspicions by claims handlers, we made entering information as simple as possible (a series of one-click menu selections) and provided a reporting score that could be used for performance reward. The second, a Suspicion Building tool, provides investigators with methods to explore a potentially fraudulent case flagged in the output of the Mass Detection tool. The tool provides an environment for experienced investigators to review and classify new types of anomaly that are entered into the Mass Detection tool by claims handlers. Thus, the system learns as new fraud types evolve. It also supports the building and recording of arguments that parallel the explanation-building and hypothesis-testing skills of experienced investigators. Further, it provides advice to less-experienced investigators on the appropriate timing and nature of searches to gather new evidence to test hypotheses. Bench tests of the tools suggest strong rates of discrimination of known fraud cases and exclusion of false positives from a sample of over 10,000 historical cases held in Axa's company database.

We believe our work contributes to de-risking insurance in three ways. First, by studying the workforce behind insurance fraud handling, one can avoid expensive investments in technologies that duplicate what people already do well. Second, our research shows how organisational changes (e.g., changing reward structures) can capitalise upon workforce skills to

enhance fraud-handling processes. Third, the skills of claims handlers and investigators provide inspiration for design of novel technologies that offer promising solutions to detecting and investigating fraud in large claim volumes. The success of our approach is indicated by information given to us recently by the fraud manager at Axa Insurance plc, in which changes introduced to fraud investigation processes as a result of our research led to an increase in annual savings by the Axa fraud investigation unit from £5m p.a. to approaching £50m p.a.

## 5.3 SHORTLISTED ENTRIES

**Carina Fearnley**

### Assigning a volcano alert level: negotiating uncertainty, risk, and complexity in decision-making processes

Insurances losses from geological disasters are continuing to rise. The 2011 Tohoku Earthquake and Tsunami in Japan (MunichRe) caused losses of over US$40bn, for example, while the on-going insurance problems and costs in Christchurch, New Zealand stand at over $13bn. While disasters in 'prepared' countries are resulting in fewer deaths (despite the large scale of some events), their economic impact is growing as business becomes more dependent on functioning infrastructure in an ever-growing technological and globalised world.

Understanding the decisions made in preparation for a significant hazard are vital so to make adequate mitigation plans, such as land-use planning, investing in seismically resilient buildings, and the construction of models for insurance calculations. Consequently a number of current research grants such as NERCs Probability, Uncertainty and Risk in the Environment (PURE) project are investigating the way in which uncertainty and risk are assessed and quantified across the natural hazards community, with the specific aim of aiding the insurance sector. Other projects such as STREVA (NERC-ESRC) and VUELCO (EU FP7) are investigating scientific assessment, decision-making, and risk communication for volcanic hazards. Together, these demonstrate the need to further integrate scientific understanding, monitoring, and forecasting for geological hazards in order to reduce potential hazards. Indeed, mistakes made during this process can be costly, both in terms of life lost, but also economically. Following the 6.3 magnitude earthquake in L'Aquila in 2009, for example, 308 people died, approximately 1,500 were injured, and 65,000 people were made homeless. In addition, the state had to foot the bills, insofar as Italy has one of the lowest earthquake insurance penetration rates. In light of severe budget constraints, much of L'Aquila remains abandoned.

L'Aquila also sent a 'shockwave' through the hazard scientific community, causing scientists to become increasingly concerned about how much hazard and risk advice they provide prior to a crisis. To date, however, there has been relatively little research into how scientists involved in geohazards make sense of scientific data and share hazard information amongst stakeholders, both in the long and short term. Without understanding this process, there is little hope of setting best practices.

The research presented in this article 'Assigning a volcano alert level: negotiating uncertainty, risk, and complexity in decision-making processes' published in the journal Environment and Planning A, is the first analysis of the decision-making processes involved in assigning a warning in a volcano alert level system. A volcano alert level system (VALS) is used to communicate warning information from scientists to civil authorities managing volcanic hazards. Using interviews conducted from 2007 to 2009 at five USGS-managed (US Geological Survey) volcano observatories in Alaska, Cascades, Hawaii, Long Valley, and Yellowstone, two key findings are presented. First, that observatory scientists encounter difficulties in interpreting scientific data, and in making decisions about what a volcano is doing, when dealing with complex volcanic processes. Second, the decision to move between alert levels is based upon a complex negotiation of perceived social and environmental risks. This research establishes that decision-making processes are problematic in the face of intrinsic uncertainties and risks, such that warning systems become complex and nonlinear. A consideration of different approaches to negotiating uncertainty and risk that are deliberative would, therefore, be beneficial in volcanic hazard management, insofar as these suggest effective practices for decision-making processes in assigning an alert level.

The paper establishes that warning decisions, ostensibly based 'just on the science,' are very much shaped by the social context in which the crises occurs, including the behaviour of the scientists, and their relationships with key stakeholders. It is argued that the development of quantitative models based on hazard information does not necessarily provide an insight into the risk of a potential disaster. Consequently if the insurance sector aims to develop more robust insurance models, there is a need to further understand the behaviour of the key decision makers in a natural hazard crisis, and to help facilitate best practices predicated on a deliberative and holistic approach to reducing risk in the face of uncertain hazards.

**Ian McLaren**

## Dissociating Expectancy of Shock and Changes in Skin Conductance: An Investigation of the Perruchet Effect Using an Electrodermal Paradigm

The human subconscious has a bigger impact than previously thought on how we respond to risk, as this study shows that our primitive response to fear can contradict our conscious assessment of danger. The findings have implications for how anxiety disorders, such as phobias, are treated, and how evaluation of risk (how dangerous is that skiing holiday?) can be influenced by conscious and subconscious factors. The research also suggests we share a primitive response to risk with other animals, despite being able to consciously anticipate and assess danger.

Participants recruited to the study sat in front of a screen, on which a coloured shape sometimes appeared. Half the time, the image was accompanied by a mild electric shock. For the rest of the time, the image appeared but no shock was given. During each trial they were asked to rate whether or not they expected a shock to be given and their 'skin conductance' was monitored. This technique measures the variation in the electrical activity of the sweat glands in the skin, which is an indication of the state of arousal of the sympathetic nervous system. In other words, it gives us a reading of a person's emotional state.

Following a series of trials involving shocks, participants were more likely to predict they would not receive a shock when the image was next shown. The complementary result was that they generally anticipated receiving a shock if they had not had one for the last few images. This phenomenon of expecting good luck after a run of bad luck and vice versa, is known as the 'gambler's fallacy'. It's the same phenomenon as expecting "tails" after a run of "heads" when tossing a coin.

The skin conductance responses revealed the opposite pattern. Following a series of shocks accompanying the image, their physical responses to the next image shown suggested participants were more likely to expect another shock, but that they were less likely to expect a shock after a run of no-shock trials. This pattern of responding is consistent with 'associative learning', associating a visual cue with a particular motivationally significant event, a phenomenon that is well known in animals. Previously it has been thought that, when using this type of procedure, humans respond differently from animals because we rely on conscious reasoning, rather than associative learning to generate our expectations. This study suggests that, despite our sophisticated mental capabilities, our responses are in fact partly driven by these more primitive processes when in danger.

