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# A MATHS TOOLKIT FOR ACTUARIES

# PART I

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***Mathematics**, the science of magnitude and number, the relation of figures and forms, and of quantities expressed as symbols. [From the Greek Mathēmatikē (epistēmē, skill, knowledge) relating to learning – mathēma – root of manthanein, to learn.]*

***Tool,** a working instrument, especially one used by hand.*

***Kit**, a container and/or the material, tools, instructions, assembled in it for some specific purpose.*

***Stochastic**, conjectural: random.*

***Conjecture**, an opinion formed without proof: an opinion formed on slight or defective evidence or none at all: a guess.*

***Artisan**, a skilled manual worker.*

***Source: Chambers Dictionary***

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## 1. Foreword and Acknowledgements

This paper is the product of the two authors, but we have been fortunate to have spent time in discussion with a number of people, whose contribution we would like to acknowledge. These are:

- John Berry;
- Andrew Cox;
- Susanne Frisby;
- John Harnett;
- Sally Horrocks;
- Roger Nye;
- Kaare Rasmussen;
- James Tanser; and
- Andreas Tsanakas.

Unfortunately, due to work commitments and moving jobs, we did not maintain the momentum which our Working Party achieved in the first few months of this year. As a result, this paper has been a dual (as opposed to a team) effort only.

Despite this, the ideas and comments expressed by the above have influenced our thinking and we hope that we have represented them fairly. The opinions expressed and errors in this paper are entirely our own.

## 2. Executive Summary

This paper discusses the potential impact on standards of the convenient analysis used by many actuaries, suggesting that greater effort is required in applying intellectual rigour and developing understanding of the underlying concepts. It identifies the rushed environment in which many businesses operate and calls for greater time to be spent in improving individuals' capacities.

The Actuarial Profession faces many challenges and the argument is presented that the greatest contribution should come from individual members, in addition to the structural changes that have already been identified and implemented. These involve greater theoretical learning and reflection on our work. The impact of new technologies is discussed, as well as the need to embrace the opportunities and competitive threats that these present.

Change presents many challenges for society and business, and actuaries have the opportunity to prove their worth in responding to these. The challenge for Fellows to remain up-to-date is highlighted, with the implications for CPD as identified by the Morris Review.

Forecasting and prediction are key roles for actuaries, along with many other professions, but our differentiating core competence is the quantification of uncertainty. The convergence of risk quantification activities in pricing, reserving, capitalisation and risk transfer can be expected to continue, and actuaries should be at the centre of these developments.

A model is presented which integrates research with the management of The Actuarial Profession's Corporate Intelligence. Our commitment to excellence is discussed, as are the benefits of interaction with academics and appropriate sponsorship models to support this. The Internet has a key role to play in identifying and supporting the adoption of new techniques, and this will be explored further in Part II to this paper.

## 3. The Model Actuary

### *A Maths Toolkit for Actuaries*

This paper discusses the intellectual equipment that the modern day actuary should have at their fingertips, and how they might get hold of it. Much of it is aspirational and, although we are looking at things from a General Insurance (GI) perspective, we believe that the points made are directly applicable to all practice areas.

This paper originally came out from the title being placed at the top of a volunteers' sheet at last year's GIRO and our signing-up to find out more. We then discovered that the person who had proposed the working party was not amongst the group that had gathered to discuss a "Maths Toolkit for Actuaries"!

Although we didn't know the original author's intent, we found quickly that there was a shared concern in our group that we were operating in a world of rushed decisions, where analysis was increasingly relying upon convenient computational solutions. This "convenience" was reducing our exposure to the underlying mathematical results and methods that our discipline is built upon, and our knowledge and ultimate effectiveness was being limited as a result.

### *Have We Dumbed Down?*

Specifically, there was concern that the typical GI actuary (which, of course, no one is) had become a one trick pony, who had become expert in the application of one simple technique, the chain ladder method for projecting claims reserves and premium, and that the same thing was happening with the use of Monte Carlo simulation to solve complex integration problems.

Both of the aforementioned methods, whilst powerful, are convenient, requiring little knowledge of the underlying statistical principles being applied. Although they do provide insight they are not the whole story, lacking depth, particularly in relation to an understanding of uncertainty and estimation error. Were we limiting ourselves to printed images when a hologram might be available, or to fixed data tables when a pivot table would do better?

