SAMI Consulting

robust decisions in uncertain times

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The Global Pandemic and Drivers of Change

How are fundamentals changing?

Huw Williams

www.samiconsulting.co.uk

How has the pandemic affected the drivers of change?

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SAMI put together a set of **_12 Drivers of Change_** back in April 2018. This Working Paper is consolidates a series of blogposts written during 2020 updating these drivers with specific reference to the impacts of the pandemic. We consolidated the 12 drivers into six wider ones. These can be contrasted with "megatrends" produced by others, as covered in our paper "Meta-Megatrends".

As an introduction, we produced a quick, subjective overview of some of the effects we might expect to see.

SAMI's 12 Drivers of Change:	Pandemic effects
• **Demographics:** Growing world population, driven by increasing longevity, especially in Africa (and not by increasing numbers of babies being born); also an ageing population	• 4 million dead worldwide so far; maybe 8 million by the end => minimal effect on total population • Disproportionate effect on older people – still not enough to be significant • Disproportionate effect on different ethnicities could yet have global impact
• **Multi-polar world:** Shifting global economic centre of gravity from West (and OECD) to East and South (especially Africa).	• Disruption to global supply chains => re-shoring • China looking to exploit opportunities, but facing a backlash • Underlying economics unchanged
• **Economic Growth**: Increasing returns to capital at the expense of labour; growing inequality within countries. Regional and sectoral distribution of economic growth set to evolve with pace of growth uncertain.	• Recession or Depression expected – range of "bounce back" forecasts. • Variable effects depending on extent of lock-down = UK, US, Brazil likely to be worst hit. .

• **Social Cohesion:** Deteriorating social cohesion leading to unrest until "third culture" becomes the norm.	• Pandemic highlighted the extent of inequality, and a degree of solidarity, so creates potential for change
• **Climate and Environmental Change:** Climate change leading to even more extreme weather events, such as more hurricanes, higher sea levels, more floods and more droughts, acidified oceans, bleached corals, California fire and mud slides, Australian fire, etc.	• Interim experiences of less pollution and fewer emissions welcomed • Many voices calling for green recovery - unclear whether they will succeed • Climate crisis identified as next disaster
• **Energy Sources:** Energy sources are increasingly diversified and decentralised as energy mix shifts.	• May accelerate deployment of renewables
• **Pervasiveness of IT/IoT:** plus blockchain/FS/data/smart infrastructure	• Strong push for medical monitoring applications
• **Machine learning and 4.0, robots:** Increasing sophistication of machine learning and adaptive IT systems (face recognition, AI, robotics, cobots, AI journalists, automated trading, etc) – impact on jobs	• AI applications: vaccines, track and trace • Blow to car-sharing models of Autonomous Vehicles
• **Biotech:** Emerging bio-age (personal medicine, manufacturing in fermentation vats, bio-engineered chemical production, biodata storage etc.).	• Big boost to vaccine development using latest techniques • Preparations for next pandemic may work at a generic level
• **Migration:** In Europe 1 million plus young immigrants a year from mostly Middle East and North Africa. Globally 21.5mn displaced yearly by natural disasters.	• Migrant camps at high risk requiring new approaches; maybe dissuades new migrants • Global scope means little direct effect
• **Urbanisation:** Continuing shift of population from rural environments to city life.	• Mega-cities, especially in the South, are high risk areas • Unlikely to significantly affect overall trend
• **Changes in personal values:** Personal aims and ambitions – how do the generations compare?	• Different generational effects – young more likely to lose employment; elders more likely to isolate • Greater awareness of non-financial objectives

1. Population dynamics

Image by Gerd Altmann from Pixabay

Our first driver is "population dynamics", encompassing the related areas of demographics, urbanisation and migration. It is perhaps the most fundamental in that it affects social, economic and political developments, with their consequential effects on technology development.

The biggest change from our 2018 work has been a radically new set of population forecasts. In their book, ***Empty Planet: The Shock of Global Population Decline***, Darrell Bricker and John Ibbotson challenged the UN's population projections for the 21st century, arguing that the likely population change will be lower than even the UN's "low" projection. Recent population forecasts from the Institute of Health Metrics and Evaluation (IHME) at the University of Washington suggest that nearly every country will have shrinking populations by the end of the century. The global population will peak in around 2064. Twenty-three nations – including Spain and Japan – are expected to see their populations halve by 2100. Countries will also age dramatically, with as many people turning 80 as there are being born.

The reason for this lower, declining forecast is widespread and sustained declines in fertility due to improvements in access to modern contraception, and the education of girls and women. This is one of the potential counter-trends that we identified in our 2018 set of drivers.