The implications of this study for our assessment of risk are subtle, yet far reaching. The research clearly demonstrates that our conscious evaluation of a given situation, and our subconscious, emotional response to that same situation can be quite different, and can change in different directions as further information about the likelihood of an event occurring is acquired. One intriguing feature of these results is that conscious expectancy, which we might consider to be based on rational assessment of risk, actually changes in a manner that can be interpreted as violating statistical norms. If we toss a coin, the chance of it coming up "heads" is 50% (assuming the coin is unbiased) whatever the past history. Similarly, in this experiment, the chance of a shock was 50% across the experiment irrespective of the preceding trials status (with the proviso that a run of three shocks was always followed by no shock and vice-versa, hence on these trials, of which there were only four, the gambler's fallacy could be said to be objectively true). Our participants conditioned to the shock, however, in an entirely rational way, in that if there had been a number of stimulus shock pairings then their response to the stimulus went up, reflecting the increase in the association between their representation of the stimulus and their representation of the outcome. Emotionally, then, our participants came to feel more threatened (i.e. subject to higher risk) when there was more evidence of danger around that time, and less threatened when their was more evidence of safety. But their conscious assessment of risk showed the diametrically opposite pattern.

This suggests that when people consider the option of taking out insurance for a given risk, the impact of their experience relevant to that risk needs to be taken into account. For example, if we return to the case of Mr. X who is considering travel insurance for a skiing holiday, it will be his past experience of skiing holidays that influences his perception of risk, but in two different ways. If there has been a run of incidents on holidays of this type then, paradoxically, he may consider them less likely to occur on the projected holiday, and so be less likely to opt for insurance against them. But his emotional response to this possibility will be heightened. Unfortunately this last factor will only be likely to come into play when he is actually presented with the relevant stimulus (i.e. goes on holiday), by which time it is typically too late to take out insurance. The implication is that some means of allowing last minute acceptance of a policy, in say the first day of a holiday, would address this issue and would be more likely to result in people taking out the necessary insurance. An approach based on mobile technology would be able to meet this need, and should result in higher sales because the delivery of the policy would be enabled at the point that the need for that policy was most felt to be greatest. Thus, basic research on how we assess risk that points towards this being based on two systems, one conscious, one subconscious, can suggest new ways of interacting with clients that are likely to improve the outcome for both insurer and insured.

**Antoinette Nicolle**

## A regret-induced status-quo bias

In July 2013, Wales became the first UK country to adopt a presumed-consent policy for organ donation, a change which is hoped to result in increased organ donation numbers. This change in policy stems from our knowledge about the human preference for accepting default or status-quo options in decision-making. Across a range of everyday decisions, including choice of bank account, insurance provider, or when choosing a can of soup at the supermarket, we all show a disproportionate tendency to accept the status-quo. Samuelson and Zeckhauser (1988) observed such bias in choice of health insurance plan by Harvard University employees, such that employees showed a strong preference to stick with the plan they had chosen in the previous year. Similar bias for the status-quo is evident in choices of retirement plans and financial investments (Samuelson and Zeckhauser, 1988). Such bias can often be suboptimal, however, since it leads the decision-maker to overlook alternative opportunities that may be more beneficial to them than is the status-quo.

One influential account links status-quo bias with anticipated regret. It is suggested that decisions to act (or to reject the status-quo) result in stronger feelings of regret than do decisions not to act (or to accept the status-quo), since the former are perceived as less "normal", less easily justified, and more directly causal of its outcome. Moreover, experience of this "action effect" in regret over time leads us to anticipate stronger possible regret from future decisions to act, than from decisions to refrain from acting. Ritov & Baron (1990) observed that a surprising number of people would prefer not to vaccinate their children, despite the risks of failing to vaccinate being far higher than the risks associated with vaccinating. This finding supported the suggestion that decisions to act (e.g. to vaccinate) are associated with greater anticipated regret than decisions not to act (e.g. not to vaccinate), and that this can promote a bias towards inaction. Decision-makers can become effectively paralysed by their regrets, and maintaining the status-quo provides a means of reducing possible feelings of regret for future choices.

Motivated by the literature connecting regret and status-quo bias, we examined the neural mechanisms underlying such a bias, in the context of error processing in the brain. The study, which was published in the Journal of Neuroscience in 2011, measured brain responses with functional magnetic resonance imaging as participants made decisions with the aim of receiving financial rewards (and avoiding losses). The task incorporated a trial-to-trial status-quo option (in the form of the participant's previous choice), such that on each trial participants could either stick with his/her previous choice or else reject that status-quo and switch to the alternative option. On every trial, participants were shown the outcome of their choice, which would be a monetary loss for incorrect responses or a monetary gain for correct responses. These monetary rewards and losses were paid out at the end of the game and so provided participants with an incentive to perform well in the task – in effect they were investing in their ability to make good decisions.

As expected, participants reported stronger feelings of regret from erroneous decisions to reject the status-quo than from erroneous decisions to accept it. We also found error-related brain responses that mirrored this asymmetry in the experience of regret, showing inflated activity for erroneous status-quo rejections (compared to erroneous status-quo acceptance), in brain regions typically involved in error processing and subjective feeling states. Moreover, our participants showed a clear overall bias toward accepting the status-quo, and this bias was predicted by activity in the same brain regions that showed the action/inaction asymmetry in response to previous errors. We concluded that inflated emotional and neurobiological responses to status quo rejection errors (compared with status-quo acceptance errors) are key contributors to the emergence of a status-quo bias.

This study provides evidence for an important role of emotion in determining and modifying preferences for the status-quo. Moreover, we show that regret-induced status-quo bias is at some level biologically determined. While these emotional influences on behaviour may be commanding, and perhaps sometimes inevitable, this is not to say that we cannot control such influences to ensure the quality of our decision-making. For example, if decision-makers are aware of the effect of anticipated regret on their preference for the status-quo, they may be better able to overcome or control such effects. They may achieve this by revaluating the importance of protecting themselves from future regret, by carefully considering the justifiability of accepting the status-quo, or by seeking the advice of others (e.g. friends, family or professionals) whose opinions should be more objective and less influenced by anticipated regrets.

It may be particularly desirable to control the effects of regret and status-quo bias when making important decisions concerning ones future (e.g. choice of financial investment, bank account, pension plan, insurance plan, registering for organ donation etc.), since we are often very bad at anticipating how we will actually feel about these decisions in the future. Indeed, we often overestimate how bad we will feel (and for how long) after future undesirable event (Wilson & Gilbert, 2003). If our anticipated emotions are often inaccurate, then, it may be better to ignore anticipated regret when evaluating the costs and benefits of our decisions. However, this may not always be easy for the decision-maker to do themselves, and so it is important that others (e.g. insurance companies, employers, policy-makers) are also aware of the impacts of regret and status-quo bias on decision-making, and they should make efforts to control such effects if necessary. This may be achieved by providing decision-makers with the objective advice and sufficient time to make their decisions with the least possible influence of regret, and through the careful selection of any default options (as with the use of presumed-consent as the default for organ donations in Wales).