Perhaps, with a less convenient set of tools in common use, the skill level and analytical capability of actuaries would be stretched, with wider benefits to the profession and those who rely upon us? We believe that more should be done to expose actuaries to consideration of the fundamental concepts underlying our analysis and to ease the process of applying new methodologies and acquiring new skills.

It is worth noting that the chain ladder methodology existed *before* any statistical frameworks were developed around it. We aren't saying that a new tool can't be used without a detailed underlying mathematical theory, but it helps and when one *is* available it seems remiss to ignore it. Also, GRIT [1] has proposed that actuaries should work to highlight and quantify uncertainty, and reminds us that understanding the fundamentals will help with this.

### *Time to Think*

Einstein is alleged to have congratulated a particularly studious student on his course work, "…this is very good, but when do you have time to think?" Although apocryphal, this story reminds us of the value Einstein, as a stunningly successful exponent of the "thought experiment", placed on having time to think. We should not forget that this is what most of us are paid to do.

Stephen Covey [2], author of the self-help book *"The Seven Habits of Highly Effective People"* talks about "sharpening the saw", and the need to manage the balance between investing in producing things and investing *in our capacity* to produce those things. He talks about recognising and making time for the important, but not urgent (Quadrant 2) activities that will help us become more effective. If you are reading this paper you are, we hope, in Q2.

***Varying the Clock Speed***

Our everyday working lives are shaped by technology, the speed of communication, of calculation and of producing our work. Key business decisions, even about strategy, are sometimes made within a matter of minutes, if not seconds; formal business meetings have long lists of agenda items, "good" communication is the one page memo, short E-mail or quick telephone conversation. Is this really good communication? Do sound-bytes really convey information effectively?

Clearly, in response to this changed environment, it is necessary to sharpen our powers of communication and to be clearer, more concise and definite in the advice we give and the decisions we make. However, in this rushed world, we may lose the time to think about what is going on beneath the immediately apparent and convenient view of the problems we face.

The Actuarial Profession, whether through the practice boards, their sub-committees, research groups and working parties, does create the time and space (though not much) to work to a different clock speed. However, not all members can spare the time to participate in the profession's activities, and some may not wish to.

We can see a challenge to create an environment in which more members of the profession can take more time to develop their own knowledge and understanding.

***The Model Actuary***

In the past, the model (as in ideal) actuary had many admirable qualities. He [sic] was unimpeachable, unflappable, fair-minded, adroit, diplomatic and able to make sense of the complex workings of the businesses he [sic] ran or advised.

Perhaps the ideal actuary of the modern age is an expert and effective communicator, again able to understand the intricate complexities and peculiarities of business, to quickly locate the best (and possibly latest) available techniques to analyse problems, to provide insights, develop and present solutions. There is probably more in common than different between our past and present models, but the differences are important and reflect changes in technology and society.

Onora O'Neill's [3] 2002 Reith Lecture *"A Question of Trust"* discussed the crisis of trust, in professionals in particular. She discussed whether our becoming more accountable, required to prove the worth and validity of our advice and decisions, might regain that trust. Although she questioned the value of prescriptive regulation and performance measurement, she did describe a form of "intelligent accountability", which we think is relevant to the actuarial profession and anticipates the findings of the Morris Review [4].

> *"Intelligent accountability, I suspect, requires more attention to good governance and fewer fantasies about total control. Good governance is possible only if institutions are allowed some margin for self-governance of a form appropriate to their particular tasks, within a framework of financial and other reporting…*
>
> *…Those who are called to account should give an account of what they have done and of their successes or failures to others who have sufficient time and experience to assess the evidence and report on it."*

There is a chance for the profession to match these ideals, but it is not just a matter of changing our organisational structures, such as creating appropriate oversight mechanisms involving others from outside the profession. The Actuarial Profession has actively and positively embraced the need for change and engaged with the Morris Review, **but individual members have the most important role to play in this process.**

***The Paranoid Survive?***

Our model actuary should be, if not paranoid, certainly more self-aware, self-critical and open to alternative views and new techniques. In short, the actuary of the modern age should, once again, think.

