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Introduction

Political events around the world over the past year have set us on a different course. But with change comes opportunity, and that has never been so true as it is today, owing to the capabilities that technology offers. Perhaps it is time to challenge conventional thinking and ask if advancements can offer us a different way of doing things.

In this issue of Predictions, we explore this idea with a focus on modelling. Irfan Akhtar, Garima Gupta, Matthew Grant and Nikunj Manani look at applications for artificial intelligence, while Gail Tverberg considers energy-economy models, offering an alternative view based on the idea that the economy is much more networked than early modellers thought. With interconnectedness comes systemic risk and Len Fisher suggests solutions to deal with such risk.

Models are used by insurers to aid decision making. Tessa Moulton and Jason Noronha reflect on how Solvency II has changed capital modelling and speculate on future developments. In a similar vein, Andy Pitman believes climate models are ripe for improvement as they are currently misrepresenting extreme weather events.

Such events can have a devastating impact on cities, and Trevor Maynard discusses how resilience should be a priority for city planners and is essential if we want to protect our society. This is a pertinent point as, after all, it is the future of society that we have been voting for at the ballot boxes.

GEMMA GREGSON
PREDICTIONS EDITOR

Sponsor’s message

The saying that an actuary’s job is ‘like driving a car by looking in the rear view mirror’ is commonly used in the profession, but technology is affecting every aspect of how we work, and forcing us to face forwards. This is especially true for the field of capital modelling – a field that didn’t exist 20 years ago.

One of the key aspects of capital modelling, which is often under-appreciated, is that it is a communication exercise between many different teams – not just an analytical exercise. Having effective communication between the actuarial team and the board is a critical component of running a successful business. Technology is having an impact on the way in which we can do this.

New software developments such as the latest edition of ReMetrica enables the shift from ‘tribal knowledge’ to global corporate data-sharing with multiple stakeholders. This is a key goal that allows actuaries to share their assumptions and results with different teams. Here, the capital model becomes a method for communication.

Coupled with an ever-evolving industry – the rise of alternative capital, disruption, changing global regulation – this puts actuaries at the heart of decision-making, and this supplement helps to predict the future role for our profession.

PAUL MAITLAND
HEAD OF REMETRICA AT AON BENFIELD
We live in interesting times. Global population has tripled since the 1950s to around 7.4bn today. In tandem with this, the proportion of people living in cities has doubled over that period to just over 50% of the global population today. Many mega trends are challenging our economic systems and providing limits to growth, such as climate change, water security, mass migrations and other resource shortages. At the same time, new technologies such as artificial intelligence (AI), blockchain and social media are both enhancing our abilities and threatening our jobs. Although ‘creative destruction’ is a normal process in economic progress, the pace of asset stranding is expected to quicken in the coming years owing to these trends. There has never been a more important time to innovate. Innovation is necessary in financial markets, in engineering and in social structures to ensure we can thrive in the future.

That’s why the Sendai framework, signed in 2015 by 187 governments, is so important. This is an aspirational agreement to limit the number of deaths caused by, and the economic burden of, natural disasters. The framework has an interesting perspective; it starts with the basic idea that there is no such thing as a natural disaster. There may be natural hazards, such as floods, earthquakes and droughts, but these only become disasters through human failings. For example, wars turn a drought into a famine; bad design turns a building into a death trap in an earthquake.

It is ironic that a politician’s ratings may increase after a disaster when they announce a rebuilding programme, yet they are rarely criticised for the fact the disaster should have been avoidable. We are keen to see a new focus on preparation ahead of time – we want it to be seen as unacceptable not to have planned ahead and worked to mitigate the risk beforehand.

In response to these challenges, Lloyd’s recently published a report, in partnership with engineering firm Arup, called Future Cities that sets out a new framework to help city officials and insurers improve the resilience of city infrastructure, such as utility and transport networks, communications systems and water supplies. The overall message of the report is simple: to be prepared for the future, you have to plan for it.

The key to doing this in cities is to regard them as ‘systems of systems’, connected networks of critical components. Modern cities include man-made assets but also natural resources, human resources, social behaviours, financial markets and governance structures.

It is vital to appreciate the system as a whole – for example, people in a city rely on energy to power the transport to get to work, to power sewage and water systems on which they depend, and to provide lighting, air conditioning and electricity for internet connectivity. But energy systems also rely on water infrastructure for cooling and on transport systems to get its employees to work.

The city system is, therefore, interconnected so the failure of any one part of the system alone can lead to widespread impacts on the city as a whole.

