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Topics of Interest 2018

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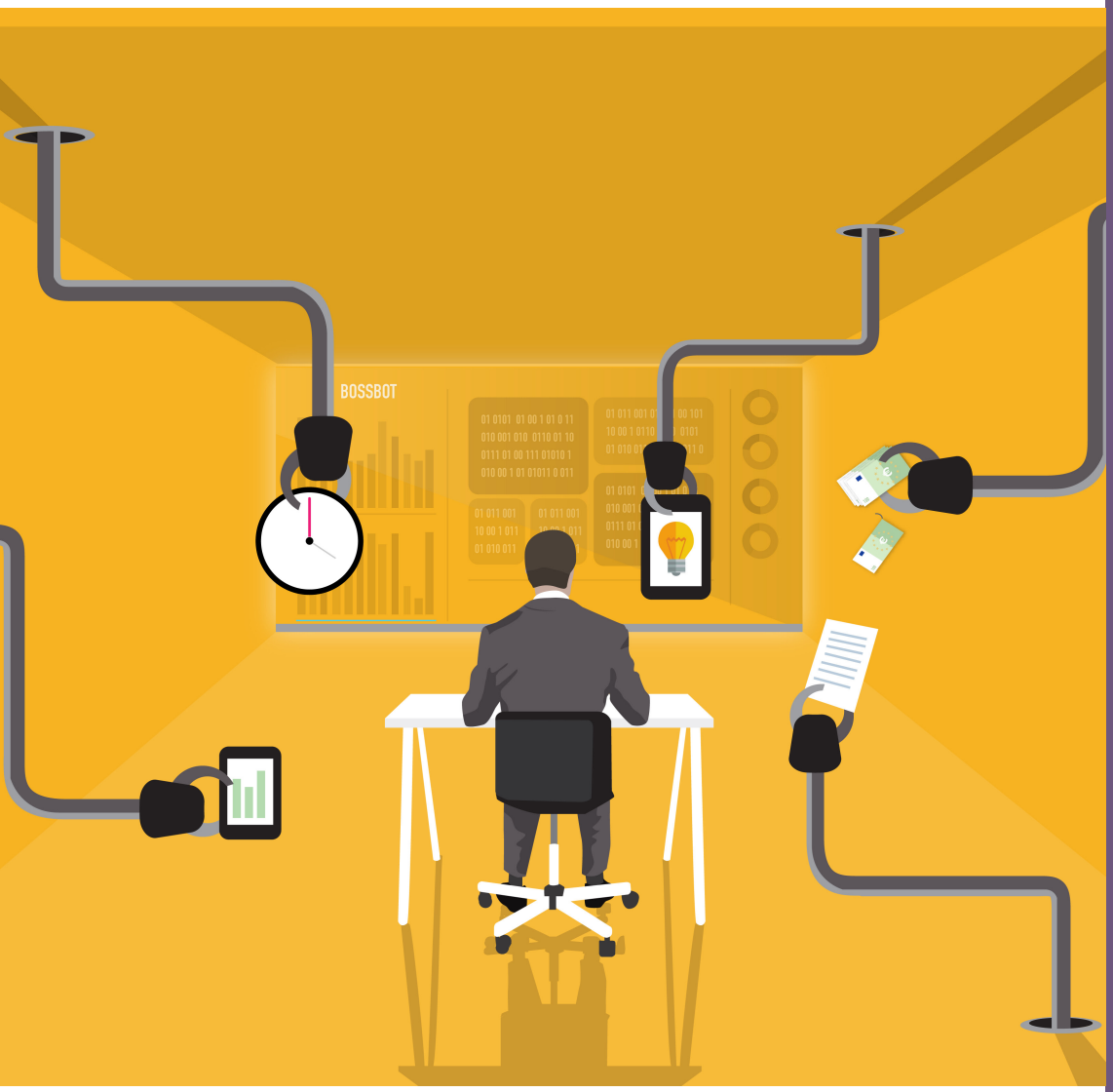

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Topic Areas Likely to be of Parliamentary Interest 2018

This list sets out the topic areas of possible parliamentary interest identified under nine different category headings (Agriculture, Fisheries, Food and Forestry; Crime; Defence; Education and Skills; Energy; Environment; Health; ICT and Robotics; and, Transport and Infrastructure). Where relevant it will inform the deliberations of the POST Board on POST's future work programme until it is updated or replaced by future horizon scanning activities. However, those topics marked with an asterisk (*) might be more appropriate work topics for other Parliamentary bodies; if these topics were taken up elsewhere, POST would look to provide support as requested.

Agriculture, Fisheries, Food and Forestry

Role of agricultural subsidies in the UK*

The Common Agriculture Policy (CAP) – the agricultural policy of the EU implementing subsidies and support programs – has highly influenced the UK agricultural landscape. Post-Brexit, reconsideration of how domestically produced agricultural goods will be subsidised, if at all, will take place. There is debate on what aspects of agriculture and land management should be publicly funded, with suggestions that the majority of payments will be for delivering environmental benefits. Decisions around acceptable levels of dependence on imports, tariffs, food shock susceptibility, the need for farming economies of scale and land use will need to be made as part of what replaces CAP, with a white paper and subsequent bill expected in May 2018.[1]

Global expansion of genetically-modified and genome-edited crops

The global acreage of crops created by genetically-modified (GM) approaches are expanding, but only four species dominate: maize, soybeans, cotton and oil seed rape. The two main traits used are herbicide tolerance and insect resistance. However, in several African countries and other developing nations, crops like bananas and sorghum are being altered for disease resistance.[2] Genome editing – involving the insertion, deletion or mutation of certain genes – is also being increasingly applied to key commodity crops to improve a much wider range of valuable characteristics and to remove undesirable ones. The regulatory status of many of these crops is the subject of debate as to whether they need to be classified as genetically modified to gain regulatory approval. After Brexit the UK could pursue an independent line of regulation, but public acceptability of these technologies is uncertain and their use would also have implications for exporting commodities and food products into the EU single market.[3]

Innovation to increase safety and reduce waste in food systems

According to the Food and Agriculture Organization (FAO), one-third of the food produced in the world gets wasted. To solve this problem, innovations have surfaced in a variety of formats from the buying, selling and donation of excess or expired products to apps that alert consumers when products are about to reach their sell-by date. Supermarkets, app developers, chain

restaurant owners and even food donation charities are involved in the movement and are looking for ways to create profit and social impact.[4] A number of technologies have the potential to extend shelf life through improving food quality assurance. Increasingly, businesses will seek ways to introduce key digital controls that ensure risks are being properly managed, such as biodegradable microsensors for temperature measurements.[5]

Food businesses that can vouch for the origins of their food, and prove the quality of food may gain a major competitive advantage as sceptical customers search for authenticity and quality. To maintain quality, provide transparency and protect reputation, distributed ledgers combined with DNA tests could be used to track food from farm to plate. For instance, Walmart is working with IBM to develop an open-source blockchain technology to help allow for the tracking and recording of how meat flows through supply chains. Blockchain assignment of unique digital identifiers could also be used to ensure food safety by storing details related to factory data, expiry dates, storage temperatures and shipping conditions.[6]This would help to prevent food waste and guide the distribution of surplus food to those who need it.

