fst journal

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THE FOUNDATION FOR SCIENCE AND TECHNOLOGY

COUNCIL

THE FOUNDATION FOR SCIENCE AND TECHNOLOGY

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Government commits to maintain funding for fusion research

The Government has signalled its willingness to maintain research collaboration with European partners after the UK leaves the EU by committing to underwrite UK funding for the Joint European Torus (JET) project, the Business and Energy Secretary Greg Clark has announced.

Subject to the EU extending the UK's contract to host the world-class nuclear fusion facility beyond 2018, the UK has agreed to underwrite its share of JET's running costs, which is based at the Culham Centre for Fusion Energy in Oxfordshire.

The JET project is home to the world's largest and most advanced nuclear fusion reactor and has led global efforts to develop a clean, safe energy source. It supports 1,300 jobs in the UK, 600 of which are highly skilled scientists and engineers.

The UK's contract to maintain and run the JET project is managed by the UK Atomic Energy Authority (UKAEA) and is due to end in December 2018. As part of this contract, the EU currently provides around £60 million of funding per year, which represents 88% of JET's running costs.

The UK's commitment to continue funding the facility will apply should the EU approve extending the UK's contract to host the facility until 2020. A discussion will then take place on the appropriate funding split.

www.gov.uk/beis

EPSRC supports Distributed Ledger Technology projects

The Engineering and Physical Sciences Research Council is supporting a series of projects that will explore the potentially transformative opportunities offered by Distributed Ledger Technology in energy, healthcare, banking and policy making. EPSRC is committing more than £3.6 million of investment, delivered through the Research Councils UK (RCUK) Digital Economy Theme.

The studies will look at new uses for digital distributed ledgers. These are databases which are shared between multiple parties and have the potential to make the systems and services they are applied to more transparent while maintaining high levels of security and privacy.

The best known use of DLT currently is in Bitcoin, a form of digital currency that uses blockchain technology, a distributed ledger formed of unchangeable and digitally-recorded data stored in packages called blocks.

A Government Office for Science report, published in 2016, said that technical innovations such as DLT could enable "revolutionary changes" that will "ultimately cause major changes in the way in which the economy and society itself is organised and governed".

The highly multi-disciplinary research projects taking place will involve a wide range of academic and industry partners, and consider the technical, economic, legal and social elements of the technology.

www.epsrc.ac.uk

Data governance in the 21st century

The Royal Society and the British Academy have conducted a review on the needs of a 21st century data governance system.

The amount of data generated from the world around us has reached levels that were previously unimaginable. Meanwhile, uses of data-enabled technologies promise benefits, from improving healthcare and treatment discovery, to better managing critical infrastructure such as transport and energy.

To realise the benefits of these new applications, societies must navigate significant choices and dilemmas: they must consider who reaps the most benefit from capturing, analysing and acting on different types of data, and who bears the most risk.

In this fast-moving landscape, governance challenges need to be addressed in a timely manner if the overall system of governance for data management and data use is to maintain public trust.

Two responses are required, say the academies:

- a set of high-level principles to help visibly shape all forms of data governance and ensure trustworthiness and trust in the management and use of data as a whole;
- the creation of a body to 'steward the evolution of the governance landscape as a whole'. Such a body would be expected to conduct expert investigation into novel questions and issues, and to enable new ways to anticipate the future consequences of today's decisions.

royalsociety.org/~/media/policy/projects/data-governance/data-management-governance.pdf

New threat to ozone recovery

Recent and rapid increases in emissions of a gas commonly used as a paint stripper and in the food industry to decaffeinate coffee and tea threaten the recovery of the ozone hole. A continued rise could delay it by up to 30 years, say researchers.

Their findings, published in *Nature Communications*, suggest that a previously ignored chemical called dichloromethane, not controlled by the Montreal Protocol, may be contributing to ozone depletion and should be included to improve future predictions of ozone recovery.

The Montreal Protocol is heralded by many as one of the most successful international agreements ever. Introduced in 1987, the agreement followed many decades of monitoring of the ozone hole over Antarctica by researchers at the British Antarctic Survey.

The researchers' projections show that continued dichloromethane increases at the average trend seen from 2004 to 2014 would delay ozone recovery over Antarctica by 30 years. If dichloromethane concentrations stay at current levels, the delay in recovery would be only five years. Although the future trajectory of dichloromethane is uncertain, without any regulations on emissions it is likely concentrations will fall somewhere in between these ranges.

www.nature.com/articles/ncomms15962

Putting science into diplomacy

Robin Grimes

Most UK Government departments have a Chief Scientific Adviser and the CSA at the Foreign & Commonwealth Office (FCO) is thus part of a network working under the guidance of the Government Chief Scientific Adviser. Together, this group provides advice on all aspects of policy concerning science and technology. Of course, individual CSAs belong to their home Departments and are accountable to their respective Permanent Secretaries. CSAs advise their Ministers, identify and share good practice in areas related to science, technology, engineering and mathematics (STEM), including the use of scientific advice in policy making. Where the FCO CSA role differs from others is the use of science diplomacy to strengthen international relationships, demonstrating its value to the Foreign Secretary, Ministers and FCO colleagues at all levels, whether working at home or at UK missions overseas.

Worldwide, there are only a few other countries with science advisers who focus on the science diplomacy agenda and which are hosted mostly, or entirely, within a Foreign Service. They are Japan, New Zealand, Senegal, Poland, Oman and the USA. The number of countries embracing this model looks likely to grow. This is aided by the International Network for Government Science Advice (INGSA).

In June 2016, for example, I joined the Canadian Science Minister's Retreat near Ottawa to talk about the UK's Chief Scientific Adviser network. This followed the announcement of the position of Chief Science Advisor for Canada. The person appointed will be responsible for providing scientific advice to the Prime Minister, the Minister of Science and members of the Canadian Cabinet. More recently, in June 2017, I joined the Spanish Science Minister in Madrid at a meeting to discuss the importance of science diplomacy to our bilateral relations.

The importance of international science engagement has long been recognised in this country. The Royal Society appointed its first foreign secretary, Philip Zollman, as long ago as 1723. Even further back, the first contact between the UK and Japan involved the exchange of scientific gifts. In 1613 Captain John Saris, representing King James I arrived in Japan with a telescope, the most cutting-edge technology available. Having met various Japanese Tokugawa shoguns Captain Saris came back to the UK with gifts including a suit of Samurai armour.

If the task is to demonstrate the value of science diplomacy at all levels, what exactly is 'science diplomacy'? In its 2010 publication *New Frontiers in Science Diplomacy*, a joint publication with the American Association for the Advancement of Science (AAAS), the Royal Society identified three aspects:

- science in diplomacy;
- science for diplomacy;
- diplomacy for science.

Many examples of all three aspects can be read in articles of the journal *Science & Diplomacy* which is published quarterly by the AAAS, who also publish the journal *Science*.

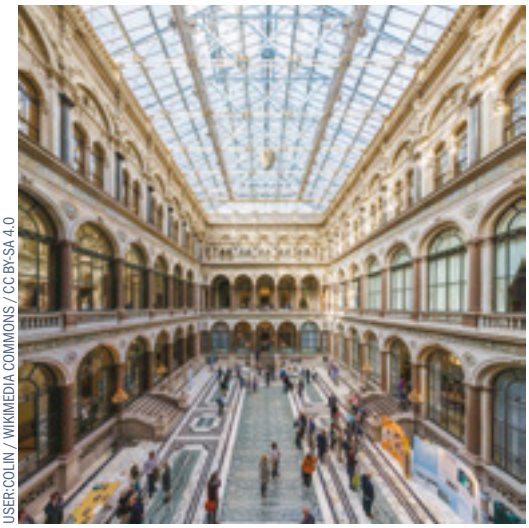
Science in diplomacy

Science can be used in diplomacy to provide robust evidence to inform policy objectives. Immediately following the accident at the Fukushima Daiichi nuclear power station after the Great East Japan Earthquake and Tsunami in 2011, the UK Government activated the Scientific Advisory Group in Emergencies (SAGE).

SAGE is responsible for ensuring that timely and coordinated scientific advice is made available to decision makers in order to support UK cross-government decisions made by COBR (the name actually stands for Cabinet Office Briefing Room). Through SAGE, the UK Government was able to use science to understand the progression of the accident and implications for British nationals in Japan. It used scientific analysis to inform our citizens through the British Embassy in Tokyo and through the media. Most British nationals based in Japan remained in the country throughout the period as details of the accident unfolded. The UK Government was confident in supporting this stance, as it was in explaining many comments made by the Japanese Government, and provided context for the data being issued. The UK response has had a beneficial effect on UK-Japan relations since the incident and led to a detailed discussion of science advisory systems[1]. The Japanese government appointed its first Chief Scientific Adviser in their Foreign Ministry in 2016.

The strength of our science and innovation relationship with Japan and many other techno-

Professor Robin Grimes has been Chief Scientific Adviser (CSA) to the Foreign and Commonwealth Office (FCO) since February 2013. He is responsible for providing advice to the Foreign Secretary, Ministers and officials on science, technology and innovation. His role is to ensure that FCO work on key issues undergoes proper scientific challenge, and to strengthen the scientific and engineering capacity within the Foreign Office. The CSA is supported in his work by the UK Science and Innovation Network attachés based in overseas posts. Professor Grimes is also Professor of Materials Physics at Imperial College. In his research, he uses computer simulation techniques to understand the behaviour of materials for energy applications including nuclear fission and fusion, fuel cells, batteries and solar cells. He is a Fellow of the Royal Academy of Engineering.



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The Durbar Court at the former India Office, now part of the Foreign & Commonwealth Office (FCO)

logically advanced nations helps to strengthen our foreign policy influence. That enables us to work in partnership towards solutions to global challenges, from climate change to cyber security.

Science for diplomacy

Science can be used to build diplomatic relations, leading to improved political, social and economic links. As the FCO's CSA, I recently participated in the Second Annual South African Science Forum. The UK is committed to African science and technology development. Active participation in events such as the forum reinforces that commitment, builds mutual understanding and widens networks.

Science for diplomacy can be an effective tool even in politically difficult circumstances. Collaboration between the Argentinian Embassy in London and our Embassy in Buenos Aires resulted in a successful four-day visit to the UK by Argentine Science Minister Lino Barañao. It included visits to key laboratories, such as the Francis Crick Institute, the Sanger Institute, Rothamsted Research, Kew Gardens and the Royal Society. It also saw the first UK-Argentina Science Dialogue with Minister Jo Johnson, hosted at the Science Museum.

At the end of the visit, the two Ministers signed a joint Statement of Intention for closer collaboration in Life Sciences, Agri-technology, Advanced Materials & Nanotechnology, Information & Communications Technology, Oceans Research and Palaeontology. Looking forward, it is also possible to consider regional science and innovation partnerships such as between the UK and Latam countries.

The scientific community often works beyond national boundaries so is well placed to support forms of diplomacy that do not depend on traditional alliances. This was recognised in a 2014 House of Lords report[2] which recommended, among other things, that the UK Government should identify ways in which science can inform diplomacy. Scientists also provide longevity, developing and maintaining international relationships over the long term, often lifetimes, complementing the often shorter-term personal relationships of diplomats and politicians. The relationships that scientists at the Royal Botanic Gardens Kew have with their international counterparts are excellent examples of this – it is hard to say when they began to receive samples from their collaborators but the first collector, Francis Masson, was appointed in 1771.

UK excellence in research is well-recognised across the globe and as such the UK is in an especially good position to make use of science for diplomacy. It enhances our national reputation, opens doors to influence trade and investment and can help with power projection when used appropriately. Further benefits arise when, for example, other nations choose to use our science structures or standards, making the UK a natural trading partner. Or again, when overseas students who studied in the UK maintain their connections with the UK. The FCO itself provides 700 scholarships per year to overseas students to study (mostly for a Masters degree) in the UK. The Chevening Scholars choose from the widest set of subjects, which includes science, engineering and technology.

Diplomacy for science

Scientists sometimes require our help as diplomats. They need us to make connections and influence policy in order to create the framework within which they can collaborate internationally, or gain access to costly facilities that are not available in the UK. This may require a full blown treaty or just a memorandum of understanding (MoU).

An example of this is the strong, ongoing set of research collaborations between UK and Indian civil nuclear laboratories, supported by a UK-India Civil Nuclear Energy agreement. This has been ongoing since 2010 when I accompanied the then Science Minister David, now Lord, Willetts to Bangalore to sign a MoU. These projects have resulted in more than 45 joint peer-reviewed papers in scientific journals as well as around 30 conference presentations, with the number growing year by year.

This collaboration is based on mutual benefit. For example, it gives the UK scientists access to large-scale Indian experimental infrastructure which is not available in the UK. On the Indian side, it provides access to expertise in aspects of engineering and materials. A third set of projects

is underway, and in Mumbai in October 2016 we started to identify a fourth set of six projects at the annual review meeting. The UK and India fund their own parts of the project, with around £1 million per year funding on the UK side coming from the Engineering & Physical Sciences Research Council (EPSRC).

The Science and Innovation Network

In 2001, UK Government set up the Science and Innovation Network (SIN)[3], with the aim of linking science more directly to its foreign policy priorities. SIN primarily contributes to diplomacy for science by providing a first point of contact and gateway to science and innovation (S&I) opportunities, for UK and host country research institutions, universities and industry. It also develops policy insight through a two-way flow of ideas between the UK and partner countries, as well as establishing new international partnerships, often acting as a catalyst for new projects.

SIN also plays a science in diplomacy role by contributing to a joined-up UK approach, using SIN experts at the heart of the UK's overseas missions, working closely with UK partner organisations to promote coherent UK engagement. It is taking an increasingly strategic approach to engagement, focussing on specific themes (e.g. antimicrobial resistance and quantum technologies) to increase its impact and ensuring a balance between short-term 'quick wins' and longer term strategic and diplomatic gains.

SIN has around 90 people working in more than 30 countries and territories around the world, building partnerships and collaborations.

Another important mechanism for UK science diplomacy is the Newton Fund programme[4,5]. This is building science and innovation partnerships with 16 partner countries, supporting their economic development and social welfare. It also develops research and innovation capacity for long-term sustainable growth.

The UK is investing £735 million from 2014 to 2021, with partner countries providing matched resources within the Fund. It forms part of the UK's Official Development Assistance (ODA) commitment, is managed by the Department for Business, Energy and Industrial Strategy (BEIS), and delivered through 15 UK Partners. The Newton Fund has appointed over 30 Officers in British overseas missions help to deliver the programme.

Science diplomacy is not, however, the exclusive domain of diplomats. Universities and their key science networks play a crucial role in improving cross-cultural understanding and collaboration. Research and the generation of new knowledge to drive innovation are international enterprises. The mobility of students and researchers is essential to this pursuit.

Science diplomacy is not, however, the exclusive domain of diplomats. Universities and their key science networks play a crucial role.

Science as a diplomatic tool

If the UK is to maintain its international profile, the UK Government must prioritise science so that other countries continue to see the UK as the place to come. I am convinced the FCO is well placed to help, especially through the SIN and Newton Officers, and we are fortunate that our Ministers and Ambassadors embrace the idea that 'science is a tool in their diplomatic tool box'[6].

All of these beneficiaries – Ministers, diplomats, universities and industry – rely upon a dedicated body of around 30,000 scientists and engineers working for UK government in the Civil Service and wider public sector. Their work covers everything from food safety to space exploration, from animal welfare to nuclear fusion. They permeate throughout the Civil Service, where they are called upon to offer remedies to a bewildering variety of ailments. Together, they are the Government Science and Engineering Profession, one of five Civil Service analytical professions[7].

As our world becomes ever more technologically challenging, we need these people to be exceptionally well-informed and internationally connected through the efforts of our overseas mission. The UK will only remain at the heart of international science, for the benefit of our society, while our diplomats continue to exercise good judgment in the field of science diplomacy. □

1. Grimes RW, Chamberlain Y & Oku A (2014) 'The UK response to Fukushima and Anglo-Japanese relations', *Science & Diplomacy*, **3**.
2. www.publications.parliament.uk/pa/ld201314/ldselect/ldsoftpower/150/15008.htm#a15
3. www.gov.uk/government/world/organisations/uk-science-and-innovation-network
4. www.newtonfund.ac.uk
5. Grimes RW and McNulty C (2016) 'The Newton Fund: Science and Innovation for Development and Diplomacy', *Science & Diplomacy*, **5**.
6. Grimes R W and Hennessey E (2015) 'Why science is in the diplomatic tool kit'. *Science in Parliament*, **72**, 10.
7. https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/426307/15-2-chief-scientific-advisers-and-officials-introduction.pdf

INDUSTRIAL STRATEGY

Early in 2017, the Government published a Green Paper for consultation, outlining its proposed industrial strategy. A meeting of the Foundation for Science and Technology on 10 May 2017 considered the different elements of the strategy and its overall aims.

What constitutes an effective industrial strategy for the UK?

Graeme Reid

Professor Graeme Reid was Specialist Adviser to the House of Lords Select Committee on Science and Technology during their inquiry into the Industrial Strategy and during earlier work on Brexit. Professor Reid has spent much of his career at the interface between science and government. He is Chair of Science and Research Policy at UCL. He is also Chairman of the Campaign for Science and Engineering, a Trustee of the Association of Medical Research Charities and Strategic Advisor to the National Centre for Universities and Business.

SUMMARY

- The political context in which this strategy was developed was particularly turbulent.
- It is not clear who within Government will have overall responsibility for delivering the strategy.
- There needs to be more clarity on how the different pillars will work together to form a coherent whole.
- An effective industrial strategy will inevitably include some of the most sensitive areas of the Brexit negotiations.

Successive Governments have published numerous industrial strategies since the middle of the 20th century. According to the Prime Minister, this one is distinct because it is a key part of the preparation for Brexit.