Future Cities suggests that city planners and policymakers should focus on improving city resilience, where resilience is defined as the ability...
The system to cope, adapt and improve in response to chronic stresses and acute shocks. This seems an obvious goal, but resilient systems are often not the most efficient ones, and efficiency is often a key economic aim. At Lloyd’s, we argue that resilience is more important than efficiency in the long run. This is a similar argument to those Friedman and Savage made to explain why risk-averse customers purchase insurance. Policyholders (should) know that the price of insurance exceeds the expected loss but they choose to purchase cover to protect their assets from catastrophic loss anyway, because this maximises their utility.

In that vein, city planners and policymakers should invest in and improve resilience to protect against disasters even though it costs more than maintaining an efficient, yet fragile system. There are some challenges inherent in this approach. City officials’ tenure often only lasts 3-5 years, which makes the long-term decision-making that’s required to build resilience less likely; the various systems that make up a city’s infrastructure typically operate in silos, meaning that it is hard to take decisions that benefit the entire system; and the rapid urban sprawl decades has not typically been designed with resilience in mind, making it a hugely complicated task to ‘retrofit’ the required resilience measures. Nevertheless, these are challenges that can be overcome, and a resilience-oriented process can and should be embedded into design decisions.

Future Cities describes the key features this process should include.

Figure 1 (above) illustrates the main ideas of the paper. Consider a city in a normal state. A major event occurs and the city’s system moves into a ‘stressed’ state. If the system is resilient it may be able to absorb the shock and either return to normal or head towards a ‘recovery’ state where additional actions are needed to restore full performance. Sometimes the shock is so severe that a ‘collapse’ state arises, and this can lead to cascading failure as the interconnected elements of the network affect one another. This state must be avoided. During the recovery phase, city systems often form new dependencies that vary from those they have in the ‘normal’ state (a reliance on scarce skilled labourers for example).

One of the key conclusions in the report is that society should aim for a ‘new normal’ after a disaster.
In other words, we should learn from the event and rebuild better infrastructure, not replicate what went before.

The focus should be on preventing failure. The key objective is to build a system that can keep operating even if one component fails. Indeed, failure should be expected and planned for, with safe predictable results. Future Cities describes multiple ways to achieve this, including: integrated planning, where surrounding land users are consulted when each new piece of infrastructure is designed; valuing ecosystem services (such as the storm-surge protection of mangrove swamps); incorporating redundancy (such as maintaining spare generators); and increasing energy mix diversity (such as having multiple electricity generation sources, from hydro-electric to nuclear).

Post-disaster, the focus should be on recovering from the stressed or collapsed states. Critical resources should be mapped in advance and the emergency response planned and tested. In a well-planned city, its infrastructure will be designed with recovery in mind, allowing each component to still function after the shutdown of all non-essential functions. Recovery systems should be independent of the overall system where possible. The report also studies the transition from the recovery state to the new normal state. There need to be incentives to encourage key stakeholders to avoid reverting to the status quo before the event.

Wide consultation is also important. For example, it is valuable to talk to first responders when redesigning the transport network, because they can share any shortcomings of existing infrastructure during a recent disaster and suggest ideas on how they could be improved. It is important to set aside time to reflect on disasters, even though there will be a strong impetus to take rapid action to rebuild. Any advance thinking and planning is invaluable at this stage. The new normal should also include an explicit culture of safety in both the public and business communities. Education and public awareness exercises can start to achieve this – and strong leadership within business is also critical for culture change. That’s because appropriate human behaviour is just as vital as strong building codes to improve resilience.

From an insurance perspective, the report suggests a number of next steps. Better data will lead to better decisions, and this is the first request. The second is for the establishment of metrics that track resilience. Our concern is that, unless there are openly published robust indices that capture risk prevention activities, these will not be incorporated into our view of risk, in which case, our premium rates and capital setting process will not reward positive action. This disincentivises such action. Therefore we call for indices that cover key resilience elements, for example: efficacy of natural defences, degree of system diversity, asset maintenance levels, emergency response times, level of critical resources and degree of independence of recovery services.

From indices come models and tools that codify our risk understanding into consistent actionable outputs. Here, we urge that such models are built in an OASIS-compliant manner, which allows interoperability (OASIS is the open source catastrophe modelling framework; see: github.com/OasisLMF). Such models can be used to give probabilistic assessments of risk to enable comparison of options and risk readiness. Insurance can make a significant contribution to resilience in cities through incentivising risk management and providing financial and material support following major events.