Managing biosecurity risks

Biosecurity – the exclusion, eradication and effective management of diseases, pests and invasive species – requires multifactorial management of the environment, tourism and trade, especially of plants and animals. For example, invasive organisms can threaten systems such as agriculture, forestry, fisheries and natural habitats, both domestically and globally. While the effects of established threats within countries are better understood, there is a paucity of studies on global impacts of invasive species. New trade agreements with countries with low levels of biosecurity may open new pathways for invasions of the UK by pests and diseases.[7] Despite an overall trend of improving control and management of endemic livestock diseases in developed countries, control of some diseases such as avian flu remain challenging and new disease outbreaks continue to occur, such as the more virulent strain of porcine epidemic diarrhoea.[8] Research suggests that the epidemiology of outbreaks can be better understood. For example, multilayer network analyses can help develop more accurate tools for predicting disease spread in animal communities and identifying transmission routes.[9]

Despite advances in plant breeding for disease-resistance, management of emerging and re-emerging plant diseases also still remains challenging. For example, recent studies have suggested an aggressive new strain of wheat rust (Ug99, first detected in Uganda in 1999) causes economic losses of approximately US$1 billion a year. There is concern that it is likely to start spreading out of Africa in the next few years via windborne spores.[10] Another plant disease of concern for the UK is the bacterial plant disease Xylella fastidiosa, with outbreaks of this disease occurring in Spain, France and Italy and effecting plants both in the wider environment and those grown commercially. The disease is spread by insects, such as spittlebugs, feeding on the feed on plant xylem fluid.[11]

Sustainability of global fish production and climate change

According to the Food and Agriculture Organization (FAO), around 90% of monitored fish stocks are fully fished or overfished, but demand is likely to increase for years to come. 20% of the world's population relies on fish as a primary protein source and 22 of the top 30 fish-consuming nations are in the developing world. For example, by volume, fish production is four times that of poultry and twenty times that of cattle in the ASEAN region. Even if realistic quotas were set for the size of the catch, 63% of the fish stocks evaluated all over the world need to be rehabilitated. Fish stocks will also be increasingly affected by climate change, which will influence the abundance, size, migratory patterns and mortality rates of wild fish stocks. Projected warming will cause spatial shifts of marine species and oxygen depletion,[12] compounding existing threats of overfishing, ocean acidification and other non-climatic stressors.

A recent eight year German research programme on ocean acidification has suggested that only organisms with short generation times, such as micro-organisms, can easily adapt to the present rate of change.[13] Fish are also expected to shrink in size by 20 to 30% as their metabolism accelerates with increasing temperature and as they need more oxygen to sustain body functions, which is limited by the surface area of gills.[14] Aquaculture is also now forecast to overtake wild-caught fish as the primary source of fish consumption in 2021, for the first time. However, aquaculture can also have environmental impacts; for instance, shrimp farming is thought to have led to the destruction of 3 million hectares of coastal wetlands, including many mangrove forests. The species that can be farmed successfully will also be affected by climate change and acidification.[15]

Climate change mitigation and adaptation in agriculture and food systems

The agricultural industry currently uses fossil fuels across its value chain to grow, transport, process, package, prepare and store food. Efforts to decarbonise the industry are likely to include the use of alternative energy sources and emissions-reducing practices such as crop-rotation, mulching and composting. Other practices, such as combined heat and power technology and energy-independent farming, are also likely come to the fore as producers and consumers seek to mitigate greenhouse gas emissions while adapting food production systems to be efficient and resilient.[16] Global agricultural production is vulnerable to climate change impacts such as severe weather events like floods and droughts, including the yield of the five crops (rice, wheat, maize, millet and sorghum) that account for 60% of energy intake for the world's population. Studies suggest that many of the most commonly raised crops and livestock animals may not be able to adapt to changes in climate. Drought and lack of water or irrigation will be a major challenge, but even in areas that become warmer and wetter, ranges and distribution of weeds, fungal pathogens and pests are likely to increase. Studies have suggest that drought and food 'shocks' have played a role in events such as the Arab Spring, the Syrian Civil War and other conflicts in Somalia, Sudan and South Sudan. Climate change food insecurity is likely to be concentrated in conflict affected regions and developing countries, but food security may rise for developed nations and corporations that are able to buy up agricultural land globally.[17]

Rising demand for meat and competition for animal feed protein sources

Demand for meat is growing with the increase in the middle classes as a proportion of the global population and is projected to double by 2050. This has implications for the cultivation of animal feed, which is largely plant-based and accounts for the largest single land use in the world, driving deforestation (see Mass Extinction and Environmental Tipping Points) and producing greenhouse gas emissions. China currently imports around £10bn worth of meat annually to help feed its population of more than 1.4 billion people and has recently signed an agreement with three Israeli lab grown meat companies.[18] In the US, companies are attracting investment through the concept of 'clean meat' – lab grown meat free of antibiotics, pathogens and other environmental pollutants.[19] Other possible protein sources for humans or animal feed include insects, duckweed, seaweed, microalgae and even single cell proteins. However, current EU legislation restricts the use of some of these products while others have not yet become mainstream. The potential of these approaches may be limited by the challenges of scaling up from lab research to production and public perceptions of new protein sources for humans or livestock. Food exporters will also still have to adhere to EU regulations to continue to sell in the single market.[20]

Precision-farming and robotic agriculture

Information technologies and autonomous systems have the potential to disrupt the agriculture industry. Such systems can improve production efficiency, monitoring and intervention techniques and operation control while replacing the need for labour. Examples include robotic milking parlours, automation of feed pushing and manure cleaning, mechanisation of chemical administration and estimation of crop yields in real-time. However, concerns about returns-on-investment and availability of cheap imports are likely to hamper investment by the UK agri-food industry after Brexit. Policies may also be needed to support adoption by the sector. For example, such policies could encourage precision-targeted agrochemical inputs by banning the 'dumb' spraying machines that apply active ingredients in the wrong places.[21] One of the Industrial Strategy Challenge Fund areas identified by the UK Government to fund the development of transformative technologies is the 'transforming food production' programme, which will seek to reduce emissions, waste and soil degradation through use of precision technologies.[22]

Technologies that go beyond precision agriculture are also under development; agricultural robots that allow farms to be managed on an individual plant or animal basis. Emerging mobile agricultural robots are likely to be slow, unmanned, light-weight and modular; their slowness means that more attention is given to each plant, their lightness means no soil compaction and their small size means potentially lower costs. While many technologies are still in early stages, a spring barley crop has been planted, tended and harvested with only drones and autonomous vehicles as part of the Hands Free Hectare project at Harper Adams University.[23]

Crime

Technology in crime committing, prevention and control

Technology is being used increasingly to commit crime as well as in preventing and controlling it.

Technology and crime committing: artificial intelligence (AI) and machine learning (ML) techniques are being used to assist in conducting attacks. AI and ML could be applied in parallel to enhance the automation, accuracy, ability and innovation in cyberattacks making them even more of a threat than they currently are today.[24]

Technology and crime prevention: there is potential for analytics to be used to identify those at risk of being victims of crime and those at risk of (re) committing crimes. For example, a pilot program in Los Angeles is using predictive models to identify the most at-risk children in the child-welfare system and provide them with services designed to help them stay out of the juvenile-justice system.[25] Algorithms have been developed to try to keep people from reoffending by predicting the support that they need before they actually need it, such as bipolar medication that doesn't get picked up from the pharmacy.

Technology and crime control: while closed-circuit television (CCTV) and dash cams have changed the crime surveillance and control approach significantly in the UK in recent years, new applications such as camera-equipped drones, location tracking and monitoring and smartphone apps for public-reporting are examples of where the policing field may be headed. The Home Office is using data analytics to support work to identify and catch the perpetrators and facilitators of modern slavery.[26] However, as new applications of technology take place, the line between responsible policing and privacy breaches must be considered carefully.[27] The use of such data carries significant risks. Among them is the risk of false positives and negatives, discrimination and bias from both human and algorithmic errors in system design. Issues of 'big data' ownership and sharing are also of relevance with large amounts of data already collected through smart meters, but the purposes of this may not be clear. In addition, it is not clear how effective prevention approaches are, with one evaluation finding that predicting technology was ineffective at reducing crime. Because algorithm-training models must rely on data about known past crimes, they can only predict future incidents that resemble the nature, time and location of prior crimes.[28]

Online reporting of crime

The implementation of online reporting and submission of digital evidence has the potential to create both cost-savings and efficiency gains in the police force. According to techUK, police time spent on low-level reporting – which currently costs some £130 million annually – could be reduced by 25% with the use of online media. Adoption of the relevant technologies would not only remove the need for the collection of physical media, but would also allow investigations to start immediately in a way that could permit collaboration between investigators who may be separated geographically. These and other

digital applications could pave the way for improved safety, access, speed and efficiency.[29]