# 6 BIOLOGICAL AND TECHNOLOGICAL RISK

## 6.1 WINNER

**Rosemary Waring**

### Risk Analysis for Biological Effects (RABE): Environmental Chemicals and Endocrine Disruption

**Background**
Endocrine disrupters (EDs) are natural or man-made chemicals which humans and other species are exposed to in the environment. They pose a significant risk by their interference with hormone systems. Very small amounts can have strong effects – the body's sensitivity to natural steroid hormones has been compared to 'a pinch of sugar in a swimming pool' - and some EDs are almost equally effective. EDs mimic or inhibit the androgenic actions of testosterone and the feminising effects of oestrogens, and are thought to cause a range of inappropriate developments in humans. In animals, amphibians and fish, ED contamination of the environment has had major effects on the reproductive systems. Importantly, the actions of EDs are not limited to interference with sex hormones. Other hormones, such as thyroxine from the thyroid gland, are also targets.
EDs achieve their damaging effects by a variety of mechanisms, such as interference in a) hormone binding to cellular proteins which mediate the action of the natural hormone, b) hormone and cofactor metabolism, and c) transport of natural hormone to and from target cells.

**Current Measurement of ED potential**
Negative reproductive potential, eg, induction of low sperm count and infertility, is currently measured by *in vivo* tests using rodents. Hundreds of animals are dosed with different levels of the ED, then mated and they and their offspring are killed to be examined at autopsy. This is very expensive in both time and animals. Furthermore, it is not certain that human beings react to EDs in the same way as rodents. This testing for reproductive toxicity is an essential requirement for licensing a compound as a drug, pesticide or industrial agent. The new REACH programme requires such data on ~30,000 new chemicals.

***In Vitro* Tests for Risk Assessment**
Therefore, there is a real need for *in vitro* tests which are much faster and cheaper than the *in vivo* ones. These would enable rapid and reliable testing for compounds with ED potential and could use human cells, giving results more relevant to humans. These tests have the commercial advantage that they enable rapid identification of compounds which would have unwanted effects long-term. Synthesis of less-damaging chemicals could then be prioritised, minimising the risk of legal claims resulting from use of marketed products subsequently found to have ED potential.

**The Results from ENDOMET**
The results in the submitted paper come from the project ENDOMET, funded under the EC 5th Framework Programme. In this study a matrix was designed where 16 compounds, all known EDs, were assayed by 23 different tests (see Table 1). Each cell of the matrix reflects the outcome of an assay and the relative strengths of the effects have been graded. Compounds with the strongest effects gave significant results at the lowest concentrations i.e. 10-7 or 10-6M (red and orange cells). It was clear from the initial results that no one single test could reliably identify all EDs. A novel cluster analysis was then designed (Professor P Jarratt) to find the minimum combination of in vitro tests which would maximise the identification of EDs (allowing at least one effect occurring at 10-6M levels). An algorithm was produced which summed the number and sensitivity of the assays which were positive for any compound and produced an overall score for any of the EDs tested.

**Results from the cited paper**
Using the results from the in vitro assays with human cell lines, it was found that:-

1. No single test will select for EDs of different chemical structures as they have different modes of action, affecting both receptor binding, steroid metabolism and steroid transport.
2. Cluster analysis can be used to find the combination of assays which could be used for routine screening to identify ED potential. Measurement with 4 assays reliably predicts the potential of any compound under test to interact with the steroid, brain or thyroid systems.
3. This interaction can be assessed semi-quantitatively, eg the plasticiser di-isononylphthalate has much less *in vitro* ED potential than the commonly used dibutylphthalate and would be a possible replacement. These semi-quantitative rankings have been validated by their agreement with *in vivo* findings.
4. Risk assessment using this method would have potentially identified several known EDs if applied before they were produced industrially on a large scale. The compound BPA (bis-phenol A), widely used in synthesis of plastics, has now been withdrawn from use in baby feeding bottles. BPA is easily identifiable as an ED in the test matrix and EFSA (European Food Safety Authority) are currently carrying out a further examination of its

possible effects in man. Permitted levels of BPA in contact with foodstuffs are likely to be further reduced and a ban on its use in this area may come into force if it can be shown to be harmful in man at low levels.

**Conclusion**

The emerging risks associated with commercial use of endocrine disrupters can be reliably assessed by using novel in vitro test combinations, derived from cluster analysis of results from toxicological assays.

Table 1

| Test | | Chemical | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | BPA | BPAD | nNP | nOP | tOP | BEHA | BBP | BEHP | DBP | DOP | DiNP | DiDP | PP | RL | DCP | CMP |
| Steroid Metabolism | SULT1A1 | | | | | | | | | | | | | | | | |
| | SULT1E1 | | | | | | | | | | | | | | | | |
| | SULT2A1 | | | | | | | | | | | | | | | | |
| | CDO | | | | | | | | | | | | | | | | |
| | SOX | | | | | | | | | | | | | | | | |
| | PAP | | | | | | | | | | | | | | | | |
| | LEC | | | | | | | | | | | | | | | | |
| | ARO | | | | | | | | | | | | | | | | |
| Nuclear Receptors | T3-screen | | | | | | | | | | | | | | | | |
| | ER | | | | | | | | | | | | | | | | |
| | AR | | | | | | | | | | | | | | | | |
| | AHR | | | | | | | | | | | | | | | | |
| Pig Ovaries | BP | | | | | | | | | | | | | | | | |
| | FP | | | | | | | | | | | | | | | | |
| | FE | | | | | | | | | | | | | | | | |
| Brain Cell Signalling | GSK | | | | | | | | | | | | | | | | |
| | ESCK | | | | | | | | | | | | | | | | |
| | O2 | | | | | | | | | | | | | | | | |
| | ROS | | | | | | | | | | | | | | | | |
| Thyroid | N3 | | | | | | | | | | | | | | | | |
| | N3+ | | | | | | | | | | | | | | | | |
| | TRE/TRß | | | | | | | | | | | | | | | | |
| | FRTL | | | | | | | | | | | | | | | | |

Measurable effect seen at: ≤$10^{-7}$ M | $10^{-6}$M | $10^{-5}$M | $10^{-4}$M | No Observed Effect

## 6.2 RUNNER UP

**Francesco Montomoli**

### Geometrical Uncertainty and Film Cooling: Fillet Radii

Despite the decline of the number of aviation accidents since 1990 and their limited number, a single accident in aviation can generate high losses in terms of human lives and property damage. From the insurance point of view, aviation is one of the smallest markets but with high risk of potential catastrophes associated to a single accident.