In summary, our new report Future Cities sets out a vision for the actions necessary to ensure that cities are resilient to change in the coming years. Cities should be viewed as systems, and modelling them as such demonstrates how cascading failures can amplify catastrophe events. Collapse can be avoided through appropriate actions and, in particular, building diversity and excess capacity into the system. This comes at an economic cost, however, but we believe this ‘insurance premium’ is well worth paying to protect society in future. In short, robust is better than optimal.
twenty-five years of research has provided us with certainty that the earth is warming because of emissions of greenhouse gases. There are multiple lines of evidence in support of this statement, including basic theory, observations and global climate models. The basic theory is old, first attributed to Svante Arrhenius in 1896. He suggested that a doubling of atmospheric carbon dioxide would warm the Earth by 5°C. Observations from deep time (millions of years), the past few thousand years and the past century provide independent support for the basic theory.

The third strand of independent evidence comes from global climate models. These build on even older science than global warming and use Newton’s laws of motion, first published in 1687, expressed through the Navier-Stokes equations, which were derived in the early 1800s. Global climate models were first developed in the late 1950s and have seen phenomenal advances in representing the earth’s weather and climate expressed both by weather prediction systems and climate models. Global climate models build on the basic physics of fluid dynamics – laws around conservation of mass, energy and momentum – and unless these fundamental laws are wrong, the basic projections made by global climate models are reliable.

The reliability of climate models requires unpacking, because this detail underpins the value of current and next-generation climate models to the insurance industry. In 2007, the Intergovernmental Panel on Climate Change evaluated climate models and concluded they were “robust tools at continental scales and above”. This statement mainly refers to averages and was more confident when applied to temperature than other variables such as rainfall.

In the decade since 2007, climate models have continued to improve, and the ability of these models over annual or seasonal timescales is impressive. Climate models are fit for purpose in this sense and provide extremely valuable information, not least to inform policymakers on the urgent need to reduce greenhouse gas emissions. However, the improvements in climate models have been designed to develop more reliable tools to predict large-scale climate, not to simulate the probability of events that might interest the insurance or business communities. These models are therefore poorly aligned with assessing the risks, and therefore the costs, of extreme weather events. To a large degree, this is because the climate science community was never asked (or resourced) to develop these tools. Now, the emergence of a recognition that some extreme events are changing in their character has led to consensus on the need for tools that connect the climate and risk communities.

**Global climate models**

Almost all events linked with weather and climate that matter to the insurance industry are expressed as weather events. Flood-inducing rainfall, hail, cyclones, severe frosts, heatwaves; all necessitate the interaction of weather-scale phenomenon superimposed on larger-scale trends in climate. Even well-known climate-scale phenomenon such as the El Niño-La Niña oscillation must be translated via synoptic scale (typically, a few hundred kilometres) events into weather. The sorts
of synoptic scale phenomenon that matter include weather fronts, cyclones and intense low pressure systems such as the east coast lows in Australia. To resolve these weather patterns in a global climate model requires a spatial resolution of 20-30 km, which is currently only just computationally feasible for carefully chosen simulations. The challenge of global climate modelling at 20-30 km resolution is profound and, in itself, probably insufficient.

While well known to the insurance industry, the climate science community has begun to recognize what we know as ‘compound events’. These are:

1. Two or more extreme events occurring simultaneously or successively;
2. Combinations of extreme events with underlying conditions that amplify the impact of the events; or
3. Combinations of events that are not themselves extremes but lead to an extreme event or impact when combined.

Examples of compound events resulting from events of different types are varied – for instance, high sea level coinciding with tropical cyclone landfall, or the impact of hot events and droughts on wildfire, or a combined risk of flooding from sea level surges and precipitation-induced, high-river discharge.

There are at least two identified Australian examples. The first is the physical connection between tropical cyclone activity in northern Australia and heatwaves (and bushfire risk) in southern Australia. The implications of this are profound. It implies that major cyclones in the north are likely to cause major heatwaves in the south; that these two phenomena are causally related and losses likely linked.

The second example is the recognition that the recent heatwave in Sydney in January 2017 (and indeed the heatwave in Moree in northern New South Wales) was not the result of warming acting vertically through the atmosphere, but rather was the absence of southerly changes that would otherwise have swept away the extreme heat and ‘reset’ the regional temperatures.

In both examples, it is not about the simulation of an event – a cyclone in the north, or a heatwave emerging in the east – it is about how the atmosphere connects the initial phenomenon within the context of the larger climate state to affect another phenomenon.

In the case of the east coast heatwave, the tropics-to-polar temperature gradient, the angle at which frontal systems impacted the southern coast and the capacity of these to propagate northward to bring cool air to negate the heatwave were important.

Incorrect predictions

Global climate models have long since predicted an increase in very hot days under global warming. However, these projections have not included the impact of any changes in synoptic conditions. This probably means we are misrepresenting how extremes will change in the future.

Reviewing details provided by the Climate Change in Australia initiative suggests increases in summer temperatures around Moree of around 1°C by 2050. The Garnaut review on climate change that was commissioned by the Australian government in 2007 hinted at warming of around 1.5°C by 2070, with Brisbane experiencing eight, and Sydney nine extra days over 35°C by 2070.

