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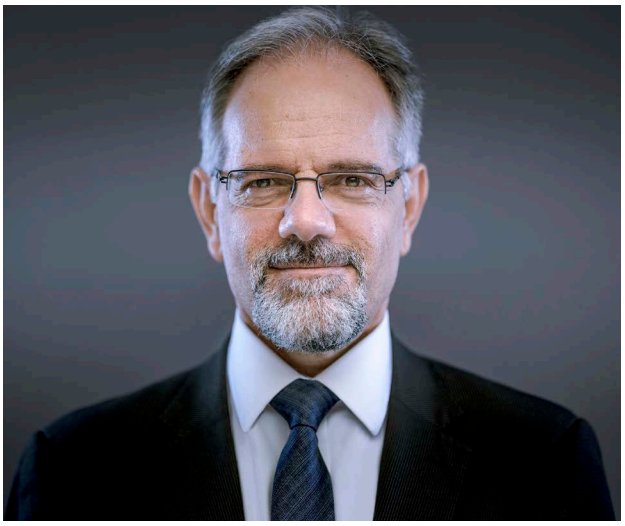
Introduction by the President of the IFoA



I am pleased to introduce this new edition of the Longevity Bulletin, looking at how technological change is affecting longevity. On behalf of the IFoA, I'd like to give thanks to the authors who have provided insights from their specialist fields.

The IFoA's Longevity Bulletin continues in the actuarial profession's tradition of drawing upon current expert opinion to examine and review the factors for change in mortality and longevity. We now recognise the significant role medical advances such as penicillin and cancer treatments have played in the increased number of people living to greater ages. Yet there are also threats which recent editions of the Longevity Bulletin have considered, such as anti-microbial resistance and the appearance of new virus outbreaks that could reach pandemic scale. Gains in life expectancy have been reported to be slowing, while longevity trends highlight issues around the quality of longer life, and the measures of healthy or unhealthy life expectancy we can anticipate.

More recently, advances in technology appear to be bringing the stuff of science fiction closer to reality. As Hans Leida reports in this issue, there have been plenty of headline predictions that some people born today will live to 150, thanks to bio-technological interventions from an emerging longevity science industry.

In this issue, the authors also consider some technological changes that are already happening. Emmanuel Tsekleves examines the internet and mobile apps that allow responsible self-diagnosis, earlier medical intervention and even measure healthier lifestyles. Mark Farrell looks at new 'safer' self-driving vehicles that may lower the chances of accidental death and life-limiting injury, or perhaps help victims reach medical assistance faster. An IFoA Working Party looks at the take-up of e-cigarettes as a less harmful alternative to tobacco, analysing the resulting impact on smoking behaviours and the rates of survival.

The pace of technological change affecting survival and longevity appears to be accelerating, but the mortality improvements arising from these technological changes are not yet fully appreciable. As Leela Damodaran notes, there are caveats for how society needs to build appropriate infrastructure and education in our digital world, so that the anticipated benefits can be better realised and measured, and data used responsibly. One of the IFoA's Actuarial Research Centre (ARC) programmes, 'Use of Big Health and Actuarial Data for Understanding Longevity and Morbidity', is already reporting from its investigations of large collective anonymised datasets of health records.

A consistent feature of the IFoA's research programme is our member-led working parties. They help the profession to make actuarial adjustments for life assurance, health insurance and the delivery of pensions, for longer and healthier lives.

Jules Constantinou
President, Institute and Faculty of Actuaries

The Internet of Health Things: opportunities and challenges for ageing well

Dr Emmanuel Tsekleves, Senior Lecturer in Design Interactions,
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Introduction

We are witnessing the dawn of a new era of the Internet of Things ('IoT'). The term 'Internet of Things' has come to describe some technologies and research disciplines that enable the internet to reach out into the real world of physical objects (Xia et al., 2012). The IoT has the potential to impact health services and be a game-changer for the healthcare industry, especially as it is predicted that by 2020 the number of internet-connected devices will likely reach 50 billion (Fernandez and Pallis, 2014). The IoT could be the basis for a new healthcare paradigm leading to more personalised, participatory, predictive and preventive health.

Although the IoT impact in healthcare is still in its initial development phases, it has captured the interest of researchers and health professionals, creating a shift in the fields of IoT and wearables from the development of sensors to the design of systems (Patel et al., 2012). This article explores the opportunities and challenges of the Internet of Things in healthcare, highlighting the benefits it may bring and obstacles it needs to overcome.

The Internet of Health Things

The Internet of Health Things ('IoHT') can be defined as IoT devices, products and services employed for the purposes of enhancing the health and well-being of their end-users. The vast majority of IoHT have been applied in clinical environments, such as hospitals and healthcare facilities, under managed care and by well-trained and specialised individuals (Dhawan, 2016). The interest in IoHT is growing outside of a clinical setting into the home environment (Burns and Adeli, 2017), where more opportunities for promoting and managing personalised health exist, but these are still limited. An example includes the interdisciplinary SPHERE project, which is exploring the development of a sensor platform for healthcare in a residential environment, involving 100 homes in the UK (Zhu et al., 2015).

Lack of robust clinical validation studies creates a challenge, leading to misuse of health and well-being related IoHT products by consumers and patients (Dhawan, 2016). As most IoHT devices and sensors have not been validated against reference methods in well-conducted and independent clinical studies, they are often portrayed as products 'not fit for medical use'. However, this can still lead to misuse of IoT for health management and decision making, as in the case of a product that led to the underestimation of blood pressure in 77% of hypertension cases (Michard, 2017).

Home care and chronic disease management

The IoHT creates opportunities that provide both patients and people at home with a leading role in the care and management of their health (Wang et al., 2017).

IoHT paves the way for enhanced home care, remote consultations (Wieringa et al., 2017) but also in monitoring health and wellness. One of the key advantages of IoHT commercially available technology will be the ability to achieve long-term monitoring of health. The benefits from this would be for both individuals and clinicians. For individuals, being able to monitor one's health and wellness will provide empowerment and more personalised health and care provision. For clinicians, a quantitative way of assessing treatment efficacy would be a valuable tool in disease management. In particular, by knowing what happens between out-patient visits, treatment interventions can be fine-tuned to the needs of individual patients (Patel et al., 2012).

There are, however, challenges too, as patient education and peer or community networks would be required to facilitate effective person-centred home care and personalised disease management. There is, therefore, a need to educate and enable individuals in taking a leading role in the monitoring and management of their own health. This is a task that requires creative ways of communicating the benefits of health self-management and knowledge sharing of how one might achieve this.