The authors of this Strategy[1] were operating in an unusually turbulent context. It must have been difficult to reach a settled position on the text with so much change taking place during the drafting process. Writing a chapter on regions with Mayoral elections taking place at the same time must have been tricky – to say nothing of writing a strategy for the whole of the UK while the First Minister of Scotland was calling for another independence referendum.

The authors themselves were operating in new organisations. The Department for Business, Energy and Industrial Strategy (BEIS) and the Department of International Trade had just been created. Given the way that the Prime Minister presented the Strategy, it seems likely that the Department for Exiting the EU and No10 had quite a lot of say on its content. Any assessment of the strategy should be set against that background.

From people I have spoken to, there has been nothing but a warm welcome for the concept of an Industrial Strategy which revisits the relationship between Government, industry and universities in a changing and stressful world.

Science and innovation

This strategy includes prominent coverage of science and innovation, built on the foundations of the large increase in funding that was announced in the last Autumn Statement. However, the list of 'ten pillars' looks remarkably like the lists appearing in previous strategies (see Table 1). One journalist called it 'the same old wish list'.

The House of Lords Science and Technology Committee observed[2] that the document resembles a portfolio of tactics rather than a coherent strategy. It includes a rich collection of tactical objectives and tactical initiatives. It is rather light on strategic objectives and even lighter on coherence.

It really is not obvious who is responsible for the overall delivery of the Strategy, who is accountable to that person and to whom that person is accountable. When the House of Lords Committee took evidence from Industry Minister Nick Hurd MP, he said that responsibility for delivery lies with the Prime Minister. While that is true in a technical sense, the Prime Minister cannot be expected to take a grip of operational delivery. So it remains unclear who is actually responsible for delivering the programme that spans several Government Departments and Devolved Administrations, what goals they will be measured against and what process will be used to hold them to account. While it was launched as a consultation document, it would be good to hear plans for responsibility and accountability in the next version.

The Ten Pillars

The Ten Pillars do connect together in some places, but not consistently or coherently. Take the relationship between science, trade and regional development. There are references to science in the regions pillar, but there is no reference to it in

The Ten Pillars of the Industrial Strategy	
Investing in science and innovation	Trade and investment
Developing skills	Energy and clean growth
Upgrading infrastructure	Cultivating sectors
Starting and growing business	Growth across the country
Public procurement	Institutions, sectors and places

Table 1: The Ten Pillars of the Industrial Strategy.

the trade chapter. Surely, if we want to address disparities in regional prosperity then some interplay between the pillars will be required to make it happen? The challenges lie not so much in what goes on inside the individual pillars but in making them work together harmoniously. That aspect of the Strategy seems un-developed.

There is a chapter on sectors which identifies a number of important sectors and names prominent individuals who have agreed to take leadership roles in ensuring the contribution of those sectors to the overall Strategy. That is to be applauded.

There is then a reference to (undefined) emerging sectors and how they might participate in the future. The underlying assumption, however, is that the economy can be categorised by industry sectors. Yet this is a world where the breakdown between conventional industry sectors can be seen frequently, together with the emergence of businesses that are really quite difficult to categorise in a sector. Now if this is already happening in front of our eyes, what about developments that are over the horizon? What kind of businesses might emerge over the time period this strategy is considering? There is not enough recognition given to this kind of future during the period covered by the strategy.

While the Green Paper is presented as a strategy for the UK as a whole, several of the pillars describe policy areas that are devolved to each of the four countries of the UK. Take higher education policy: there is an aspiration to initiate discussions between the four governments. Having spoken to people in the Scottish and Welsh administrations, I found that neither was involved in the preparation of this Strategy or feels committed to the single overarching picture set out in the document.

Given the diverse political dispositions of the different governments in the UK, there is an evident gap in the thinking on how to handle the complexities of devolved politics, a complexity which is increasing with the election of city mayors who will have devolved powers related directly to some of the pillars in the Strategy.

One of the most important relationships between business and Government lies in the domain of taxation and regulation. Here, the UK might attempt to seize competitive advantage as we develop the economy outside of the European Union. Yet there is no chapter on Tax and Regulation, just a fleeting mention.

This is, of course, a sensitive area. In the exchange of correspondence between the Prime Minister and the EU over the terms of Brexit negotiation, there was a warning from the EU that the UK shouldn't attempt to derive advantage by manipulating tax and regulation and yet this is clearly an area of potential advantage that the UK can explore.

It must be difficult to write a document as part of our preparations for Brexit that addresses some of the most sensitive areas for negotiation. Tax, regulation, immigration, terms of trade and the relationship between government, business and universities are all core elements of an effective industrial strategy and all core elements of the Brexit negotiations due to begin shortly after the Green Paper was published – no wonder there are gaps in the document.

The UK faces persistent challenges in addressing its relatively low productivity, the unacceptable regional distribution of prosperity and harvesting the benefits of its strong science base.

This Strategy is a sensible and timely approach to these challenges, each one of which has frustrated one Government after another. Whether or not we support Brexit, it may well provide a stimulus for tackling these issues effectively instead of just commissioning even more policy reviews and going through the same debates one more time. □

1. *Building our Industrial Strategy*: green paper www.gov.uk/government/consultations/building-our-industrial-strategy

2. House of Lords Select Committee on Science and Technology: *Letter to the Secretary of State for Business, Energy and Industrial Strategy* www.parliament.uk/documents/lords-committees/science-technology/Industrial-strategy/2017-05-02-Industrial-strategy-ltr-to-BEIS-Secretary-of-state.pdf

This Strategy is a sensible and timely approach to the challenges that have frustrated one Government after another.

A bold vision is needed for our industrial future

Ann Dowling

Professor Dame Ann Dowling OM DBE FRS FREng is President of the Royal Academy of Engineering. She is a non-executive director of BP plc and is a non-executive member of the board of the Department of Business, Energy and Industrial Strategy (BEIS). Previously she was a non-executive member of the board of the Department of Business, Innovation and Skills (BIS) and chaired the Main Panel B: Physical Sciences, Engineering and Mathematics in the 2014 Research Excellence Framework. In 2015, she chaired a review for BIS on business-university research collaborations.

SUMMARY

- The industrial strategy should offer an ambitious, bold and global vision of the UK's economic future.
- Employment in future will need people with a broad range of technical, digital and communication skills.
- The Government should set a target of 3% of GDP for total public/private annual R&D investment.
- Business awareness of support schemes remains low and this must be addressed.
- The future is digital. Business must embrace digital technologies.

The Royal Academy of Engineering has long advocated a modern industrial strategy to create the conditions for our industries and businesses to thrive. It welcomed the establishment of a Department for Business, Energy and Industrial Strategy (BEIS) and the Green Paper that followed.

In order to produce a response that represented the whole of the engineering profession, it joined forces with 38 professional organisations from across our community. Together, we represent some 450,000 engineers. The wide-ranging response included comments on all 10 pillars of the strategy.

Vision

An essential component of any strategy is a clearly-defined vision of what constitutes a successful outcome. An industrial strategy must set an ambitious, bold, global vision for the UK as an outward-looking leading trading nation – a favoured destination for inward investment and for international talent. In doing so, it should draw on the UK's credentials as a leader in research and innovation, in engineering, in manufacturing and so many other things.

There must also be a commitment to persevere with the strategy, providing the long-term vision against which industry and other stakeholders can plan and align activity. Stability and continuity are absolutely crucial to give businesses the confidence to invest. That means cross-party support needs to be secured for its key elements so that they endure beyond the five-year life of any parliament.

While an effective policy framework is necessary, it is not sufficient. Government needs to develop a genuine partnership with industry. This should not be a Government strategy for industry, it has to be an industrial strategy with industry – and wider stakeholder engagement is critical, too.

The development of such a strategy provides a powerful opportunity to promote UK industry and academia assertively on the global stage. In addition, it can generate coherent and aligned messaging across the various parts of Government and among non-governmental UK stakeholders.

It is vital for such a plan to succeed that there is greater awareness of the support that is on offer, especially to SMEs.

There is also much to be done to change public perceptions and advance a more positive image of industry and of modern engineering. Engineering employers recognise this and are ready to play their part.

During our consultations, we were repeatedly told that people must be at the core of any successful industrial strategy. Supporting people in gaining the right education and skills for the future has to be central to the Government's plans. It is heartening that the green paper includes highlights the challenge of developing skills of the workforce.

A survey we undertook with the engineering community suggests that constraints on time and finance are the main obstacles to companies investing in additional training for their staff. Solutions range from offering learning which fits in with employees' schedules, to professional bodies encouraging members to invest in their own development.

Of course, investment in education and skills begins long before individuals arrive in the workplace. The industrial strategy does not give enough weight to the work that must be done in schools. A coherent, integrated plan is required which starts at

Survey findings suggest that constraints on time and finance are the main obstacles to companies investing in additional training for their staff.

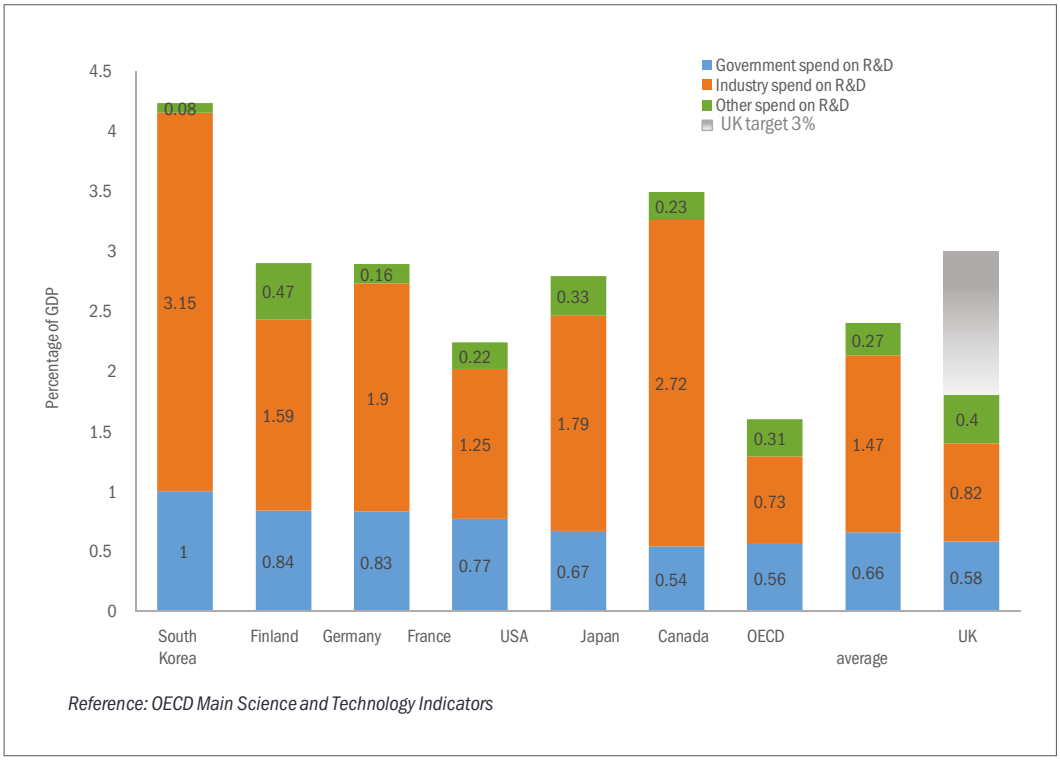

Figure 1. How a 3% target for R&D would compare with international competitors.

primary level and inspires an interest in science, technology and engineering.

It is so important to tackle teacher shortages in the STEM subjects, yet it is unlikely that even the best teachers will have the experience of working in business or engineering. There is a clear need to provide a real life context to the science and maths taught in the schools, in order to make these subjects interesting and inspiring. Employers recognise this and are increasingly interacting with schools. However, these interactions are currently haphazard and uncoordinated which means there is limited opportunity to transfer best practice. It is imperative to simplify that interface between businesses and schools.

Further education

Half of the skills shortages in engineering occur at higher apprenticeship and technician level. Further Education needs stable, long-term investment and the funding systems must enable colleges to provide high-cost subjects such as engineering.

Our consultation uncovered serious concern about the shortage of qualified tutors and lecturers in FE. The funding set aside for institutes of technology should be focussed on people who will teach rather than on bricks and mortar. Improving salaries and providing support for technical tutors should be the priorities.

The current A-level route to Higher Education forces early decisions which narrow career opportunities. The majority of young people will cease to study mathematics or a physical science at age 16. From a cohort of over half a million students in any year, only 30,000 (5%) will continue to study maths and physics at A-level.

The engineering community would like to see a broader post-16 curriculum, including a combination of sciences, mathematics and digital skills alongside humanities and arts subjects. Employment in the future will need broadly-qualified people with the technical and digital knowledge as well as strong communication skills.

Innovation

The industrial strategy could provide the opportunity to upgrade the role of research, science, engineering and innovation in the UK's economy. While not sufficient to achieve innovation, money is necessary. The UK's investment in R&D (public and private) is significantly lower than the OECD average. The additional £4.7 billion for R&D announced in the Autumn Statement is very welcome, but the UK needs to be more ambitious.

Therefore, one of our main recommendations is that Government should set a target of 3% of GDP combined public/private R&D investment and work with the private sector to formulate a roadmap to achieve that. Most innovation is undertaken in the private sector, but Government has a piv-

The funding set aside for institutes of technology should be focussed on people who will teach rather than on bricks and mortar.

TRANSPORT SYSTEMS CATAPULT

The LUTZ Pathfinder driverless pod is being trialled in Milton Keynes

otal role to play in stimulating this activity. Supportive policy and catalytic public funding can encourage the private sector to invest. The engineering community recommends that any new sector deals should require a shared commitment by businesses to boost investment in R&D (or in innovation and manufacturing) alongside Government co-investment.

Incentivising investment

Respondents to the survey identified academia/industry interaction as an effective way to incentivise investment in R&D (which brings benefits to both parties). Yet, if technical innovations are to succeed, they must be tested in real world environments. We believe that the UK should prioritise the provision of high quality opportunities for companies to test and demonstrate at scale. Existing UK infrastructure could be utilised for this.

This is already happening informally. The streets of Milton Keynes are being used to test autonomous vehicles, while predictive policing approaches are being trialled in Kent. In the future, drones could be tested at disused airfields and hospitals could trial innovative approaches to data-driven services. Running such schemes across the country could extend the geographical reach of innovation activities beyond the current centres of excellence.

Innovation is inherently risky with an uncertain outcome, particularly when it involves disruptive technologies with high potential. The UK is very cautious when it comes to innovation but Government should have a greater willingness to accept the risk of failure in its support for innovation.

Supporting business

The industrial strategy aims to support industry and grow businesses. One of the greatest challenges is to make companies aware of the support available to them. However, with hundreds of publicly-funded schemes in existence to support businesses, there is a clear need for simplification.

Business awareness of some key initiatives is very low. For example, about half of respondents to the survey were unaware of growth hubs or Local Enterprise Partnerships (LEPs). Over 80% were unaware of the small business research initiative (SBRI). SMEs need much clearer – and simpler – signposting to sources of advice and support, using existing contact points such as banks, HMRC and Companies House.

Business owners who have successfully scaled-up, or indeed who have founded companies with global aspirations, should be promoted as role models and their stories used as case studies to inspire others.

Support for SMEs should build on existing successful initiatives and institutions. Local institutions such as LEPs, Catapults and universities need to sustain consistent national levels of excellence and their services must be promoted more widely to those that could benefit.

Another important area that needs support is infrastructure. Poor infrastructure was repeatedly raised as a constraint on economic growth. Local transport infrastructure was singled out as a major barrier to growth by more than 80% of those that responded. A clear, long-term strategy for infrastructure is necessary to give industry confidence to invest in the future. Regional plans that understand local needs must be integrated with national strategies through the National Infrastructure Committee.

Digital technologies

The future is digital. Modern manufacturing and industry rely on the transfer of data over fast, secure networks. Digital analytics are opening up huge possibilities to improve performance and create whole new markets. Every business is now a digital business with a global potential. The UK is strongly placed to develop a leading digitally-driven and data-enabled economy. Continued investment in the UK's digital infrastructure and enhancing digital skills at all levels will be key enablers of the industrial strategy. The ability of the UK workforce to be confident and competent at a high level in digital skills will be pivotal to securing our competitiveness across a whole range of sectors and technologies. ❐

Implementing an industrial strategy – the practical aspects

Andrew Barker

SUMMARY

- Supporting sectors where the UK already has a leading position will help to further advance business involvement.
- Aviation is a key enabler of trade in the modern world.
- Engagement between Government and industry is necessary to maximise benefits to both.
- The Government needs to consider carefully how to integrate its fiscal policy across different sectors.
- Leveraging the huge sums of money in the pension funds could help to galvanise research and innovation.

I want to consider some of the practical ways in which a big business like International Airlines Group (IAG) could make use of an industrial strategy, grow employment in the UK and connect the UK better to the rest of the world.

Pillar 2 of the strategy set out in the Green Paper is concerned with the development of skills. Some 8,000 people in our workforce have the formal designation of 'engineer'. They are not just working on and maintaining our aircraft – although many are employed in these areas – but others work with the manufacturers of engines and airframes to develop new aircraft. We are, after all, one of the main potential buyers of planes in the future.

IAG has two major UK bases in Heathrow and Gatwick, although in the last 20 years there have also been investment in greenfield sites for engineering, in Glasgow and in South Wales. So, the group has a core skills base in aeronautical engineering where the UK has a long-term leading position. Any support in this area through an industrial strategy would be very welcome and could influence decisions at board level. IAG has inherited a number of bases from operating companies acquired over the last five years. In the next three years, the business will need to decide whether to centralise specific functions in certain countries.