In January 2017, Moree experienced 27 consecutive days of temperatures over 35°C, breaking the previous record of 17 days. This is significant, because current models predicted that this prolonged period of high temperatures would not happen until 2070 and that, even then, there would have to be a major increase in greenhouse gases for this to occur.

In short, there is considerable evidence that projections from climate models lacking synoptic-scale processes fail to reflect how our weather and climate will respond to climate change and risk lulling us into a deep sense of poorly assessed security.

While there is no immediate ‘off the shelf’ solution to this, the ways forward for the climate science community are clear. Weather needs to be properly represented in our global climate models. This requires:

A Major advances in climate modelling spatial resolution to around 20 km;
B A re-evaluation of how processes are represented at these scales; and
C A careful evaluation of how weather-related compound events are represented.

This is almost impossible to do for both technical and computational reasons – but only almost. Groups have recently begun examining how best to resolve these problems. It is one of the transformative pieces of science that the newly funded Australian Research Council Centre of Excellence for Climate Extremes plans to address over the next five to seven years.
Rethinking energy economics

Gail Tverberg discusses the problems with existing energy-economy models and proposes a physics-based modelling approach, warning of economic collapse as complexity and wage disparity grow.

Energy economics is concerned with the human use of energy resources. Simple models from the 1950s-1970s suggest that problems with energy supplies are still many years ahead. Unfortunately, as we examine new information from many research areas, it is becoming increasingly clear that these simple models give a wrong view of the predicament ahead.

The story most of us have heard about future energy supplies is as follows:

- Oil is especially a problem. Supplies will eventually run short, and prices will spike to high levels.
- Demand for energy products will always be sufficient. The glut of oil supplies and low oil prices that we are encountering today are signs that our oil problems are still many years away.

This is a reasonable model, if a person thinks that the only way that a shortage in energy supplies can be expressed is as high prices. Unfortunately, based on recent research, this story seems to be completely incorrect.

Recent analysis suggests that we should expect the following problems as we approach energy limits:

- Slowing world economic growth
- Growing wage disparity
- Wages of non-elite workers lagging behind the rising cost of living
- Prices of energy products lagging behind the rising cost of production
- Gluts of oil becoming a problem, indirectly because of falling affordability by non-elite workers
- Debt levels rising
- Interest rates falling to very low levels, to accommodate high debt levels.

In the end, energy prices are likely to fall too low, leading to a collapsing economy. There is considerable evidence that we are already reaching energy limits. We have heard stories about slow world economic growth and growing wage disparity for several years now. Furthermore, energy prices started to fall far below the cost of production in mid-2014. Producers can temporarily work around low prices by adding debt, but eventually production must stop.

Physics-based model

A major problem with early models is that the economy is much more networked than early modellers understood. In practice, an energy shortfall can appear in completely different ways than most would expect: low energy prices and low wages.

Low energy prices are important because they cause energy producers to leave markets. Low wages are important because they lead to gluts of oil and other energy products, related to low affordability.

In recent years, there have been advances in many related fields, including complexity theory and the physics of 'open' systems. We have also gained knowledge through the analysis of prior civilisations that collapsed. Combining this information can help us develop an alternative energy-economy model.

The world economy is a self-organised system of governments, businesses, and consumers. The economy gradually gets larger, as more businesses are added (and a few are subtracted), and as consumers are added and laws change. New products are added, and unneeded ones are discontinued. The economy is in some sense hollow because the economy optimises the use of resources by eliminating products that are no longer needed, such as floppy disks and horse-drawn carriages. Thus, it cannot easily shrink back to a prior technology.

One critical part of this networked economic system is the energy flows that make economic activity possible. Some of these flows are from the sun; some are from the burning of fuels, such as biomass, coal, oil and natural gas. Some of the energy used by the economy is human energy, including thinking, talking and walking.

Of course, this human energy is only possible...
by eating food – also an energy product. These flows of energy are what allow the processes that underlie gross domestic product to occur. For example, the burning of fuels allows industrial processes that require heat to take place. Fuels also allow vehicles to be operated to transport goods. The availability of electricity together with human energy allows the economy to provide all kinds of services, including data analysis and communication.

We know from recent physics studies that many types of structures self-organise and ‘grow’ in the presence of energy flows. Some of these structures are things that we consider living beings, such as plants and animals, including humans. Some of these things are inanimate, such as hurricanes, stars, ecosystems and economies. The name given to structures that form in the presence of energy flows is ‘dissipative structures’.

Figure 1 illustrates my view of how the economy operates as a dissipative structure.