Preventive and diagnostic

Apart from disease management, the IoHT offers additional applications in the fields of diagnosis and prevention (Wieringa et al., 2017). Continuous monitoring of physiological signals could help to detect and diagnose several cardiovascular, neurological, neurodegenerative and pulmonary diseases at their early onset (Majumder et al., 2017). For instance, this can provide complementary information about the symptoms of people living with Parkinson's disease or cardiovascular diseases. In these cases, early detection of changes in a person's health status (e.g. progression of symptoms) can inform when clinical intervention is required (Patel et al., 2012), potentially reducing hospital visits/waits and improving quality of life.

However, one of the most promising applications of IoHT lies in disease prevention. More precisely, activity and physiological monitoring within the home environment form promising preventative methods in many different areas of medicine, such as cardiopulmonary, vascular, endocrine, neurological function and rehabilitation medicine (Appelboom et al., 2014).

IoHT devices can be regarded as enablers for influencing human behaviour, for example exercise or dietary (Wieringa et al., 2017). Home monitoring along with the quantified self-movement (Appelboom et al., 2014) could revolutionize patient behaviour as they adopt healthy behavioural changes into preventative measures (Wieringa et al., 2017). As such, provided IoHT services are well-designed, they could alter the way that governments fund healthcare services, set guidelines for protocols regarding preventative and post-operative monitoring and augment the physician-patient relationship. (Appelboom et al., 2014).

Data privacy and trust

In the context of the IoHT, an individual can often be identified by data resulting from such connected devices. Indeed, such personal information, especially in the field of health and healthcare, raise much higher concerns and challenges for privacy and trust (Majumder et al., 2017).

Especially when one considers the acceptance of IoHT within the context of the home environment and continuous activity monitoring, several more legal and ethical issues arise. These include the balance between the patient as the owner of data, the documentation and use of the data (Appelboom et al., 2014), patient identification and confidentiality, and data sharing and management (Majumder et al., 2017).

Despite the demand for more research and technological development to ensure information privacy and data security (Majumder et al., 2017), there is an unmet and urgent need for research in this field too. As the adoption of these technologies, within this context, depends on its acceptance in society (Pasluosta et al., 2015), additional research is required in mapping and drawing out such concerns and in raising questions regarding the societal, economic, legal and ethical issues of current and future IoHT.

The challenges around data privacy and trust provide an opportunity for research into 'privacy by design'. With patient privacy and confidentiality always at the forefront (Appelboom et al., 2014), researchers and policy makers can explore 'privacy by design' methods that enable the development of innovative solutions by making data protection by design and by default (Martín-Ruíz et al., 2017). In fact, work in this field has already commenced with principles and guidelines for the ethical design of health-related IoHT devices and data protocols being proposed (Mittelstadt, 2017).

Usability and user acceptance

Acceptance and ease of use of health-related wearable devices and IoHT are among the top priorities and challenges in this field (Majumder et al., 2017). The complexity of IoHT systems and wearables hinders wider adoption by service users. The reason behind this lies in the way such systems are designed and evaluated, especially as several prototypes of such products and systems are not adequately evaluated (Burns and Adeli, 2017). There is a lack of high-quality studies in this area, resulting in numerous attractive systems presented in the literature, which are essentially clinically unproven prototypes (McAdams et al., 2011). The impact of such practices is that they tend to ignore the key problem areas to be addressed in wearable and IoHT monitoring, namely those associated with the end-user/sensor interface.

As health IoT products and systems will be ineffective if service users and/or clinicians do not want to use them, user preferences will have to be taken into account in order to design devices that will gain acceptance both in a clinical and home setting (Bergmann and McGregor, 2012). In light of this, designers

and design researchers will need to address the challenge of designing robust products and services which are accepted by patients and reliable over time (McAdams et al., 2011).

Conclusion

It is clear that IoT in health and care is not going away. There is already, as described above, a body of knowledge and various emerging dimensions. However, it is a complex environment of products and services, users, suppliers, individuals and communities. Several of the challenges are now emerging from the technology-led research and development of IoHT, such as issues with acceptance, lack of end-user compliance and ease of use of IoHT, data privacy and trust issues.

The time has come for researchers and relevant organisations to focus their efforts in these areas in delivering research for the future implementation of IoT in health and care.

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Biography

Dr Emmanuel Tsekleves is a senior lecturer for Design Interactions at Imagination@Lancaster at Lancaster University. He leads cross-disciplinary international research in design interactions for health, which lies at the intersection of public health, design for behaviour change and technology. Emmanuel conducts research in the design of health interventions and services, which are co-created with end users and are aimed at improving the quality of life and well-being of people into old age, including people with chronic and non-communicable diseases.

The IFoA's Impact of Wearables and the Internet of Things Working Party

Anna Spender, chair of the Working Party

The rapid evolution of wearable technology and the Internet of Things has significant implications for health and care providers, and much more broadly for the actuarial profession. The key objectives of the working party are to:

1. understand how stakeholders are responding to this emerging technology, and how this might evolve in the future
2. understand how the current and known future technologies can be used to measure health and wellbeing, what data is captured and how, the accuracy and reliability of the data, and how end users would typically engage with this technology
3. consider the practical uses, opportunities and challenges for this technology within the life and health insurance market.

While attempting to be thorough in explorations and analysis, this subject is peculiar in that the rate of growth of the wearable technology, and perhaps even more so the Internet of Things, means that through the duration of the research, there have been changes to the notions of what can or cannot be done. With many yet unanswered questions, the working party's recent research paper (Spender et al., 2018) focuses on pulling together in one place relevant information for the consideration of the health and care actuary. It also seeks to open the reader's eyes to potential future innovations by drawing on use of the technology in other markets and spheres, and the 'science-fiction-like' new technology that is just around the corner.

Insurers across a range of fields are already engaging with this type of technology in their proposition designs in areas such as customer engagement, marketing, and underwriting. With limited quantifiable evidence currently available on the potential experience and impact from the use of this technology, alongside evolving propositions, insurers who engage now are likely to be on an evolving business case model and product development journey, over which they can build up their understanding and interpretation of the data that this technology can provide.

An exciting area full of potential – when and how will you get involved?

Further details about this working party and its recent research paper can be found at: **http://bit.ly/ifoa2389**

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Self-care and longevity through sustainable community-based technologies

Professor Leela Damodaran, Emeritus Professor of Digital Inclusion and Participation, Loughborough University

Introduction

Information and communications technologies (ICTs) are all-pervasive, offering 'e-everything' about all aspects of life in our digital society. The potential and actual impact of ICTs on longevity is multi-faceted, offering both an extension of lifespan and an enhanced quality of life. This article briefly examines the emergence of self-care and the growing role of ICTs in this. It considers the application and limitations of ICTs and the need for a face-to-face support infrastructure appropriate to the needs of users, particularly older and disabled people.