However, there are concerns that only a small proportion of police forces around the world offer citizens the ability to report crime online and then to track the progress of their case. A joint call for research on cybercrime between UK, Netherlands and Nordic countries has recently awarded funding to a number of projects in this area.[30] A review undertaken for the Home Office found that initiatives including a smartphone app for local police communications and a case-tracking system for victims of crime provided information. However, this alone was unlikely to stimulate greater public engagement in police accountability, without wider activity to educate members of the public on how they might use the information to do this effectively. The review concluded that such initiatives need a 'hook' to keep people returning to them. Encouraging users to create an account and sign up for alerts, tailored to individual location and interest, would be useful for maintaining engagement.[31]

Inequality and its impact on crime

Evidence suggests that there is a correlation between income inequality and crime. A review of time-series and panel studies of income inequality and crime, which included seven studies examining homicide rates (five conducted in the United States or Canada or by international cross-country comparisons), found a significant increase in the murder rate with rising income inequality.[32,33] The existence of inequality in society may be of critical relevance to the presence and nature of crime. More equal societies have the potential to create communities that are more willing to assist one another, trust one another and contribute to community life. Rising inequality, on the other hand, can lead to fading of trust and increased crime and violence. As policy action attempts to deal with inequality trends, consideration of the implications on social justice and the prevalence of crime is of concern.[34]

Technology and domestic abuse

Domestic abuse been shown to have serious long-term consequences for children as well as impacting upon provision of public services such as health and housing demand. The 2017 Queen's Speech announced that the Government intends to introduce a draft Domestic Violence and Abuse Bill this parliamentary session, and measures in the Courts Bill to deal with suspects cross examining victims. HMIC recently published a review exploring the connections between domestic abuse and stalking and found that people who have suffered repeated harassment or stalking were frequently being let down by under-recording of these offences, inconsistent services and a lack of understanding by the criminal justice system.

Technology is increasingly being used to identify abuse and to help protect victims of it. For example, smart home sensors can be used to identify the intimate behaviours of victims in order to identify a perpetrator's patterns of abuse, violence and control. New devices are being brought to market that change the way individuals' access security networks when in need. For instance, products that manifest as an accessory keychain can – when activated through the press of a button – connect individuals to police, emergency contacts and a global network of guardians while also transmitting

location data to help support an individual in distress. The What Works Centre for Crime Reduction has recently commissioned a systematic review of the effect of personal security alarms in reducing assaults against healthcare staff.[35] These products can be used to assist key vulnerable groups in society, but challenges such as affordability, uptake and privacy may exist.[36] At the same time, recent case studies and research show that such technology can be used for abusive purposes.[37] In a 2015 survey of 546 domestic violence workers, 98% said they had clients who had experienced technology-facilitated abuse.[38] Technology-facilitated abuse is the use of tools such as social media, mobile phones and tracking devices to stalk, monitor, threaten and abuse.[39]

Defence

Increasing potential for cyber warfare

The potential for cyber warfare is high and is being considered from both offensive and defensive positions in the UK. The new National Cyber Security Strategy references the UK's offensive cyber capabilities for the first time, describing deliberate intrusions into opponents' systems or networks with the intention of causing damage, disruption or destruction. The UK government aims to develop such capabilities for deterrence and operational use. At the same time, the UK armed forces' use of information and communication technologies makes it vulnerable to cyberattacks. Issues in this area include the ambiguity of international laws surrounding cyber warfare, and difficulties in reliably identifying the source of a cyber-attack.[40]

Traditional vs asymmetric threats

Throughout the Cold War, the UK's defence was built on the assumption that its adversaries would be foreign states with comparable resources, motives and strategies. Since then, the perceived threat has shifted to asymmetric actors, such as terrorist groups and insurgencies. More recently, however, this situation seems to be evolving such that the UK will have to be able to confront both types of adversaries as tensions rise in Russia and North Korea. This has led to questions over how the UK's armed forces will develop to meet these new kinds of threats, and if they will be able to respond to different threats, potentially in different regions simultaneously.[41]

Future vulnerabilities of the trident nuclear deterrent

In July 2016, Parliament voted to renew the Trident nuclear deterrent, which allows for the replacement of the UK's four nuclear-armed submarines. The replacements are due to come into service in the 2030s at an estimated cost of £31bn. Concerns have been raised about the high costs and lengthy time frame of the replacement programme, especially given the potential for anti-submarine technologies (such as improved remote-sensing technologies or mini-submarines) to be developed in the meantime that may undermine the effectiveness of the replacements.[42]

Terrorist and counter-terrorist material online

Terrorist groups routinely post material online aimed at advertising, recruiting, providing training and tactical advice, and assisting with travel to restricted areas (such as Syria or Iraq).[43] Current enforcement measures include a specialist police unit to whom the public can flag potential problem material that can then be removed. However, this system is limited since it is human-operated, reactive and dependent on cooperative content hosts. The Home Secretary has called for communications service providers to improve the automation of the detection and subsequent removal of new terrorist content online.[44] There are typically more people online who actively oppose the views of terrorist groups than those supporting them (one estimate suggests there are six times the number of ISIS opponents than there are supporters on Twitter). It has been suggested that data-driven marketing and media strategies could allow opponents of terrorist groups to be more effective. However, this would require significant marketing and advertising expertise.[45]

The UK's defence role post-Brexit

The UK is the most capable military and intelligence power in Western Europe.[46] There has been discussion that Brexit might cause the UK to lose its position as the NATO Deputy Supreme Allied Commander, which it has held since 1951. After Theresa May referenced security alongside the economy in the letter announcing the UK's withdrawal from the EU, there has been speculation about whether security co-operation may be affected by Brexit negotiations.[47] The Royal United Services Institute think tank have argued that this would undermine confidence in the UK's commitment to mutual defence, a key component of NATO's credible defence; instead they argue that strong security co-operation can reinforce shared values and close relationships post-Brexit.[48]

Low-yield nuclear weapons

In 2003 (and again in 2016), the US Defense Science Board recommended the development of a 'more flexible nuclear enterprise that could produce, if needed, a rapid, tailored nuclear option for limited use should existing non-nuclear or nuclear options prove insufficient'.[49] This refers to nuclear weapons with high precision but much lower explosive power and radioactive fallout than a standard nuclear weapon. Such 'mini-nukes' would have potential uses in destroying well-defended strategic targets such as underground bunkers. Critics have argued that the development of such warheads would lower the threshold for nuclear war, as their deployment would be seen to be less significant than conventional nuclear weapons but could potentially lead to escalation. Adding to the nuclear arsenal could also increase the probability of accidental explosions.[50]

Development of electronic warfare

Electronic warfare describes efforts to control the electromagnetic spectrum in a combat zone. It encompasses three main categories: attack (using electromagnetic energy to damage or disrupt enemy capability); protection (measures taken to defend against electronic attack); and warfare support (attempts to gain information about the battlefield from intentional or unintentional electromagnetic signatures of the enemy).[51] The Russians have made extensive use of modern electronic weapons in Ukraine and Syria. In particular, Ukrainian forces suffered heavily disrupted communications as a result of Russian signal-jammers and targeting systems that could track emissions.[52]

North Korea's weapons programme

The rate of North Korea's weapons test has recently accelerated, with the tests coming in 2006, 2009, 2013, 2016 and 2017. Kim Jong-Un has claimed that the latest tests were of hydrogen bombs, using nuclear fusion rather than fission. These are more powerful than older versions and have the potential to be fitted to a ballistic missile. The estimated yield of a subsequent nuclear test will be an important measure of the country's current capabilities.[53]

Psychological warfare capabilities

The UK set up a new brigade in 2015 ('77th Brigade) that will use psychological operations and social media to help fight wars 'in the information age'.[54] Despite attempts in Russia and the US to use psychological

warfare, it has proven difficult to reliably assess the success of such programmes. Challenges include difficulties associated with observing changes in behaviour and attitudes, lengthy timelines to achieve impact, causal ambiguity and difficulties in presenting results in ways that are useful to stakeholders and decision-makers.[55]

Education and Skills

Use of digital technologies to improve teaching, research and use of evidence

Technology is being used to support learning across different stages of education. For example, technologies such as location specific resources can be used to better support new and existing students. The Future Cities catapult is working with the University of Glasgow to develop a strategy for a Smart Campus that will take into account changes in technology and learning whilst also protecting their heritage (both cultural and physical) and realising cost savings. Technologies are also being used to engage learners including augmented reality technology (such as Google Cardboard), adaptive learning technologies (Dreambox, ALEKS, Reasoning Mind), and holographic learning (Microsoft HoloLens).