It is not just about hardware engineers; software engineers are vital too. Avios, the international travel rewards programme (part of IAG), is a purely digital business – it has no assets other than algorithms and people. It makes huge investments in data analytics and artificial intelligence. It is based exclusively in the UK because of this country's prowess within Europe for digital technology. The UK is the best place to locate this type of business.

Trade and investment

Pillar 6 is concerned with encouraging trade and inward investment. It is an obvious point, but airlines do connect the UK to the rest of the world, allowing people to export their services and bringing other people here.

In terms of aviation – both in terms of engineering and delivery – the UK is unquestionably world-leading already. Look at the major cities around the world and the number of people going through their airports in 2015 (see Figure 1, page 12). Over 147 million people went through London's airports (i.e. Heathrow, Gatwick, Stansted, Luton and London City). The next biggest throughput was New York, then Tokyo, Hong Kong Shenzhen, Beijing, Atlanta, Paris, Chicago and Shanghai. Even with relatively low growth in the future (it may be significantly higher if the industrial strategy is successful) London will still be in the top three in 30 years' time.

The airline industry has always been fragile. BA, for example, has only paid a dividend three times in the past 15 years. Yet many in Government seem to think the sector makes a lot of money and does not need any help – hopefully this industrial strategy will provide a platform where we can start to transform those perceptions.

Engagement

There need to be foundations under these pillars to help us really make use of the strategy. The first could be termed 'quality engagement'. Take the debate about the third runway at Heathrow. IAG has had no engagement with Government on this issue, despite the fact that we have £10 billion of assets based at this airport. Over the next 25 years we, and other airlines at this airport, will have to spend £40 billion in aircraft equivalents to stay in business there.

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Figure 1. Air traffic through the world's major cities

The current proposal is for the new Heathrow runway to cross the M25 (the busiest motorway in Europe) at its busiest point next to the junction with the M4 (which is the busiest motorway junction in Europe). The engineering solution has not been designed yet, but it will probably cost in excess of £3 billion to build that bridge.

Yet from the airlines' point of view, the runway does not need to be 3,500 metres as proposed. If it were 2,800 metres, then perhaps 5% of the aircraft, on the hottest day of the year, flying to the furthest destinations in the world, might have to use one of the other two runways. At that length, the third runway would not need to cross the M25, potentially saving £3 billion.

If the industrial strategy just allowed officials to engage with key stakeholders in a more constructive way, that would be an enormous advance.

Fiscal policy

Infrastructure development at Heathrow is going to be entirely funded by the private sector. In addition, airlines have to collect air passenger duty for the Treasury – this is a business tax bringing in more than £3 billion a year. Yet how efficient is this instrument?

Figure 2 shows the number of Japanese tourists going to the UK and those going to Spain. In Spain, numbers fell by 13% between 2000 and 2015. The Spanish government does not tax Japanese visitors. A family of four visiting the UK from Japan has to pay £300 for the privilege – and the numbers are down by 60% over that period. The UK stands out as being a country that has significantly lost out.

An average tourist spends £1,200 while here – think of the VAT collected compared to the Air Passenger Duty. Again, we would like to have a more open-minded debate with the Treasury on this and other issues.

Patient capital

International, long-term, patient, capital providers such as sovereign wealth funds, the super funds in Australia and indeed some American venture capitalists have recognised a gap in UK provision – and are stepping in to fill it. The gap is that the UK has a great science base, but no adequate mechanism for providing scale-up capital to exploit that expertise.

There is no UK sovereign wealth fund. There are indeed huge investment funds, though, but they are not sovereign. The total assets in UK defined-benefit pension schemes, according to the Purple Book (which is the annual digest of these schemes) amount to £1.34 trillion.

Quantitative easing has pumped money into the economy and created an enormous black hole in pension liabilities which companies have had to fill. They have done so partly by selling UK equities. But money has then been re-invested in foreign equities.

So, 5,700 pension funds have been diversifying their portfolios according to good portfolio theory, but this has resulted in a huge drain of corporate capital from the UK to other parts of the world, instead of supporting UK businesses. UK allocation of equities in pension funds has gone from 29% in 2006 to just 6.7% now. That matters – 10.9 million people are in these schemes and 60% of those are in UK companies with more than 10,000 people.

If the Government were to underwrite the industry's future liability (which could be as much as £450 billion) and pension trustees were to pool their funds in a wider, independently managed

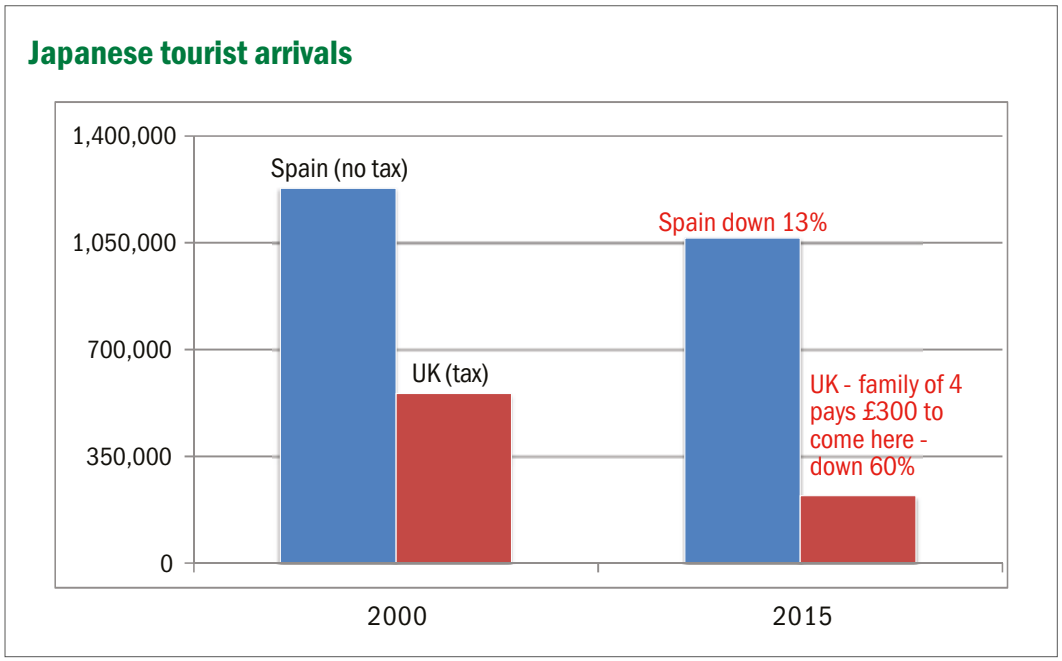

Figure 2. Intelligent fiscal policy

fund, this would unquestionably be one of the largest sovereign wealth funds in the world.

The Government could underpin an industrial strategy with an investment strategy for this fund. If a fraction of it were to be placed into patient capital funding of science research, innovation and translation, that could be a hugely game-changing move. □

Bridging the old divides

Anthony Lilley

SUMMARY

- Outdated science versus arts stereotypes are unhelpful in the 21st century.
- The creative industries employ large numbers of people and are a growth sector.
- Innovation in this sector has generated large amounts of income for the UK.
- Investment in the creative industries should not be dismissed as mere subsidy.
- Timescales in the Industrial Strategy do not reflect the realities of the creative industries.

Some 20 years ago, I founded what would be called today a digital media agency (although the term did not exist at the time). It aimed to be a fusion of content and digital technology. For most of that 20 year period I faced questions about what I actually was: a geek, or a 'luvvy'. People like stereotypes in this field. I see myself as in some sense sitting in between the two poles, trying to understand culture and human behaviour, usually in relation to media technology. I try to set up the conditions – financial, organisational, technological – for really creative people to create moments of enjoyment or learning or challenge. I do this in the commercial world and it makes money!

So in policy terms, I work in the creative industries. The dictionary definition is: "The industries have their origin in individual creativity, skill and talent and they have a potential for wealth and job creation through the generation and exploitation of intellectual property." It is not an exclusive definition, so actually it may be more interesting and helpful to describe the products, services, experiences and content that are created.

Within the creative industries are areas including advertising, architecture, art and antiques, crafts, design, fashion, film and video, interactive leisure software, music, performing arts, publishing, TV and radio. These are the 'sectors'.

The UK is pretty good at these – Gross Value Added from the creative industries was £84.1 billion in 2014 and it accounted for 5.2% of the UK economy. It is strange how difficult it is to get the

Anthony Lilley is Chief Executive and Chief Creative Officer at Magic Lantern. He is a media and arts producer, strategist and consultant. He has BAFTA, RTS and Peabody awards to his name. His credits include FourDocs for C4, Dr Who and Top Gear, as well as BBC and web, mobile, TV, games and strategy projects. From 2007-15, Anthony chaired Lighthouse, Brighton's digital culture agency. He is a member of the Arts and Humanities Research Council.

Policy makers seem to disbelieve their own numbers about the creative sector. I know of no other sector where official figures are given such scant regard.

Treasury and others to take these industries seriously. For four years running, creative industries have grown as a proportion of UK GVA. Creative industries GVA increased by 8.9% from 2013 to 2014. There are 1.8 million people employed – 30% are in London but there are 50 clusters around the country and exports are worth £18 billion.

It has been argued that the net value to the UK economy of the Harry Potter brand is as large as any single UK-developed pharmaceutical drug over the same period.

I spent quite a lot of time in the creative world building companies, while public policy roles have been partly sector-representational, partly regulatory – I was at Ofcom as a regulator and have just finished at the Gambling Commission where we ran the National Lottery. On the academic side, I have had visiting Chairs in Bournemouth and Oxford and now at Ulster: these all focus on the intersection between digital technology, culture, creativity and public policy. Today, I am a member of the Council of the AHRC. But most of the time, I have a 'real job' in the creative industries.

The Industrial Strategy

Looking at the proposals in the Green Paper, I welcome the new funding for research. However, I am very disappointed at some of the thinking about my sector, which typifies the split between manufacturing versus services that runs through the document.

The landscape that the strategy envisages is not something I recognise from the creative digital viewpoint, it has a very 'heavy industrial' feel. The mindset, which colleagues refer to as 'proper job syndrome', has its roots in a nonsensical cultural divide between arts and sciences which people in my industry just do not understand.

One very clear expression of that is the definition of R&D. Why? Because it excludes everything we do – everything that happens in arts and humanities and much of the social sciences (and therefore pretty much all of the creative industries) does not fit within the definition of R&D.

Subsidy or investment

The muddled thinking about the sector is particularly surprising and deeply disappointing. There is an unsophisticated understanding of the relationship between cultural subsidy and the creative industries. The creative industries policy of this country is not 'oh they want another theatre in Liverpool', that is really not what this is about.

In fact, all of the many hundreds of millions, possibly billions, of pounds that have come from the musical Les Miserables began with the subsidised Royal Shakespeare Company. The hundreds of millions of pounds to come from the musical Matilda also began with the RSC.

Innovation in the public cultural sector is regarded as the result of subsidy, instead of being thought of as investment. Now, that thinking is really behind the curve.

There is similar confusion about some of the beneficial taxation schemes and regulatory interventions that have happened in the sector. The 2003 *Communications Act* brought about a significant shift of rights ownership from UK broadcasters to UK production companies. That has created a billion pound a year export industry.

There is a paradoxical willingness to dismiss the social and cultural power of the creative industries in this country whilst extolling their soft power abroad. Neither do we appreciate the sector's contribution to cultural cohesion and diversity.

A matter of facts

Policy makers seem to disbelieve their own numbers about my sector. The figures for GVA come from the Department for Culture, Media and Sport (DCMS), but they are constantly challenged by policy makers themselves. So, improve the accuracy of the numbers, or explain why they are not credible. I know of no other sector where official figures are given such scant regard.

Another difficulty with the strategy is that the timescales do not make sense for my industry. The timescales used to measure success are too short – ridiculously so. It will take me two or three years to put on a show in the West End. It will take four or five years to put a film on a screen. Yet this Industrial Strategy will be done and dusted in that time, so there is a real mismatch.

Priorities

Skills are vital in my industry too. Creative, communicative individuals are needed here just as much in STEM subjects. Does anybody really believe in such exclusive silos? There are interesting policy discussions about how to think about robotics in the context of creative industries. I have recently finished a piece of consultancy work with Google on that topic. They are interested in those sorts of questions. Those skills are in new, emerging areas.

The research landscape needs to reflect the needs and opportunities our industries represent. I think the new Strategy Fund is a great opportunity to construct effective models of R&D between industry and the research base. I am hopeful of discovering powerful synergies with bodies like Innovate UK to push this forward.

It is also important to recognise the value of public investment in the sector. The BBC, the

Arts Council and others should be acknowledged as foundations for innovation. The University of Ulster is about to launch a Creative Industries Research and Impact Laboratory. This will examine the creative industries over a decade-long trajectory. Northern Ireland has already seen an enormous influx of creative industries investment. *Game of Thrones* is made in Belfast – the craft skills, the sets, the make-up, the costumes are all done there. There could be a very long-lasting benefit. In an economy the size of the Northern Irish economy, it represents an enormous net incoming benefit.

In the 21st century, conventional divides between sectors and skills will start to disappear and that will necessitate an understanding of what the humanities can bring to this computerised machine age. I like to think of myself as an anti-disciplinarian – somebody who thinks across sectors, not between sectors, but in spite of sectors. I am interested in the problems, the solutions and what happens to society and culture as a result.

The Industrial Strategy is silent on that way of thinking – I would not expect it to be otherwise, but I hope views that come from such perspectives will be listened to. ❐

The debate

There should be more effective regional investment in innovation, but competition between regional bodies needs to be avoided. National schemes of support, with national quality assurance but local implementation, should be considered.

Environmental concerns are not well covered in the Strategy, although one pillar focusses on energy and clean growth. During the Brexit negotiations, the Government will have important decisions to take on whether to retain all the current EU environmental regulation. The impact of these on economic growth needs further reflection. The Brexit negotiations will also need to look again at the current state aid regulations.

A Government approach based on giving business freedom to innovate, without increased regulation, has much to commend it but is not considered in the strategy. Singapore's system, for example, has less direct intervention by Ministers. Germany's success may be due to its commitments to continuity and stability. The US system of support for innovation through national laboratories, where priorities are not dictated by Ministers, also has much to commend it. If the research sector has the ability to pick research winners, then procurement certainly has a key role in pulling through the resulting innovation.

The development of Amazon and Uber, with their access to patient capital and breaking through traditional sectors, should make Government cautious of relying on a sectoral approach. Current debates about whether internet service providers should have responsibilities as publishers needs thoughtful legislative action.

There was support for broader pre-university education and for the breadth of studies in the International Baccalaureate. Giving as many university students as possible direct experience of industry would also be helpful. The apparent focus of the strategy on manufacturing sectors needed to be amended to recognise that 80% of the UK economy was now based on services. Traditional engineering skills need to be combined with an understanding of behaviour. Creative subjects at school develop resilience and self-reliance, which are vital to the modern economy. In a 50-year career, the ability to change pension arrangements mid-career so that a portion of the total pot could be used to retrain ought to be considered.

The building sector is not renowned for innovation and it is beset with low productivity. Advanced manufacturing techniques and digital technologies could transform the construction sector. Leading companies need encouragement to invest in this innovation.

The UK has to remain competitive in a global trading economy. There would be more chance of success with less bureaucracy. ❐

Issues covered in the debate after the main speeches included regional investment, the environment and the dangers of a sectoral approach.

FURTHER INFORMATION

***Building our Industrial Strategy*: green paper**
www.gov.uk/government/consultations/building-our-industrial-strategy

House of Lords Science Select Committee Industrial Strategy Inquiry
www.parliament.uk/business/committees/committees-a-z/lords-select/science-and-technology-committee/inquiries/parliament-2015/science-and-technology-and-the-industrial-strategy

House of Lords Select Committee on Science and Technology: *Letter to the Secretary of State for Business, Energy and Industrial Strategy*
www.parliament.uk/documents/lords-committees/science-technology/Industrial-strategy/2017-05-02-Industrial-strategy-ltr-to-BEIS-Secretary-of-state.pdf

Successive governments have argued that upgrading work skills is essential for increasing prosperity but the UK still lags behind other G7 countries. The challenge was debated at a meeting of the Foundation for Science and Technology on 1 March 2017.

Lifting skills to meet the needs of society and the economy

Mark Walport

Sir Mark Walport FRS FMedSci spoke in his capacity as the Chief Scientific Adviser to HM Government and Head of the Government Office for Science. Sir Mark is to become the Chief Executive of UK Research and Innovation. Previously, Sir Mark was Director of the Wellcome Trust. Before this he was Professor of Medicine and Head of the Division of Medicine at Imperial College London. He is Co-Chair of the Prime Minister's Council for Science and Technology and has been a member since 2004. In 2010 he undertook an independent review for the UK Government on secondary education: *Science and Mathematics: Secondary Education for the 21st Century*.

SUMMARY

- Government has been focussing a great deal of attention on the issue of skills
- There are significant regional disparities in skills levels and economic prosperity
- Employers need to be more engaged with education professionals to prepare young people for the world of work
- The experience of education as a child has implications for learning later in life
- The influence of parents' educational experience should not be under-estimated

Skills are ultimately acquired by a combination of education, training and practice. There has been a great deal of attention to skills: the Apprenticeship Levy comes into force in April; there is the Post-16 Skills Plan; and the Industrial Strategy highlights the issue very clearly indeed.

The Government Office for Science has been undertaking a piece of work within its Foresight programme on the topic of skills. The project identified five key issues:

1. High skills levels are not equally distributed around the country and there is a very important geographical link.
2. Skills are not always utilised in the most effective way, although perceptions differ about the 'appropriate skills' for particular jobs.
3. The UK does not do as well as it might in ensuring young people are 'work-ready'.
4. Many young adults have poor literacy and numeracy.
5. There has been a decline in the amount of lifelong learning people undertake.