The emergence of self-care

Population projections (Office for National Statistics, 2015 and 2017) suggest that the proportion of older people in the population is set to rise significantly in the UK. In response, a growing trend in the delivery of healthcare is the policy and practice of 'self-care'. In May 2011, the UK Department of Health set up the Self Care Forum ('the Forum') to co-ordinate and advance community self-care that was solution-focused. The Forum assumed the operations of the Self Care Campaign, whose professional membership included the NHS Alliance, Royal College of Nursing, National Association of Primary Care, National Association of Patient Participation, and Proprietary Association of Great Britain.

To accompany the Health and Social Care Act 2012, NHS England produced statutory guidance Transforming Participation in Health and Care (2013). This was replaced by new guidance in April 2017 (NHS England, 2017). Its purpose has been to support healthcare practitioners in understanding the needs of their patient community and to provide more effective and innovative services.

The NHS Five Year Forward View (2014) presented a new concept in patient self-care within the NHS system, setting forth the 'Test Bed' programme. Five sites across the NHS were chosen to combine and implement different and innovative technologies in service delivery settings.

Engaging with digital technologies to enable self-care and extend longevity

The key tenets of the above public health initiatives and changes are to reduce costs and to give patients more control and responsibility to manage their own health conditions outside clinical settings. The declared intention is to achieve this through the use of the internet and ICT monitoring devices in the patient's home, where possible and appropriate. This intention calls into question the preparedness and ability of patients to utilise and benefit from technological developments.

Increasingly, older people are becoming more active in using the internet and social media platforms for personal, social and recreational purposes. Additionally, older users now find that they are expected, even required, under the increasingly pervasive 'digital by default' strategy of public authorities, businesses and health services, to manage their daily lives using a bewildering array of ICTs. This trend requires older patients to use ICT devices, such as diabetic testing monitors and cardiac and sleep apnoea equipment, at home without the direct supervision of health professionals. Access to and use of such technologies by older people are seen increasingly as self-care tools for the effective management of healthcare. Getting to grips with ICT as it relates to an individual's management of their own physical, mental and emotional health can be a daunting prospect within our fast-paced digital society, especially for segments of our population for whom ICT is a peripheral reality.

Innovative applications of digital technologies to prolong life expectancy, maintain physical capability and enhance the quality of life are emerging with increasing rapidity. However, it is not the condition-specific technological devices per se that make the important difference. The social benefits of digital participation include combatting loneliness, keeping in touch with friends and family, increasing self-efficacy, and greater opportunities to pursue hobbies and interests. These in turn contribute to improved health, well-being and longevity. To realise the vast potential of digital technologies for such enrichment and empowerment requires awareness, understanding, competence and confidence on the part of the user. Whether the requirement is to know how to use your 'Wii-Fit' to exercise in an enjoyable, playful and sociable way; use the self-monitoring device from your GP appropriately; or to search for advice on preventative measures, older users need on-going ICT learning opportunities and trouble-shooting support. Given that many patients will be older and disabled people and 'slower' adaptors in significant numbers, the education, support and monitoring of their usage of such devices will be critical to the success of health self-care. For example, making effective use of the ICT devices increasingly provided by GPs requires users to have easy access to on-going ICT learning support embedded in the community or provided through dedicated outreach services. Unless a support infrastructure which clearly meets the expressed needs of older users is implemented and older people are empowered in adapting to ICT-based health self-care, the potential of the technologies will remain aspirational.

Meeting user needs and achieving 'user pull'

Evidence shows that to achieve successful digital participation requires the needs of users to be met effectively. In collaborative research (KT Equal, 2012), users have articulated clearly their requirements for ICT learning and support, as listed below:

- readily available
- trusted and sustained
- delivered in familiar, welcoming and local venues
- embedded in social activities and personal interests
- free of time pressure and assessments
- inclusive of problem solving and troubleshooting
- offering impartial advice and 'try before you buy'.

Achieving widespread digital participation can only come about through the confident and successful participation of older people and other 'slower' adaptors into the digital world. The experience begins with providing a comfortable and benign setting in which they can select and learn about digital services that will be impacting on their lives soon.

In many instances the older adaptor does not wish to embrace digital technology at all if its use is technically daunting, makes them feel inadequate, creates discomfort, or if they are not convinced that it is necessary or will be of significant personal benefit. Providing stress-free and enjoyable learning experiences is vital and can be facilitated through accessible walk-in venues such as local libraries, parish councils and community centres where users can attend without appointments, access equipment, learn from experts and peers, and get help to apply ICT solutions to their situations.

Regarding self-care, this could be of great benefit to individuals trying to manage health conditions. They could communicate with their GP and others using smartphone health apps, Skype and online forums. This in turn can significantly reduce visits to GP surgeries and hospitals. This has already been demonstrated in pilots and trials such as the innovative community-based programme conducted by Portsmouth NHS Trust in 2015 to enable chronic obstructive pulmonary disease (COPD) sufferers to manage their condition at home using an app ('myCOPD') on a smartphone or an iPad (Pugh, 2016).

Implementing community-based ICT learning support

As society moves towards a self-care regime in which digital technologies play a pivotal role, it is increasingly evident that ICT-related support to older people is essential to enable them to negotiate and manage their needs more effectively. Local government, health services and business communities will need to work closely with end-users to develop appropriate user-led and user-defined solutions for ICT learning support in the community. There is a well-developed and published proposition available for this (Damodaran and Olphert, 2012). There are examples of good practice which indicate that the user needs listed above can be met very effectively in the community – demonstrating 'user-pull' into action and delivering long-term and enduring benefits. Successful practice in promoting digital participation is built upon user engagement at a grass-roots local level, collaborative processes and knowledge sharing through peer support and continuity of provision.

This 'empowerment and participation' approach has been successfully sustained since 2005 by the user-led ICT support provision at the Long Eaton 50+ Group (Damodaran, Olphert and Sandhu, 2018) in Derbyshire in the United Kingdom.

Conclusion

For digital technologies to succeed in enabling self-care, access to technological devices alone will not be sufficient. Face-to-face support is critical and goes alongside easy access to technical expertise. Investment in local support infrastructure is therefore as crucial as the investment in the technological developments and infrastructure. For those unfamiliar with ICTs, friendly, accessible guidance, learning support and reassurance are as essential as the technological device, broadband infrastructure and a power supply. It is becoming increasingly clear that such an ICT support infrastructure is going to be fundamental to the successful use of most online services and especially to support the move to self-care in the NHS (where increasing numbers of people are being expected to cope with differing digital devices

to monitor complex long-term conditions – often multiple conditions which may require the use of several devices).