It is still puzzling that actuaries were largely absent from the "quant" revolution in investment and finance that began in the seventies with the introduction of computers into the banking industry. As mathematical specialists, actuaries should have been a natural choice, but instead others with a scientific background and training from outside of finance were hugely successful.

Although many banks are now discovering actuaries and their potential value, it is notable that the CFA Institute (forerunner of the Institute of Chartered Financial Analysts) is the qualification of choice for many working in investment around the world. This path is being chosen by many numerate graduates who might otherwise study actuarial science if it had a better reputation.

So we have concluded that continual theoretical learning and reflecting is a fundamental ingredient of this profession's future. When is the model actuary of the modern age going to have time to do this? Our belief is that, to thrive and survive, our commitment to developing our knowledge and capabilities, and engaging with the wider intellectual community must be at a far higher level.

***Tool Talk***

There is no doubt that an attraction of signing-up to a "Maths Toolkit for Actuaries" was the worthy, workmanlike imagery of an artisan, skilful in the use of a handy, portable selection of tools that were an extension of the hand (or mind). A toolkit contains the most useful and familiar of tools, both portable and fit for purpose, which can be put to use in solving a wide range of potential problems.

A medieval carpenter's toolkit would look very different to a 21$^{st}$ century carpenter's. It is interesting that we have a mental concept of what one is, "a person who can make things out of wood (or material with similar qualities) to make our lives easier or more pleasant". This image is independent of time on the one hand, but we expect them to move *with* the times; if we call a carpenter from the yellow pages we expect them to have the latest tools.

Is there a mental image of an actuary? We think there is and it might be something like, "a person who can solve and communicate the results of difficult quantitative financial problems by quickly finding and using mathematical techniques". When we look at the modern day GI actuary's toolkit, we see some tried and tested favourites, such as the Chain Ladder, with variations, including B-F. These are hosted on many platforms but dominant amongst these is the spreadsheet.

The spreadsheet, particularly combined with macros or programmes, is an enormously versatile and powerful tool. As a thought experiment, how might we be solving today's problems if this vast computing power had been available before insurance was developed? Are we being constrained to incremental improvements of existing methods? Are we really aware of what can now be done – the power of modern desktops is truly staggering – are we using them to their full potential?

And, of course, there is the Internet, on which more, later.

## 4. The Rate of Change

***Change?***

Change has become a constant in all of our lives. It is increasingly easy to write a list of the major challenges that change presents to society:

- globalisation of trade, production, movement of capital and workers;
- "compensation" culture;
- changing regulation;
- ageing populations;
- population growth;
- new technologies;
- climate change;
- energy supply;
- water supply;
- terrorism.

Our ability to contribute to the well-being and economic growth of our communities (and, thereby, the economic awards given to us) will be determined by how well we use our existing skills and knowledge, and acquire new ones, to address these challenges.

***The Next Missed Opportunity?***

The last chapter mentioned the "quant" revolution and the profession's minor role in it. A quick survey of present developments in insurance suggests that some opportunities may be grasped, but some may go begging.

The last ten years has seen an explosive growth in the use of catastrophe modelling to predict the financial consequence of earthquakes, hurricanes, floods and even terrorist attacks. In modelling the liability profile of an insurance portfolio, this activity sits comfortably within an actuary's sphere of interest and many actuaries are involved in this area.

However, our role is largely as a passive end-user and we do not yet play an active role in influencing standards of practice in this young field, where improving the depth of understanding and consistency of approach could make an enormous contribution to risk management standards within the industry.

We believe that The Actuarial Profession should create a course similar to the certificate in derivatives (working with universities and catastrophe modelling companies) to give an in-depth training in these methods to actuaries working in the field; we believe this qualification should be open to non actuaries as well.

Perhaps we could work with the CII, who could offer a basic level course for general catastrophe modellers, with The Actuarial Profession's involvement being at a higher level, covering:

- technical mathematical details (hard maths);
- high level issues – how should results be used in pricing, capital setting etc?