**Economic collapse**

Dissipative structures generally cannot shrink back very much without collapsing. The per capita consumption of energy must stay fairly close to level if an economy is not to collapse.

Also, all dissipative structures – even economies – are temporary in nature. The exact reason for the failure of a particular dissipative structure varies. Lack of energy supply is one reason for collapse: animals can starve; hurricanes can move over land.

One of the issues with this organisation of the economy is that both ‘other energy’ (meaning non-human energy) and mineral resources are subject to diminishing returns. Businesses extract the easiest-to-extract resources first. Later resources require more inputs, including energy inputs, to create desired outputs. Thus, diminishing returns will tend to make the economy less and less efficient over time, unless offsetting efficiency improvements can be made.

Another issue with this system is that while adding ‘tools and technology’ can temporarily be helpful, such growth tends to be self-limiting for three reasons:

1. When tools and technology are added, the nature of enterprises changes. Businesses become larger and more hierarchical. Some workers receive specialised training, while others do not. Some citizens become owners, while others do not.

2. When new tools and technology are added, these new devices allow workers to become more efficient. However, there is a timing mismatch: if a tool lasts for 50 years, and is made in year one, the workers who make the tool (and the raw materials going into the tool) must be paid in year one. Thus, adding tools and technology tends to increase an economy’s need for debt.

3. Growing use of tools and technology nearly always requires increased use of ‘other energy’ because these new devices are made using energy products. They also tend to use energy products in their ongoing operation.

It is hard to see any good fixes to these issues. The system will collapse if inputs are inadequate, or if waste outputs are too harmful. We are approaching energy limits, and, while renewable energy sources were once thought of as solutions to our energy problems, they cannot directly be used to operate the electric grid, creating extra costs and adding complexity. We live in a world of technological advancements, but these are likely to generate economic waste products. Unless we find a way to add energy supply and at the same time decrease complexity, we are likely to end up in a state of economic collapse.
Capital models are used by insurers to understand their risk profiles and make business decisions. Regulatory changes have transformed capital modelling in recent years and so, to understand how the field is evolving, Predictions spoke to Tessa Moulton, one of the product managers for Aon Benfield’s capital modelling tool, ReMetrica, and Jason Noronha, head of the actuarial consulting team at Aon Global Risk Consulting.

How has capital modelling changed over recent years?

Tessa Moulton (TM):
Regulation has had a significant impact on capital modelling in the UK since 2004, which was when the Individual Capital Adequacy Statement (ICAS) regime came in. ICAS was a fairly lightweight regulatory model and so the impact was much less than we have seen with Solvency II. Although Solvency II didn’t come into force until 2016, it started to make a big difference to capital modelling teams from around 2010.

Jason Noronha (JN):
Solvency II is a lot more detailed and prescriptive than ICAS was and this has added complexity to models. There is now more of a focus on regulatory compliance and that can be a big part of the job, especially for smaller capital modelling teams. There is now a much greater awareness of models throughout the business, as a core principle of having your model approved for use in regulatory capital setting is the ‘use test’, which demonstrates to the regulator that you are using it for business decisions.

What challenges has Solvency II brought to capital modelling teams?

JN: Responding to ad-hoc requests is a much bigger deal than it used to be. There needs to be a balance between having a model that is well controlled, documented, audited, and robust, and giving the team flexibility to react and make changes, and to respond to things as they come in. It is something that we have seen the market struggling with over the last few years, especially in the bigger firms which might be more governance-focused, which can remove some of the flexibility.

TM: Companies must do a lot more documentation and need to get specific reporting metrics out of models. Models have become complex so there is a danger that not many people understand them anymore. It’s not unusual for there to be only one or two people in the team that develop and understand the model thoroughly and that is a really big risk. Some capital modelling teams are also stuck in a loop of training people up who then leave. Businesses struggle to move forward with their understanding or development of their capital models while this is happening, especially if the models have been developed in a very bespoke way.

There are concerns about a talent drain in capital modelling. It was once seen as the sexy bit of the actuarial profession – it was new and exciting and everyone wanted to get on the capital modelling team. The Solvency II component has really changed being an actuary and there are other areas such as data analytics that are perceived as more exciting. I also wonder whether we are losing some of the top mathematical quantitative graduates to the world of software.

Although these analytic teams that are being set up at some of the big insurers and brokers present a threat, they also present a massive opportunity for the actuarial community. We can bring wider industry knowledge into these teams, along with actuarial skills such as judgment that a data scientist or a statistician won’t necessarily have.

What are the important attributes for a capital modelling actuary?