An integrated strategic approach in which human and technological components are recognised as complementary will be essential for digital participation and self-care in the future.

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Biography

Leela Damodaran's expertise is in the behavioural aspects and human use of information and communications technologies (ICTs), the planning of change and transition, strategies for social and digital inclusion, citizen engagement and participation. As well as engaging in research, Leela works as an independent policy advisor with government departments, local government, commercial companies, and other key stakeholder groups to inform policy and strategic decisions relating to ICT use and digital participation. She also works with communities and grass-roots organisations in the east Midlands and south-east England to promote successful digital participation of older people.

The IFoA's Impact of e-Cigarettes Working Party

Niel Daniels, chair of the Working Party

The IFoA's e-Cigarettes Working Party was established in 2016 with the objective of investigating the impact of e-cigarettes on the life insurance industry. The group brings together a multi-disciplinary team of insurance professionals, including actuaries, underwriters and claims personnel, who have a broad range of experience across a number of sectors. By looking at a variety of products (life insurance, critical illness, annuities) from different perspectives (pricing, product design, underwriting, claims) we hope to better inform our industry colleagues on how to assess the effects of e-cigarette use from an insurance perspective.

In 2017, there were approximately 2.8 million e-cigarette users in the UK (ONS, 2017; ASH, 2017). While there has been some suggestion, most notably by Public Health England, that e-cigarettes are '95% safer' to use than tobacco smoking (McNeill et al., 2015; and McNeill and Hajek, 2018), their true long-term effect on health is currently uncertain. Add to this the unknown impact on the health and behaviours of both smokers and non-smokers, as well as the confused public perception over e-cigarette risk, and it becomes clear that work is needed to better understand their overall impact.

The working party is considering four key streams of work:

- Research and medical underwriting
- Social demographics and international aspects
- Legislation and public policy
- Modelling.

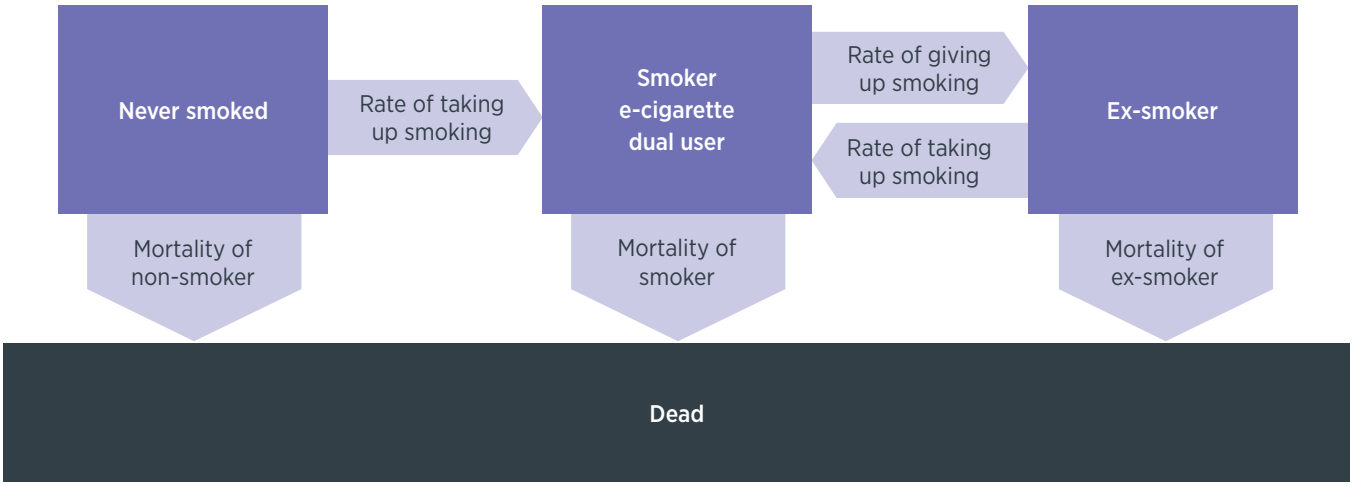
We believe that the multi-state model below shows the various transitions required to model the impact of e-cigarettes.

This led to 14 different parameters needing to be assessed in order to quantify the impacts, of which the key ones are:

- Usage of e-cigarettes
- Impact on rate of giving up smoking / prevalence rates of conventional cigarettes
- Relative risk of usage.

Unfortunately, the latter two are difficult to ascertain. To date, relevant studies have been small and short-term, and have focused on the almost immediate impact, e.g. genetic mutation,

Figure 1



(**Note:** The rate flows are all expected to be a function of age and the length of time the person has been in the various states. This is an adaptation of an actuarially notated chart presented at IFoA conferences in 2017.)

or have just looked at the compositional analyses of e-cigarettes versus traditional cigarettes rather than the true relative risk (which requires greater time required for analysis of data and larger sample sizes). While these approaches are informative, they do not truly determine the long-term impact on mortality and morbidity.

Where possible, we are collecting data that is split by a variety of rating factors – gender, age, socio-economic status, etc. This will be vital in trying to assess the impact on particular populations that purchase different insurance products. We are also making use of doctors to help us interpret the relevant medical research.

The working party aims to share its ongoing findings through presentations at conferences, papers and articles.

Further details about this working party, its recent research paper and chart models can be found at: **http://bit.ly/ifoa2880**

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Autonomous vehicles: mortality and insurance implications

Dr Mark Farrell, Programme Director and Senior Lecturer, Queen's University Belfast

In 1908 Henry Ford profoundly changed the automotive industry by developing and manufacturing automobiles at scale. The Ford Model T is generally considered to have been the first affordable car, subsequently ushering in the era of mass-market transportation and leading to widespread societal changes around the world.

110 years later, in 2018, the recent advances in computing power and artificial intelligence have made the previously science-fiction idea of living among unmanned vehicles, capable of navigating their landscapes without human input, a reality. A number of companies are already testing their vehicles in various locations and, since 2009, Google-owned Waymo has already driven more than five million (real road) miles, using self-driving technology (Waymo, 2018). Clearly, in a similar fashion to Ford's global impact, autonomous vehicles are also set to change society, by significantly altering the way in which we travel.