In a broad sense, this works deals with some of new design techniques developed to increase the safety of aircraft engines. Despite the high level of safety of modern jet engines, proved by the decline of accident rate, there is a continuous quest for highest safety standard. Aviation Authorities such as ICAO and ACARE, as part of the plan to reduce even further the accident rate, are demanding more and more reliable jet engines. Despite the requirements, this is becoming particularly challenging. In fact, in order to reduce the fuel consumption and the emissions, the temperature of the gases flowing in jet engines has been increased over the melting point of the alloys used to produce the different parts and the components can survive only because are heavily cooled. The engine life is driven by the performance of the coolant system. The coolant system is a complex network of channels and holes, feeding each part of the turbine with cold flow and preventing them from melting down. Due to the small size of these channels, microscopic geometrical variations can reduce the life by more than 30%, but this is not acceptable for nowadays safety standard. Unfortunately, due to the technological limit of nowadays drilling technologies, it is not possible to avoid these errors.

With nowadays design techniques and with the technological limits of manufacturing methods it is very difficult to achieve the safety margins required by the aviation authorities: the uncertainties introduced by the manufacturing errors reduce the capability to predict the engine life accurately. A possible solution has been presented in this work for the first time and since then the methodologies proposed in this paper have been applied to jet engine design. In the paper the standard film cooling geometry has been chosen as test case, being representative of almost all coolant systems found in modern jet engines and responsible for the life of the engine.

The work shows that the state of the art of Computational Fluid Dynamics (CFD) applied to a film cooling geometry is not able to predict the same performance measured in the experiments: CFD methods assume idealised geometries but ideal geometries do not exist, cannot be manufactured and their performance differs from real ones. However by applying geometrical variations of few microns, the agreement with experiments improved dramatically. Unfortunately the manufacturing errors in engines or in experiments are unknown.

In order to overcome this limitation, the baseline geometry was considered as affected by different Probability Density Functions of manufacturing errors. By doing this operation it was possible to predict the overall variation of the coolant mass flow using Uncertainty Quantification techniques. It was found that some geometries are not affected by manufacturing errors, meaning that it is possible to design safer engines. This work was showing that nowadays manufacturing limits can be overcame designing engines not dependent from the accuracy of the manufacturing technique. In particular it was observed that for particular geometries, the impact of the standard deviation of manufacturing errors was negligible. The consequence is that a coolant system designed using these geometries will be more reliable and, as consequence, that the engine life will be not anymore affected by manufacturing errors.

Instead of trying to improve the manufacturing accuracy or to change completely the layout of the engine, stochastic methods, known as Uncertainty Quantification, applied to Computational Fluid Dynamics, were able to show a new path to improve the current design. It was showing that with nowadays technology was possible to improve the next generation of aircraft engines, with unprecedented safety levels. This work has been the first one to identify such solution for the coolant system, showing how to obtain more reliable gas turbines. These stochastic methodologies, derived from the financial and the economic sector, were uncommon in aerodynamics and jet engine, but they become one of the most popular methods to reduce the risk of failure and to increase the components life.

This work shows that the potential catastrophe generated by the failure of an aircraft engine relies on the prediction of the correct behaviour of a microscopic coolant systems. This work quantify the possibility of such failure showing that it is possible to design components that are inherently less “risky” and more reliable.

## 6.3 SHORTLISTED ENTRIES

**Jennifer Cole**

### Antimicrobial resistance, infection control and planning for pandemics: The importance of knowledge transfer in healthcare resilience and emergency planning

Over the last 70 years, the efficacy, ready availability and relatively low cost of antimicrobial drugs – medicines that kill microorganisms such as bacteria and viruses or inhibit their multiplication, growth and pathogenic action – has led to their considerable overuse. It is estimated that nearly 50 per cent of all antimicrobial use in hospitals is unnecessary or inappropriate while in neonatal care, the figure is even higher, with infection confirmed in less than five per cent of neonates treated with antibiotics. The more antimicrobials are used, the faster the microorganisms they target evolve into new, resistant strains, a natural process of evolution that threatens to undermine the tremendous life-saving potential of these drugs.

AMR places a significant burden on international governments and tackling it requires changes to thinking across a number of government departments. In 2011, the Transatlantic Taskforce on Antimicrobial Resistance (TATFAR) published Recommendations for future collaboration between the US and EU1 and both the EU and the UK's Department of Health have recently developed new AMR strategies and Action Plans.

The risks from serious infectious disease are well-recognised with the security and resilience spheres. Pandemic influenza, comparable only to 'Catastrophic terrorist attacks' at the top of the UK's National Risk Register may well result from the emergence of a strain that cannot be treated effectively with currently available drugs or from one that quickly develops resistance to the stockpiled countermeasures. Multidrug-resistant tuberculosis impacts on immigration policy, while methicillin-resistant Staphylococcus aureus (MRSA) is a major cause of hospital-acquired infections that poses an ongoing challenge for the health sector. The increase in drug-resistant strains of malaria is problematic both in its own right and as an additional consequence of climate change.

In recent years, severe acute respiratory syndrome (SARS), H5N1 'avian flu', the H1N1 'swine flu' pandemic and foot and mouth disease, not to mention the emergence of the human immunodeficiency virus (HIV) in the 1980s, has shown the impact that unexpected disease outbreaks can have, particularly where they are difficult or impossible to treat. In and above these currently recognised health threats, AMR is becoming of increasing concern in its own right, with academics linking it to national security and the US National Center for Biotechnology Information, the World Health Organization (WHO), the EU and national government departments responsible for human and animal health all pushing it further up their security agendas. The European Commission's Seventh Framework Programme of Research and Development invested €147m in AMR research between 2007 and 2013, stating: 'Antimicrobial resistance is reaching alarming levels and is a very significant health threat to all Europeans'.

Disease outbreaks that impact outside the health sector need to be of interest to emergency planners and insurers. In the case of a pandemic or bioterrorism attack, the microorganisms may already have, or quickly develop, resistance to any stockpiled countermeasures, including treatments and vaccines. Knowledge transfer between the resilience, security and healthcare sectors can help to address challenges across multiple disciplines. This is not least because the best response is not always the most scientific. Simple measures such as good personal hygiene and social distancing, as well as more accurate diagnosis and better mapping of outbreak 'hot spots', can be just as effective as the rapid development of new medical countermeasures. In particular, by better understanding the risks and threats, emergency planners can play an important role in raising awareness of the issues likely to be encountered during healthcare emergencies, ensuring effective communication of public information programmes and taking an active stance in responding to emerging healthcare challenges. Prevention strategies that embed personal hygiene behaviours among employees can reduce infection spread and bring down levels of illness and staff absenteeism throughout the year, not only during healthcare emergencies.

This paper will explore the cross-disciplinary policy challenges that AMR presents and the difficulties that are likely to be faced in implementing current policy recommendations. It will compare and contrast the efficacy of some of the programmes already in place to help reduce or better target the use of antimicrobials and discuss potential areas for further research and development into tackling a growing international problem.

**Research findings**
The threat AMR poses is growing. Many of the ways in which people can build resilience to it are relatively simple, but requires the risks to be acknowledged and understood outside of the healthcare sector alone. Combatting its spread requires a strong, cross-sector education campaign, better embedding of infection control practices into businesses and organisations, and a better understanding of the impact serious disease outbreaks will have on routine operations. Corporate responsibility programmes need to be encouraged to support research into AMR mitigation and prevention strategies.