One of the wild-cards we identified was a pandemic. As of August 2020 there were 800,000 confirmed deaths globally due to Covid-19 – this is likely to be an under-estimate due to difficulties in recording data. The US and Brazil recorded over 100,000 deaths; Mexico and India over 50,000. The final toll will depend on many things, in particular when (or, indeed, whether) an effective vaccine becomes widely available. There are also other excess deaths caused by other diseases which health services have been unable to treat. But even if we assume as many as 5

million excess deaths from Covid-19 and other causes, that makes little impact overall on a global population of 8 billion people.

There are differential effects of the pandemic too. Older people have a higher death rate – but not to the extent of reversing the pattern of population ageing. In the West, those of a black heritage also have a higher death rate, but this pattern appears not to be replicated in sub-Saharan Africa – death rates in Kenya and Malawi are notably lower, for reasons as yet unknown.

Deaths from AIDS, malaria and tuberculosis (TB), three of the deadliest infectious diseases, together kill 2.4 million people every year and because of the pandemic deaths from these diseases could double over the next year.

Those from the Indian sub-continent also have a higher than average death rate, due it is thought to a higher prevalence of diabetes –32 million in India alone. But again this is unlikely to deflect the overall population trends.

As identified in our 2018 document, climate change driven migration remains a likely trend. By 2070 the proportion of the world that is a barely liveable hot zone is projected to have risen from 1% to 19%. Up to a billion people will be driven by droughts and crop failures from central Africa, central America, India and Eastern China. Many will move towards local cities – others to the US or Europe. And there is no sign of other drivers of migration – state-failures, advent of new modes of conflict, proliferation of regional wars – declining. Indeed these are themselves often caused by migration and climate change. Our 2018 document suggested "Global Peace" as a wild card that would stop the trend, but that remains a distant prospect. What might change is the Western attitude to migration. Populism and nationalism have been growing in recent years, but the economic benefits of welcoming migrants into a rapidly ageing population could overcome these attitudes. The IHME even suggest we could see countries competing for immigrants through increasingly liberal immigration policies. A more dystopian view would be an increase in policies that intrude on women's fertility – restrictions on abortion and contraception, financial rewards for larger families. There have been some suggestions along these lines in Eastern Europe already.

There is also the prospect that the economic inequalities between countries might decline, reducing the motivation for migration. Nigeria, for example, is projected to leap up the GDP league table as its population continues to grow. This is likely to result in further urbanisation, as mega-cities become engines of economic growth. Although the pandemic may have painful effects on densely populated mega-cities and on migrant transit camps, it seems unlikely that it will have a significant effect on the overall trends. We did refer to pandemics as a possible disruptive wildcard in 2018, but in practice this one appears not to be having very much effect on the scale of most megacities so far.

However, in London and New York there has been a boost to remote working which could continue into the future. <u>Many organisations are re-thinking</u> their working structures; <u>Shroders</u> for example looks to make home-working permanent. If the trend continued, the consequences for organisational structures (more sub-contracting, wider supply chains, micro-multinationals) and cities (supporting service industries badly hit) would be significant, even if people did go to the office a few days a week. The trend seems <u>less pronounced in other countries</u>, so the global trend towards megacities can be anticipated to continue.

2. Climate emergency and renewable energy sources

Image by Anja 🙆#helpinghands #solidarity#stays healthy🙆 from Pixabay

In this section, we look at the climate emergency and renewable energy.

Recent events attributed to climate change include wildfires in:

- Australia: record-breaking temperatures and months of severe drought in an extended 2019/2020 fire season fuelled a series of massive bushfires in NSW and Victoria. In NSW alone fire affected more than five million hectares, destroying more than 2,000 houses; an estimated 25,000 koalas were killed and several endangered species threatened when flames devastated the Kangaroo Island nature reserve in South Australia. Air quality was seriously affected and harmful plumes of black carbon blown to New Zealand, blackening glaciers, and across the Pacific to South America, creating a further global heating feedback loop. Climate scientists say that the bushfires were more catastrophic than any simulation of the changing climate predicted.

- Western USA: In Oregon, "unprecedented" fires burned destroyed than 900,000 acres and half a million people – about 10% of the state's population – were under evacuation orders. Parts of the state saw fires of greater intensity than any in the last 300 or 400 years. California has seen six of the 20 largest wildfires in its history this year, which have burned a record 3.1m acres. The fires are also hitting before the traditional start of fire season in the fall. The smoke turned the skies orange, and created "fire thunderstorms". In Washington state more than half a million acres have burned.

- In Brazil, the world's largest tropical wetland, the Patanal, is not supposed to burn. But fires there have destroyed some 25,000 square kilometres— roughly four times the area burnt in California so far. A UNESCO heritage site and one of the world's most diverse ecosystems — home to dozens of endangered species and the densest concentration of jaguars anywhere — is in jeopardy.