JN: Communication skills are essential for a capital actuary to help make changes to a business and help companies make risk-based decisions. You really need to be able to communicate with non-technical users and make them feel comfortable with what the models say. You also need to help people understand that there are limitations of the model. Validation, the process of checking and challenging the model, can sometimes be a false comfort – just because the model has been validated does not mean that it has the future truth, or tells you everything you need to know about what is going to happen.
Being a capital actuary is a big-picture type of role. You want to have that view of what all the risks in the company are and understand the proportionality so that you don’t get bogged down in something that has no material impact. Adding value to the business is about communication, focusing on what is important because none of it is right really, it is all just a guess, but what is important is how close that guess is in the areas where it matters most.

What new areas will we see being modelled in the next few years?

Lloyd’s recent report with Arium on modelling liability accumulation risk is really bringing catastrophe modelling-type techniques to liability exposures, which is something that hasn’t been done before.

You can’t go anywhere in the insurance market without somebody saying cyber. Especially in the Lloyd’s market, many syndicates are offering some sort of cyber cover. It is difficult to reflect those risks in a capital model because there is very little data. The recent WannaCry ransomware attack shows that the effects of cyber attacks can be wide reaching, and it is a big challenge to model that.

What impact will advances in technology have on capital modelling?

Technology is obviously changing all the time and mostly in a positive way. It’s not too expensive now to scale up hardware, so the potential to speed up model runs is definitely there. However, in reality, there is a bit of tolerance for how long it takes a model to run and people just tend to add complexity up to that tolerance.

There is a perspective that doing things more detailed is better, but often that’s not true, because we don’t have data at that level to parameterise the model. I think we need to challenge people, as I think some of that complexity is probably not necessary and companies could get away with being lither and leaner.

What will be the impact of changes in regulation on capital modelling?

IRFS17 is also an interesting one because the way in which the balance sheet is constructed is similar to Solvency II. There will be a need to run more stochastic simulations to get the results you need and so I think we will see capital models being used more widely for helping the accounts department set their balance sheets.
Present-day actuaries are faced with assessing a new type of risk. Well, not new, exactly – it has always been with us. But it is arising with increasing frequency. Unless and until we learn to deal with it, we will be flying blind into the future.

I am referring, of course, to systemic risk – risk associated with a system as a whole, when the system may have emergent properties that are more than the sum of its parts. Sometimes much more.

Systemic risk arises because of interconnectedness, which can make a system more efficient but also render it more vulnerable, as the Sony Pictures hacking and recent WannaCry ransomware attack on our cyber systems have shown.

The more that a society, an economy or an ecosystem is interconnected, the greater the chance that a small change in one part of the system will produce disproportionate effects in some other part – witness the way in which the failure of Lehman Brothers propagated rapidly through the highly interconnected world financial system in the 2007-2008 financial crisis.

Systemic risk has been the subject of intense scientific investigation over the past two decades. Much of this investigation has been concerned with the behaviour of networks, consisting of nodes (people, groups of people, organisations) connected by links through which they interact. Our modern, globalised, increasingly interconnected socio-economic-ecological world is an example of a complex adaptive network, where nodes or links can change in response to their previous communication history. Links may get stronger or weaker; they may break, and new ones may form; new nodes may also enter; interactions may reinforce or undermine.

Such networks may also contain attractors – regions in the landscape of possible system behaviours that act to maintain stability as the system gyrates around them. A social attractor may be a village, town or city; a political system; urbanisation; an economic system; or even a religion.

A key finding, and a major problem for the actuary, is that the amplification of small changes, or encounters with alternative attractors, can lead to situations where periods of reassuring stability may be rudely and unexpectedly interrupted, with a tipping point being reached where the whole system ‘flips’ to a quite different state via a critical transition. Such critical transitions, and their sometimes disastrous consequences, appear to be on the increase. To quote from the Chartered Institute of Management Accountants 2016 report Thinking The Unthinkable: “2014 was the year of ‘the great wake up’... President Putin’s seizure of Crimea was quickly followed by the rise of so-called Islamic State, the devastating outbreak of Ebola, the sudden 60% collapse in oil prices, and the cyber-attack on Sony. ‘Unthinkable’ events continued into 2015, led in impact by the sudden tsunami of refugees and migrants into Europe... At the start of 2016, the uncertainty created by ‘unthinkables’ reached...
ever-greater depths. Prices of oil and commodities kept tumbling. The failure of China’s leadership to grip and halt the giant nation’s economic slowdown catalysed the New Year downturn in global stockmarkets... And what about the once unthinkable... election of Donald Trump to president?”

That event, of course, come to pass, as has the Brexit vote in the UK, triggered by fears of mass refugee influx. How can actuaries hope to cope with assessing the risk and consequences of such events?