The other "big thing" to happen in recent times is in the field of risk based capital. Thanks to the FSA, and the ICAS requirements, this has apparently been dropped into the profession's lap. Most of the work in this area has been undertaken by actuaries, as has much of the development of software to support analysis. The role and relevance of actuaries in this area is accepted and it would be instructive to understand how this situation has been arrived at.

Also, although growth in the alternative risk transfer market has been modest, a number of actuaries are involved in the interface between the insurance industry and capital markets, and we must wish them well as ambassadors in a land from which we have previously been excluded!

The "next big thing" is open to debate, but the introduction of Solvency II, and the development and implementation of fair value accounting standards are strong candidates. These areas are actively discussed within the profession and members are contributing to their development, which is encouraging.

***Basic Training***

Actuaries, as a group, are a pretty bright and industrious lot. However, in discussions with academics, it has been commented that The Actuarial Profession is surprisingly unsuccessful at training their members once they become Fellows.

The overhaul of the educational programme and the introduction of professional training to support students can be expected to raise qualification standards, but it is notable that the Morris Review made particular mention of the education of actuaries and encouraged us to engage more with non-actuaries and academic actuaries to develop our skills and keep our knowledge up-to-date.

The debate about CPD is on-going and is receiving more attention than we could hope to match in this paper. So, to save time, we shall quote from the Morris Review:

- *the Profession should clarify the objectives of the CPD scheme, consider increasing the amount and quality of formal CPD required for reserved role holders, and foster closer links between those within the Profession with responsibility for syllabus development, the actuarial research community and those concerned with CPD; and*
- *the Profession should ensure that the CPD scheme is relevant, up-to-date and takes account of developments in actuarial science, financial markets and other disciplines.*

In the spirit of Onora O'Neill's "intelligent accountability", CPD should be less about minimum standards and more about striving to be excellent; it is difficult to criticise those who have done their best with commitment, creativity and intelligence.

Returning briefly to our "paranoid" theme, highly numerate business trained graduates and PHDs are coming from universities into the financial services, much as their non-finance-trained predecessors did into banking. They don't have to take the exams, which typically take 5 years of effort, so they can start immediately on building on their mathematical toolkit. If they have more techniques in their toolkit than us we have to be very careful we don't become obsolete.

How did carpenters avoid becoming obsolete? The need for someone skilled in hewing wood has remained over time, but the Guilds, whereby skilled artisans grouped together under trade groups that set the costs and maintained standards for all members, have largely disappeared. The downside of control was restrictive practices and inefficiency, but complete deregulation might see an industry where the consumer can have little assurance of quality and only partial knowledge of the correct price for services provided. This is an unlikely outcome for the profession, but we should not underestimate the power of market forces.

## 5. The Subject of Conjecture

### *The March of Time*

In “Making Financial Sense of the Future”, the actuary needs to form a view on what none of us can know. If we think of ourselves travelling through time, unfolding at 60 seconds a minute, we are continuously mapping out the range of possible financial outcomes, for different activities and timescales into the future.

Many other professions do likewise, such as economists, statisticians, demographers, geologists, meteorologists and climatologists. Although we have an apparently narrow focus on financial matters, all of these practice areas are relevant to our work and we have to draw on, understand and use their views of the future.

Looking closer to home, our closest business relation is probably the underwriter, who is having to form a view of the future, negotiate that view with a client or broker, adjust and agree a legal contract to reflect that negotiated view, then settle the price for the privilege of being exposed to financial risk.

All of us are in the guessing game.

### *The Corridor of Uncertainty*

Recently attributed to Geoff Boycott by Timothy Bramham [5], the “corridor of uncertainty” and our familiar “expanding funnel of doubt” are common representations of future uncertainty. However, this is just a snapshot of the process of prediction and realisation of the future that underlies so much of our work, and it too marches forward, changing with the unravelling of time.

Participants in a recent Professionalism Course were asked to suggest a light-hearted, alternative strap-line for the profession. Their memorable response was:

*“Our guess is probably better than yours.”*

The word “probably” was added afterwards! However, even this is a bold claim if we think about the discussions held with underwriters and others in setting reserves. In how many areas of practice can we honestly make this claim, and is there any evidence that we might have or might produce to support this?