- Arctic Circle: apart from seeming rather incongruous, the fires burning in the Arctic for the second extraordinary fire season in a row are even more worrying. The burning carbon-rich peat lands emitted a record 244 megatonnes of carbon dioxide — 35% more than last year, which was itself a record. The feedback loop: as peatlands release more carbon, global warming increases, which thaws more peat and causes more wildfires. Northern peatlands could eventually shift from being a net sink for carbon to a net source of carbon, further accelerating climate change.

And the 3-month season from June through August 2020 was the Northern Hemisphere's hottest summer on record, surpassing both 2019 and 2016 which were previously tied for hottest.

Climate scientists continue to update their forecasts. Recent research narrowed the range of global heating forecasts. Until now, the IPCC has estimated a doubling of atmospheric carbon dioxide from its pre-industrial level of about 280 parts per million has a 66% chance of heating the planet by between 1.5°C to 4.5°C. The new research reduces that range to 2.6°C and 3.9°C, a move away from the catastrophic upper forecast, but well above the Paris accord targets. It estimates with a 90% level of probability that climate sensitivity is between 2.3°C and 4.7°C; the most likely level of climate sensitivity is slightly above 3°C; a figure below 2°C is extremely unlikely; above 5°C remains possible, though the study lowers that likelihood to 10%.

The upper estimates could be made more likely by feedback loops. Computer simulations of clouds have begun to suggest that as the Earth warms, clouds become scarcer. With fewer white surfaces reflecting sunlight back to space, the Earth gets even warmer, leading to more cloud loss. This feedback loop causes warming to spiral out of control. The simulation revealed a tipping point: a level of warming at which stratocumulus clouds break up altogether. When the tipping point is breached, Earth's temperature soars 8°C, in addition to the 4° of warming caused by the CO2 directly.

Climate change is also forecast to hit the economy. It will cut global GDP, with hotter countries like India suffering the most.

The reduction in economic activity caused by the pandemic has in effect been an experiment showing the effects on CO_2 emissions. Lockdown measures caused electricity demand in England, Scotland and Wales to fall by 13% in the second

quarter, compared with the same months last year. This also helped the share of renewables to grow by a third to 40% of the energy mix.

Lower levels of traffic have also reduced carbon emissions (transport accounts for 25% of global emissions) and improved air quality in cities. In early April, daily fossil fuel emissions worldwide were roughly 17 percent lower than they were in 2019. Several cities, notably Paris and Milan, are attempting to keep these gains.

However, as the world returns from lockdown, emissions are rising again and it is thought that the pandemic overall will have a negligible effect on climate change. This is because CO_2 is so persistent in the atmosphere, short-term emission reductions resulting directly from the pandemic lockdowns lead to undetectable reductions in warming.

Several commentators and politicians are pushing for a green recovery from the pandemic recession. Some optimistically point to green growth after the last recession. The coal industry is particularly likely to be affected, because the crisis has proved renewable energy is cheaper for consumers and a safer bet for investors. An important exception, however, may be China, where coal growth is returning.

Oil firms too are recognising the challenge. Seven top firms downgraded assets by $87bn in 9 months and reduced payments to shareholders. The price of Brent crude oil fell from around $70 a barrel at the beginning of the year to $15 on April 1st, returning now to around $40.

BP's annual energy outlook examines three scenarios for the "liquid fuels" global market – in all of them 2020 seems be the year of "peak oil". However, it is clear that radical action is required to reach "Net zero" by 2050.

They conclude with an eye-catching message: "The world is on an unsustainable path…. Delaying policy measures and societal shifts may lead to significant economic costs and disruption." And this is from an oil company, remember.

BP demonstrated its belief in the renewables market and its desire to "pivot to truly becoming an integrated energy company" by investing $1.1bn in a strategic partnership with US off-shore wind company Equinor to further develop that market. Offshore wind generally withstood the effects of the pandemic, with investments totalling $35 billion, up 319% year-on-year and in fact well above 2019's record full-year figure (a revised $31.9 billion).

In the UK, BEIS acknowledged that electricity generated from wind and solar is 30-50% cheaper than previously thought. As a result, electricity from onshore wind or solar could be supplied in 2025 at half the cost of gas-fired power.

Further out, hydrogen is regarded by many as the best option to replace fossil fuels. Hydrogen can be used as a feedstock, a fuel or an energy carrier and storage, and has many possible applications across industry, transport, power and buildings sectors. But most hydrogen today is produced using fossil fuels. The EU published its hydrogen strategy recently, in which it plans to move decarbonise hydrogen production and scale up its use. Hydrogen becomes in effect a storage and delivery mechanism for electricity generated by renewables. Japan planned to make the Tokyo the "Hydrogen Olympics", with hydrogen powered transport and even a hydrogen Olympic flame. Chile is also looking to become a leader in "green hydrogen".