The areas of potential impact are wide and far-reaching and could include:

- reduced car ownership
- radically different car design geared more towards comfort and luxury
- more older drivers, fewer taxi/bus/truck/delivery drivers
- lighter burden on hospital and emergency services from fewer road accident injuries
- significant improvements to rush-hour traffic.

However, perhaps the most significant and important implications, at least to the actuarial profession, are expected to be reduced mortality and morbidity from traffic-related accidents and an overhaul of personal auto-insurance risks.

Mortality and morbidity implications

Previous research has indicated that more than 90% of road accidents today are a result of human error. For example, the National Motor Vehicle Crash Causation Survey conducted between 2005 and 2007 attributed critical crash causation as follows:

Figure 1: Vehicle Crash Attribution

Crash Attributed to:	Percentage
Drivers	94%
Vehicles	2%
Environment	2%
Unknown critical reasons	2%
Total	100%

Source: National Motor Vehicle Crash Causation Survey (USA), 2005-2007 (cited in Singh, 2018)

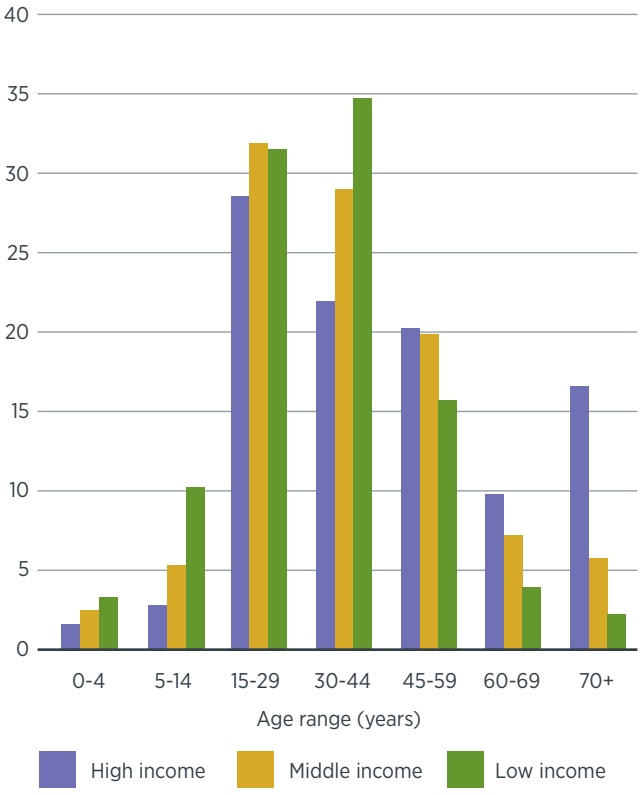
As we try to forecast and imagine the future driverless world implications, we should firstly note that nearly 1.3 million people die globally in road crashes each year and an additional 20 to 50 million people worldwide are injured or disabled (Association for Safe International Road Travel, 2013). Indeed, road traffic injuries are currently estimated to be the ninth leading cause of death across all age groups globally and the leading cause of death among people aged 15-29 years (World Health Organisation, 2015). Given the potential for driverless cars to reduce accidents caused by human error, clearly the mortality and morbidity implications from autonomous vehicles are profound.

It is of particular interest to consider where these mortality effects are likely to have most impact. Unsurprisingly, traffic-related deaths are not uniform across geographic location, socio-economic status, gender and age groups.

The World Health Organisation (WHO) highlights some of these disparities, as follows:

- **Income:** The global average number of deaths per 100,000 population is 17.4. However, the breakdown between low-income, middle-income and high-income is 24.1, 18.4 and 9.2 respectively (WHO, 2015).
- **Location:** The African region has the highest fatality rates (26.6 per 100,000 population) and Europe has the lowest (9.3 per 100,000 population) (WHO, 2015).
- **Age:** 60% of road traffic deaths are among 15-44 year olds (WHO, 2013).
- **Gender:** 77% of all road traffic deaths are men (WHO, 2013).

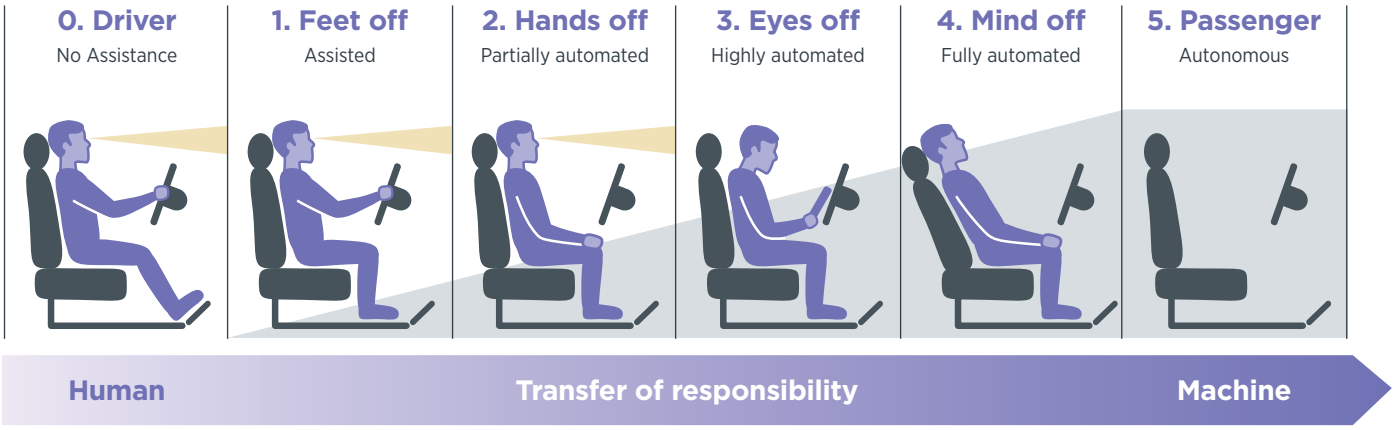
Figure 2 (opposite): Proportion of road traffic deaths by age range and country income status



Source: World Health Organization (2013)
Figure reprinted with kind permission © World Health Organization

In terms of the potential for improvements in vehicle accident-related mortality and morbidity, this may depend on the degree to which drivers in society can and wish to transition from fully operating vehicles to vehicles that are completely automated. Despite recent advances, there are still many hurdles and obstacles to overcome, and like any innovation there will be a prolonged period of transitionary change before autonomous vehicles become mainstream. According to the Society of Automotive Engineers' (SAE) J3016 standard there are six different levels of automation from level 0 (no automation) to level 6 (full automation), as shown below.