The first step, of course, is to understand the statistics. The risk of systemic extreme events does not follow the traditional normal curve, where the chance of large deviations from the mean drops off exponentially, and becomes very low indeed far out from that mean. Because of the way that many networks behave, the chance of disasters and other extreme events often instead follows a power-law distribution. Power-law distributions have relatively fat tails, so that extreme events can be much more common than intuition, based on the normal curve, would suggest. They are still relatively rare but, as pointed out by Oxford social theoretician Anders Sandberg: “Just because the most recent events have not been extreme, does not mean the heavy tail will not [eventually] side-swipe the actuary.” In fact, it is almost sure to.

As far back as 1960, the English polymath Lewis Fry Richardson used a statistical approach to predict the occurrence of wars with different degrees of severity. Richardson’s approach was empirical, based on historical evidence. Today’s approaches to predicting the occurrence of sudden, large-scale change are based on modelling and mathematics.

An important approach, developed by Marten Scheffer and his colleagues at the University of Wageningen, has been to use rigorous mathematics to understand the warning signs that might help to predict the occurrence of an upcoming critical transition. The analysis suggests that critical transitions are often preceded by a period where the system is slow to recover from small perturbations, and also shows that there are likely to be increasingly frequent swings between increasingly extreme states prior to such a transition.

These would seem to be very useful tools for the actuary. Unfortunately, the time scale for action by human institutions (including insurance companies) is usually such that, by the time the risk becomes obvious, it is too late to avert the transition.

Computer modelling, already a staple of actuarial practice, provides another possible tool for assessing systemic risk. The development of appropriate models for such applications as weather forecasting has progressed rapidly, but their use for understanding and predicting development and change in whole societies and economies is still at an early stage.

It should also be noted that computer modelling can carry its own systemic risk, even when applied to relatively simple situations. To quote from the Systemic Risk of Modelling in Insurance white paper, produced by the Oxford Martin School at the University of Oxford: “A risk model intends to make probability estimates of a risk, which will then be used to make decisions. If it underestimates the probability of a risk, actions will be taken in false confidence. If it overestimates risk, resources will be misallocated. If it causes correlated actions across an organisation or market, systematical or systemic risk emerges.”

What hope do we have in the face of all of these obstacles? I would like to make a revolutionary suggestion – that such hope as we have will be considerably increased if the insurance industry, and its actuarial practitioners, adopts a proactive rather than a reactive approach.

What I mean is that the industry should seek actively to change the behaviour and habits of its customers in the face of systemic risk. It is clear both from the analysis and the history that we can only avoid (or, at least, ameliorate) such risk if we are quick on our feet, and able to adapt rapidly to changing circumstances. Yaneer Bar-Yam, head of the New England Complex Systems Institute, has argued that the structures of our present governmental and business institutions are not fit for purpose in the face of such risk. I agree.

We need structures that are quick to respond when systemic risk threatens. One way, suggested by former Royal Society president Bob May and Bank of England chief economist Andy Haldane, is to break large systems such as the global financial system into smaller, less interconnected, but more nimble units. As experience has already shown, it’s not going to happen. What could happen, however, is for the insurance industry to raise premiums for firms with less adaptability, and to reduce premiums for those that have made better preparations to cope with systemic risk if and when it arises (for example, by introducing fuzzy cognitive mapping (dx.doi.org/10.5751/ES-08599-210418) as a quick response mechanism). It’s a long shot – but then, we are insuring against long shots. So let’s fight fire with fire, and stop flying blind into the future.
The potential of AI

Irfan Akhtar and Garima Gupta look at how artificial intelligence could boost business and drive product innovation.

The talk of artificial intelligence (AI), big data and the internet of things is all the rage at the moment but probably quite daunting for companies trying to grapple with it for the first time. Also, with media hype and controversial headlines about employees being replaced with robots, some may be reluctant to embark on this journey.

The opportunities are immense, from efficiency savings and enhanced productivity to product innovations and gaining access to new markets, but where to start?

We are already seeing new technology driving product innovation in personal lines such as wearable tech in health, and telematics for motor and home sensors. There is also massive potential in commercial lines. For example, in marine and aviation using real-time data streams from internet-enabled equipment to pre-empt failure, known as ‘anomaly detection’, can augment maintenance schedules and optimise the lifetime of components.

The first step to exploring how AI could boost your business is looking at enhancing efficiency of processes. The perception that AIs could replace jobs is likely to be greater than the actual reality, certainly in the short to medium term. What we see is that most organisations are converting mundane, but well-defined, human tasks and cutting through bottlenecks in operational processes by using pretty straightforward machine learning techniques that can replicate the often repetitive actions of humans. This frees up employees to be more useful and add value to the company in other more sophisticated ways.