Now, while diagnosis may be easier than determining the appropriate therapy, an ailment cannot be treated without that initial assessment.

Skills equilibria

Consider first the issue of skills equilibria. In a high-skills equilibrium there will be a combination of high supply and high demand. That results in high wages, high productivity jobs, people with high educationally-obtained skills, high employment and, if the situation truly is in equilibrium, balanced migration in and out. Obviously, that is a desirable state to be in.

On the other hand, in a low skills equilibrium, a vicious circle is created where low-wage jobs and low productivity are associated with a workforce that has low educational attainment and skills. That is very susceptible to the buffeting of economic cycles. Anyone in that environment who has a good level of skill will want to go somewhere better. That in turn creates skills gaps and shortages in one place and a skills surplus in others – in the latter case there are too many skilled people for low productivity jobs.

It is important to recognise the evidence of skills disparities across the UK and that is reflected in the economic state of different parts of the country.

Low skills equilibrium

Sectors in which a low skills equilibrium is particularly prominent include hospitality, retail and social care. Improved training standards and greater professional certification could be used to tackle this issue – and, to some extent, the apprentice programme is designed to do just that. Providing more support to less productive firms could help them get the most out of their employees and increase their skills.

Ensuring that employers have a central role in shaping training provision can help satisfy unmet development needs among staff. This has been demonstrated by the Scottish Care sector who engaged with the Open University in Scotland to

deliver a specially designed training module to up-skill supervisors within the social services workforce. As an outcome of the project, supervisors' skills and knowledge were better utilised in the workplace, leading to improved care and greater job satisfaction. The Post-16 Skills Plan also aims to join up prospective employers and education providers to ensure that technical education programmes reflect the needs of employers. In addition, the Apprenticeship Levy is designed to encourage employer investment in higher skills.

Under-utilisation

To a certain extent, the assessment of 'under-utilisation' lies in the eye of the beholder. Half of all UK graduates consider themselves to be over-qualified for the jobs they are doing, according to a study in 2012[1]. Sectors where such views are prevalent include hotels, construction and the extractive industries. This perception applies across a broad range of groups and neither ethnicity nor gender make any real difference. Part-time workers are more likely to describe themselves as underutilised.

Work-readiness

The other side of the coin is the employer's view of how prepared education leavers are for work. Perhaps not surprisingly, preparedness improves with the level of qualification. For people with degree level qualifications, employers rated 81% of university and HE leavers as well-prepared for work in a 2014 study[2] – although there were still 15% who were not, which is not a trivial number.

However, in the same research, employers only considered 53% of school leavers to be well-prepared against 42% who were not. 'Skills' in this context are not just literacy and numeracy but also socio-emotional abilities – turning up at work on time, being properly turned-out, being polite and communicative. Such skills are highly valued and important for employment.

Among the approaches that could be taken here is to promote and embed experience as part of educational courses. Employer-led initiatives that feed into the education environment could influence the preparation that education provides.

There is a double responsibility here – that of the education system to prepare youngsters for the workplace but equally an employer responsibility to work with the education system and communicate needs.

Whether looking at the world of work through the eyes of education providers or employers, the UK performs poorly in comparison with the USA, Germany, Mexico, etc (see Figure 1, page 18). In all cases though, education providers are more satisfied with their performance than employers are! Even so, in the UK only 61% of the education providers consider that they are preparing their students well and just 36% of employers agree, which is low in comparison with competitors.

In Greater London, more than 45% are offering work experience, yet there are other areas of the country where the figure falls to 30% and below.

Work experience

A 2014 UKCES survey[3] looked at the number of employers that offered work experience in the previous 12 months – it covered 10,000 employers. In Greater London, more than 45% are offering work experience, yet there are other areas of the country where the figure falls to 30% and below. Location plays a significant part in work experience opportunities.

Similarly, a consideration of the distribution of those students achieving five A* to C GCSEs, shows a high rate of more than 60% in the South East while significant parts of the country fail to achieve 53%. Overlay these results with the work experience results and there are close geographical correlations.

Levels of literacy and numeracy in the UK are also poor on international comparisons. Not only is the mean lower for both, but the spread between the best and the worse is dramatically greater in the UK than almost every other country in the OECD.

Adult learning

Then there is the decline in adult learning. A very significant fraction of adults – one-third – has not engaged in any form of learning since they left school. All the evidence indicates that strong education early in life is likely to be maintained through later years. Previously successful learners are much more motivated to continue.

Yet there has been a fall over many years in workplace training and in adults participating in FE and HE. Respondents cite logistical barriers and motivational barriers. However, comparing the reasons given by those with higher degree-level qualifications and those with no qualifications

A third of adults have not engaged in any learning since they left school. Previously successful learners are much more motivated to continue.

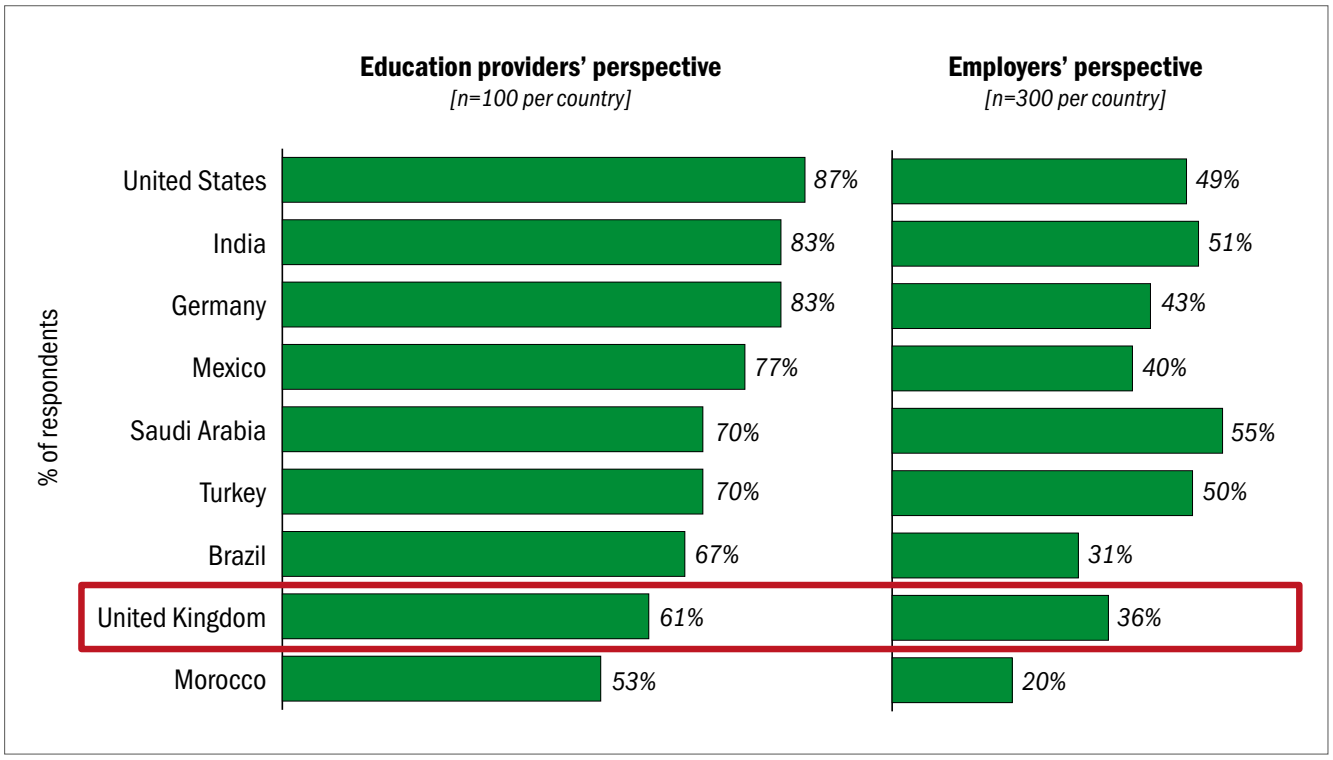

Figure 1. Perceptions of adequate preparedness of new hires/graduates (Barton *et al*, 2012[4])

is very revealing. Motivational barriers – 'I'm too old to learn', 'I lack confidence', 'I'm not interested in learning' – are dominant among people that do not have qualifications. This shows how the lack of early education in schools impacts later in life.

Is there any opportunity to address this through community and family-led programmes? Generational learning could be important. Adult learning – and the lack of it – remains a significant issue.

Current initiatives

There are a number of educational initiatives to increase maths education. There is much being done to develop the skills pipeline through apprenticeships and more technical approaches to education. And it is a very long pipeline.

One message is very clear: the education of one's parents really matters, so it is vital to find ways to support people and families where parents do not have advanced levels of education. The idea that the benefits of early education can somehow be compensated later in life is difficult, because the motivation to learn later depends critically on earlier life stages.

Part of the answer to the question 'How to switch the disengaged learner to an active learner?' involves stronger relationships between employers and the education system as a whole.

The idea that the benefits of early education can be compensated later in life is difficult.

Firms in the low equilibrium, low skill sectors must be encouraged to move up the skills/value chain. Employees who progress must be rewarded: making sure they have better jobs is a real reward for developing their skills and is one way of reaching families and communities.

Place is also very important to this – one size does not fit all for the whole of the United Kingdom.

The Industrial Strategy

The Government's Industrial Strategy sets skills as a very high national priority. There is no lack of political motivation to improve the skills situation and there are many initiatives: the challenge is to have the patience to see those through.

At the end of the day, skills are enormously important to the UK: they facilitate social mobility, inclusion and wellbeing. □

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2. UKCES, 2014 www.gov.uk/government/uploads/system/uploads/attachment_data/file/373769/14.11.11._EPS_2014_-_Main_Report_full_V2.pdf
3. UKCES, 2015 www.gov.uk/government/uploads/system/uploads/attachment_data/file/404997/15.02.18._Youth_report_V17.pdf
4. Barton, D., Farrell, D. & Mourshed, M., 2012. *Education to Employment: Designing a System that Works*, NY, USA: McKinsey&Company.

The fundamental role of mathematics

Adrian Smith

SUMMARY

- Almost three-quarters of 16 year-olds achieving A*–C at GCSE choose not to go further with mathematics.
- Gender, ethnicity and geography all influence participation in mathematics.
- A substantial element of mathematical studies will be delivered by FE colleges which are already under pressure for resources.
- Universities have an important role to play in supporting maths provision in schools and colleges.
- An horizon-scanning study is needed to determine the impact of new technology on mathematics education in the near to medium term.

In March 2016, I was asked to undertake, on behalf of HM Treasury and the Department for Education, a review of mathematics education for 16-18 year olds. The review was prompted by two related issues: first, the increasing importance of mathematical and quantitative skills to the future workforce; and second, the low percentage of students in England continuing mathematics post-16 in comparison with competitor economies.

The comparisons in Table 1 are quite stark. Almost three-quarters of students attaining A*-C in GCSE mathematics at age 16 choose not to study mathematics beyond this level.

Over and beyond the headline international comparisons, the UK also has significant gender and regional discrepancy issues. An exacerbating factor is the longstanding comparative national neglect of technical and vocational education.

In addition, I was asked to consider the case for (and feasibility of) all students continuing to study some form of mathematics until 18. In this context, mathematics is interpreted in its broadest sense, including basic quantitative skills, statistics and data analysis.

The review was structured under four broad headings:

- the appropriate range of 16-18 mathematics pathways;
- the factors that encourage or discourage participation by individuals;
- levels of attainment and progression;
- the capacity to deliver, both in terms of provision of courses and teaching capability.

Wider issues

Two wide policy issues have also emerged, which go beyond the narrow confines of 16-18 mathematics education, but which are crucial.

First, there is a need to pay closer attention to gender, regional, ethnic and institutional variations in provision and attainment, and to develop appropriate interventions. In mathematics, there is a significant gender gap in progression to AS/A level, despite good GCSE achievements by girls. In 2014-15, only 50% of girls with GCSE A grades continued to AS/A level compared to 71% of boys.

There are concerning differences between local areas in mathematics participation, which cannot be explained away by prior attainment. In 2014-15, London students who achieved A*-C were the most likely to carry on to Level 3 mathematics (33%) while students in the North East (20%) and Yorkshire & Humber (22%) were least likely.

These stark regional and sub-regional differences in attainment and participation in 16-18 mathematics require more targeted and intensive responses.

The Post-16 Skills Plan

The second major policy issue relates to the need to recognise more explicitly the fundamental importance of Further Education in the post-16 landscape. This was underlined by the publication (during the course of this review) of Lord Sainsbury's proposals for technical education.

Significant reforms to the technical education landscape were outlined in the Government's Post-16 Skills Plan in response to the Sainsbury report. Under the auspices of the newly created Institute for Apprenticeships, panels of industry professionals will determine the mathematical content of the 15 technical education routes, presented by Sainsbury, where these directly relate to occupational requirements.

Panels will need to ensure that this content reflects the needs of the profession, society and the

Professor Sir Adrian Smith FRS is Vice-Chancellor of the University of London. He is leading an inquiry into whether compulsory teaching of mathematics should continue through to age 18. Previously, Sir Adrian was Director General, Knowledge and Innovation in the Department for Business, Innovation and Skills (BIS). In 2003-04, he undertook an Inquiry into Post-14 Mathematics Education for the UK Secretary of State for Education and Skills.

Table 1. Proportion of students in post-16 (or 'upper secondary') education or training studying any mathematics, based on the 2010 Nuffield Foundation report[1]

Proportion	Country
All (95-100%)	Czech Republic, Estonia, Finland, Japan, Korea, Russia, Sweden, Taiwan
Most (81-94%)	Canada (BC), France, Germany, Hungary, Ireland, USA (Mass.)
Many (51-80%)	Australia (NSW), Netherlands, New Zealand, Singapore
Some (21-50%)	Hong Kong, Scotland, Spain
Few (6-20%)	England, Wales, Northern Ireland

emerging economy: this therefore needs appropriate mathematical education expertise. The bulk of this provision will have to be provided in FE Colleges. However, these are already stretched in terms of the resources for the teaching of mathematics, in part due to the Government's current GSCE resit policy. Since 2014, 16-18 year-olds without A*-C in GCSE mathematics have been required to continue studying the subject and most do so in FE colleges.

This is not only resource-intensive, but many respondents to the review questioned the effectiveness of the policy. They point to GCSE resit success rates continuing to be disappointingly low and the need instead to provide alternative, more meaningful pathways.

Level 3 mathematics

Encouraging students to choose Level 3 mathematics is critical. There remain significant challenges in getting adequate information to young people in order to properly inform their subject and life choices. Careers advice must make clear from the earliest stage the importance of mathematics to a wide range of future careers.

Yet schools and colleges are also heavily influenced by entry requirements set by universities. Higher Education has a role to play in overtly recognising the value of Level 3 mathematics qualifications for entry to those undergraduate courses with a significant quantitative element.

When establishing new schools, sponsoring existing schools or providing other support, universities should encourage mathematics, particularly in local areas where Level 3 participation and achievement is poor.

Funding

There are serious concerns regarding the funding models for schools and colleges. A combination of changes to A levels (the 'decoupling' of AS) and to funding (per student rather than per qualification) are combining to present serious risks to the provision of AS/A level Further Mathematics – a point made by a number of respondents to the review.

lf the number of Further Mathematics entrants from state schools were reduced, this could impact on their representation at research-intensive universities.

ln addition, core maths qualifications are always studied as an addition to a student's main programme. Yet, the current funding model does not incentivise core maths provision, despite widespread enthusiasm for this.

It is important for the Government to ensure that funding models for schools and colleges do not lead to unintended financial disincentives for mathematics provision.

Teaching capacity

Schools report significant challenges recruiting skilled mathematics teachers. The Department for Education is putting in place a range of additional measures to improve school teacher supply and quality. However, at the current time, the Department has only smaller-scale measures to improve both supply and the quality of existing teachers in FE to meet the challenges in the sector. This needs to be addressed.

Technology

Technology is already adding value to 16-18 teaching but there do not appear to be any widely-adopted technological solutions in regard to capacity-building for specialist teaching. As part of the strategy to increase and enhance mathematics teaching, a much-improved evidence base is needed on the role and effectiveness of technology.

Culture

Negative attitudes towards mathematics are a cause for concern. Gender has a heavy influence on mathematics participation, reflecting entrenched cultural attitudes. There is an urgent

Careers advice must make clear from the earliest stage the importance of mathematics to a wide range of future careers.

need to understand and address the cultural (and other) root causes of negative attitudes.

Longer term

The increasing sophistication of technology is driving change across the economy and changing the nature of work. This increases the demand for mathematics and quantitative skills, while also changing the nature of required skillsets, in particular those relating to the analysis and use of 'big data'.

We urgently need an horizon scanning study of the long-term educational implications of the rise of data science for both mathematics and quantitative skills. □

[1] Nuffield Foundation (2010) *Is the UK an outlier? An international comparison of upper secondary mathematics.* www.nuffieldfoundation.org/sites/default/files/files/Is%20the%20UK%20an%20Outlier_Nuffield%20Foundation_v_FINAL.pdf

The view from manufacturing industry

Judith Hackitt

SUMMARY

- There is a mismatch between education system provision and employer needs.
- The proportion of vacancies in manufacturing considered 'hard to fill' is rising.
- Apprenticeship should be accepted as equally valid and worthwhile to undergraduate studies.
- Manufacturers are looking abroad to fill vacancies but this may become more difficult after Brexit.
- The UK education system still fails to inspire young people to work in industry. That must not continue.