Figure 3: The five stages of vehicle autonomy



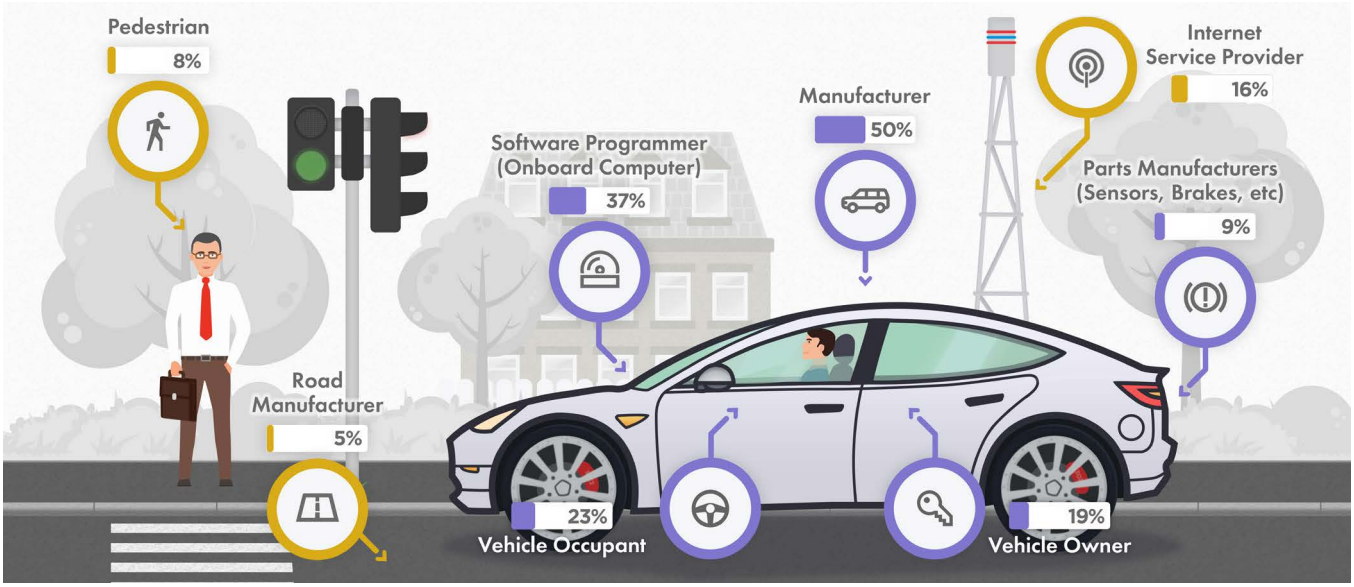
Source: Society of Automotive Engineers International, 2016

Insurance implications

Inevitably, the motor insurance world is going to change drastically as we move through the six levels of autonomy. As previously discussed, it's estimated that more than 90% of road accidents today are a result of human error. Hence, personal car insurance will be redefined as risk moves from vehicle users to vehicle manufacturers and software/hardware suppliers.

Attribution of liability will become a much more grey area as shown by AIG's survey (2017). Respondents were asked who would be 'most liable' in crash scenarios involving driverless cars (shown on the next page):

Figure 4: 'Risk shifting from driver to entities inside and outside the car'



Source: AIG (The Future of Mobility and Shifting Risk, 2017); reproduced with kind permission.

As the inevitable driverless world takes over, many traditional auto-related risks will no longer be as prevalent. Risks such as those caused by reckless or distracted driving, speeding, ignoring stop signs/red lights, unsafe lane changes, tailgating and road rage will be replaced by new, emerging risks such as malfunctioning software and cybersecurity.

The migration and ensuing calculation of risk will be particularly challenging during the 'chaotic middle' transition period where vehicle owners and the AI software share responsibility for the vehicle's operation and any resulting liability.

Clearly, we are entering a new era of transportation. Despite the many challenges ahead, it appears that significant changes will be increasingly felt across many different aspects of society, as autonomous vehicles make their way into our everyday lives.

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Biography

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Altered Carbon, actuarial escape velocity, and insurance in a post-human world

Hans K. Leida, Principal and Consulting Actuary, Milliman Inc.

While the new Netflix television series *Altered Carbon*[1] explores well-trodden ground by science fiction standards – it's a murder mystery set in a future where people can upload their minds into virtual worlds or new bodies whenever their current one dies – it does take a few interesting detours from the action to explore the thorny ethical and legal issues that such life extension technology might create.

Sadly, the series spends very little time delving into how insurance works in a world where individuals can die and then restore their last saved copy of themselves, or even embody multiple copies of their minds. A central theme in the show is that only the very rich can afford to purchase new bodies for their consciousness when their existing one dies. Middle or lower class people seem to be able to purchase some sort of insurance that might allow them one or two extra lives, but often in a body that does not align well with their prior identity (for example, a seven-year old girl is reincarnated in an old woman's body).

To me, science fiction is at its best when it encourages us to contemplate ethical, moral and legal challenges we are likely to face in the future – and by doing so it also holds a mirror up to those that already exist. Moreover, although the mind downloading technology in *Altered Carbon* and other similar stories can seem far-fetched, the significant and potentially discontinuous progression of technology affecting both the interface of mind and machine (Wise, 2017, and Wu and Rao, 2017) as well as life expectancy may mean such questions loom nearer on the horizon than one might think.

The search for life extension methods has its history of enterprises of dreamers and schemers. However, these days, a burgeoning longevity science industry – backed by significant venture capital and other funding – is actively working on solving the problem of senescence, whether by preventing ageing or reversing its effects. Some of these researchers are making rather startling claims in the media about how near we may be to achieving radical increases in life expectancy and increased quality of life during our later years. Perhaps the most well-known evangelist of the subject, the gerontologist Aubrey de Grey, has said he believes that the first human who will live to the age of 1,000 has probably already been born (de Grey, 2004). David Sinclair, a researcher at Harvard Medical School, is not quite as optimistic but believes that the first human who will live to 150 has been born (Nuland, 2005).

While these predictions make for fantastic headlines, it can be hard to gauge how realistic such assertions might be. Justifications for such statements often tend to rely on faith in anticipated (often unspecified) technological advancements, or on optimistically extending a graph of historical changes in life expectancy to reach 'actuarial escape velocity' – the point at which life expectancy is increasing by more than one year per year – sometime in the next few decades or centuries.[2]

Changes in life expectancy are complex and generally occur because of multiple underlying drivers. To date, most of the observed increases in life expectancy stem from decreases in mortality at various demographic points below the maximum observed age rather than extensions of maximum lifetime itself. Under that paradigm (sometimes called 'squaring the survival curve'), there are diminishing returns to increased life expectancy. One can imagine a future population in which most live until they are about 120-130 years old, but nobody lives beyond then.