For example, predicting future longevity risk from past mortality data on a myriad of cohorts can be done by an algorithm but assessing the causal links is still the domain of human analysts. Possible environmental changes in the future will not be captured by past data and so the algorithm will either need to augment this human understanding or we should put caveats around the outcome.

Good business problems for machine learning methods are those that require ‘learning’ rather than automation. You will also need to consider the data available. ‘Supervised learning’ is the most common method to build an AI. This means the AI learns from data (the training set) that specifies various inputs and maps them to certain outcomes, so the AI can build a relationship between the two. You have to be confident that the outcomes can be fairly based on the data you feed in. If other/external data affects the outcome the algorithm won’t know about it.

We have seen from other industries that rather than seeking new sources of information, useful applications of AI tend to use data that had previously lain dormant.

For example, you may have transcripts or audio recordings of customer service conversations. An algorithm can rapidly review this to predict performance of your salespeople and score them relative to each other. This would normally be too

FIGURE 1: Hypothetical example of a neural network

Gender Age Temperature
Adjustable weights

Healthy Low risk Risk level 1 Risk level 2

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expensive or time consuming for people to do. These models can augment human analysts and it is still up to the company to decide how much to rely on the AI.

One example of usage in life insurance is the analysis of medical records and reports from doctors to find new ‘predictors’ of health. Electronic processing of medical reports can hugely change the way the current underwriting process works. Automatically identifying the risk profile of each individual can have many advantages such as reducing the length of the underwriting process for healthy customers leading to higher conversion rates on sales campaigns and reducing pricing and reserving risk.

Most electronic patient records are in the form of narrative text but semantic text parsing methods can be used to interpret and map clinical information to a more structured format such as natural language processing (NLP) systems. This contains some linguistic knowledge and in addition with convolutional neural networks can be employed to index or categorise reports based on severity of health status. A hypothetical example of a neural network is shown below. The goal is to diagnose conditions classified into categories. Inputs correspond to demographic data or measured values for age, temperature, and more.

It is easy to engage the data science community if you do not have the required skills in-house. We have seen many working models giving companies a cost-effective approach to experimenting with new technology. Once your board has seen the benefits of new technology in practice then you can consider building a team to attack more complex problems with machine learning.

Other industries have already hired, or are considering hiring their first chief AI officer. Insurance is not there yet but given the rate of change and potential for disruption we all need to take a deeper look earlier rather than later.

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### Power surge ahead

Artificial intelligence (AI) has many exciting applications. One area where AI techniques are set to bring value for insurers is in the claims reserving and claims handling processes, where existing predictive analytics methods could be enhanced by machine learning techniques.

#### The challenge

Traditionally, actuaries have used development pattern approaches, such as the chain ladder method, on portfolios of claims in order to derive ultimate claim costs. These methods use the paid or incurred position of the claims cohort, but effectively discard a lot of the other information that comes with a claim, such as the claims description.

What if, by exploiting more of the qualitative, as well as the quantitative data that often comes with a claim, it were possible to predict whether a given claim is likely to turn into a large claim? If that were the case, then it might be possible for an insurer to identify large claims early on, manage them carefully, and attempt to settle them more quickly.

#### The goal

Often a distribution of claims is such that the largest 10% make up over half of the overall claims cost. If even a 10% saving can be made on each of these claims by identifying them early, this would translate into a large saving on the entire book of claims.

#### The solution

The power of a variety of predictive analytics techniques makes this a real possibility:

- Categorisation techniques are particularly useful for this challenge, for example K-nearest neighbours and decision trees.
- In terms of the useful fields, the claims description offers immense opportunity when used in conjunction with the text mining algorithms that

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**Matthew Grant** and **Nikunj Manani** ask whether machine learning techniques could be used to transform claims handling processes.

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Risk level 3: High risk: Very high risk

- White blood count
- Cholesterol...etc
have been developed by data scientists. The occurrence of words (or groups of words) in a claim description is often seen to have a strong relationship to the size of a claim. For instance, in liability lines, ‘slip’, ‘trip’ and ‘head injury’ may bear some relationship to the size of a claim.

- Supplementing datasets with external data can also prove effective. For example, replacing a postcode in a claims listing with a crime or an employment metric for that area may enable the classification algorithms to utilise yet more of the dataset.

Putting theory into practice
Typically, once a historical dataset has been obtained, the actuary would begin the analysis by categorising claims in the dataset into large and small claims. This dataset would then be split into training data (used for specifying the model) and test data (used for trialling the performance of model on unseen data).

Once an acceptable model has been found, this can be applied to new claims that come in, and hopefully correctly identify claims with the potential to become large. As claims settle, this just provides more data to further refine the model, and more accurately identify large claims; the power of the model grows by itself.

“It might be possible for an insurer to identify large claims early on and manage them carefully”