Industry continues to struggle to recruit sufficient suitable young people, with far too many lacking the skills that manufacturers need. While action has been taken to fill some gaps and avoid a crisis, it is a moot point whether there is a new crisis looming as Brexit approaches.

There is still a mismatch between the skills the education and training system is delivering and those that employers require. Far greater numbers of school leavers need to go into apprenticeships and there is an urgent requirement for a more integrated approach to skills.

It is well known that the UK has fallen behind many other nations in regard to productivity. Although manufacturing productivity growth has outperformed the UK economy as a whole, it does not fare well in comparison to other countries. Manufacturers are ambitious to change this and almost all business plans have productivity improvement embedded in them. However, productivity improvement requires two key things:

- continuous improvement, including developing the talent and skills of the workforce;
- investment which brings step changes in productivity through technological breakthrough and R&D.

Underpinning both is a significant increase in leadership and management and skills. Without these, productivity gains will not happen. Yet the skills gap is about much more than leaders and managers. There are clear gaps in skills across the board, including production-related technical skills, as well as craft and technician skills.

The proportion of vacancies in manufacturing which were considered 'hard to fill' in 2015 stood at 35%. It was the same in 2013 and has worsened significantly since 2011. The main reason was a lack of technical skills among applicants – a problem cited by 68% of survey respondents. Employers also report that applicants lack relevant experience.

Concerns about both the quality and quantity of candidates are leading to problems in recruitment in manufacturing.

Addressing the skills gaps

The UK has to close the productivity gap and compete globally in a fast-moving and technologically-driven era. This imperative drives the demand for specific skills and competences. A greater focus on IT skills reflects the expected growth in digital connectivity as industry transforms itself in today's fourth industrial revolution.

Three quarters of the companies surveyed were concerned about finding the skills their

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Manufacturers are continuing to invest in apprenticeships, and saw significant value in them even before the introduction of the Apprenticeship Levy

SHUTTERSTOCK / MONKEY BUSINESS IMAGES

businesses needed. This can often lead to begging, borrowing and stealing, with companies recruiting either from competitors or from their own supply chains.

However, industry recognises this is not someone else's problem. So, it is taking action itself. Manufacturers are continuing to invest in apprenticeships, they are increasing their training budgets and offering generous remuneration packages to attract and retain the right people when they can find them.

The majority of manufacturers saw significant value in apprenticeships even before the introduction of the Apprenticeship Levy. EEF owns and runs a centre for its members in Aston in Birmingham. Currently, there are close to 1,000 apprentices in training there, using state-of-the-art facilities. The number of well-equipped technical centres like this continues to grow.

The problem lies in finding sufficient young people to fill the opportunities available. In September 2016, EEF were only able to offer places to 330 apprentices. Some 8,500 applications had been received but far too many simply did not meet the required basic levels of Maths and English.

Apprenticeships

Apprenticeships make sense for manufacturers:

- apprentices learn about the company and acquire skills that are immediately relevant in the workplace;
- their time is split between learning and on-the-job experience which enables faster integration into the workforce;
- apprentices are much more likely to become full-time employees and to stay with their employer than those recruited through the inefficient and leaky pipeline of Higher Education graduates;
- the best apprentices go on to study for degrees based upon their strong foundation experience.

Manufacturers do not specifically favour vocational learners over more academic learners. The numbers planning to recruit apprentices and graduates are very similar. As the Apprenticeship Levy takes effect, though, it seems logical that more employers will focus their efforts on apprentices in an effort to claw back their payments.

Employers are struggling to recruit the right calibre of graduates. It may be that what is taught on many undergraduate courses is not keeping pace with industry expectations.

Perversely, the introduction of tuition fees has seen a significant increase in the take-up of engineering courses but this trend does not look likely to continue going forward.

Indeed, the number of 15-19 year-olds in the UK population is projected to fall from over 3.7 million in 2014 to around 3.5 million by 2019. Almost a quarter of manufacturing employers have recruited graduates from outside the EU in the past three years in an effort to fill the gaps. This is not an easy process and is set to become even harder after Brexit and the tightening of our borders.

A decline in the number of young people makes the challenge of encouraging more students to study STEM subjects (Science, Technology, Engineering and Mathematics) even more difficult. Even though young people must take Maths, English and Science GCSEs, they may not achieve the results needed. Almost half of young people do not achieve the required A*-C grades in

A decline in the number of young people makes the challenge of encouraging more students to study STEM subjects even more difficult.

English and Maths. At A-level, the story is even worse. The numbers studying Maths, Physics and Chemistry drop even further and there is a yawning gap between the numbers of men and women studying these key subjects.

Choosing a career

There is a strong case for much better careers advice in schools in order to encourage young people into STEM and thence to careers in industry. Careers advice typically comes too late to make a difference. It is offered to pupils at an age where they have already made subject choices. Much earlier intervention is needed and this should inspire and enthuse kids to see industry as it is today. They need to see that it is just as exciting and interesting as the games they play on their tablets and iPhones – history lessons about what a great engineer Brunel was will not do the job!

Then young people must be given a real choice, where apprenticeships are presented as a good and valid option which is in no way inferior to university. The evidence from industry is that industrial apprenticeships are an increasingly attractive and effective route into the sector; and it is high time this message was conveyed to young people, their teachers and their parents.

Outdated perceptions take time to change. The gender gap which persists in manufacturing amply demonstrates our failure to convince young women (and those who influence them) that they are welcome and valued.

When I decided to become an engineer more than 40 years ago, people around me thought it was odd and not something a girl should do. That this attitude continues in places today is sad and does not compare well with the progress made by other countries in addressing gender and diversity issues.

Is the UK's education system producing the skills our society needs? Of course it is – in many ways and in many areas. However, there are serious gaps in areas which will be even more essential to society and the UK economy post-Brexit.

Industrial strategy

The country has world-class universities, delivering outstanding research which is recognised the world over. We are known as a nation of innovators and inventors not just in the past but today, in the 21st century. Our ability to turn those talents into economic growth and prosperity requires a sound and robust industrial strategy.

One of the 10 pillars of the Government's recent Green Paper on this subject is about developing skills – building a proper system of technical education and boosting key skills in science and technology, engineering and maths, as well as digital proficiency: all aimed at meeting employer needs. Many of us believe this to be the single biggest challenge in delivering the Strategy. None of it can succeed unless we have the right people, in the right numbers, with the right skills, working together to create a thriving 21st century UK industry.

The renaissance of apprenticeships is great news. But to deliver the right skills for industry requires significant investment and funding. Apprenticeships must be of high quality, using up-to-date technologies and with trainers who have current industry knowledge and expertise.

FE colleges will struggle to deliver this requirement alongside the myriad other demands they face in a time of very tight funding. Institutes of technology sound like a good idea but they must be built on the model of what is already working, with considerable input from industry and they must continue to evolve as industry's needs change. They will also need considerably greater funding levels than those currently envisaged in the Industrial Strategy Green Paper if they are to have the needed impact.

The post-16 landscape

Lord Sainsbury's recommendations to simplify the landscape of post-16 skills form a vital piece of the jigsaw. Universities and the whole professional engineering system must also address some of the real issues:

- a shortage of people with the right skills to meet the needs of industry;
- the leakiness of the graduate pipeline and understanding the reasons for it;
- the lack of integration between vocational routes and Higher Education.

Industry, too, must do better in:

- articulating its needs;
- creating an inspiring and up-to-date image of industry in the 21st century;
- working coherently to inspire young people and those who influence them.

The most important message is that we all need to act. The time is fast approaching when recruitment of foreign workers is going to become more difficult, from both the EU and beyond.

We simply cannot continue to have half of our young people thinking that Engineering is not something that girls do. Neither can we afford for our young people to see Maths and Science as a burden rather than something exciting.

We are still failing to provide an education system which inspires young people for the role we need them to take in industry. That must not continue. □

The renaissance of apprenticeships is great news. But to deliver the right skills for industry requires significant investment and funding.

The debate

In a wide-ranging discussion following the formal presentations, a number of issues were raised and debated.

It was suggested that greater use of accreditation schemes and later re-registration of skills could increase the motivation for continued learning at all ages. Greater use of digital technology as a platform for learning would help students, teachers and families to improve their learning and skills.

Those retiring from a career in industry often have a lifetime of practical experience in their field. Perhaps some could be encouraged to become teachers and impart some of their knowledge to a new generation.

While three-quarters of the population does not achieve Level 2 Maths (A*-C GCSE) these skills are fundamental to the UK's ability to prosper in a post-Brexit world. Greater encouragement must be given at primary school stage to encourage the pursuit of mathematics learning by the young.

Most primary school teachers have a humanities, rather than a STEM, background. The teacher training system needs to address this and ensure they acquire the necessary science skills to teach and enthuse their pupils.

Tax incentives

A 'skills passport' might help to facilitate movement between professions and careers. One contribution to improved productivity could be a taxation system which incentivises investment in human assets as much as investment in physical assets.

It should be recognised that STEM does not exist in a bubble. Those studying these subjects also need to be equipped with literacy skills – and particularly the ability to communicate their learning. □

FURTHER INFORMATION

***Building Our Industrial Strategy*, Green Paper**
beisgovuk.citizenspace.com/strategy/industrial-strategy

Independent Panel Report on Technical Education (the Sainsbury report)
www.gov.uk/government/uploads/system/uploads/attachment_data/file/536046/Report_of_the_Independent_Panel_on_Technical_Education.pdf

The Government response to the Sainsbury report
www.gov.uk/government/publications/post-16-skills-plan-and-independent-report-on-technical-education

Government Office of Science Evidence Review for the Foresight Future of Skills & Lifelong Learning project
www.gov.uk/government/collections/future-of-skills-and-lifelong-learning

***The UK's Skills Mix: Current Trends and Future Needs*. Professor Mike Campbell, December 2016**
www.gov.uk/government/uploads/system/uploads/attachment_data/file/571675/ER5_The_UK_s_Skills_Mix_Current_Trends_and_Future_Needs.pdf

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***Making Mathematics Count*. The 2004 report of Professor Adrian Smith's Inquiry into Post-14 Mathematics Education**
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***The UK skills system: how aligned are public policy and employer views of training provision?* Anne Green and Terence Hogarth, August 2016**
www.gov.uk/government/uploads/system/uploads/attachment_data/file/571695/ER8_The_UK_skills_system_how_aligned_are_public_policy_and_employer_views_of_training_provision.pdf

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***Skills Demand, Training and Skills Mismatch: A Review of Key Concepts, Theory and Evidence*. Frances Green, August 2016**
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Review of Vocational Education: The Wolf Report
www.gov.uk/government/uploads/system/uploads/attachment_data/file/180504/DFE-00031-2011.pdf

Making a city a place where people want to live and work is a challenge for city managers. Science and engineering can contribute a great deal to its smooth running. A meeting of the Foundation for Science and Technology on 24 May 2017 looked at that contribution.

Taking a smart approach to 21st century infrastructure

Robert Mair

SUMMARY

- Smart cities need smart infrastructure to make them work.
- Much of our infrastructure is old and often has to accommodate different loadings today than when it was designed.
- Smart infrastructure can alert owners and operators about vulnerabilities before problems become critical.
- Continuous condition monitoring can enable a rational, risk-based approach to asset management of infrastructure throughout its lifetime.
- Innovative sensor technologies applied to advanced health monitoring can lead to considerable design and performance efficiencies for infrastructure.

People will have different views about what a smart city actually is. But ask what factors are important to make a smart city and the answers are likely to include: environment, health and wellbeing, culture, recreation, education, employment, energy, transportation and mobility, as well as infrastructure (physical and digital). The infrastructure is a very important part of what makes a smart city work. Smart infrastructure is really the interaction between physical and digital, so that it responds intelligently to changes in its environment, with the ability to influence and direct its own delivery, use, maintenance and support.

There are many challenges facing the infrastructure of our cities. First, there is its age – a great deal of the UK's infrastructure is very old. The loading it has to bear today is much changed from the days of its original Victorian engineering. It also has an uncertain future due to circumstances such as climate change. These challenges have implications for risk and resilience, for asset management and for design.

We should be aware of the vulnerability of city infrastructure. Burst water pipes, for example, are an increasing problem: large numbers of properties were flooded in Stoke Newington in London in 2016.

The Mississippi River Bridge in Minneapolis was a major steel bridge, built in 1967, carrying 140,000 vehicles every day. Yet 40 years later, on 1 August 2007, it collapsed with no warning. Over 100 cars were involved, many of them falling into the river, 13 people were killed and 145 injured. Particularly significant in the ensuing investigation was the evidence of a photograph taken four years earlier which showed deformed gusset plates. Nothing had been done though and that is, in part, the reason for the dramatic collapse. There are over 600,000 highway bridges in the USA, of which 180,000 are steel bridges; around 29,000 of these are deemed to be structurally deficient. In the UK, we have tens of thousands of bridges of many types. The problem is that we do not know their real condition or how fast they are deteriorating.

Vital data

Smart infrastructure would be able to communicate its physical condition at any point in time. Bridges will have sensors measuring all kinds of parameters as will our tunnels and buildings. These sensors will give the information that the managers of our cities and the owners of our infrastructure need. They will tell us exactly how all that infrastructure is performing. It will be health-monitoring of the physical environment.

In the Engineering Department at Cambridge, I lead the Centre for Smart Infrastructure and Construction (CSIC) and our mission is to transform the future of infrastructure through smarter innovation. The Centre is receiving about £22 million of funding over 10 years from the UK

Professor the Lord Mair CBE FRS FREng is the Sir Kirby Laing Professor of Civil Engineering and was Master of Jesus College in Cambridge. Before he was appointed to a Professorship at Cambridge in 1998 he worked in industry for 27 years, in 1983 founding the Geotechnical Consulting Group, an international consulting company based in London. In his career he has specialised principally in underground construction, providing advice on numerous projects worldwide. In the UK, he has been closely involved with the design and construction of the Jubilee Line Extension for London Underground, as well as the Channel Tunnel Rail Link (now HS1) and Crossrail projects. He is President-elect of the Institution of Civil Engineers and was appointed a crossbench peer in the House of Lords in 2015.

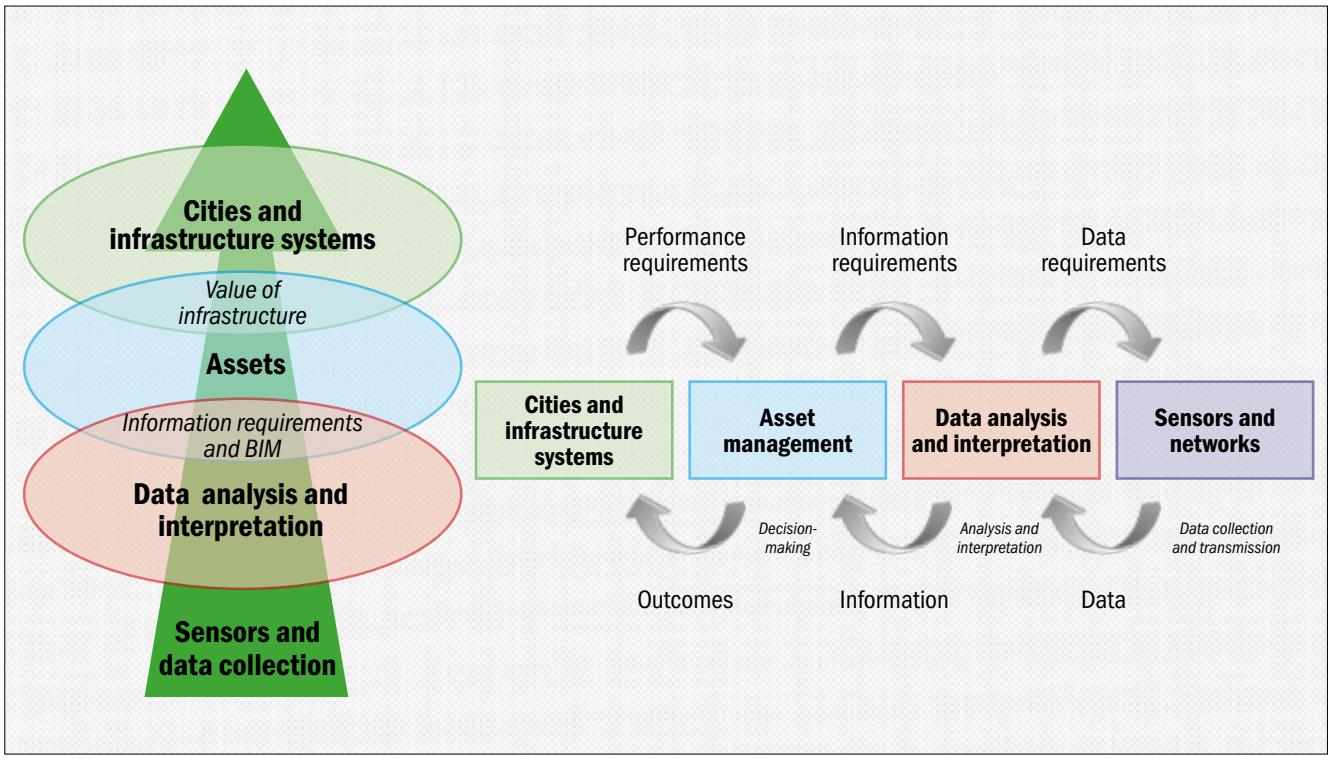

Figure 1. Four scales of challenge

Government - Innovate UK and EPSRC - and also, very significantly, from industry, including infrastructure owners and operators like London Underground, Transport for London and Network Rail.

We see four scales of challenge (see Figure 1, above). The sensors and data collection lead through to analysis and interpretation, enabling improved design, construction and management of infrastructure assets throughout operational life. This then leads to the wider city level with its infrastructure systems. All of these are dependent upon one another. All cities and all infrastructure systems have performance requirements which require management, being informed by data analysis and interpretation – and that is provided by sensors. All of this is underpinned by innovation in sensors and data interpretation.