Since 2013, Google has invested substantial funds setting up a research and development biotech company called Calico that is investigating ageing (Regalado, 2016). Calico's mission is to 'harness advanced technologies to increase our understanding of the biology that controls lifespan' and to 'use that knowledge to devise interventions that enable people to lead longer and healthier lives' (Calico, 2018). At the time of writing, the most recent scholarly publication cited on Calico's website is entitled 'Naked mole-rat mortality rates defy Gompertzian laws by not increasing with age' (Ruby, Smith and Buffenstein, 2018) which to me sounds a prime candidate for required actuarial exam reading.

1. Based on the 2002 novel of the same name by Richard K. Morgan.
2. At least for the super-rich who can afford cutting-edge treatments.

What are actuaries and others to make of these extraordinary claims and visions of the future? Life-extension technologies – or success in achieving other 'post-human' forms to inhabit – would require a re-engineering of many financial and insurance products on a scale that makes the possible disruption caused by self-driving cars seem minor by comparison. Here are just a few questions that spring to mind:

- Will comprehensive health insurance cover life extension technology? Is access to such treatment 'medically necessary' or not? Is it a basic human right? Will coverage depend on the type of technology or the particular problem being fixed?
- How will 'life' and 'death' – as defined in existing life insurance policies, income annuities, and disability income policies – be interpreted if the life extension involves moving consciousness to a new body (carbon or silicon)?
- If disability policies provide income only to a given attained age, or if pension plans provide benefits in relation to a given attained age, will public policy force a reinterpretation of those contracts to reflect a belief that 'the new age 65' is now age 75?
- Might life insurers offer to fund life extension in order to postpone paying death benefits into the future? Will whole-of-life policies need to reflect a non-zero probability that the insured never dies?
- How might underwriting need to change for life insurance and for annuities (or other longevity products)? What new product practices might develop as medical science expands the list of ailments it can cure and disabilities it can reverse?
- If life extension comes at the price of increasing long-term nursing care needs or income support needs, will society be equipped to provide that care and support?
- Similarly, how will companies and individuals adapt to the changes? Radical changes to lifespans would greatly increase existing pension and annuity obligations, and could also increase healthcare spending. Conversely, claims on life policies might be greatly reduced. Might life companies find it advantageous to pay for advanced medical treatment for certain policyholders to achieve those claim reductions? Might health insurers find it advantageous to pay for people to upgrade or replace their bodies when they become sick, to avoid costly end-of-life care?

Besides being a pleasant diversion, contemplating how actuarial methods might be applied to solve new societal problems in various potential futures is good mental exercise. It might also be a good source of fresh ideas about how to tackle continuing problems of financial inequity and lack of access to required financial security products for large portions of the global population today. By virtue of the nature of their products, many insurers must necessarily operate on longer time horizons than most other businesses, and therefore have more incentive to take the potential of disruptive technology seriously and plan accordingly. As a result, actuaries may have a vital role to play in ensuring we end up in a utopia rather than the alternative.

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Biography

Hans Leida is a Principal and Consulting Actuary with Milliman, Inc. Hans consults with clients on many aspects of healthcare financing, particularly those related to healthcare reform in the USA and to applications of predictive modelling to health data. With Bill Bluhm, he wrote the textbook *Individual Health Insurance* which has been required reading on the Society of Actuaries exam syllabus for many years. Hans is frequently quoted in the news, and a paper he wrote was cited by the Chief Justice of the US Supreme Court in a major decision on healthcare reform.

Recent developments and events

News from the IFoA's Actuarial Research Centre

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ARC Webinar Series 2018

Join the second ARC webinar series this autumn and learn about some of the recent findings of the ARC's research programmes:

- 17 September 2018 – **Use of Big Health and Actuarial Data for understanding Longevity and Morbidity** – New statistical and actuarial methods in the use of Big Data, in the context of health and wider applications.

  Speaker: Prof Elena Kulinskaya (University of East Anglia)

  http://bit.ly/arc2173

- 2 October 2018 – **Modelling, Measurement and Management of Longevity and Morbidity Risk** – Developing a new generation of mortality and morbidity models, with a specific focus on the drivers for mortality.

  Speaker: Prof Andrew Cairns (Heriot-Watt University)

  http://bit.ly/arc2165

- 3 October 2018 – **Minimising Longevity and Investment Risk while Optimising Future Pension Plans** – Development of pension product designs that keep the customers' needs at the forefront, with a real income in retirement that minimises costs for the customer.

  Speaker: Dr Catherine Donnelly (Heriot-Watt University)

  http://bit.ly/arc2142

- 4 October 2018 – **Behavioural Aspects of Institutional Investment Decision-Making** – Exploring the decision-making of institutional investors, in particular insurers and pension schemes, and the biases that may affect their investment decisions.

  Speaker: Prof Peter Ayton (City, University of London)

  http://bit.ly/arc2976

These webinars are free to join and a great opportunity to put questions via a live feed to our panel of research academics and practitioners, joining in the debate wherever you are located in the world. These events are eligible for CPD and will run twice at 09.00 and 17.00 UK time (BST). We will also be recording the live webinars and they will be available as recordings on the IFoA website and YouTube channel, shortly after the event.

The 2017 webinar series can also be viewed through the IFoA website (**http://bit.ly/ifoa1589**) or YouTube channel.

For further information please contact **arc@actuaries.org.uk**

Recent events and publications from the ARC programmes

Three of the ARC programmes have presented at IFoA sessional meetings over the last year and can be viewed for free via the IFoA's website (**http://bit.ly/ifoasessional**). All papers and outputs from all the ARC programmes can be accessed by all through the IFoA's website (**http://bit.ly/arcresearch**). The IFoA Library also indexes papers of ARC-supported researchers as they are published in research journals: **http://bit.ly/ifoalibarc**

Institute and Faculty of Actuaries

Mortality and Longevity seminar, 19 June 2018

This year's seminar brought together perspectives from actuaries, longevity science entrepreneurs and surveyors of national and international mortality data. Of a theme with this Longevity Bulletin, entrepreneur Jim Mellon surveyed the current state of longevity science in developing bio-technological interventions to affect the ageing process for extended life.

Other presentations considered the case for longevity indices of basis risk, the advice on 'idiosyncratic mortality risk' in smaller workforces to trustees of occupational pension schemes, and older age dynamics. There was a report on the Human Mortality Database's (HMD) developing collation of national datasets, and recent concern for the emerging trend in drug-related deaths in the United States affecting the trend of improving life expectancy.