If the current levels of antimicrobial use are not addressed and reduced, there is a real danger that there will be a future in which medical techniques taken for granted during the past century become obsolete by the next.

**Why this research is relevant to the insurance industry**

This research is relevant to the insurance industry as the increasing risk from antimicrobial resistance is having a growing health and economic impact. Health insurance in particular may need to be more aware of its impact in future. Infections and conditions that are considered routine today may become more difficult and costly to treat, and may even become life-threatening in future. There may be an increase in compensation claims made against the healthcare sector by patients, and by employees against their company or co-workers, where infections have been picked up through real or perceived lack of appropriate infection control processes. In addition, companies need to be aware of how staff absenteeism during serious disease outbreaks will impact on their business processes and ability to fulfil contractual obligations.

**Martin Mullins**

## The Insurability of Nanomaterial Production Risk

The insurance industry is a key stakeholder in managing the risks inherent in technological innovation and thus ensures the sustainability of the high-tech sector. The key role insurers occupy is, at times, overlooked by the scientific community and this is no different in the area of nanotechnology. In large part, the purpose of this paper has been to bridge this divide between these two groups. The article, *The Insurability of Nanomaterial Production Risk*, performs this function through highlighting, to the scientific community, the issues insurers are wrestling with in this field whilst, at the same time, pointing a way forward for insurers underwriting these risks. At present, nanotechnology liability risks reside outside conventional insurance practice due to an absence of data on the frequency and severity of insurance losses. This paper offers a way forward in providing a firmer methodological footing for the underwriting of nanotechnology risk.

Currently, workers, consumers, the public and environment are exposed to a variety of engineered nanomaterials in different industries and through different consumables such as food, cosmetics, computing, clothing and medicine. Nanoscientists are encouraging producers to adopt the precautionary principle by minimizing their exposure to unbound nanoparticles and nanomaterials. That said, we argue that insurers should themselves take action with a view to controlling or at least monitoring their exposure to nanomaterial risks particularly in the areas of employer's, product and environmental liability.

In this paper, Dr. Martin Mullins and colleagues from the University of Limerick in Ireland propose a scalable framework based on control banding that can incorporate existing practices and emerging regulatory changes. Such an approach is designed to facilitate insurance firms in the risk-selection and decision-making process for underwriting a particular nanomaterial liability risk in the portfolio of insurance risks. This paper differs from the existing studies on nanotechnology and nanomaterial risks in that it moves away from describing the potential risks to actually proposing an insurance model for managing these risks under the current level of knowledge.

Our focus is on Employer's Liability as it is workers that are most likely to be exposed to unbound nanoparticles and nanomaterials. The control banding approach allows both exposure and toxicity potential to be categorized and appropriate risk weightings applied to these categories. The exposure assessment can be performed by scoring different factors such as state of matter (aerosol, powder, liquid form and so on), quantity (experimental or mass production), emission potential (cleanroom environment or open space), frequency and duration of use. The overall score can then be used to determine the level of exposure potential. Similarly, toxicity levels can be assigned with the help of a scientific literature review or existing lab analysis (that is, in vivo and in vitro tests) as well as applying scores to parameters such as chemical composition, particle size, solubility, aggregation and agglomeration of nanomaterials. By identifying the coordinates of the different exposure and toxicity levels with a control band, an insurer can distinguish between acceptable and unacceptable risk. At the same time, the nanotechnology sector can use the control-banding framework to reduce risk and insurance costs. This control banding approach is an iterative process whereby greater levels of complexity might be added by the introduction of a third dimension, which could include phenomena such as engineering control, worker training or regulatory jurisdiction.

As the framework matures, weightings can be attached to the toxicity and exposure factors and ultimately, a quantitative model will result affording underwriters a sophisticated risk-measurement system. However, in the short term, this framework will provide an indicative model allowing insurers to rank the risk associated with various production processes in those industries using or producing nanomaterials. The suggested framework is not only useful in terms of risk calculation but also for the wording of the insurance contract. For example, adherence to established guidelines in the handling and use of nanomaterials would be documented in the insurance contract as a condition of cover. Over time this framework will alter risk perceptions among the underwriting community, with nanotechnology activities increasingly differentiated in terms of the risk they represent.

Nanotechnology represents a difficult challenge to the insurance industry. In this field, regulatory controls remain under-developed and there is a lack of legal clarity. Given this backdrop, control banding will allow nanoparticle production to be put on a more sustainable footing as the science in this emerging area develops.

**Peter Wilkinson**

## Ensuring resilience in building design using fire engineering

1. THE APPLICATION OF FIRE ENGINEERING

Whilst fire engineering, the performance-based design method, was originally the pioneering way of enabling successful design of buildings such as airport terminals and shopping centres, such practice is now commonplace. The new frontier for fire engineering design includes the design of very tall buildings and helping to address the balance between protection of the environment and prudent use of natural resources.

Despite many successes, significant concerns exist regarding the availability of the data and tools required to undertake advanced fire engineering analysis. Furthermore, the motivations for using fire engineering are increasingly being questioned. Examples are documented where architects are seen to be trying to find a way out of problems of poor design with complex technology and inappropriate fire engineering arguments. It appears to be common practice for some projects to concentrate solely on life safety because this is mandated by the UK building regulations process, without regard for what effect this could have on property and business protection.

In order to investigate these concerns, I undertook research using an extensive series of interviews with key members of fire engineering stakeholder groups, including academics, fire engineering practitioners, insurers, and enforcers. This investigation concluded that the common expectation across all stakeholder groups was that fire engineering would facilitate architectural design freedom and support creative construction allowing the UK, and more specifically the city of London, to continue to develop its reputation as a centre for world-class developments. The research also revealed that since fire engineering has become accepted, significant concerns have been raised regarding various elements of the design process including,

- The real motivations of the client and design team for using fire engineering techniques are often economically driven motivations, or a means of addressing design errors or omissions;
- The ability of building control professionals to approve designs, and of fire and rescue service personnel to contribute to the process;
- The lack of involvement of the insurer and the ability to consider design objectives other than life safety;
- The validity of fire engineered solutions during the building's life-cycle, and the continued input of fire engineers from design to demolition; and
- The limitations of the knowledge, data and tools that support fire engineering design concepts.

All these issues need to be addressed if fire engineering is to enjoy continued growth as a profession, and continued acceptance as a legitimate contribution to the building design process.

2. THE ROLE OF THE INSURER

A framework for a fire engineered approach to building design is described in BS7974-0 The first part of this process is a Qualitative design review (QDR) where the scope and the objectives of the fire safety design are defined. Within the BS7974-0 framework, support is given to the consideration of property protection and continuity of operations objectives. Therefore, in order to meet the requirements of the end-user client and their insurers, the fire safety objectives of the QDR should include property and business protection matters to the extent determined by the agreed acceptance criteria. Does this happen in reality?