### *Being Certain about Uncertainty*

So, if predicting the future is so difficult and it is even harder to show that actuaries are pre-eminent, what is our unique selling point? In our opinion, one of the strongest cards that we could play would be our ability to combine financial modelling with statistics and probability theory to quantify uncertainty, coupled with a strong set of professional standards.

It is still early days for the insurance industry in grasping quantitative risk management. Nonetheless, we have GRIT’s recommendations, and strong regulatory drivers in ICAS and Solvency II to promote this area of study. Also, developments in exposure and catastrophe modelling present an opportunity to give businesses a fuller understanding of their risk profiles.

Although we live in a stochastic world, businesses can only make deterministic (as in single path) decisions, whether accepting risks, or setting premiums or capital. However, some sophistication and regard for uncertainty is possible in setting terms and conditions or in designing and buying protection (whether conventional reinsurance or ART). All these decisions will be on a firmer footing if they pay regard to uncertainty and attempt to quantify it.

***A Short Lesson in Uncertainty***

Given the importance of uncertainty to our work and the recommendations from GRIT, we can all expect to be spending more time considering uncertainty and trying to quantify it. The following result and definitions are relevant to this:

*"Prediction Variance = Process Variance + Estimation Variance"*

From England and Verrall [6], reminds us that it is not sufficient to estimate parameter values to determine a statistical distribution that describes our range of possible outcomes, but also to consider the estimation errors that will arise from being uncertain about those parameter values themselves.

Also, from Grossi and Kunreuther [7]:

> *"Since catastrophe modeling is a fairly new field of application, there are no historical classifications of catastrophe modeling uncertainty, per se. However, building on the concepts from probabilistic hazards analyses, uncertainty can be characterized as either aleatory or epistemic in nature (Budnitz et al., 1997). Aleatory uncertainty is the inherent randomness associated with natural hazard events, such as earthquakes, hurricanes, and floods. It cannot be reduced by the collection of additional data. In contrast, epistemic uncertainty is the uncertainty due to lack of information or knowledge of the hazard. Unlike aleatory uncertainty, epistemic uncertainty can be reduced by the collection of additional data.*
>
> *While the advantage of differentiating between aleatory and epistemic uncertainty in an analysis is clear (only epistemic uncertainty can be reduced), the necessity of distinguishing between aleatory and epistemic uncertainty is not. 'Epistemic and aleatory uncertainties are fixed neither in space…nor in time. What is aleatory uncertainty in one model can be epistemic uncertainty in another model, at least in part. And what appears to be aleatory uncertainty at the present time may be cast, at least in part, into epistemic uncertainty at a later date' (Hanks and Cornell, 1994). Therefore, developers of catastrophe models do not necessarily distinguish between these two types of uncertainty; instead, model developers concentrate on not ignoring or double counting uncertainties and clearly documenting the process in which they represent and quantify uncertainties."*

Clearly there is much to learn and to do in this field of study!

***A Unified Theory of Almost Everything (to do with insurance)***

As well as considering the explosion of challenges and opportunities that have arisen in the field of General Insurance in recent years, it is useful to pause and consider the strong connections and similarities between pricing, reserving, capitalisation and risk transfer (reinsurance/ART) design. These activities all involve consideration of an unknown future, and looking at the emerging reality (of a business process) at different points in time. Although not mainstream for actuaries, we can also add catastrophe modelling and underwriting portfolio/aggregation management to this list.

The modern GI actuary will need to be conversant, if not expert, in all of these areas and the discussion of how a business operates with its management will need to include uncertainty, what it means, where it comes from and what to do about it. There are clear practical challenges to creating links between these areas, but many leading businesses are already well down the path, not least in the dynamic allocation of capital to profitable lines of business. Any actuary who has not embraced uncertainty and a stochastic approach to modelling will be at a disadvantage in this world.