CSIC is interested in modelling urban development, human interactions with infrastructure and whole-life value approaches to asset management. This is not just about building another piece of infrastructure but also providing smart information for asset management, design and construction. That allows performance to be tracked all the way through the life of the asset, indicating whether it needs to be repaired, maintained, or part of it replaced.

At the level of sensors, CSIC focuses on four areas: distributed fibre optic strain sensors; wireless sensor networks and MEMS devices; energy harvesting (i.e. sensors without batteries, that make use of vibrations on bridges or tunnels as their energy sources); and computer vision.

Fibre optic strain sensors

If light is passed along an optical fibre a very high proportion is transmitted through it, but a small proportion is back-scattered. There are several unique scattering signatures in the frequency spectrum of the back-scattered light (Raman and Brillouin). If the optical fibre is strained at a particular point, there is a shift in the signature. Effectively, the optical fibre becomes one continuous strain gauge – and a very cheap one. The fibre can be hundreds of metres long, even kilometres long, and we can see exactly how the strain is changing at any point along the length.

So, for example, in the Crossrail tunnels at Liverpool Street Station, optical fibre has been placed within the sprayed concrete linings to measure their performance and calibrate the design models – these platform tunnels are 11m in diameter. What was learnt from this fibre optic sensor system has immediate application in providing evidence for potential design changes in reducing the thickness of concrete around cross-passages between adjacent tunnels. This exercise has been

Optical fibre within the sprayed concrete linings of the Crossrail tunnels at Liverpool Street Station measures performance

very useful in making future construction much more economic while still being safe.

Elsewhere in London, there was some concern about sections of existing London Underground tunnel linings, specifically the movement and deformation of these linings. By installing fibre optics, a very comprehensive picture could be built up as to what is actually happening.

Bridges

Traditional asset management of bridges relies very heavily on visual observation data. So people have to abseil off bridges, or they might have to be lowered down the side of a bridge to inspect it. There might even have to be underwater inspections of some parts. Visual observation is the only way, currently, of inspecting bridges. Now, there are many opportunities for sensors to be used which would be much more quantitative, providing invaluable data.

Masonry bridges are particularly important here: there are about 18,000 bridges in the UK constructed of masonry in uncertain condition. There have been three incidents of masonry bridges collapsing in 2015 and 2016. In many cases the masonry is old, while axle loads on trains are typically two or three times what they were in the 19th century when those structures were built.

There is plenty of evidence of damage and so in many cities there are speed restrictions for railway bridges which result in service delays. In Leeds, for example, there is one masonry bridge which is quite substantially cracked. The combination of large cracks, evidence of settlement of the arch and the need for speed restriction focused attention on it.

Yet a combination of fibre optics and computer vision has shown very clearly that there is in fact no need for speed restrictions. That is a really important application of the way sensors can provide answers to decision makers, enabling a rational assessment of whether a piece of infrastructure is safe or instead needs to be closed down or repaired.

Sensor networks

Sensor networks have enormous potential, now that we are living in a wireless world. Today sensors can be placed in tunnels, or on a bridge, or on any piece of infrastructure, and these can be programmed to wake up, take a reading, transmit the data to the adjacent one in a sequence, all the way to a gateway which then goes into a mobile network and on to the internet.

So in a London Underground tunnel, for example, a number of sensors measure crack width and inclination, all placed in the tunnel with no wires. They can make measurements remotely and transmit those measurements from each of the sensors – this is attractive to the tunnel operators.

Smart infrastructure enables us to have a full understanding of the performance of our assets during construction and throughout their life.

Hammersmith Flyover is an interesting bridge. It was built in the 1960s and the papers at the time stated this "should not cost a halfpenny to maintain over the next 100 years". Just before the London Olympics a chance inspection inside a manhole cover revealed that 50% of the post-tensioning tendons had corroded away completely. The bridge was consequently shut for four months while repairs were carried out, causing considerable traffic congestion. It came at a very bad time with the Games just about to start. The bridge was subsequently equipped with wireless sensors – this is just the type of innovative sensing that can stop this kind of major disruption to city infrastructure.

MEMS sensors

Micro Electro Mechanical Systems (MEMS) sensors are essentially strain gauges that can be designed on chips. These are just a millimetre or two in size, but etched into the silicon. There is a huge potential for producing cheap and highly versatile strain gauges using this kind of technology.

One of our PhD students at Cambridge designed and developed a very neat little wireless sensor called the 'Utterberry', which can measure displacement, tilt, temperature, humidity and other parameters. She has won a number of innovation awards and her device is being deployed quite extensively on Crossrail and other projects. It only requires very small amounts of power.

In summary, there have been many recent innovations in sensor technologies and there are various sensor systems available today which can be easily installed in robust networks to give us the information we need. Sensors and smart infrastructure deliver value when they are exploited for managing assets throughout their life, whether they be roads, tunnels, bridges, sewers, flood defences or buildings.

Smart infrastructure enables us to have a full understanding of the performance of our assets both during construction and throughout their operational life. This gives greater efficiencies in design and performance, and facilitates rational strategies for whole life maintenance and asset management. There is huge potential here for city infrastructure, both old and new, and this will be of great benefit to its citizens. ❐

Engaging the citizen in policy making for cities

Tom Saunders

Tom Saunders is a principal researcher in the international innovation team at Nesta, the innovation foundation. His current work focuses on cities, with a particular focus on how cities can use digital technologies and data to address the challenges they face. He leads Nesta's research and engagement with China.

SUMMARY

- Data is part of policy making, but politics is the larger part
- Technology can promote bottom-up citizen engagement in decision making
- Start by identifying problems to be solved, not with trying to find a new application for a technology
- Opening up policy making could let to more and better ideas for urban living

Nesta focusses on social outcomes and social innovation. We think that the smart city has great potential to make urban living fairer, more democratic, healthier and also more fun. Often in debates about the smart city, it is quite a dreary discussion about problems. But we should not forget that cities are places of culture and opportunity, where technology has a role to play too.

Our own work on smart cities is concentrated on policy making. How can smarter use of data, people and technology improve the way that decisions are made in cities? Now there is a slightly dystopian idea of the smart city in which, with enough data, fast enough computers and powerful enough algorithms, decisions can be made without people. Actually, this is not a correct view of how policy making works. Data is part of policy making, but politics is a larger part. Resolving competing interests between the young and the old, new arrivals versus people who have been here for a long time, cyclists versus taxi drivers – there is no data and no technology which is going to give the correct answer on these issues!

Towards a collaborative city

Combining technology with citizen input and citizen engagement can, I believe, create this fairer, more collaborative city. Going through a number of examples around the world, the main thing to notice is that they are all very new. The iPhone is only 10 years old, so this is a new field where people are learning and experimenting.

Policy is often made by elites – in Whitehall or wherever it might be. It is important to recognise – and mitigate – the risk of missing the real issue that people face out there in a real city. In Seoul, there has recently been an initiative to establish a night bus service. Budget was very limited, so there was no possibility of replicating the daytime network. There are about 7,000 daytime services, but only budget for around 30 buses for the evenings.

So the bus company worked with a telecoms company to map the movements of people at night and then combine that with address data to work out where people were moving from and to. This was all anonymised. In fact, the new services cover about 50% of demand for evening transport with only 30 buses.

Passive engagement

Now that engagement is – from the citizens' point of view – quite passive as they do not need to do anything. In other mobile-based initiatives, citizens can actively engage. *Fix My Street* is a very simple idea for reporting problems and there are many similar apps available around the world now. The aim, though, is to allow city governments to become aware of issues that they might not normally find out about. Of course, without a mobile phone it might be difficult to participate at all, but it is an interesting start.

In Indonesia, Twitter data is being used to map flooding. This only works in areas where a lot of people are tweeting about this (so it would not work in London, for example), but in Jakarta many people die every year due to flooding. With thousands and thousands of tweets, researchers have been able to create a map of the city using the social media data. They have added actual sensors as well and the map is now in real time. Previously, it took about six hours to update, based on traditional methods of flood officers going out around the city and checking the weather. It is a very interesting blended use of sensors and data from people.

Open innovation

The idea of 'open innovation' is that the best ideas are not in R&D departments but are out in society with some start-up or some researcher. Yet Gov-

ernment still clings to the idea that it alone has the best ideas for policies. Opening up policy making could potentially lead to much better ideas about how we should manage our cities.

One approach is the crowd-sourcing of ideas from citizens for developments in cities. However, ask individuals what they want and they are likely to focus on their personal needs which is not necessarily the best thing for the community. Much better ideas arise through deliberation and there are now a number of platforms which allow citizens to come together, debate and deliberate on what they wish to see built in their city. *Better Reykjavik* is a simple website with a debate forum where people can propose ideas. Other contributors can vote on these and the most popular go to the city council who then discuss and decide on them. These may be about quite simple projects around parks and suchlike, but it demonstrates the principle that citizens can come up with intelligent ideas which the council can then act upon.

There are also many technologies available to engage a much wider pool of experts and expertise. So instead of just having an expert roundtable in a particular location, it is possible to engage experts in any particular field from across the world to help come up with an answer.

Decision making

All these apps and platforms allow citizens to debate and contribute, but ultimately someone in the city government makes the decision about whether a particular course of action is feasible or not. However, there are now experiments in which can be termed 'participatory budgeting', essentially delegating decision making authority to citizens.

Paris has a fund of about €500 million to be spent over five years on ideas that come from citizens. In one sense it is similar to Better Reykjavik and similar initiatives, but the key thing is that it has a budget attached. This is important. City councils often complain that citizens are not engaging. But why should they spend their time going to meetings or coming up with ideas if in all likelihood they are going to be ignored? Participatory budgeting and similar approaches are very good ways of motivating citizens to engage but for councils it means a different way of working.

Then there is the question of oversight – letting citizens monitor programmes. Now why would a city want to do that? Well, one reason is that it has been found to increase acceptance of decisions. Lewisham Council had to cut large sums of money from their budget and the people who live there obviously were not happy. So the council created a game: how would you spend our budget if you had this money? The aim was to increase acceptance of the difficult situation that many cities are now in regarding budgets. Helsinki has a very simple smartphone/computer interface where people can search council decisions, sign up to different debates, or go online and debate with fellow citizens.

Table 1: Informing policy – six lessons

1 Start with a problem, not a technology project
2 Build on existing knowledge and share evidence
3 Open up the innovation process
4 Keep it simple
5 Invest in smart people
6 Remember, there is a world beyond the internet

Emerging science of collaboration

All of these examples are very new. This is an emerging science of collaboration with citizens through technology. There is a lot to learn. What is needed here is a spirit of experimentation among policy makers. As part of a big £10 million internet of things programme, for example, it might be worth considering a citizen engagement aspect to pilot some of these new ideas to help solve some of the huge urban issues facing society.

In our report *Governing with Collective Intelligence*[1], Nesta came up with six lessons that we think any city government trying to support and promote this approach should follow (see Table 1, above). Too often, the debate on smart cities revolves around: "Here's a piece of tech, what can you do with it?" There really needs to be more bottom-up thinking to, first, identify a problem and then, if technology is indeed needed to solve it, identify that technology.

With smartphone apps and data sources and devices there has to be someone using them. So, we think that it is important to include training in any smart cities programme – what is data, how to use it, what does it mean. This can help governments take ownership of decision making, without having to rely on external data experts to interpret the data and make the decisions on their behalf. □

1. www.nesta.org.uk/publications/governing-collective-intelligence

There are now a number of platforms which allow citizens to come together, debate and deliberate on what they wish to see built in their city.

The smart city as a place for communities to thrive

Peter Marland

Councillor Peter Marland is Leader of Milton Keynes Council. He initiated the innovative MK Futures 2050 Commission and helped develop the concept of MK:IT, a university for Milton Keynes based on developing skills and employment around knowledge intensive industry. He is a Board Member of Milton Keynes Development Partnership, the South East Midlands Enterprise Partnership and MK Gallery. He helped establish the Fast Growing Cities Group of local authorities including Oxford and Cambridge, and is a member of the Resources Board of the Local Government Association.

SUMMARY

- To thrive, cities have to focus on their culture, remaining relevant and resilient.
- By 2050, 70% of the global population will live in cities.
- Cities will have to become much better at the efficient use of resources.
- Smart cities will be those that change their inhabitants' lives for the better.
- Smart cities will be places designed for people, not just to showcase the latest infrastructure and technologies.

Milton Keynes is "different by design, loved by its population and admired by others. Known as a place of learning and innovation with fantastic green space, MK is a place where they just get it right for people, innovation and entrepreneurs." That is taken from our recently published *MK Futures 2050* document – that is the vision of the city we want to create for Milton Keynes by 2050, as a result of a commission set up with the help of the Vice-Chancellor of Cranfield University Sir Peter Gregson. Nowhere does it mention grid roads, nowhere does it mention roundabouts or what type of buildings there are. Instead, it mentions people and it talks about what it is to be a city.

Milton Keynes was a collection of 13 villages in 1967 – we are celebrating our 50th birthday this year. It had a population of about 40,000 people then. This year, we are approaching 300,000 people and by 2050 we will be 500,000 people.

It is currently the biggest city between London and Birmingham. We are bigger than Oxford, Cambridge, Reading or Peterborough. Milton Keynes is a big city, yet people still think of us in terms of concrete cows and roundabouts – we are so much more than that.

But I would not want to follow the path of places like Crewe. Crewe had connectivity; it was ideally placed between Manchester and Liverpool (as Milton Keynes is between London and Birmingham). However, when the industrial activity of Manchester and Liverpool – and the relationship between them – changed, Crewe was not needed in the same way and it lost the role it once had.

When I became leader of the council, I was absolutely determined to make sure that something similar did not happen to Milton Keynes. That's why I set up the commission.

What should a city want and aspire to in 2050? To me it is simple, it is about culture, about being relevant and resilient. London is the greatest city in the world, but it is not the city the Romans founded, it is not the city of King Charles II when he set up the Royal Society and the Royal Academy.

Cities change and innovate and adapt and I want to make sure Milton Keynes changes and innovates and adapts. Some 60% of our jobs are in danger of being automated in the next 20 years: these are not blue collar manual jobs, but doctors, lawyers, jobs that command over £100,000 annual salary.

Milton Keynes did not have an elderly population 15 years ago because so many moved in during the 70s and 80s. So these people are all getting old at exactly the same time. However, this year there were twice as many children in the first year of nursery as there are leaving secondary school. We build 1% of the total housing output of the UK – 1,750 houses a year – and there are much heavier traffic flows. We need more resources. Yet, for a city that was built only 50 years ago, we also have areas of deprivation.

There are also global challenges. By 2050 there will be 10 billion people on this planet. 70% will live in cities. Yet, there will not be 40% more resources. Our power usage every decade is going up by 50% - there will not be 200% more electricity in that time, so the challenge is to harvest our resources better, while making cities absolutely places where people want to live.

The future

So, what are we doing in Milton Keynes? I am quite clear we need a city of young entrepreneurs and educated people. As part of that we need an undergraduate university (we do not have one at the moment), because if the future is built on anything, it is built on entrepreneurs.

We have a 'Living Streets' project where we close streets to traffic to make streets liveable

EVERYMAN FILMS (EVERYMAN FILMS)

One of the electric buses in Arriva's fleet in Milton Keynes

again. We are deploying sensors in every single car parking space to make sure that in every one of our 22,000 car parking spaces people know where they are. The city has the world's first commercial electric bus service.

Among our community projects is one called MK:SMART[1]. Every bit of data from most of the services in Milton Keynes is placed into an open data platform run by the Open University, BT and other collaborators. It allows citizens, who can be private individuals or entrepreneurs, to go in, look at the data and propose (sometimes disruptive) ways of improving things. That is a challenge for a politician, who may be used to telling people "I have all the answers, vote for me."

I believe a great deal of the technology we are currently producing is just managing the way we do things now. We need to be looking to the future, but in a smart way.

I know a city that spent a great deal of money buying bin compactors, allowing twice the amount of rubbish to be put in each bin. Unfortunately, the bin was then twice as heavy. So, while they had ensured that they could reduce collections to once a fortnight, they then needed two men to do those collections because the bins were so heavy – or else they would have to buy a really expensive machine to empty them. Yet, no-one asked why there was so much rubbish in that bin in the first place. No-one asked "How can we make sure that there is less rubbish for collection?"

Smart cities are ones that can transform services that manage current demand into ones that change people's lives. How can we, instead of spending lots of money in the NHS on hip or knee operations, use technology to inform a 20 year old that the way they walk could mean by age 60 they have a hip problem? The technology exists and we can use it to save a lot of money down the line: we just have to shift the spend from managing failure to preventative services.

Changing behaviours

We have to change behaviours. We have to get citizens involved in the way that decisions are made. We live in an era of Facebook and Twitter and instant feedback. That feedback is often quite negative, but some of that is concerned with my performance as council leader: "Why is my street dirty? Why is this or that service being cut?" My challenge back is: "What are you doing to fix it as a citizen – as a citizen of your street, as a member of your community? What are you doing, because I don't have the money to do it?"

Technology is dumb, people are smart. As a leader you have to trust people and their communities. I think we need to make smart cities, not technological cities. We have to make communities, not places, and we have to make real cities that are for people, not for big items of infrastructure. □

[1] www.mksmart.org

I know a city that spent a great deal of money buying bin compactors. No-one asked why there was so much rubbish in that bin in the first place.

The debate

Issues raised by the audience included: air quality, climate change, planning powers and the role of universities.

Earth observation data from satellites is already saving money for councils in their enforcement of permitted planning developments. China is leading innovation in monitoring air quality data via mobile devices. By contrast, London is a long way behind in installing widespread air quality sensors.