Further research I conducted involved a case-study investigation to fully understand current practice relating to the involvement of the commercial property insurance industry within the fire safety engineering design process. This research concluded that, at least within the largest insurance companies, there is an understanding of the differences between prescriptive, 'code-compliant' buildings and performance-based, 'fire engineered' buildings. There is an acknowledgement that the insurance underwriting for fire engineered buildings should take account of these differences.

However, despite a small number of minor examples, it is clear that the end-user client, or their insurer does not play an appropriate active role in the building design process, and when they do, their poor levels of knowledge and understanding precludes any meaningful interaction. This is due to a number of reasons;

- Commercial property insurers are often not involved at the conceptual design stage and are therefore not able to participate;
- If a contract works insurer is appointed, their attention is usually focused on the construction process, rather than the finished building;
- Insurance brokers, acting as the intermediary between the insurer and the client, can mean that any opportunities to be involved with design are missed;
- In a soft market, insurers are less inclined to insist on costly fire protection measures when they are competing for income premium against other insurers, and are therefore less likely to want to participate in the design process, or fearful of losing the client;

- Fire engineering designers are often reluctant to invite insurers into the QDR process for fear of the project incurring costly fire protection features in addition to the mandated life safety requirements; and
- End-user clients are often not well informed about the business benefits and market advantage that can be gained from appropriately robust buildings and facilities.

Insurers have a big commitment to the risk management of the properties they have a financial interest in, but appear to lack the skills, and sometimes the will or authority, to commit the same effort when properties are being designed. Even with the best intentions and regardless of whether the insurer is involved in the design process or not, the current approach is not effective and the robustness of the fire engineering design becomes questionable.

## 3. ENSURING RESILIENCE AT BUILDING DESIGN STAGE

In response to the concerns raised above, a new approach to fire engineering objective setting is required. An important step is to actively involve the end-user client, i.e. the organisation who has commissioned the new building and intends to occupy and use the facilities, in order to derive a complete set of design requirements. Therefore, I developed the process which is used to assess business risks, known as business impact analysis (BIA), and adapted it to inform the fire engineering objective-setting process.

BIA is defined as the procedure for collecting and analysing the urgency of organisational functions or activities, and their tolerance of loss. It describes the resources necessary for the activities to be accomplished and BIA is fundamental to ensuring a successful building design that fully meets the needs of the client. Central to the BIA process is the identification of critical activities and the resources upon which they depend. Resources are often grouped into categories such as people, plant, premises and infrastructure, and where the built environment is a part of the provision of these resources, there is clearly a need to consider them during the building design phase. Whilst the protection of resources that underpin critical activities with fire suppression systems goes some way towards reducing the likelihood of critical damage from fire, no system is infallible. Solutions relevant to the built environment where fire engineering tools may be used include the duplication of assets, splitting and separation of assets, protection of assets, and early detection of threat.

The effects of fire are only some of the causes of disruptions that would be identified and managed within a holistic business continuity plan. However, by identifying these fire-related disruptions and potential consequences at the design stage of a building or plant, it is possible to incorporate design features designed to reduce property loss, assist in ensuring business continuity and provide resilience against the effects of fire.

For the fire safety engineer, the BIA process will;

- Identify those activities critical to the end user client's organisation,
- Identify the resources needed to support the activities, and,
- Identify the fire safety objectives necessary to protect the resources.

Using this information to augment the mandated life safety objectives the fire safety objectives for consideration could contain activity specific requirements such as;

- Fire must be detected and extinguished before reaching x kW in size
- Compartment / equipment must be recovered in 7 days
- Business Stream must be operational in 14 days

Whilst fire safety engineering alone will be unable to, or not be the most appropriate means to achieve these aims, some building elements could be instrumental in meeting these goals.

## 4. A NEW STANDARD

In order to help consulting fire engineers, and architectural design teams, incorporate business protection objectives in their fire safety designs, I gained support from the Technical Committee responsible and led the team who enhanced the established British Standard. Since September 2012, PD 7974-8 Application of fire safety engineering principles to the design of buildings- Part 8: Property protection, mission continuity and resilience has been available. This new document embeds the use of BIA as an integral part of the QDR process, and my research is central to the process described.

For the first time, this new document enables the building designer to be fully cognisant of the client's critical processes and the resources required to support these processes. It, therefore, enables the appropriate fire safety measures to be incorporated into the building design to enhance business resilience and protect insurance exposures.

# 7 GEOPOLITICAL AND SOCIETAL RISK

## 7.1 WINNER

**Tim Bedford**

**Decision making for group risk reduction: dealing with epistemic uncertainty**

Societal, or group, risk measurement seeks to capture the overall impacts of human activities or natural disasters at a population level. In contrast to individual risk measurement, which is typically measured in terms of probability of fatality per year per individual, societal fatality risk is measured through the frequency of incidents causing N fatalities (N=1,2,…). This risk is often represented using a Farmer Curve, also known as an FN curve, plotting the frequency of accidents causing at least N fatalities against N, on logarithmic axes . Most advanced countries use individual and group risk measures for risk regulation, official guidance, or risk communication. The Hong Kong S.A.R. Government has for example has incorporated a group risk criterion using so-called FN curves, discussed further below, into its regulations. The Netherlands government uses group risk criteria for major industrial hazards, and is extending this to flood risk.

FN curves provide an attractive representation of group risk arising from a particular natural or man-made phenomenon. However, a single curve would misrepresent the amount of state-of-knowledge (or epistemic) uncertainty that there typically is, especially at the high consequence end: a family of uncertain curves would be a better representation of our state of knowledge. A second issue is that it is difficult to compare different curves, and even more difficult to compare two different families of curves, to assess whether one risk source is "worse" than another, or indeed to assess the impact of possible risk mitigation measures.

Both of these issues are of interest to the Insurance industry. State of knowledge uncertainty represents the potential range of risk arising from our lack of knowledge around the natural or man-made phenomena, as opposed to its intrinsic randomness. This lack of knowledge can – to an large extent – be captured through parametric and/or model uncertainties, and in this way models can be constructed that provide credible assessments of risk ranges. Such ranges can be reduced through reducing our state of knowledge uncertainty – in practice this is through further study, additional measurement, etc usually at a cost) – and, if we are prepared to wait, through experiencing the risks and collecting data through time. The reduction of state of knowledge uncertainties is a key part of making risks insurable. By reducing the state of knowledge uncertainties, we keep only the aleatory uncertainty – the residual uncertainty that captures the intrinsic randomness of the phenomena under study.

The notion of "disutility" has been used since the mid 1970's to summarize FN-curves by a single number representing the overall size of the risk. A family of disutility functions was defined with a single parameter controlling the degree of "risk aversion". In our paper, we show that this work rests on a subtle confusion between probabilities and frequencies. By formulating the problem in terms of "number of accidents per year of each possible accident size", we are able to show that this older notion of disutility is a bone-fide disutility (in the sense of rational decision theory), but that instead of being risk averse, it is actually risk neutral, disaster averse, and completely insensitive to state-of-knowledge uncertainty.