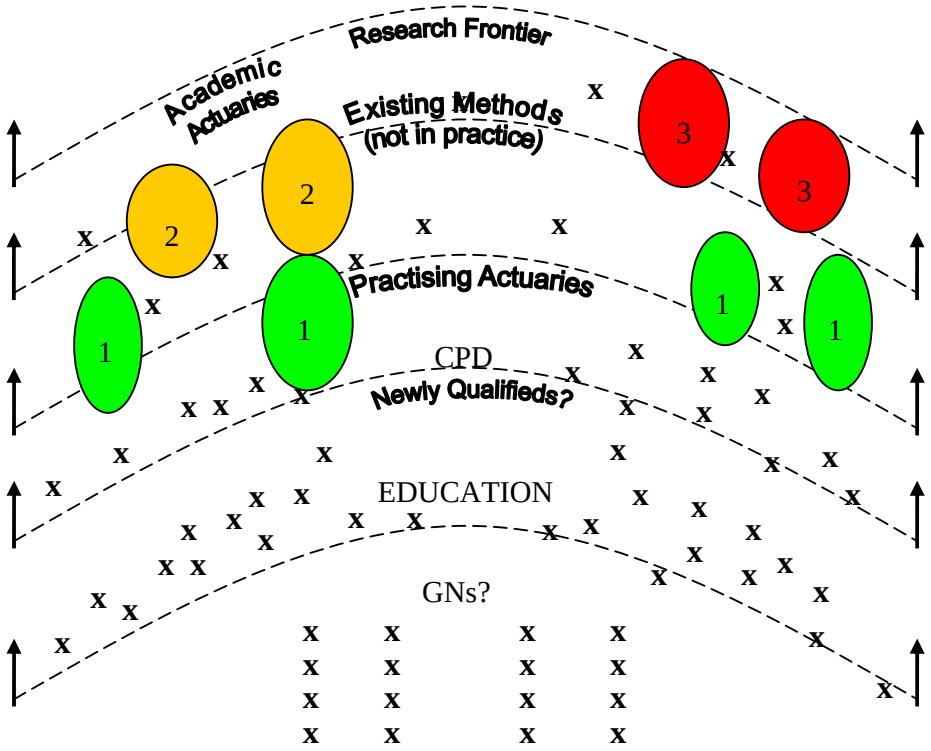
## 6. The Continuously Developing Profession

The previous chapters have set out the various challenges and, we hope, provided some motivation for actuaries to reconsider the state of their own toolkit. It is our intention, in Part II, to follow this paper, which we hope to produce prior to GIRO, to present specific methods and analytical tools that we believe will be of value to actuaries. However, in the meantime, we describe some of the specific actions that we believe will help the profession raise its collective game.

***The Research Frontier***

In considering the research strategy for The Actuarial Profession (both authors are members of the Research Steering Committee), we developed the following picture of the research frontier and the management of the Actuarial Profession's Corporate Intelligence.

The "x"s refer to packets of knowledge – theories, methodologies or applications, depending on how far down the diagram they are. The oval shapes refer to particular activities supported by the Research Steering Committee (RSC), described below.




Perhaps this is a rather Platonic view of the world, of a hidden order being revealed to us through our investigations and study, but it is useful to think of the Profession as a collective organisation moving through time, discovering and absorbing knowledge, much as higher-order organisms do in nature.

A number of activities are supported by the RSC in helping to manage this Corporate Intelligence:

1. Surveying and, where appropriate, influencing research by practising actuaries in liaison with the Pensions Technical Support & Research Committee, Life Research Committee, GIRO, Finance & Investment Board and Social Policy Board.

2. Funding research by, predominantly, academic actuaries to develop new techniques for application to actuarial problems, through its own research grants programme.

3. Funding research by a wider range of academics to develop new techniques for application in the field of Quantitative Finance, in collaboration with the Engineering and Physical Sciences Research Council (EPSRC).

Towards the top of the picture, the knowledge packets ("x"s) are probably more theoretical and these need to be incorporated in methodologies that can then be used as applications. As we move down the picture, the applicability of the knowledge is better established, to the point where it is enshrined in the exams syllabus or even Guidance Notes.

To manage its Corporate Intelligence, to respond to change and meet the challenges of the future, the Profession needs to be effective at capturing and using knowledge. As is said:

*"The essence of knowledge is, having it, to use it."*

There are clear examples of actuaries, or those working in the actuarial field, who are familiar with the theories and methodologies available in the actuarial research field, or in other fields, which they have then been able to marry with a knowledge of the issues and challenges faced by the businesses they advise to develop solutions, and even applications, to great advantage.