The papers are listed under 'Mortality and Longevity Seminar 2018' for viewing among Conference papers for 2018, via the IFoA website: **http://bit.ly/ifoapapers2018**

Annals of Actuarial Science (AAS) and British Actuarial Journal (BAJ)

The AAS attracts and peer-reviews articles of theoretical and applied research on all aspects of actuarial science from authors worldwide (**http://bit.ly/ifoa2531**). Recently published papers include:

- *A stochastic Expectation–Maximisation (EM) algorithm for construction of mortality tables*
- *Modelling multi-state health transitions in China: a generalised linear model with time trends*
- *Cohort effects in mortality modelling: a Bayesian state-space approach*

The BAJ publishes papers presented at the sessional research meetings of the IFoA as well as papers of interest to practitioners. (**http://bit.ly/ifoa9125**). Recent papers and discussions include:

- *Abstracts of papers from the International Mortality and Longevity Symposium*
- *Viable retirement solutions for the long-run*
- *Product options for enhanced retirement income*
- IFoA 2017 Spring Lecture by Dame Sally Davies on anti-microbial resistance

Cambridge University Press International Series on Actuarial Science

Mortality modelling with actuarial applications (Macdonald, A.S., Richards, S.J. and Currie, I. D.) is set to become a standard reference for the IFoA's new set of examinations. This title reflects how recent research on mortality and computing programmes like 'R' have moved into the staple education of the actuarial student and the qualified actuary's toolkit.

Life Conference 2018, Liverpool, 21-23 November 2018

The Life Conference is the IFoA's largest UK gathering of members and other experts informing new analysis and informed by latest research. For more information and bookings, please visit: **http://bit.ly/ifoalife2018**

Continuous Mortality Investigation

Institute and Faculty of Actuaries

The Continuous Mortality Investigation (CMI) carries out research into mortality and morbidity experience, providing outputs that are widely used by UK life insurance companies and pension funds.

The following is a summary of the CMI's latest outputs. Please note that some outputs are available only to subscribers and to researchers for non-commercial use. However, papers relating to methodology may be made more widely available.

The CMI Mortality Projections Model

The latest version of the CMI Model, CMI_2017, was published in March 2018. The Model is calibrated to mortality data for the general population of England and Wales covering the period 1 January 1977 to 31 December 2017. Mortality improvements in 2017 were close to zero, leading to lower cohort life expectancies in CMI_2017 than in CMI_2016; with reductions of around two months, for both males and females, at age 65.

A briefing note on CMI_2017 (**http://bit.ly/cmi_2017bn**) was issued alongside the paper. This is publicly available and provides an overview of the latest version of the Model. The Model and supporting documentation are available alongside Working Paper 105 (**http://bit.ly/cmiwp105**).

The paper includes illustrations of possible results from CMI_2018 (assuming no changes in method) for given levels of mortality improvement in 2018. For the Core Model, if mortality improvements in 2018 are in line with CMI_2017's projections then life expectancies are expected to be lower in CMI_2018 than in CMI_2017.

In an additional measure to help manage expectations regarding future versions of the Model, the CMI intends to issue quarterly updates, analysing emerging population mortality in England and Wales, starting in July 2018.

The CMI's Mortality Projections Committee hosted a discussion on mortality improvements at the Staple Inn Actuarial Society (SIAS) in April 2018. Slides and an audio recording of the event can be found on the SIAS website: **https://sias.org.uk/resources/**

A proposed approach to closing off CMI mortality tables and 'S3' Series mortality tables

The High Age Mortality Working Party has proposed an approach for extending future CMI mortality tables to high ages. Working Paper 106 (**http://bit.ly/cmiwp106**) describes the method, based on convergence to mortality rates for the general UK population. The paper includes an illustrative case study on the proposed 'S3' Series mortality tables, which use the proposed high age extension.

The proposed 'S3' tables were published by the CMI Self-Administered Pension Schemes (SAPS) Committee alongside Working Paper 107 (**http://bit.ly/cmiwp107**). The paper describes the dataset and graduation methods used, and includes a comparison to the 'S2' Series tables. The proposed 'S3' Series has more tables than 'S2', including 'Very Light' tables based on the experience of pension scheme members with very high pension amounts. It is expected that the 'S3' tables will be finalised later in 2018.

Experience of term assurances for the period 2011 to 2015

Working Paper 108 (**http://bit.ly/cmiwp108**) describes the interim results of mortality and critical illness experience of term assurance policies in the period 2011-2015. It contains an overview of the data received from life insurance companies, along with comparisons of the experience with that in 2007-2010.

Experience of pension annuities in payment for the period 2011 to 2014

Working Paper 101 (**http://bit.ly/cmiwp101**) includes an overview of the data received from life insurers for pension annuities in payment for the period 2011-2014, including analysis by product type. The CMI is undertaking further analysis of this dataset, which it expects to publish soon, but is seeking data to the end of 2017 before producing new tables.

Income protection experience in 2003 to 2010 and proposed 'IP06' claim inception rates

Analysis of the individual income protection experience by benefit amount band and by policy duration, over the period 2003 to 2010, was published in Working Paper 102 (**http://bit.ly/cmiwp102**). These factors are not currently included in standard CMI income protection analyses.

The CMI has also issued proposed 'IP06' claim inception rates of CMI income protection experience in those years, alongside Working Paper 109 (**http://bit.ly/cmiwp109**). The inception rates are issued as part of a consultation process with claim termination rates yet to be produced.

If you have any questions about the CMI or are interested in becoming a subscriber to the CMI's outputs, please email us at **info@cmilimited.co.uk**

News from around the community

International Actuarial Association (IAA): Mortality Working Group

The Mortality Working Group is one of the IAA's scientific committees with a membership from around the world: **http://bit.ly/iaamortality** Its members regularly survey mortality and longevity research for an 'Information Base', and contribute country updates. The Working Group has ongoing investigations into areas of mortality research, with regular reports at events and meetings.

International Congress of Actuaries, Berlin, 4-8 June 2018

From the first plenary session on 'Future of Demography/ Longevity', mortality and longevity research and its applications were well represented in papers for the Congress programme. This included presentations from IFoA-supported research on Basis risk in Index based longevity hedges (led by Prof Andrew Cairns Heriot-Watt University) and Population Ageing, Implications for Asset Values, and Impact for Pension Plans (led by Kathleen Rybczynski, University of Waterloo).

Please see the full ICA programme for further details, **https://ica2018.com/full-program**

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