Technologies are further being used to support teaching. For example, one school has used two of SoftBank's human-looking robots and AI to grade students' written answers. Technology can also be used for administrative purposes such as monitoring attendance automatically. Examples include small digital "badges" signifying completion of a training task, using analytics to boost fair access and retention and lead to improved student satisfaction and attainment. Other technologies such as Brain Computer Interface (BCI) systems – programs that connect the brain or nervous system to a computer – are at an earlier stage but may help support users with significant physical or sensory deficits. They can collect information on attention levels of students and can store and manage educational data concerning learning processes.[56]

Future of the labour market

Human labour is being rapidly replaced as the demand for new skills, such as the use of digital technologies, rises. This trend is accompanied by the increased use of automation in our world. Together, these trends have the potential to shift the way in which educational systems prepare students for working life. Retraining programs and the adult education market are likely to attract greater attention and use as the need for lifelong learning increases. Other earlier stages of education – from pre-primary to secondary – are likely to experience change as they respond to changes in the labour world.[57]

Social and emotional competencies are an important focus in the realm of education. As technology advances, the nature of these high-value human skills may play a more significant role in careers and human life.[58] Research suggests that skills that are harder to automate – such as creativity, dexterity and social intelligence – are likely to be more valuable in the long term. Collaborative problem solving is a skill that brings together perspectives and ideas and is predicted to be a useful human endeavour in the long-term that can reinforce knowledge and improve attainment while preparing people for the future workplace. The approach has also gained international attention in the field of education; in 2017, the Program for International Student Assessment (PISA) will release its first country rankings for collaborative problem solving.[59]

Prison education*

Correctional education has been shown to reduce recidivism rates while also improving the chance of obtaining employment after release. Moreover, such efforts can be conducted in a cost-effective manner with regard to reducing recidivism. While education in prisons can progress in an inclusive and effective manner, budget cuts and private management preferences have had an effect on the number, choice and types of courses available.[60]

Nutrition standards in school meals*

Nutrition is critical to educational performance from a behavioural, cognitive and academic standpoint. Regular meals of high quality can provide adequate energy for students, especially those who do not have adequate access to nutrition outside of educational facilities. Thus, the provision of meals has been argued to improve educational performance of students, especially among lower socioeconomic groups. While nutritional standards are set for primary school level, no such standards are in place for early education. Other impacts may result from the social interactions and atmosphere associated with dining as a community.[61]

Mental health in schools

The school environment provides an opportunity for students to understand and learn to cope with mental health issues at an early stage. It is here that prevention and intervention can begin to take place allowing for improved student quality of life, attainment maximisation and even long-term cost savings for the NHS.[62]

Higher education student poverty

Issues of student poverty are becoming more prevalent. For example, there is a growing awareness of student homelessness being a hidden problem amongst some segments of students. The scale of the problem is not yet clearly defined and it is not clear what impact higher tuition fees and living costs is having on this issue and which groups of students are most affected. With child homelessness in England up by 37% - or some 30 000 in absolute numbers – demand on local government for housing support is increasing. The lack of a stable residence, be it in early childhood or in adulthood, can affect educational outcomes.[64]

Open access publications by default

The demand for open access publications, open data for research projects and open education (such as massive open online courses, MOOCs) is driving a movement for freely available education. Policy-driven implications may result from the effects of this demand on institutions and from their need for support in dealing with change.[65] The Open Data Institute is a world-leading centre aimed at becoming a source for data that can deal with the challenges of publishing freely available data, creating commercial gain from open data and employing the best technologies to ensure it is used appropriately and transparently.

Global access to education and empowerment

Widening access to education is likely to drive and be influenced by individual empowerment, which may also have knock-on effects for gender equality. As countries seek to develop knowledge-based economies, this issue will become increasingly salient. In this process, new technologies and learning formats, such as distance learning, MOOCs and new methods for measuring and monitoring performance, could offer low-cost opportunities for access and more personalised education. For some, these dynamics could increase education attainment rates and reduce the education gap between regions and nations.[66]

Early education*

There is a growing body of evidence that children starting strong in their learning and well-being will have better outcomes when they grow older. Benefits from early interventions are conditional on the level of "quality" of the early education. A 2011 systematic review highlighted findings of the best-evidence synthesis of early years interventions showing that early childhood programmes with explicit emergent literacy instruction and clear teaching objectives provide the greatest improvements in school readiness when they are implemented in a developmentally appropriate way. Teacher qualification levels are also found to be important.[67]

Energy

Post-Brexit energy landscape*

There are numerous interdependencies between the UK and EU energy systems spanning physical, legal, regulatory and economic dimensions. Given this, the withdrawal of the UK from the EU presents barriers to continued participation in the EU Internal Energy Market. Among other potential risks, the considerable uncertainty surrounding the outcome of negotiations and future energy relationships has potential implications for emissions trading, funding for energy research and infrastructure, continued operation of the UK nuclear sector and participation in interconnected gas and electricity markets.[68]

Flexible energy systems

The electricity network is facing a period of upheaval as it moves from a centralised, thermal generator model to a 'smarter' dynamic system where consumers increasingly produce some or all of their own energy through various low-carbon methods closer to its point of use. As a result, the distribution network is becoming bidirectional – allowing consumers to both produce and consume electricity – making real-time balancing of networks both more important and also more challenging. In response to these challenges, the UK Government and Ofgem released a Smart Systems and Flexibility Plan in 2017 outlining their aims to facilitate a more flexible system. Predictions estimate that efforts to create a smarter electricity system could save consumers £8 billion per year.[69]

UK leadership in low-carbon goods, services and green finance

As ambitions to tackle climate change increase, competitive international markets in low-carbon goods and services are likely to emerge and grow. The development of the global green financial sector (in the form of green bonds, infrastructure schemes and financial instruments) is likely to be integral for meeting the Paris goals; the London Stock Exchange has expressed its intention of becoming the preferred listing venue for low green financial instruments, with many UK institutions beginning to issue these. The UK is also engaged in a number of other low-carbon industries, with strengths in energy technologies, electricity distribution and financial and legal services in the energy industry. The Industrial Strategy White Paper, alongside the Clean Growth Strategy, set out the Government's ambition to capture international market share in industries such as electric vehicles and energy storage. It is undertaking a review of export strategy, and has established a Green Finance Task Force.[70]

Medium-term support for low-carbon energy

The Committee on Climate Change suggested in July 2017 that there was a policy gap between the UK's emissions targets under the Climate Change 2008 Act and the extent to which the current policy landscape can achieve these reductions post-2020. Support for low-carbon technologies and long-term frameworks for low-carbon heat and transport were included in these missing policies. At the time, this prompted concern that the UK may struggle to stay within the fourth and fifth carbon budgets. In October 2017 the UK Government set out its intention to address this issue in its statutory

Clean Growth Strategy. While the Strategy's level of ambition was broadly welcomed, it has drawn criticism for failing to provide sufficient detail on the concrete policies and mechanisms for reaching medium- and long-term carbon targets.[71]

First trials of UK greenhouse gas removal technologies

The National Environment Research Council has announced £8.6m support for pioneering research into greenhouse gas removal (GGR) technologies. The funded technologies include soil carbon management, afforestation, bioenergy with carbon capture and storage, enhanced weathering and direct capture of methane from the air. The UK Government has also announced that it will consider how to remove barriers to, and provide policy incentives for, the deployment of GGRs. GGR is thought to be important for global achievement of the Paris Agreement and the UK's target fulfillment under the Climate Change Act, but uncertainty exists over whether it can be deployed in a timely and appropriate manner without causing other environmental and social effects.[72]