Examples of this successful cross-over include the application of Financial Economics to the embedded options problems of life offices and the use of copula theory in developing liability dependency structures in Dynamic Financial Analysis (DFA) packages. However, there is only a handful of such people and their interest in research is often a personal one.

Of course (with thanks to Louise Pryor):

*"In theory, there is no difference between theory and practice;*
*in practice, there is."*

There is still a divide, despite the research supported by the Profession, between the knowledge of theories and methodologies within the academic/research community, and the awareness of the challenges and problems faced by practitioners.

Locally, the most effective way to bridge this gap is by having individuals cross the divide from academia into practice - embedded researchers or in-house boffins. However, we believe that we can also bridge the gap, without potentially undermining the academic community's resources, by bringing together academics and practitioners on a regular basis, to share knowledge of available techniques (they need not necessarily be leading edge or brand new), and of the current work and challenges faced by business.

For instance, a joint academic and practitioner forum would have researchers present on a broad range of methods that they had identified. Practitioners would also explain their current work and a range of challenges that they were dealing with. An additional option would be to have methods identified from this process researched by younger (recently qualified) members and developed into short introductory papers for actuaries. This would assist in the translation process and give younger members experience of research.

Our intention, within the RSC, is that we should develop the model of the Profession's Corporate Intelligence presented in the picture and explore the way that it is managed, with particular regard to developing sustainable interaction between the research and practice areas. From this, our aim is to develop specific proposals (such as those described in the paragraph above) that improve the quality and rate with which new methods are developed, captured, grown and consolidated by the Profession within its Corporate Intelligence.

***A Right to Quality***

Although the typical GI actuary (who, as explained earlier, none of us are) does come in for criticism from others within the insurance industry, it is noticeable that "actuarial" is synonymous with "mathematical". People talk of making something more "actuarial", meaning more rigorous, quantitative and scientific. This is a good place to begin, but how do we keep people thinking this and how do we raise our game?

Returning to Stephen Covey, how do we develop our abilities to perform at the highest level? What does it take? Sport shows us that the highest levels of performance don't just take talent but enormous commitment, as displayed by Paula Radcliffe or Tiger Woods. Clearly, we are not directly comparable with elite sports men and women, but we are an elite profession and our standards should be challenging, as we are in competition every day.

The Morris Review questioned the effectiveness of an education programme that relied so much on on-the-job training. Although there is no denying that "what we need to learn to do, we learn by doing", elite performers spend vastly more time in training and in practice than in competition or in the concert hall. Particularly for qualified Fellows, who are no longer influenced by the examination syllabus, there is a need to actively develop skills and knowledge beyond those acquired simply through work.

***The Next Step***

The authors have recently had the pleasure of working with an MSc student who was working on their dissertation in statistics. We were able to pick up several significant learning points as a result:

- the student had access to a top quality theoretical expert (their academic supervisor) who was able to suggest techniques appropriate to the question (in this case the problem related to a short time series and the approach suggested was "Generalised Estimating Equations", akin to GLMs);

- the student had been trained in a raft of statistical techniques and was able to perform a number of diagnostic checks on the data to confirm that the suggested, more complex, method was appropriate;

- the student had knowledge of a variety of graphical techniques for presenting and illuminating the multivariate data. However *knowledge* of them is not (in our opinion) sufficient and crucially…

  …the student also had a deep knowledge of a software package that allowed the analysis and graphical techniques to be carried out quickly and efficiently.

There may be several actuaries reading this who feel that none of this is new and they would be able to do all of the above. This is likely if they have gone through a statistical training at university for example. However, people become actuaries through many routes and even mathematics graduates may have studied in other fields.

We are quite happy to admit that we are in the group that would not have been able to do the above! However, we are of the belief that we are capable and *should* be able to do this kind of analysis. So what is standing in our way? The most important issue is that we may not even know about the techniques. We need access to the expert who can direct our investigations. Later we discuss ways we could achieve this.

Another key obstacle is not having had a statistical training beyond that in the actuarial syllabus (which is an excellent *grounding*). There is just so much to know and it can be difficult to produce one's own reading list (having tried, we can vouch for this).