A new approach is outlined that has a number of attractive properties. This is a novel approach that is made possible by a completely new formulation of the set of consequences that FN curves seek to describe. The formulation allows us to distinguish between risk aversion and disaster aversion, two concepts that have been confused in the literature until now. A two-parameter family of disutilities generalizing the previous approach is defined where one parameter controls risk aversion and the other disaster aversion. The family is sensitive to epistemic uncertainties. Such disutilities may, for example, be used to compare the impact of system design changes on group risks, or might form the basis for valuing reductions in group risk in a cost benefit analysis.

The "expected number of fatalities per year" is a special case of this two parameter family, and is the measure that is most frequently used in safety assessment because of the "per fatality" costs that are the basis of an ALARP cost-benefit case. However, it does not take into account the epistemic uncertainties around the future consequences: how certain are we about future accident rates (especially for large accidents)? If we have simply underestimated the frequency of larger accidents then the insurance premiums will not have been correctly determined leading to financial losses, and potential further reputational losses if cover is withdrawn.

The novel approach taken in the paper, on the other hand, provides a coherent framework within which the "size" of state-of-knowledge uncertainty on future accident rates can be represented, and provides the potential for different insurers to choose their own levels of risk aversion to those state-of-knowledge uncertainties.

## 7.2 RUNNER UP

**Neil Adger**

### Renegotiating social contracts that shape the balance between public and private risk

The insurance industry does not operate in a vacuum. It operates in a societal context where some risks are effectively made public and pooled through government action, while some are the responsibility of individuals. Which risks are private responsibility, and which are public, are not fixed. In effect there is a social contract between governments and individuals on their duties and responsibilities. Such contracts, often implicit rather than written down, specify the relative roles of states and markets, including insurance, to manage risk.

We suggest and test the idea that public and private roles are renegotiated following events that change the relative of responsibility of states, markets and individuals. Our paper is, in effect, a political science analysis of the scope and scale of the landscape in which private insurance operates.

Our paper proposes social contract theory as important in explaining the evolution of public and private responsibility and tests it in the context of policy responses to flood risk in two different countries, the UK and Ireland. It examines whether there is a shared understanding of responsibility within societies as to whether governments handle risk or devolve that responsibility to individuals. There may be a consensus that a primary role of government in all areas of public policy is to protect the vulnerable. But governments need to balance this objective with avoiding sending perverse signals that induce risk-taking behavior, so-called moral hazards. Expectations are likely to change and are likely to be a source of intense conflict as the risks themselves change, as they will do for weather and climate-related hazards.

We examined how this implicit social contract evolves when events drive public pressure for change. In November 2009, rainfall caused significant flooding in England, centred in Cumbria, and extensively in many parts of Ireland. The differential responsibility across the two jurisdictions and the response to that flooding event represent, in effect, a natural experiment. What citizens expect their government to do for them in the context of these changing risks has changed.

We examined the public response to the floods through two means. First we analysed the public discourse, agency reaction and media coverage of the events and their aftermath. Second, we surveyed people in their houses, both those who had been flooded and those who escaped, in towns and villages across Cumbria and Galway.

Our results demonstrate a profound difference in how individuals see their own responsibility for future adaptation. In essence, the Irish political and economic situation of an enormous retrenchment of state services and responsibility in the recent economic downturn has shifted both the adaptive capacity of the state and lowered expectations of government. As a result, some individuals perceive that they are much more vulnerable and exposed into the future.

But there are stark differences between those in Ireland and those in England when it comes to willingness to undertake their own actions rather than insisting on government interventions. The implicit social contract is by no means static, but rather open to renegotiation and revision, often after event.

The implications of our observations and of this type of study for how society handles risk and for the insurance sector are significant. Climate change will be experienced as events. These experiences will, we suggest, lead to the demand for policy change. Those people experiencing weather related disasters may demand policy change for decarbonizing the economy to avoid climate change, though the evidence on those motivations are mixed. But the experience in the UK related to the results of our paper shows significant demand for public action on flood defense and public under-writing of risk. Such policy demand, articulated by political processes, results in diverse solutions where responsibilities for risks are renegotiated among private actors, public institutions and individuals. A clear example is Flood-Re now being developed in the UK.

This paper exemplifies how, more generally, social contract theory could be used to explain public expectations of how much risk is legitimately retained by government. These ideas apply in many policy areas, from disasters to public health and economic crisis. Such analysis focuses on processes through which the social contract is renegotiated, and how this occurs, whether through evolution, election or revolution.

## 7.3 SHORTLISTED ENTRIES

**Dean Fantazzini**

**Global oil risks in the early 21st century**

The Deepwater Horizon incident demonstrated that most of the oil left is deep offshore or in other difficult to reach locations. Moreover, obtaining the oil remaining in currently producing reservoirs requires additional equipment and technology that come at a higher price in both capital and energy. In this regard, we reviewed the physical perspective of peak oil and some of the limitations on producing ever-increasing quantities of oil were highlighted as well as the possibility of the peak of production occurring this decade. We then briefly discussed the economics of oil supply and demand, showing why the available supply is basically fixed in the short-medium term and highlighting the importance of a high energy expenditure share as a percentage of total consumer expenditures as an alarm bell for economic recessions. Moreover, we remarked that the potential financial resources that can be made available in the future to switch to alternative sources of energy will be limited due to several factors ranging from the high levels of debt (both private and public) to the ageing of the populations in the Western countries and China. We also noted that, even with very slight production decline rates, net oil exports decline significantly faster than total oil production as the economies of producer countries grow. In such a context, risk mitigation practices are called for, both at the government level and at the business level to prepare for high and likely volatile oil prices. Governments should begin educating their citizenry of the risk of contraction to minimize the potential future social discord. Businesses should examine their operations and balance sheets with the aim of building in resilience. It also implies preparing for a scenario in which capital and energy are much more expensive than in the business-as- usual one.

**Aled Jones**

## Resource Constraints: the evidence and scenarios for the future

A systemic risk in the financial sector and across the global economy exists. The implications for the finance sector are complex and many.

On January 17th 2013 the Actuarial Profession launched a major report entitled "*Resource constraints: sharing a finite world*". The evidence shows that resource constraints will, at best, steadily increase energy and commodity prices over the next century and, at worst, could contribute towards an uncertain and unstable economic paradigm. How resource constraints impact the economy is complex and depends on a number of factors. Political and market responses to the challenges associated with resource constraints will have far reaching consequences which need to be understood. To a large extent the impacts can be managed, or at the very least influenced.

**Economic Growth and risk**
In 1972 the Club of Rome[1] produced a report called the Limits to Growth. This used systems dynamics theory and computer modelling to analyze the long term causes and consequences of growth in the world's population and material economy. Twelve scenarios illustrated how world population and resource use interact with a variety of limits. In every realistic scenario the model found that these limits force an end to growth, or even a collapse, sometime in the 21st century. The report attracted significant controversy and rejection of its scenarios, however the actual path taken by the various measures modelled in the report over the last 40 years agrees worryingly well with the projections.