Future energy demand

The efficiency with which energy is used has increased significantly in recent decades and this trend may continue. In the UK, these efficiency gains have recently contributed to a peak in annual primary energy demand. However, future global demand for energy is still predicted to increase as global living standards and the population rises. Considerable uncertainty exists around how the changing profile of energy generation, energy innovation (including a swathe of nascent technologies still far from commercialisation) and changing patterns of human behavior will affect demand both globally and in the UK. These are all likely to be key drivers of future energy demand with resultant impacts on future carbon emissions. Commentators have called for a programme of domestic energy efficiency as a "national infrastructure priority", as supported by the Scottish Government. This has been credited as having the potential for job creation, GDP growth and continued reductions in energy demand. The UK Government announced a number of energy efficiency policies in the 2017 Clean Growth Strategy, including an industrial energy efficiency scheme and minimum efficiency ratings for domestic properties by the 2030s.[73]

International energy and climate change diplomacy

In June 2017, the newly-elected US President announced that the administration would be withdrawing the US from the 2015 Paris Climate Accord. The US Federal Government has concurrently rolled back domestic energy and environment legislation aimed at climate change mitigation and local environmental protection. Commentators have expressed concern that the change in stance on climate could affect the future success of the 2015 Paris Climate Accord. However, other national governments have since reaffirmed their commitments, notably at the UN COP23 in November 2017, and other nations may emerge as leaders in climate change advocacy on the global stage.[74]

Low-carbon cooling of buildings

Cooling has been estimated to account for 30% of UK office electricity consumption. This could be exacerbated by future climate change, with concerns mounting over the related health effects from overheating. Current cooling technologies often involve inefficient electric devices. Sustainable approaches to cooling include passive cooling, district cooling, shallow geothermal and seasonal cold storage and may be important in the context of increasing global temperatures and rising global energy demands.[75]

Carbon capture, utilisation and storage (CCUS)

Canada has deployed the world's first large-scale power sector carbon capture and storage (CCS) project through a dam-integrated system in 2014. As of January 2017, 16 similar projects have been developed worldwide, though none currently operate in the UK. The UK Government announced some support for CCS within the 2017 Clean Growth Strategy. Many stakeholders regard CCS as being critically important to the UK achieving its decarbonisation targets under the Climate Change Act. Furthermore, there is increasing focus on using the captured carbon within economically productive processes, such as bolstering plant growth within agricultural greenhouses or enhanced oil recovery. The UK Government announced up to £100 million in funding for carbon CCUS in its Industrial Strategy White Paper.[76]

Large-scale renewable generation

Much of the progress in renewable energy deployment in the UK has occurred at a large-scale through offshore wind projects, biomass-fired power generation and potentially through tidal lagoon initiatives in the future. These large-scale projects have unique electricity output profiles, ownership structures and market dynamics. They are potentially at odds with some advocates' vision of a future energy system focused around more decentralised technologies, such as home renewable systems and local microgrids. Each model implies different policy approaches, and subsidy schemes, such as the Contracts for Difference (CfD), may be designed to incentivise each of these differently. Tidal lagoons will not be supported in the near-term under 2017 Autumn Budget announcements on the CfD.[77]

Environment

Evidence of the effects of pollution on human health and the environment

Despite regulatory efforts from the 1960s onwards, pollution is still having a substantial impact on human health and the environment. Recent estimates suggest globally nine million deaths a year are caused by pollution.[78] Growing evidence suggests an association between air pollution and numerous undesirable health outcomes including respiratory disease, heart disease, cancer, antibiotic resistance, premature birth and even childhood mental health. Estimated to kill 1 in 8 people globally, both short and long-term exposure to air pollution are problematic for human health.[79] Evidence of less well understood sub-lethal health effects of pollutants, such as endocrine disruption, are only emerging from extensive monitoring of exposure and possible effects.[80] Characterising the environmental risks of new pollution challenges is also likely to be a slow process. For example, light pollution from public lighting using light emitting diodes (LEDs) includes more blue-wavelength light that penetrates further into water and influences melatonin – a modulator of sleep. Given that light plays a significant role in biological processes by affecting gene expression, behaviour and circadian rhythms, an increase in light-mediated impacts on a wide range of species are anticipated, but the precise effects on most species are still unknown and may operate by complex pathways.[81] Unforeseen environmental effects of human and veterinary medicines are also an area of concern since the decline of Indian vultures was shown to have been caused by the use of an anti-inflammatory drug (diclofenac) administered to livestock.[82]

Brexit's impact on UK environmental legislation

Separation from the EU has triggered a need to reconsider some 850 pieces of environmental legislation in the context of the new relationship between the UK and the EU and require making around 100 Statutory Instruments.[83] Though some environmental requirements will fall away as Brexit progresses, legislation will need to deal with accountability for meeting regulatory standards to both protect the environment and maintain trade into the EU single market. Key areas that will need to be addressed include: the extent to which legislation is 'retained'; monitoring that was previously reported to EU institutions; accountability for meeting environmental targets and standards including the implications for devolution; and creating independent regulatory approval frameworks that are compatible with EU ones, such as REACH.[84] It remains unclear whether the '1 in 3 out' rule will apply to environmental regulations brought forward in this process.

Economic gains from efficient resource use

The ongoing growth of the global population is projected to lead to a 71% increase in resources used per capita by 2050. Without steps to increase efficiency, such as circular economy measures, the global use of metals, biomass, minerals, and other materials will increase from 85 to 186 billion tonnes per year by 2050. The UN predicts that this increase could be reduced by 28% through ambitious climate policies and improved resource efficiency achieved through compensation and transfer policies. These efforts could inject two trillion USD into the global economy while offsetting costs of ambitious climate change action. However, the economic gains of resource

efficiency and slower resource extractions would be uneven and would reduce revenues that could affect jobs in some industries. Studies suggest that demand management measures are critical to this process.[85] It is not clear if the UK Government will institute the Circular Economy package before leaving the EU,[86] but it committed to moving towards a more circular economy and raising the resource productivity of businesses in the UK Industrial Strategy White Paper.[87]

Applying innovative technology for environmental benefits

Innovative technologies – such as geoengineering, nanotechnology and synthetic biology – have the potential to offer environmental benefits, but need to have legislation to enable their responsible use, financial feasibility and development. Examples of such innovation include explosive-sensitive carbon nanotubes being embedded in spinach leaves; tubular microbots that can capture lead from water; and, bacteria that fluoresce to signal environmental contamination. These innovations can minimise and reverse environmental impacts while contributing to economic growth. However, some of these technologies may have substantial transboundary effects, such as geoengineering, or may raise specific ethical acceptability such as the use of synthetic biology – the process of developing or redesigning new biological entities and systems. For instance, synthetic organisms could be used for products that have been extracted from plants or animals, such as rhino horn, to reduce wildlife crime.

However, new pressures or risks could also emerge from the use of synthetic organisms,[89] such as increasing demand for biomass production of fuels and pharmaceuticals synthetically and driving land use change.[90] Another example is biocontrols – natural predators of invasive species – that are already widely used in horticulture to control pests, particularly in glasshouses, and to control invasive species, but are now being developed as biocontrol agents and biostimulant mixes to increase crop yield. However, the possible adverse effects remains poorly understood, such as how microbial crop agents will interact with soil microbial communities. Greater understanding of unintended environmental effects of biocontrols, particularly the manipulation of microbiota to enhance crop production, would clarify whether the benefits of reduced chemical use outweigh any possible risk.[91]

Environmental impacts of renewable technology

While renewable energy technologies offer numerous advantages, their environmental effects are still being explored. Examples of some known impacts include wind turbine effects on bat and bird mortality and hydropower dam effects on aquatic life. Another concern is the resource consumption levels of renewable technology, including rare earth elements that most commercially established photovoltaic technologies use. Costs, impacts on various species and energy and resource consumption profiles of these technologies are still being explored through lifecycle analyses. Identifying knowledge gaps and relevant methodologies to address them would lead to improved greenhouse gas mitigation accounting, more efficient resource use, and more effective environmental impact assessments to mitigate impact.[92]

Mass extinction and environmental tipping points

Farming, logging and building have transformed between a third and a half of the world's land surface, and even these figures probably understate the effect, since land not being actively exploited may still be fragmented. Humans have also now used half the world's readily accessible freshwater runoff; chemical plants fix more atmospheric nitrogen than all natural terrestrial processes combined; and fisheries remove more than a third of the primary production of the temperate coastal waters of the oceans. If such pressures lead to ecological thresholds being crossed, changes in species composition, biogeochemistry and ecosystem services may be permanent.