In our experience the majority of data analysis, in practice, is carried out in Excel. This is an excellent, powerful and flexible program and, using Visual Basic, it is possible to customise it. However, this:

- is time consuming to set up;
- requires a greater knowledge of the methodology than required to just (successfully) use the approach; and
- leaves the company with two risks:
    - that there is an embedded error within it; and
    - the designer leaves the company and no-one else knows how it works.

Most data analysis, in our experience, has as its aim to find the answer (the reserve, the mortality assumption, the amount of capital etc); we have rarely seen a statistical analysis of residuals (for example) or any attempt to consider how credible the answer is in practice. There is some basic analysis functionality within Excel itself, but we have rarely seen this used.

If such methodology is not in common use then it will not be picked up on the job; this is the way most techniques are learnt in our experience, the other method being through the examination syllabus. This suggests that the methodology needs to be taught; in our view it is vital that this is not just in theory and suggest that the exams, or even CPD, might require the training and use of statistical software. We give more details of this recommendation in the solutions section below.

***Proposed Solutions***

We could commission an academic to look at the range of techniques that are available and compare them to actuarial education – to see where the missing areas are. We could then ask them to produce a reading list that would "fast track" the actuary to competence in the area.

We believe that, on qualification, actuaries are often keen to become involved with the profession but may not feel sufficiently confident to join a working party until they have more experience. We could tap into this enthusiasm by encouraging students to write a SIAS paper or a short article for "The Actuary" on a technique with the potential to improve the profession's capabilities.

Firms could consider allowing MSc students to work over the summer on their dissertations; they could then pick their brains whilst they were there. A longer term solution is to sponsor PhD students. Both of these approaches have been successfully undertaken at Lloyd's (where both of the authors have worked and been involved directly in the projects).

We have been discussing this issue with academics recently and understand some schemes of learning already exist in other professions. For example, engineers often pay to send their staff to university a day a week to get access to new techniques.

The examination syllabus might include the requirement to learn (to full competence) a recognised piece of statistical software. The student would be required to produce a dissertation using these techniques and then demonstrate (to an accredited user within their firm perhaps, possibly supported by an academic expert) that they can use the software. This would be a real, tangible tool in the tool kit! Note there are several freely available software options, so this need not cost anything.

Many people studied maths/science at university – they will have covered many areas in their syllabus that are very relevant to modern financial mathematics – but do they know it? (e.g. linear algebra – fundamental to statistics; functional analysis – fundamental to financial economics; measure theory – fundamental to financial economics, etc). There could be a theme of converting things you know (or once knew!) to things that are useful…

For example, the existence of deflators for a large class of cash-flows is guaranteed by a theorem in functional analysis called the Reisz representation theorem. One of the authors studied this at university but never made the connection. [The other author hasn't a clue!]

***Part II – What's to Follow***

In keeping up to date with new techniques from actuarial circles and beyond we must surely consider the Internet as a powerful resource. One problem is the vast amount of content now available; the problem is no longer being starved of information but drowning in it. How can we filter the good from the bad?

Search engines can help and are becoming ever more useful; but there are newer techniques that combine the unique filtering abilities of human beings with the data storage and organisation capacity of computers. It appears to us that a global brain is developing; individuals who are not part of this are missing out. In Part II to this paper, which will be published prior to GIRO, we intend to illustrate some of the techniques.

This seems one area where CPD is required. Actuaries should be proficient users and contributors within this new technology; in many applications it isn't even difficult. Again the essence of knowledge is, having it, to use it! These really are tools for the toolkit. One plea is that we don't try to create an actuaries-only area; or develop something that sits on The Actuarial Profession's website – these concepts can be developed in existing sites (Wikipedia for example) and should be open to all; this is our best hope of keeping in touch with other disciplines and the professionals and academics working within them.

## 7. Conclusions

The challenges and opportunities facing actuaries have never been greater. Important structural changes are being made to the way we organise and run The Actuarial Profession, but the most important contribution to meeting these challenges will come from individual members.

We have sought to describe these challenges and opportunities in this paper, and to begin to discuss how we might respond to the former and realise the latter. Much of this will involve getting closer to new techniques and fields of research, both actuarial and non-actuarial. We hope to show how in Part II to this paper, and in our presentations at GIRO.

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