Even without resource constraints, it has been argued that we have already entered a period of low economic growth, and the current economic crisis has reinvigorated the debate on how society should react. Opinions put forward can be grouped around four broad themes:

1) Growth is the solution
   *Economic growth brings with it technological innovation that would bring about the required changes to meet resource constraint challenges.*

2) Green growth
   *By examining and changing indicators of growth to be more aligned with resource constraints (and climate change) global economic development would more naturally develop the required solutions to the global challenges.*

3) End of growth
   *The finite size of the planet combined with the fact that the economy is now operating on a world-wide scale means that growth cannot continue and must stabilise to remain within global boundaries*

4) Beyond the limits.
   *Resource limits and/or climate change have been ignored for too long and the global economy and population is now too large to be supported at current rates of consumption. A long-term decline is inevitable*

**Impacts on financial assumptions and insurance**
If economic growth is limited by resource constraints, this could be reasonably expected to significantly affect future financial and demographic outcomes. If these future outcomes are indeed affected, then the assumptions that the finance sector uses should take into account these future developments. While the report developed a worked example for one aspect of actuarial models – pension funds –resource constraints will also have a significant impact on insurance companies. In particular the risks associated with insurance company investment funds but also the indirect impacts that political instability, price volatility and climate change will have on insurance products themselves could be significant. More work on scenario mapping in this area is required and is underway.

The overall factors that might be caused by resource constraints that may affect finance modelling assumptions include:

1. Reduced economic growth caused by resource constraints and reduced confidence
2. Reduced access to many commodities, and hence increase prices or lack of availability
3. A series of price shocks caused by 2)
4. Reduced international security and coordination as countries compete for scarce resources
5. Repression of investment returns as governments seek to direct investment into sectors that are required to make the economy more resilient
6. Increased differential of investment returns in different countries that are starting from different allocation of resources, efficiency and debt levels
7. Lower growth could lead to increased bankruptcies as heavily indebted countries, companies and individuals are unable to pay their debts due to the lack of growth
8. Warmer temperatures and more unpredictable weather caused by climate change

[1] Donella Meadows, Jorgen Randers, Dennis Meadows & William W Behrens *The Limits to Growth, 1972*.

9. Increased domestic social tension brought about by inequality and hardships exacerbated by resource constraints and lower economic growth.
10. Possible changes to life expectancy and morbidity caused by changes in temperature, lack of access to resources, or changing ability to afford medical care

Three broad categories are explored in more detail in the published report, namely discount rates (this includes interest rates and investment returns), inflation (including salary and prices), and demographic factors (mortality and morbidity).

How society reacts will be a major determinant of outcome. This can be in a number of ways, but includes the reaction of monetary authorities to increases in commodity prices – this will determine whether increases in commodities result in general inflation. Society will also need to invest more and consume less and the way this is achieved will determine investment returns both absolute and relative to wage growth. In certain circumstances governments could pro-actively or re-actively intervene in allocating investment, to react to a perceived or actual threat which could constrain investment returns and wage growth. Resource constraints could lead to international tension, with potentially reduced trade, economic activity or possible breakdown in security. They will also have a clear impact on international investment and many institutions rely on returns generated internationally both directly or indirectly (via domestically listed entities operating internationally).

If resource constraints do provide a limit to economic growth then these impacts need to be understood.

**Paul Palmer**

### Probabilistic estimation of future emissions of isoprene and surface oxidant chemistry associated with land-use change in response to growing food needs

Current UN estimates of the global population in 2030 range from 8.0 to 8.9 billion, depending on assumptions about fertility rates, compared to a current day value of 7.2 billion. Regional populations will grow at different rates, with developing countries generally having higher growth rates. Changes in the size, demographic breakdown, and geographical location of the human population have far-reaching implications for climate change, including, for example, food and water security, conflict, direct emissions of greenhouse gases, and indirect emissions from land-use change. We are only beginning to explore these links and to quantify the associated economic and humanitarian impacts.

In this study, Dr Catherine Hardacre and Professor Paul Palmer, working with colleagues at the Universities of Edinburgh and Lund, investigated how future land-use change associated with growing demands for food and biofuel will affect emissions of chemically reactive gases that subsequently impact local and regional air quality. They used a simplified system dynamics model, driven by changes in consumption of commodities, to determine changes in global land cover. These changes in consumption are driven by four climate scenario storylines that describe a range of economic, environmental, and societal conditions. The climate scenarios were considered together with two biofuel scenario storylines that range from "business as usual" to imposing a fuel policy that aims to keep global mean atmospheric CO2 concentrations below 450 ppm.

The simplicity of the land-use model allowed the investigators to adopt a probabilistic approach for which they used a large ensemble of model runs to sample the full probability distribution function, compared to the conventional approach of relying on a few realizations from a more complex model. Land-use change from converting grasslands and forests to agriculture land is substantial, ranging from -1x1012 m2 to 6x1012 m2 corresponding to changes of -20–80% from 1990 values.

The associated changes in the type of plant grown will affect the emission of isoprene, a chemically reactive gas emitted by vegetation, which under certain environmental conditions can lead to the chemical production of surface ozone. Surface ozone is a surface air pollutant that at elevated concentrations leads to damaged crops and human respiratory illness. Global annual increases in isoprene emission in 2030, largely reflecting land-use change in the northern hemisphere, range from a reduction of 8x1012 g to an increase of 6x1012 g, corresponding to only a change of 1—2% in the global budget but this masks much larger regional changes. Isoprene emissions increased in North America, southwest Russia, and northeast China due to adding a large area of isoprene-emitting crops for biofuel cultivation. Conversely, over Brazil and sub-Saharan replacing strongly emitting isoprene forest and grasslands with crops led to a decrease in regional isoprene emissions.

The authors quantified the impact of these changes in isoprene emission on surface ozone by using a global atmospheric chemistry transport model, including meteorological data from NASA and detailed ozone chemistry, to move chemical air masses across the world. They generally found that land-use change due to increasing food production and biofuel cultivation had only a small effect on surface ozone at the global scale. However, on local scales they found that ozone increased by 5—12 ppb over temperate North America, China, and boreal Eurasia driven by land-use change for biofuel cultivation. These increases exacerbate high surface ozone concentrations over these regions and will likely increase the frequency of air quality exceedances with implications for hospital admissions due to acute respiratory illness and reduced yields of agricultural crops.

This study is an example of an emerging science that quantifies the human element of climate change, bringing together physical and social scientists to tackle a challenge that cannot be addressed by either community alone. Surface air pollution associated with land-use change can be classed as a secondary effect, similar to associated emissions of greenhouse gases and soil degradation. Assessing the risks of human-driven land-use change must integrate all primary, secondary, and higher effects, which are not available from current climate models.

More generally, there is a gap between the information from current climate models and the information demanded by decision makers, including the insurance industry, to assess climate risks. The probabilistic approach of investigating land-use change and the subsequent impact on surface air quality, described in this study, is better suited than conventional integrated assessment models to capture the stochastic nature of the human element that is driving the change. This approach also has the advantage of providing uncertainty bounds on the estimates that enable actionable projections for decision makers and the insurance industry by identifying the most probable projections rather than the range of plausible projections.