However, studies to understand such tipping points and 'early warning' are in their infancy while mass extinction events may already be underway.[93] In particular, loss of rainforests may cross tipping points with global consequences. For instance, modelling studies suggest that the Amazon may have two "tipping points", namely, a temperature increase of 4°C or deforestation exceeding 40% of forest area. If transgressed, large-scale "savannization" of mostly the southern and eastern Amazon may take place thereby affecting global climate.[94] Rainforests cover 6% of Earth's surface but house half of the world's plant and animal species. They play a key role in regulating climate, the water cycle and the livelihoods of approximately 1.6 billion people. However, the extent of deforestation and degradation in South America, Africa and Southeast Asia, means they are now releasing more greenhouse gases than they are absorbing.[95] A substantial proportion of deforestation has been linked to the production of agricultural commodities, such as palm oil and soya; 447 companies have made commitments to halt deforestation in supply chains linked to commodities, but this only represents a proportion of markets and countries.

Environmental data and support tools

The amount of data available on different aspects of the environment is expected to grow rapidly with innovation in remote monitoring and satellite technologies while costs are expected to drop as technology and usage advance. This data could be used to inform land design and planning, natural resource management, air and water quality mechanisms and other environment-related activities. For example, traces of organisms' DNA in the environment, known as environmental DNA (eDNA), can be monitored to paint a picture of biodiversity. Though in its infancy, this advancing research can be used to assess biodiversity in a landscape – for instance, in river systems - using less effort and at a lower cost than traditional sampling methods.[96] In theory, the increase in data provides opportunities for managing the same area of land for multiple benefits and risks, such as floating housing in areas used for flood storage, and the technologies to facilitate this, such as environmental decision support software tools. However, challenges currently being faced include image resolution, data accuracy, ease of processing, the quality and objectiveness of many models, uncertainties around issues such as what aspects of natural capital underpin ecosystem services in a particular area and appropriate regulatory frameworks.[97] For example, the National Trust and the Green Alliance recently proposed a payments for ecosystem service (PES) model in which groups of farmers sell services such as flood protection and clean water to water companies and other beneficiaries downstream. Any such system of green markets and services will require evidence of contribution to desired outcomes that can be valued, such as

flood management or carbon storage. Those benefits where it is difficult to determine contributions and value them, such as biodiversity, may be comparatively disadvantaged.

Weather extremes in the UK

There could be a higher frequency of extreme weather events and flooding in the UK than has been predicted by current modelling. Deviations from expected weather patterns have been experienced in recent years in the UK. Examples of this include the persistent and heavy rainfall in the summers of 2007-2012 and 2017 associated with changes to the jet stream, and the extreme precipitation and flooding in the winter of December 2015 associated with atmospheric rivers (narrow structures in the lower troposphere that transport large amounts of moisture to land masses). Studies suggest that these atmospheric river frequencies off the coast of the British Isles in winter will double by the end of the 21st century with climate change. Changes in the behaviour of the jet stream in the summer could affect areas in Europe that are critical for global food security, such as the wheat growing areas in Ukraine. The increased frequency and persistence of extreme weather events is already creating significant challenges for drainage, flooding and coastal protection infrastructures as highlighted by the 2017 Climate Change Risk Assessment.[98] For example, extreme weather could increase the incidence of flooding and landslides disrupting road and rail infrastructure. Clearing surface water more quickly from roads and from the rail network may require higher capacity drainage systems, multifunctional green spaces near roads, reinstatement of natural flood plains and intelligent monitoring systems. In other cases, it may be necessary to raise the heights of roads and railways or re-route them to avoid communities being cut off.[99]

Human-wildlife conflict

Human population growth, agricultural intensification and wealth creation has limited the living space and resources for both humans and other animals, creating conflict that threatens both human and wildlife survival. If solutions to conflicts are not adequate, local support for conservation also declines as people lose their crops, livestock, property and sometimes their lives. Additionally, the animals, many of which are already threatened or endangered, face the potential for death through retaliation aimed at preventing future conflicts due to an absence of proper solutions. Wildlife-human conflicts occur in a number of contexts within the UK from the disease interactions between wildlife and livestock to predation of ground nesting gamebirds in upland areas.[100]

Health

The threat of antimicrobial resistance

The development of resistance to antivirals, antifungals and antibiotics across a wide range of pathogens may render many infections untreatable. This will have implications for the effectiveness of existing antimicrobials, and require careful stewardship of their use. It also presents challenges for the pharmaceutical industry to develop new classes of drugs. This may require new models of pharmaceutical development as the current models do not provide a sufficient incentive to make investment in antimicrobial research by the private sector attractive.

Emerging infectious diseases

Of particular concern are the emergence of novel pathogens that cause disease in humans or in animals of agricultural importance. Also of concern are the spread of existing human and animal pathogens (for example due to climate change). Recent examples of human pathogens include the ebola and zika viruses for which few or no medical countermeasures existed, whereas animal pathogens of concern include African Swine Fever and Avian Influenza.

Genome data and therapeutic genome editing

Advent of high speed, low cost, high throughput genome sequencing means that we can now generate whole genome data at a near trivial cost. Studies such as the 100,000 genome project are routinely generating genome data in an effort to try and understand the genetic and environmental components of a wide range of disease. The key to understanding this plethora of genome data will linking it to medical, health and environmental data to get a better idea of the genetic contribution to disease. At the same time, the development of therapeutic genome editing techniques means that once the genetic components of a disease become better understood, researchers and clinicians may have new tools at their disposal for treating conditions. Use of genome editing as a somatic therapy is relatively uncontroversial as it only raises the usual risk/benefit issues for the individual patient. However, use of genome editing to correct genetic disorders in germ cells (germline therapy) would be highly controversial because such use may affect future generations.

Obesity

No public health measures have so far resulted in reversing the trend towards increasingly obese adults and children at a population level. Evidence suggests that public health measures based on persuading obese and overweight people to eat a healthier diet and take more exercise are likely to have only a limited impact. Evidence also suggests that the high burden that obesity places on the healthcare system manifests itself largely through associated co-morbidities such as cardiovascular disease and type 2 diabetes. Dealing with these challenges may require measures to address the socio-economic inequalities that are associated with high rates of obesity and overweight.

Challenges facing the UK healthcare system

Among the key challenges facing the NHS in the years to come are ensuring equity of access to the system, meeting the demands of an ageing population (see below), being able to recruit and retain suitably qualified staff in

sufficient numbers post-Brexit, being able to fund the increasingly expensive bespoke therapies being delivered by current medical research and increasing competition from the private sector.

Treating an ageing population

An ageing population means that more people are living long enough to develop diseases such as neurodegenerative disorders and certain types of cancer that are associated with older people and expensive to treat. Changing lifestyles (diet, physical inactivity, etc), urbanisation and decline in manual labour means that more people are suffering from a greater number of co-morbidities for longer and require a greater range of medical and social care. The trend towards personalised medicine also means that new treatment, where available, tend to be more expensive than existing treatments.

End of life care

Medical technology is increasingly extending the possibilities for prolonging life during end of life care. As a result, clinicians are facing difficult decisions about balancing the costs of end of life care against their responsibility to deliver high quality care, that takes account of an individual's preferences.