The most successful cities are inexorably drawing in more people. Shifting people to other cities would be challenging. The rapid decline of Rome at the end of the Roman Empire shows that people only stay for good reasons. Greater online working from home could disrupt city growth significantly.

Climate change

Some substantial world cities face great challenges from climate change. It can create significant issues for some physical infrastructure, but is slipping from the political agenda in the UK. Citizen feedback might halt such decline, particularly in some cities. There are still substantial benefits to be secured for citizens through energy efficiency investment.

MERLION444

Singapore: a long-term approach to planning

Inevitably there are risks with dependence on technology, as the recent global problems with ransomware have shown. Results of pilot studies undertaken by city authorities must be made openly available. The reliability and security of data are very important, particularly in areas of critical infrastructure such as nuclear power stations.

Inclusive growth, based on use of technologies, is an important consideration for smart cities. Inclusivity means incorporating the perspectives of those not using the internet, for example through community meetings.

Implementing city visions is much harder when planning powers remain highly centralised. A potential benefit of Brexit may be that procurement frameworks for cities move away from simple best economic value to allow more consideration of tenders with social benefits.

Universities can generate substantial benefits to the cities in which they are located, because they attract talented researchers from around the world and their families. They are also likely to generate innovative use of technology locally.

Some participants highlighted the long term perspective inherent in Singapore's approach to planning. This was linked to skills: from primary school on, education in digital technologies is promoted.

Technology has great potential for monitoring the physical infrastructure on which smart cities depend. Citizens should be fully involved in how technology should be applied. ❐

FURTHER INFORMATION

Forum for the future: future cities dialogue
www.forumforthefuture.org/project/future-cities-dialogue/overview

Government Office of Science – Future of Cities Report
www.gov.uk/government/collections/future-of-cities

Government Office for Science – Future Cities: foresight for cities
www.gov.uk/government/publications/future-of-cities-foresight-for-cities

Milton Keynes Futures:2050
www.mkfutures2050.com

NESTA – Governing with Collective Intelligence
www.nesta.org.uk/sites/default/files/governing_with_collective_intelligence.pdf

NESTA - Rethinking Smart Cities from The Ground Up
www.nesta.org.uk/sites/default/files/rethinking_smart_cities_from_the_ground_up_2015.pdf

University of Reading report for RICS Research Trust on Big Data and Smart Cities
www.rics.org/uk/knowledge/research/research-reports/smart-cities-big-data-and-the-built-environment-whats-required

University of Reading paper on smart and sustainable cities
www.reading.ac.uk/web/files/cme/cme-Dixon_SCME_big_data_paper_AS_v_11_WEB_(1).pdf

A special meeting of the Foundation for Science and Technology, held at the Royal Society on 21 June 2017, considered the effects of demographics and medical trends on the UK health and social care systems.

The challenges facing the UK's health and social care systems

Chris Whitty

SUMMARY

- The number of older people in our society is set to increase substantially but the majority of the population will continue to be of working age – and healthier.
- Most countries in the world are converging in terms of life expectancy and healthcare demands.
- Medicine has been responsible for real and remarkable advances in health across the globe, but this means the demand for medical, nursing and social care will rise everywhere. Supply of health and social care workers is probably rising less rapidly.
- Internal migration in the UK will mean a shift towards increased healthcare demand in suburban and rural communities.
- Rises in costs for healthcare (both of medicines and treatment) are not primarily driven by demographic change.

The data I am using are uncontroversial in the sense that they come from widely accepted and respectable sources. They are mainly Office of National Statistics (ONS) data, World Health Organisation (WHO) data, UN data or trustworthy major charity data. How they are interpreted is a slightly different question.

Table 1 (see page 40) gives ONS projections of where we are roughly now and then where we will be in 2039. These projections can be read in two ways – both are correct. The first is that the number of people who are elderly is going to roughly double. This is going to be a significant challenge for the health and care services.

An alternative view is that, even projecting forward to 2039, the great majority of people will be in younger, employed periods of life and most of them will be healthier than they are now.

Both statements are correct and they need to be balanced against each another.

The progress of medicine

One lesson of recent history is that medicine genuinely has progressed – everywhere. In 1910, just over 100 years ago, virtually every country in the world had an average mortality of somewhere between 20 and 40 years. The richest countries of the world had a mortality rate of around 55.

Project forward to 1948 and the demographic that the NHS was set up to deal with. At this point, in the UK and the USA average mortality had risen to the late 60s. Most countries in the world were still down in the 40s.

The extraordinary thing that has happened since is that, not only has every country got better, but there is a grand convergence towards a similar age of mortality. Even the poorest countries in the world with the weakest health services have a better life expectancy than the richest countries had 100 years ago. The average life expectancy in most of Africa is better than the UK had when the NHS was formed – that is an astonishing achievement.

Medicine genuinely does progress – the world is getting healthier. There is some debate about what the average age of death will be in 40 years but most people think it will probably be somewhere in the 80s.

Healthcare workers

Why is that important? Well, as a start health care and social care are tradeable assets. To have a medical degree, to have a nursing qualification or to be prepared to care for elderly, frail people with dementia is an asset which you can trade anywhere.

In most countries of the world, the need for healthcare will increase and the proportion of younger people will start shrinking. This means a massively increased need for doctors, nurses and care staff. There will be more global wealth to pay

Professor Chris Whitty CB FMedSci is Chief Scientific Adviser at the Department of Health and Deputy Government Chief Scientific Adviser. He is an epidemiologist and physician. He is also the Professor of Public and International Health at the London School of Hygiene & Tropical Medicine and a Consultant Physician in acute medicine and infectious diseases at University College London Hospitals and the Hospital for Tropical Diseases. He was previously Chief Scientific Adviser and Director of Research & Evidence at the Department for International Development.

Table 1. Population projections (millions) for the UK (Source: ONS)

Age	2019	2039
0-14	12.0	12.4
15-29	12.4	13.5
30-39	12.9	13.2
40-59	13.4	13.4
60-74	10.4	12.0
75-84	4.1	6.3
85+	1.7	3.7

for them, but probably around the world not enough health workers are being trained currently.

The UK is below the replacement level of fertility now, but only just. Most countries in Europe, though, are well below: 2.1 is the level needed to keep the population stable – many countries in Europe have a fertility rate of 1.5 or lower.

Looking back to 1985, the UK was almost the oldest country in Europe. Project forward a couple of decades and we will become one of the youngest. In Germany, for example, a large section of the population is currently aged between 40-70. All of these people are going to retire in quick succession. Germany is due to hit a demographic wall in about 15 years. For most other countries in Europe other than Germany, this event is a further decade away but still inevitable.

It takes about 20 years to train a consultant from the time they enter medical school, so the people who should be leading us through this phenomenal challenge for our continent should be entering medical school now – but they are not, at least not in sufficient numbers.

The challenge for the UK is that it has always been able to rely on importing healthcare workers – both highly trained and unskilled – into our system. Yet a massive increase in demand everywhere is coinciding with a much slower increase in supply. The result will probably be that the cost of healthcare labour goes up, there will be shortages or quality will go down – that is inevitable unless we plan ahead.

Internal migration

People worry a great deal about external migration, but this is much less important than internal migration for future health services. In our country, people go to the cities in their late teens or early 20s. They stay there until, usually, they have their second child, at which point they move out. The cycle then repeats. This creates the situation of a young city maintaining its demographic profile.

As a result, suburban and rural areas are going to age much faster over time than the averages would suggest. Take Lambeth in London: the demographic profile in 2037 will be almost identical to what it is now, but therefore – as the national average changes – places like Norfolk and Devon are going to get very old, very quickly.

This internal migration is going to make the demographic challenge harder. It is already difficult to deliver healthcare in rural areas and the problem is set to increase. At the same time, the number of people of working age in these parts of the country will diminish, so the age-support ratio will get worse. This is not just a medical challenge but especially one of social care.

Mortality and cardio-vascular disease

Even over the last 15 years – quite a short period – a substantial improvement in mortality has occurred across the entire country. This is reducing some of the disparities in health provision.

Very few people outside of medicine appreciate the astonishing reduction in cardio-vascular disease over the last 40 years. Mortality in men and women has begun to converge, largely because of changes in smoking habits, but also because of very big changes in the incidence of cardio-vascular disease, stroke and heart disease.

Take stroke. Until recently, this was considered a disease about which we could do little. Yet the incidence of stroke has decreased steadily, by 19% for example from 1990 to 2010. Mortality rates for this period decreased by 46%. While this is undoubtedly good news on both counts, it does mean that the number of people living with a stroke has therefore gone up and is not evenly distributed.

Look back to 1985, the UK was the oldest country in Europe. Project forward a couple of decades and we will become one of the youngest.

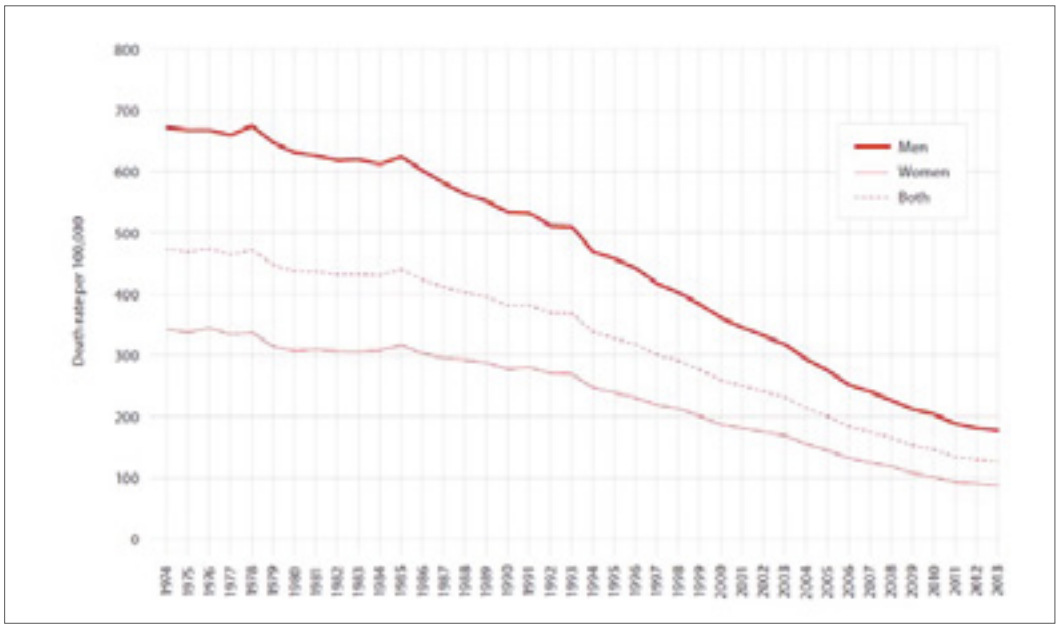

Figure 1: Age-standardised coronary heart disease mortality rates, UK 1974-2013. 73% reduction overall, 81% reduction on those under 75 years. (Source: BHF)

Look at London. Young people tend to live in the centre and they do not often have strokes. Older people live around the outside and, in fact, incidence goes up with distance from the centre. Our specialist stroke units are often in the city centres – that probably needs a rethink.

Interestingly and importantly, because age is increasingly the dominant risk factor for most of these conditions, the relative importance of socio-economic status is decreasing: that is not because the differences are getting smaller, it is a fact of biology. This has been accompanied by some really quite profound changes in the delivery of care. The rate of cardiac surgery has decreased over a long period of time. The number of people having angioplasty on the other hand has steadily increased, because this procedure is cheaper and above all safer.

So, cardio-vascular disease is no longer the most important cause of mortality. Treatments are getting cheaper and better. More people survive attacks and life is better for those recovering from a heart attack or a stroke.

Other conditions

On the other hand, projections for dementia are going up, not because there is more dementia but because people are not dying of other things. Dementia is an increasing (epidemiological) burden: it is going steadily to increase until there is a significant change in the science, for which there is currently no evidence.

An important paper last year suggested that while the total number of cases is going up, the rate of new cases looks to be going down. Now this is only one study but if the findings were to be replicated in other research, it represents good news – but only for half the population. It suggests that all of that advantage is in men and there is no improvement in women.

This may lead to quite a significant shift in the geography of ill-health in the UK – we are seeing a decrease in the geography of ill-health dominated by smoking and therefore cardio-vascular disease, but an increase in ill-health due to frailty and dementia.

There will be a shift in demand from urban to rural and there will be a shift between different areas of the UK as a result of medical advances. There will also be significant changes in the need for different skill sets in the medical population.

Traditionally, cancer has been another big killer. Overall, we have moved from a situation where three-quarters of sufferers died within 10 years to one where now only one-half will die and improvements are continuing steadily.

The pace of change and new challenges

Many scientists believe advances happen by way of a breakthrough followed by a permanent step change in health. This is not true. All of these improvements discussed have been made up of multiple very small advances, rolled out in relatively gradual ways, meaning that improvements happen in a fairly predictable steady way. It is therefore possible to predict survival rates for different cancers into the future.

While recent advances are very good news in

There will be a shift in demand from urban to rural and there will be a shift between different areas of the UK as a result of medical advances.

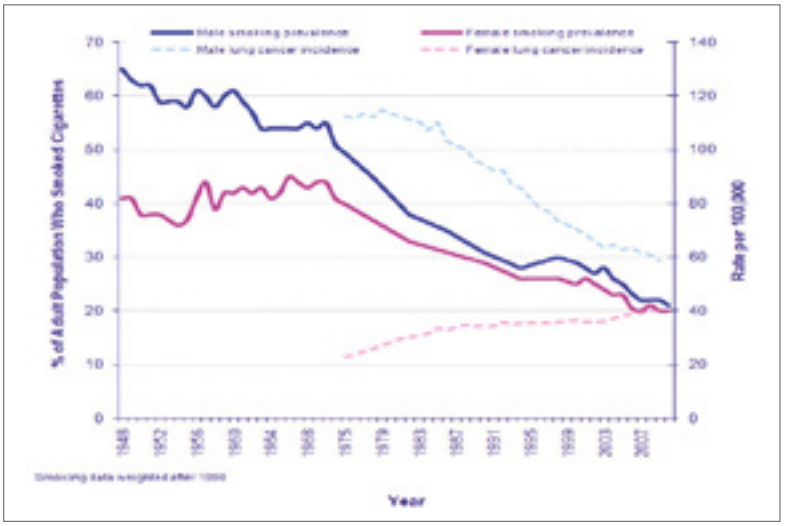

Figure 2: UK smoking and lung cancer rates. There will be a roughly 20 year lag.

terms of treatment, they come at a cost. Most of the drugs being put onto the market are still on patent. A few drug companies increase their costs of drugs by roughly 10% twice a year and the market bears that; in some instances, the prices are even steeper. This is a significant policy issue.

There are also areas where new challenges have arisen. The UK is typical of industrialised countries (probably towards the leading edge, sadly), with male obesity rising from 13% to 26% of men over a decade. NOx air pollution was not predicted a decade ago – so there are, from time to time, unexpected challenges emerging.

Prevention

Another major issue which has emerged over recent years is the onset of Anti-Microbial Resistance (AMR). Here, too, the statistics show an encouraging story. Recent data for UK smoking showed yet another drop, down to just over 15% of the population – an astonishing improvement. Health gains from this in terms of cardio-vascular disease come through relatively quickly. Cancer gains come roughly 20 years after. The lung cancer rates for 20 years hence can be predicted on the basis of smoking rates – and they will be decreasing.

There are some cancers which the Government has been able to affect through the introduction of clear public health measures. The UK has stopped using asbestos in buildings. While we were using it, mesothelium, a cancer which almost exclusively affects people exposed to asbestos, steadily increased. Now we have stopped using it, the rate will progressively drop to virtually zero.

In every aspect of our healthcare system, the demand for services is going up at a rate higher than would be predictable by demography alone.

There is currently a vaccine in the UK that reduces the incidence of cervical cancer by roughly 50%. A further vaccine already available in some countries will reduce it by about 95%. Add screening to that and hardly anyone will contract the disease in 20-30 years' time.

New issues

At this point in time, for every two years of life gained through better healthcare, only one is healthy life. That second, unhealthy year will require care or medicine, or both. This will lead to a significant challenge unless we reconsider the current focussing of medicine on mortality.

In addition, an increasing proportion of the population who are ill have multiple, apparently unrelated illnesses. However, the current medical system has increasingly moved towards specialisation. The NICE system (National Institute for Health and Care Excellence) is based on the concept of treating a single disease pathway. There is a mismatch here between an increasingly stove-piped care system and increasing multi-morbidity which needs to be addressed.

Total per capita spend on healthcare has steadily increased in the UK. Now, there is a widely-held belief that this is being driven mainly by demography – which is wrong. The Office of Budget Responsibility (OBR), in its 2007 Fiscal Sustainability Report, said: "In the UK, public spending on health has increased by 3.8% a year on average in real terms since 1978-79. The economy has grown by an average of just 2.2 % a year." It added: "Demographic effects have explained only a small part of the increase" which, having looked at the data in some detail, is in my view correct.

There is no doubt that most healthcare costs tend to occur towards the end of life, but whenever you die the majority of your care will be in the last six months. In every aspect of our healthcare system, the demand for services is going up at a rate higher than would be predictable by demography alone – even under the most pessimistic scenarios. This is the OBR's view.

As another example of the non-demographic nature of healthcare demand, look at outpatient attendances. In the UK, this is going up at between 5-7% a year. The rate of increase is just as fast in 20-59 year olds (who are healthier than their equivalents 20 years ago) as it is in people of 60-79. So to argue that this is driven by age simply does not hold water. There is a big increase, but it is not driven primarily by demographics.