The use of health data

There is enormous potential for data collected in the course of clinical care to be used for improving health, care and services through research and planning. However, there are challenges for getting the right infrastructure for the health service to make the most of these data. There are also significant ethical questions about who should be able to use this data, for what purposes and how it should be protected.

Information and Communications Technology and Robotics

Cybersecurity

According to the UK's National Crime Unit, over 2 million cyber crimes were reported in 2016, with these outnumbering traditional crime for the first time.[101] In particular, the use of Ransomware (where files are taken 'hostage' in an attempt to elicit payment from the owner) is a rapidly growing concern. The global cost for organisations is predicted to reach $5 billion by the end of 2017, a 400% increase on 2016 estimates.[102] Cybercrime-as-a-service (CAAS) is also a growing industry involving cybercriminals buying tools and technology to allow them to launch cyberattacks without the technical skills and resources needed to create the tools themselves.[104] The increased threat of cyberattack poses challenges for government, business and individuals. The UK Government's National Cyber Security Strategy 2016-21[104] aims to develop the UK's capacity to take offensive action in cyberspace, but it will need the help of private sector actors who are the only ones who can implement many of these measures. At the same time, individual businesses and the general public will need to learn how to protect themselves against (and respond to) cyberattacks.[105]

The future of the UK's communications networks

There are a number of issues likely to influence how the UK's communications networks will develop over the next few years. These include: the growing demands of mobile data traffic, which are likely to lead to further radio spectrum management;[106] the Government's intention to introduce a universal service obligation,[107] which is creating debate around what the universal service level should be and how technology can be used to meet it; the development of 5G,[108] which aims to provide faster mobile broadband data with low latency and high reliability; and the Government's plans to migrate the communications system used by the UK's emergency services from a dedicated network to one that uses the commercial 4G mobile network.[109]

Trust and technology

Trust can be understood as a dynamic process - people have to evaluate what to trust, why to trust and when to trust on an ongoing basis. Technologies, such as artificial intelligence or devices that pervasively collect data, may present challenges this. The relationship between public trust and technology is of critical importance for the successful development and adoption of technologies.[110] Being able to reliably verify the identity of the parties involved in an online interaction is an important part of building trust. The Government has developed the 'Verify.gov' system to allow Government online services to use existing commercial services (such as banks or the Post Office) to validate someone's identity before forwarding them on to the Government service that they want to access. The Government has stated its ambition for 25 million people to be using this system by 2020.[111]

Robotics and autonomous systems

The UK government predicts that robotics and autonomous systems (RAS) have the potential to increase UK productivity across the economy by up to £218 billion.[112] The Boston Consulting Group predict that robots will become

cheaper and more efficient in the coming years, replacing human workers faster than expected while driving labour costs down by 16%. Automating tasks previously undertaken by human workers may lead to the loss of significant numbers of existing jobs while potentially creating new types of jobs with different skills requirements.[113] Artificial intelligence is a key RAS technology that raises legal and ethical questions relating to who should take responsibility for the decisions made by AI; who has legal liability when systems may be created and maintained by many different companies; and when in an automated process a human should intervene.[114]

Internet of things

Machine-to-machine communication is making it possible to connect billions of devices together to create an Internet-of-Things (IoT).[115] The IoT has numerous possible applications across healthcare, utilities, leisure, transport, retail, manufacturing, construction, agriculture, etc. Examples include using medical devices to collect physiological data from patients to help monitor their conditions whilst at home; using sensors in public bins to plan more efficient refuse collection routes; and autonomous cars. The IoT is also closely associated with the concept of 'Industry 4.0', in which digital technologies are being applied to conventional industrial processes. While there are sizeable potential economic benefits from the IoT, questions about standardisation, privacy, security, replacement of human labour and access remain.[116]

Increasing use of cloud computing

Cloud computing can be used to access software, processing power, data storage and other computing resources as a service. However, it raises questions for data ownership, control and security; privacy; and organisation resilience (e.g. if companies are dependent on other businesses for critical services). The implementation of the EU General Data Protection Regulation in 2018 will require any company handling data belonging to EU citizens to comply with more stringent data protection requirements. Brexit may create opportunities to diverge from these standards, however opportunities for divergence may be limited for organizations wishing to process the data of EU citizens.[117]

Quantum computing

If developed, quantum computers could explore multiple different solutions to a problem simultaneously, allowing them to tackle certain tasks that would take conventional computers millions of years. In addition to revolutionising computing, quantum computers could also significantly affect computer security by allowing for the breaking of encryption systems used worldwide to protect sensitive data (e.g. in banking, medicine, commerce and government).[118]

Big data

Increasing quantities of data are being collected and analysed, producing new insights into how people think and act, and how systems behave.[119] Analysis of this data has the potential to enable the personalisation of products and services, improvements in efficiency and the creation of new jobs and economic growth. However, this also has many potential policy implications, including for possible infringements of privacy, the security of data, consumer protection and the potential for discrimination. The EU General Data

Protection Regulation is due to come into force in 2018; however, there is uncertainty about what UK data protection legislation will look like post-Brexit.[120]

Darkweb

The Darkweb is used to refer to websites whose operators can conceal their identity with sophisticated anonymity systems. It allows internet users to access the web and to create websites called Tor Hidden Services without revealing their identity, thus providing a platform for journalism, whistle-blowing, law enforcement investigations and the circumvention of internet censorship, as well as for drug dealing and other crimes.[121] Preventing such crimes is a major challenge for law enforcement agencies that find difficulty in identifying which entities are initiating activity. While this community may create a platform for criminal activity, it has been argued that potential benefits exist as well. For instance, online drug markets like Silk Road may shorten the supply chain from drug producers to consumers, potentially reducing the number of drug-related crimes.[122]

Distributed ledger technologies

Distributed ledgers are digital records that can be shared among many different locations or users, without needing to have a central intermediary. Their characteristics vary, but all involve distributed and secure information sharing. This technology was originally developed for digital currencies – for instance, the blockchain ledger behind Bitcoin. However, blockchains could be used more broadly, since they provide a way of creating securely shared records for essentially any asset or transaction. Potential applications include: supply chain transparency, smart contracts, government operations and instant global financial transactions. Questions remain as to how this will affect central institutions like governments and central banks, how it will be regulated, how it will overcome technical and commercial challenges for widespread use and how to maximise its benefits.[123] For instance, Distributed Ledger Technology (DLT) could be used to develop innovative solutions to financial crime. The BBA has already estimated financial crime compliance processes costs its members some £5bn a year and credit institutions filed around 318,000 suspicious activity reports in 2014-15, suggesting that DLT solutions could provide significant savings. However, such solutions also raise issues around consumer protection as it can be difficult to apply existing laws to business models that blur the boundaries between consumers and businesses.

Transport and Infrastructure

Realising the social benefits of smart cities

Smart cities – cities that use information and data technology to optimise living – can hold data on numerous aspects of a citizen's life such as energy usage, location data, routine habits and more. Municipalities can incorporate smart technology into their environments to save money, enhance the lives of their constituents and entice business start-ups. Internet of Things technology can optimise a city's use of resources, including water, fuel, energy and even waste. To do so, a multi-input strategy is needed that brings together efforts in a coordinated, strategic manner, but authorities often adopt connected technologies without coordinating their efforts. With an uncoordinated approach, key day-to-day data ends up siloed off making it difficult to fully capitalise on the extent of data collection made possible by the internet of things. As well connecting siloed information, proactive collaboration with residents to build well-informed healthy communities is a key process.[124] For example, by creating an autonomous smart bus network and offering free citywide Wi-Fi, Barcelona has encouraged its residents to drive less and walk more allowing for a reduction in pollution rates and obesity.[125] However, without regulation to protect privacy, public concerns about the extent of data collected are likely to arise, especially if these systems are vulnerable to attack by external parties.[126] For example, China has stated that by 2020 they envision a fully smart infrastructure in which citizens will be graded on a points system that rewards 'good' behaviour.[127]

The rise of autonomous transport

The current infrastructure of most cities is not designed for the use of autonomous modes of transport. For example, the widespread use of autonomous vehicles will require appropriate urban planning that is adapted to its purposes on public transit, private transit and urban design fronts. Moreover, the influence autonomous transport will have on human behaviour – such as effects on living arrangements, physical activity and demand for public transport – may call for alternative city designs. For instance, the reduced 'cost' of travelling would reduce the advantage of living close to a city centre, potentially leading to more dispersed cities with less dense urban centres. Autonomous transport also promise an unprecedented level of data, which could track everything from what times people leave for work to which roads they take, thereby resulting in both challenges and opportunities.[128] Some have also raised concerns over the potential for autonomous vehicles to be used for criminal or terrorist purposes.[129] Industry are looking to produce autonomous vehicles within a decade, and larger drones are also likely to be used as passenger vehicles in the near future; at least six developers have retail road-air vehicles in the pipeline,[130] such as the Airbus Vahana project that is due to have its first test flight in 2018.[131]

Regulation of autonomous modes of transport will be a particular challenge during the transition to transport systems becoming fully autonomous, but safety could be helped by technologies, such as geo-fencing and collision avoidance for UAVs, as well as regulators requiring companies to share safety lessons learned. Various approaches are also being developed to implement vehicle-vehicle and vehicle-infrastructure technologies. For instance, in the US, a sensor network is being used to collect information on traffic volume, structural stress and other road conditions for the federal government.[132] The

UK Government has set the UK the challenge of becoming a world leader in shaping the future of mobility as one of the grand challenges in the Industrial Strategy white paper.[133]

Development of spaceplane infrastructure

Spaceplanes are vehicles that operate as an aircraft within Earth's atmosphere and as a spacecraft above it where air pressure is insufficient for conventional carriers. Such planes could offer spaceflight experience, research possibilities and satellite deployment platforms but could also fly shorter and lower trajectories with limited payloads. The cost of spaceplanes, their re-usability and their take-off requirements are challenges that are being worked on. For example, Space X has recently suggested its next generation of rocket will be fully reusable and could be used to travel between terrestrial destinations.[134] The Civil Aviation Authority anticipates spaceplanes' commercial availability within 5-10 years, and if fulfilled, would require appropriate regulation for spaceplane transport and spaceport location in the UK; the Space Industry Bill introduced to the House of Lords sets out a proposed legislative framework. The different proposed designs would require different spaceport facilities such as runway lengths and fuel supplies.[135] However, increased dependence on space technologies may lead to greater vulnerabilities to 'space weather'. Space weather describes changes in the near-Earth space environment caused by conditions within the Sun's atmosphere involving the ejection of highly energetic particles and radiation. These events have the potential to affect satellites, aviation equipment and parts of the electricity network, but can be mitigated by improving forecasting, planning and resilience measures.[136]

Building information management (BIM)

BIM is a software platform that generates 3D models of buildings for use from design and construction through operation to demolition. Models can include information on dimension, material, cost and other relevant features to simulate the building's existence throughout its lifecycle. BIM can be complemented by sensor technology and drone monitoring for inspections as well as virtual and augmented reality for design and maintenance. BIM is classified into 3 different levels, and in the UK, level 2 has been a mandatory requirement for centrally procured government projects since 2016. The Government estimated that BIM saved construction costs of £840 million in 2013/2014. Further use of BIM will need to overcome copyright and liability issues along with further technological investment and skill development.[137] This includes the development of models and software to make effective use of high performance computing platforms to generate as-is models at a large scale.[138] As part of the 'Transforming Construction' Industrial Strategy Challenge Fund Investment, the UK Government has launched the Centre for Digital Britain at the University of Cambridge, which will develop BIM, sensors, data analytics and smart systems that can be embedded in building projects.[139]

SESAR air traffic control)

Single European Sky Air Traffic Management Research (SESAR) is a European Commission project aiming to improve air traffic management through modernisation and harmonisation of systems across Europe. The future of European air transport – both commercial and private – relies on the full integration of airports as nodes into the network, which implies collaborative decision making, public and private cooperation and enhanced airport

operations. For example, work carried out in one of SESAR's airports package helped develop the concept of Time-Based Separation whereby aircraft are separated by time instead of distance. This concept significantly improves resilience in strong headwind conditions and is expected to save 80 000 minutes of delay per year at Heathrow. SESAR is currently in its third and final phase of deployment where concepts and technologies developed are being introduced across Europe, but this is expected to take at least 5 years. Post-Brexit, the UK's involvement in SESAR and its ability to shape future regulation in the aviation industry is unclear.[140] However, the UK Government is developing a new aviation strategy.[141]

Electric vehicle infrastructure

The use of electric vehicles – be they battery-powered, from overhead wires, plug-in hybrids, rechargeable hybrids or fuel cell vehicles – will require enabling infrastructure to achieve widespread use. Such infrastructure would include carpark charging points, service stations and the ability to transport hydrogen across the country (for fuel cell vehicles). Given the ability for electric vehicles to cut greenhouse gas emissions and help the UK meet legal targets, the Government's Office for Low Emission Vehicles is investing over £900 million to support the development of ultra-low emission vehicles. The UK and France have both pledged a deadline of 2040 to phase out fossil fuel cars and vans; India plans to have only electric cars on its roads by 2030; Norway plans to sell only electric vehicles by 2025; and the Chinese government has set quotas mandating that electric and hybrid vehicles should account for 12% of all car sales by 2020 as it sets a timeline for complete phase out.[142] The world's first electric road is being inaugurated near the city of Gävle in central Sweden. The new technology, which is the result of several years of cooperation between the Swedish Government and the private sector, permits trucks to operate as electric vehicles when on the electrified road and as regular hybrid vehicles at other times. Using a pantograph mount, trucks receive power directly when on the 2-kilometre stretch and can freely connect and disconnect from overhead wires while in motion.

By contrast, the UK is trialling dynamic wireless power transfer technologies, which allow drivers of ultra-low emission vehicles to travel long distances without needing to stop and charge the car's battery.[143] In the U.S., 48 national electric-vehicle (EV) charging networks on nearly 25,000 miles of highways in 35 states are being set up under the 2015 FAST Act.[144] The UK Government has stated in the Industrial Strategy White Paper it will support electric vehicles through £400m charging infrastructure investment and an extra £100m to extend the plug-in grant.[145]

Key innovations for making cities resilient

The number and severity of natural disasters occurring around the world is increasing while projected population surges will greatly increase pressures on existing infrastructure. Having an accurate picture or inventory of the infrastructure assets in a town or city is crucial to making informed decisions about future development. Innovations that achieve this aim are numerous and varied: geographic information system inventory; drone-monitor systems; sensor-equipped buildings; and, new technologies such as sensors, robots, cameras. However, the UK would have to develop approaches to retrofitting existing infrastructure assets and buildings with digital technologies to create such inventories. Such technologies can make it easier and cheaper for urban

planners to incorporate resilience into their designs and can complement current approaches to city design and infrastructure, such as building codes and standards.[146] Green infrastructure assets– infrastructure aimed at promoting environmental health or preservation – has also been suggested as a means of increasing resilience. These include assets such as retention ponds, green roofs and living walls, but assessing their quality requires knowledge of how relationships among plant species influence ecosystem functions. Such knowledge could be applied to improve benefits such as urban cooling, habitat creation and storm water management.[147] The World Bank suggested recently that the costs of natural disasters are 60% higher than originally estimated placing a burden on the global economy of $520 billion USD in lost consumption each year. This discrepancy arises because the poor suffer disproportionately from natural disasters, but this is not reflected in current estimates.[148]

Digitising rail technology

Network Rail has been developing a program for the national roll-out of a new railway signalling technology. This strategy includes elements of the European Rail Traffic Management System (ERTMS), which the EU has agreed should become standard for all its high-speed lines to enhance safety, reliability and capacity while reducing costs. ERTMS involves a computerised traffic management system that uses train data and radio signals to update movement almost continually and to optimise network movement. Brexit raises questions for whether the UK will continue to adopt ERTMS standards or pursue its own approach.[149]

Endnotes

Realising the social benefits of smart cities

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