Global demographic shifts will have implications for healthcare workers, social care workers and industry, and these impacts have not fully been internalised by policy makers. Internal

migration is very important and, in my view, much more important than external migration, but tends to be overlooked – particularly the profound shift towards rural care which is much more difficult to deliver.

There are major shifts in the relative importance and geography of diseases due to medical advances which, in my view, are largely predictable based on current, steady trends. It should be possible to identify where healthcare pressures are going either to increase or decrease based on trends – this does not require any speculation about future science. Future science may change this, but current trends are largely predictable.

Scientific advances absolutely improve health and I am passionately committed to maintaining that, but we must also be honest and admit that this will also increase costs. Science does actually buy you something – and that is better health for your money.

Science does actually buy you something – and that is better health for your money.

The impact of demography on health will be real but, relative to many other factors, will be much smaller than is popularly imagined. The combined challenges of aging, internal migration and multi-morbid frailty pose a very serious social care challenge in addition to the healthcare challenge. ❐

After the lecture by Professor Whitty, there were two formal responses before the audience were invited to contribute. The two responses were from Sir Robert Lechler and Professor Marcel Levi.

Addressing the challenges to health and social care

Robert Lechler

Sir Robert Lechler is President of the Academy of Medical Sciences. He is currently also Vice Principal (Health) at King's College London and Executive Director of King's Health Partners. His clinical and research career have been focussed on the pursuit of clinical transplantation tolerance. He worked on in vitro and in vivo rodent models. However, more recently he has helped to define biomarkers of clinical tolerance and is now helping to lead the first in-man trials of cell therapy aimed at promoting immune-tolerance in recipients of kidney and liver organ transplants.

There is no question but that the health and social care system in the UK is going to come under increasing pressure. Several factors are going to intensify that pressure and these are worth bearing in mind at this point in our political cycle.

The decision to leave the EU is already having an impact on recruitment from continental Europe. At the same time, the Government is changing the way nursing education is funded. It is moving away from the bursary structure used up till now, and instead is instigating a fee regime, much like that for other students who have to pay £9,000 a year. As someone who is overseeing a faculty of nurse training, I can see this is already having a negative impact on mature students entering the workforce.

Those of us engaging with the challenges of Brexit have tended to focus on the highly-skilled part of the workforce and the need for us to attract the very best talent, particularly in the context of research. I hope we do not overlook the fact that our social care system depends on people at the lower end of the skills range. Many of those, too, come from overseas and particularly from continental Europe. There is a real threat from Brexit in this regard to which we need to pay attention.

SUMMARY

- The health and social care system is facing increased pressure.
- The political situation is adding to pressures on staffing and training.
- We must be better at delivering value-based healthcare.
- Medical advances are reducing deaths but how can they also improve quality of life?
- A public debate is needed on the future options for health and social care.

Empowerment

Progressive patient empowerment will also need to be taken into account. Most people endorse patient empowerment which will include increasing ownership of your own health records and by extension increasing ownership of your own health. Patients can access information about their disease through the internet and come along to meet their clinician with a well-informed view of their condition.

That will increase patient expectations too. The risk is that there will be greater intolerance of

The Government's move away from a bursary structure of funding for training is already having a negative impact on mature students entering the workforce.

JOHN GOMEZ / SHUTTERSTOCK.COM

unexplained variation in outcomes – whether by geography, postcode lottery, by healthcare provider, even by individual clinician.

The Academy of Medical Sciences has produced a report called *Improving the Health of the Public 2040* looking at the factors that are going to influence the population's health in two decades time. It highlights the fact that external factors, not just an individual's health and lifestyle, influence a population's health. These include the natural environment, climate change, the built environment, political decisions, employment, changes in science and technology (genomics is likely to play an important part, for example) – all have an impact and have to be taken into account.

Looking forward

There are a number of things we need to do – and do better. First, there is much discussion about value-based healthcare, however most of the debate is in fact about better outcome measures, rather than value. Working in the NHS, physicians do whatever they think is best for the patient. As it is free at the point of delivery, little thought is given to cost. Indeed, practitioners are not trained to think about value. We need to get much better at remodelling patient pathways to improve outcomes at lower cost. We have to become serious about delivering value-based healthcare.

Second, there is an urgent need to increase the volume and quality of research that explores these challenges effectively and provides a reliable evidence base for policy decisions.

Third, there has been a remarkable improvement in the incidence of cardio-vascular catastrophic events, both from myocardial infarction and stroke. Many more people are surviving those events, but in consequence are getting older and more frail. Maybe quantity of life is increasing but quality of life is not increasing at the same rate. Discussion needs to take place about how to die well.

The bulk of healthcare spend is on the last few years of life. So a key question is, what is the quality of those last few years and how many years at lower quality is desirable? It is a really difficult conversation to have – but an important one.

Public debate

Fourth, there must be a public dialogue about how to fund our health and social care system. Closer integration of health and social care has to happen and will be beneficial. However, the options are rather limited. An hypothecated tax for the NHS is one route or else some co-payment model. Otherwise there might have to be some rationing in the broadest sense.

That debate needs to happen if we are going to address this challenge in a way that is acceptable to the public. ❐

Maybe quantity of life is increasing, but quality of life is not increasing at the same rate. Discussion needs to take place about how to die well.

Focussing our efforts on patient needs

Marcel Levi

SUMMARY

- We are living in the golden age of medicine.
- While fewer people are dying of disease, more face chronic morbidity and multi-morbidity.
- Medical advances are expensive – it would be naïve to ignore this.
- While specialism is necessary given the advances in biomedical science, a generalist approach to training is needed to ensure practitioners can relate to patients with multiple medical conditions.
- Research needs to be better aligned with patient needs.

While we are right to celebrate the success of medicine and medical science, if we do not implement change then we will increasingly be the victims of our own success. I am personally convinced that we are living in the golden age of medicine. Advances in molecular genetics, cell biology, physics and other areas are being translated into better diagnosis, management and treatment of a whole range of diseases.

For the first time in the history of mankind, better medicine leads to longer life. Longevity has up to now been attributable to better hygiene and social care, but better medical care is now having an impact as well. When I was a resident in internal medicine, doing my cardiology rotation, patients that were admitted with myocardial infarction had a risk of not leaving the hospital alive of 15-17%. Now, this has dropped to less than 0.5%! There are many other examples that could be given.

Now, though, we are faced with new challenges because we are converting mortality into chronic morbidity and even chronic multi-morbidity. While an individual may be much less likely to die of infectious diseases, cardio-vascular illness and cancer, there is much greater risk of contracting a degenerative disease like dementia but also other issues such as impaired vision and impaired hearing.

Medical advances have not only increased life expectancy, but have also resulted in more effective disease management. For example, up to 1% of the population suffers from rheumatoid arthritis. Some 20 years ago a majority of patients were in wheelchairs – rheumatology was a wheelchair-centred profession. Now there is not a single wheelchair to be seen in rheumatology waiting rooms: new drugs mean that virtually all patients are in remission, they will not have the debilitating effects of this disease and, indeed, they can actually be cured.

When I was a medical student viral hepatitis C did not even exist – it was called 'non-A, non-B hepatitis'. Now it has been identified, it can be diagnosed and treated very simply with a pill without any adverse effect in only three months. While the treatment is extremely expensive, more than 98% of patients with hepatitis C can be cured nowadays. The list of similar improvements is endless.

It is an illusion, though, to think that this is going to be a free ride. It is going to be more expensive than it was and it would be naïve to ignore this.

Other challenges

I have only been in this country for a few months and one of my biggest surprises has been the very slow and almost reluctant approach to training more nurses, doctors and healthcare professionals. The UK is the only country in western Europe that is not self-sufficient in this regard. That is quite paradoxical because here we have fantastic universities and the best hospitals in Europe. There is an excellent world-class training environment but we are actually not training the people that the country needs.

There are also concerns about the way our healthcare professionals are trained. There is nothing wrong with sub-specialisation given the increase in biomedical knowledge: we need people who know a great deal about specific areas in medicine. The biggest risk, though, is that while specialists know a lot about their own areas, they

Professor Marcel Levi is Chief Executive of University College London Hospitals NHS Foundation Trust. UCLH is one of the most complex NHS Trusts in the UK, serving a large and diverse population. It provides academically-led acute and specialist services to people from the local area, as well as patients from across the UK and overseas. UCLH has a turnover of £882 million. It has contracts with over 70 primary care trust commissioning bodies to provide services, seeing over 950,000 outpatients and admitting over 156,000 inpatients each year.

One of my biggest surprises has been the very slow and almost reluctant approach to training more nurses, doctors and healthcare professionals.

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The challenges of the next few decades will include geriatric medicine

may not pay much attention to other aspects. Some of our colleagues are becoming so focussed on their favourite organ or favourite cell or favourite cancer that they do not care about all the other diseases that their patients have. So those patients have to travel from one specialist to another and then onto the next, with all the ensuing problems of communication and interaction between all these specialists.

The health professionals of the future may be sub-specialists, but they should have a generalist approach to medical problems. I see this as an important trend.

Research

I find myself wondering whether our research effort actually matches the burden of disease and my conclusion is that it does not. The challenges of the next few decades are going to be geriatric medicine and the increase in acute medicine, but these are not the areas we do much research in.

Research tends to focus much more on very rare diseases, or diseases that affect only relatively few people. So there is an imbalance.

Research tends to focus much more on very rare diseases, or diseases that affect only relatively few people. This effort is not crucial in terms of the overall burden of disease. So there is an imbalance between the money we invest in research and the burden of disease that is common to us.

I am very involved in research on sepsis which is a serious infection. People have been looking for a drug for sepsis for decades now. There have been a couple of candidates and some very large trials. However, the real progress has not been in finding a drug against sepsis, instead it was in the control group! There has been a steep decrease in the mortality rates of placebo-treated patients. It turns out that this has nothing to do with better antibiotics or a better understanding of infectious disease. Instead, it has everything to do with better intensive care medicine, better organ preservation in those patients with organ failure, better nursing, better cardiovascular protection and so on. Steady progress and innovation is more important than a big breakthrough!

We need to change the focus of our research to better address the healthcare needs of the future. Yet we should still remember that we are celebrating a real success story – we should not forget that. ❐

The debate

Issues raised in the debate following the main presentations included dialogue with industry, public debate about funding, integrating technology into care pathways, and skills and training.

A focus on effective treatment during pregnancy and infancy could help deliver a healthier old age. The benefits of a reduction in smoking are clear but obesity is a less tractable problem. An effective dialogue with the food industry on the development of healthier products could deliver significant improvements without threatening the commercial viability of food producers.

Dementia issues

Dementia cases have reduced in the last 20 years, though there is some increase in mild disability. Drugs are not yet making a significant difference but public concerns have driven a focus on drug discovery when increased community support for families managing dementia would be more valuable.

If the current model of social care is not sustainable for the coming decades, there must be an open debate on the respective roles of the state and family support. The public is arguably ahead of the profession in valuing quality of life over duration when there is a trade-off to be evaluated.

Medical schools need to encourage good communication skills in their students and also teach more about the links between physical and mental health. Artificial intelligence may help to improve pathology and identification of tumours, but is unlikely to replace patient interaction – machines do not deliver care.

The integration of technology into a whole care pathway is important. There is also scope to use process engineering skills to improve NHS efficiency.

Medical training

The supply of doctors remains a concern. It may be premature to talk of a wholesale movement out of the profession, but more needs to be done to stimulate the next generation to look at medical careers. Given the time needed to fully train a doctor, strategic choices should be made now about the skills likely to be needed in 20 years' time. Adjusting skillsets is easier in the case of nurses or care workers who generally have a shorter training period.

There is a smaller risk of global pandemics than in the past. Better sanitation, nutrition and housing make people more resilient in fighting infections. However, excessive public responses e.g. to SARS show that there remains a problem of perception.

UK health outcomes have improved significantly in recent decades. More resources are undoubtedly required and there is scope for greater integration of health and social care systems. ❐

DOUG COLDWELL

Strategic choices must be made about future medical skillsets

FURTHER INFORMATION

Enhancing the use of scientific evidence to judge the potential benefits and harms of medicines
www.acmedsci.ac.uk/file-download/44970096

Improving the health of the public by 2040: optimising the research environment for a healthier, fairer future.
www.acmedsci.ac.uk/file-download/41399-5807581429f81.pdf

How can we make better decisions about medicines?
www.sciencemediacentre.org/how-can-we-make-better-decisions-about-medicines

Presentations and audio from all Foundation events are available at **www.foundation.org.uk**

The impact of demographic and medical trends on the health and social care systems of the UK

21 Jun 2017

Professor Chris Whitty CB FMedSci, Chief Scientific Adviser, Department of Health, Deputy Government Chief Scientific Adviser
Sir Robert Lechler PMedSci, President, Academy of Medical Sciences
Professor Marcel Levi, Chief Executive, University College London Hospitals NHS Foundation Trust

Making cities work - the application of technology, science and infrastructure improvements to create a place where citizens wish to live

24 May 2017

Professor The Lord Mair CBE FRS FREng, Sir Kirby Laing Professor of Civil Engineering, Department of Engineering, University of Cambridge
Tom Saunders, Principal Researcher, International Innovation, Nesta
Councillor Peter Marland, Leader, Milton Keynes Council

What constitutes an effective industrial strategy for the UK?

10 May 2017

Professor Graeme Reid, Specialist Adviser to the House of Lords Select Committee on Science and Technology
Professor Dame Ann Dowling DBE FRS FREng, President, Royal Academy of Engineering
Andrew Barker, Head of Investor Relations, International Airlines Group
Anthony Lilley OBE, Chief Executive and Chief Creative Officer, Magic Lantern
Dr Andrew Harter FREng FIET FBCS, Chair, Cambridge Network and Founder and CEO, RealVNC [Panellist]

What needs to be done to meet urban air quality targets and what are the consequences if the targets are not met?

26 Apr 2017

Eliott Treharne, Air Quality Manager, Greater London Authority
Dr Stephen Bryce, Vice-President, Fuels Technology, Shell Projects and Technology
Professor Frank Kelly, Professor of Environmental Health, King's College London
Dr Christa Hasenkopf, Chief Executive and Co-Founder, OpenEQ [Panellist]

How can skill levels be raised to meet the needs of society and the economy?

1 March 2017

Sir Mark Walport FRS FMedSci, Government Chief Scientific Adviser, Government Office for Science
Sir Adrian Smith FRS, Chair of the Smith Inquiry into mathematics education for 16 to 18 year olds and Vice Chancellor of the University of London
Dame Judith Hackitt DBE FREng, Chair, EEF (formerly the Engineering Employers' Federation)
Stephen Metcalfe MP, Chair, House of Commons Select Committee on Science and Technology [Panellist]

Making good use of science and innovation in overseas development programmes

14 December 2016

Professor Charlotte Watts FMedSci, Chief Scientific Adviser and Director Research and Evidence Division, Department for International Development
Jon Ridley, Head, M-KOPA Labs, M-KOPA Solar
Rowan Douglas CBE, Chief Executive, Capital, Science & Policy Practice and Chair, Willis Research Network, Willis Towers Watson

The opportunities for and threats to the research and innovation communities from Brexit

16 November 2016

Sir Venki Ramakrishnan PRS FMedSci, President, The Royal Society
Professor Louise Richardson FRSE, Vice-Chancellor, University of Oxford
The Rt Hon the Lord Willetts, House of Lords
Dr Hermann Hauser KBE FRS FREng, Co-Founder, Amadeus Capital Partners [Panellist]
Professor Madeleine Atkins CBE, Chief Executive, Higher Education Funding Council for England [Panellist]

The vision for UK Research and Innovation (UKRI)

9 November 2016

Sir John Kingman KCB, Chair, UK Research and Innovation, Department of Business, Energy and Industrial Strategy
Professor Dame Julia Goodfellow DBE FMedSci, President, Universities UK and Vice-Chancellor, University of Kent
Phil Smith, Chair, Cisco UK & Ireland, Chair, Innovate UK and Chair, The Tech Partnership

Health, happiness and wellbeing: supporting the transition from adolescence to adulthood

26 October 2016

Dr Joanne McLean, Research and Development Manager, Scotland, Mental Health Foundation
Dr Helen Sweeting, Reader, MRC/CSO Social and Political Health Sciences Unit, University of Glasgow
Lord Layard FBA, Director, Wellbeing Programme, Centre for Economic Performance, London School of Economics and Political Science
Catherine Calderwood FRCP, Chief Medical Officer for Scotland, Scottish Government [Panellist]

The National Flood Resilience Review: the lessons learned from recent flood events in the United Kingdom

12 October 2016

Professor Dame Julia Slingo DBE FRS, Chief Scientist, Met Office
Dr Doug Wilson, Director, Scientific & Evidence Services, Environment Agency
Simon Warsop, Chief Underwriting Officer, Personal Lines, Aviva
Professor Charles Godfray CBE FRS, Chair, Defra Science Advisory Council and University of Oxford
Professor Bas Jonkman, Professor of Integral Hydraulic Engineering, Delft University of Technology
Katharine Hammond, Director, Civil Contingencies Secretariat, Cabinet Office

What is the value to the economy of the finance and insurance sectors?

6 July 2016

Anne Richards CVO CBE FRSE, Chief Executive, M&G Investments
John Nelson, Chairman, Lloyd's of London
Professor John Kay CBE FRSE FBA, Economist and Financial Times Columnist

How should universities and Research Councils proactively respond to gender bias in success rates in grant applications?

22 June 2016

Professor Paul Boyle CBE FBA FRSE, President and Vice-Chancellor, University of Leicester
Professor Henrietta O'Connor, Deputy Head of College of Social Science, Arts and Humanities and Professor of Sociology, University of Leicester
Linda Holliday, Director of Capacity and Skills Development, Medical Research Council

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