So despite horrific effects of the climate emergency becoming increasingly clear and "business as usual" forecasts warning of unmanageable levels of global heating, there remains good reason to hope that the economic benefits of renewables will drive their uptake and enable countries to reach "net zero" targets. The pandemic has created an opportunity for "green growth", though it is as yet unclear whether this will come about.

3. Geo-political dynamics

Image by Gordon Johnson from Pixabay

The third of our revised set of drivers of change is a combination of three drivers–poly-nodal world, economic growth and social cohesion (including inequality) – which we are calling "geo-political dynamics". Naturally there are still inter-relationships with other drivers, notably demographics and climate change, but also technology and social attitudes. This is also an area significantly affected by the Covid-19 pandemic.

As we noted above, the demographic trends will lead to declining and ageing populations in the West and advanced economies, with significant continued growth only in India and central Asia until the end of the century and Africa throughout. Population is a key long-term driver of GDP and hence of geo-political power. So we can expect to see a shift towards a poly-nodal world.

China's rise will not continue unabated, though in the short term it is taking an increasing aggressive stance globally and cultivating a sense of nationalism. The unity of the Chinese Communist Party may itself start to fracture as President Xi is said to facing widespread opposition within the party. The costs of being a superpower are already seemingly causing concern, and spending on the Belt and Road Initiative has been falling since 2017.

In the second half of the century, the growth of Africa will be rewarded with more influence. The growing middle class in Africa has consumer power and will likely increase pressure to more open economic systems Nigeria's working-age population is forecast to grow over the course of the century (from 86 million in 2017

to 458 million in 2100), supporting rapid economic growth and its rise in GDP rankings from 23rd place in 2017 to 9th place in 2100.

All bets are off forecasting GDP growth over the next few years because of the extended recession caused by the pandemic. Economic forecasts vary widely, from a "bounce-back" V-shaped recovery, a W-shaped one as a second wave hits, to an L-shaped, which isnot really a recovery at all. The World Bank's "Global Economic Prospects" report in June envisaged deep recessions leaving lasting scars through lower investment, an erosion of human capital through lost work and schooling, and fragmentation of global trade and supply linkages. Countries hit hardest by the pandemic would have lower growth – US, India, Brazil, UK. Areas of the East Asia and the Pacific would be relatively better off.

We will discuss possible regional scenarios in future blogposts based on our work for the EC Research and Innovation Directorate.

Policy decisions will also hugely influence the speed and scale of recovery. In the EU at least there seems to be an appetite for a substantial continued investment funded by borrowing, though some commentators believe even this is insufficient. Alongside that it is looking to take a more leading role in global politics, filling the space being vacated by the US, being more willing to challenge Russian misbehaviour, and looking for a revised relationship with China based on handling climate change and mutual economic interests. In the UK, conversely, most discussion has revolved around increased taxation versus more spending cuts. Social attitudes, such as populism and resistance to immigration also affect the way governments relate to the rest of the world. Whatever the outcome of the US election, its population continues to exhibit a weakening enthusiasm for globalisation and a reluctance to engage in multinational organisations. We shall also look at changing social attitudes in a future blogpost.

Social cohesion is eroded by inequality, which had been continuing to rise in developed countries over recent years, though there has been some push-back against the gig economy, part-time working and zero-hours contracts. Nonetheless, recovery from the pandemic may revive calls for de-regulation.

The pandemic brought a wave of community spirit with clapping for health workers and an encouraging increase in neighbourly support. But it also exposed inequalities and vulnerabilities of precarious employment. Over 52% of lower income adults in the US say that they or someone in their household has lost a job or taken a cut in pay due to the outbreak, compared with a national average of 33% in the latter half of March. Only about one-in-four (23%) say they have rainy day funds set aside that would cover their expenses for three months in case of an emergency such as job loss, sickness or an economic downturn, compared with 48% of middle-

income adults. Conversely, U.S. billionaires saw their fortunes grow by $434 billion during the nation's lockdown between mid-March and mid-May. This gap between the 0.1% and the rest is fertile ground for social unrest in the future, and is not limited to the United States.

The climate emergency also drives geo-political change. Climate-driven migration and competition for water resources increase regional tensions, and this is likely to grow as a problem. The melting of the Arctic ice-cap opens up new trade routes and drives increased competition amongst regional players for its oil, gas and uranium reserves. Melting permafrost causes problems to Russia's oil industry infrastructure, though there is Russian research suggesting that new regions may become viable for agriculture.   Continued heating in Africa could bring migration, famine, wars caused by population movement, degradation of the natural environment, some areas rendered unliveable through heat undermining their potential for growth.

If commitments to "net-zero" carbon emissions are to be met (and heaven help us all if they are not), then the use of fossil fuels has to fall dramatically. The price of oil is already falling causing oil giants like Shell to shed 9,000 jobs. Countries whose economies depend on fossil fuels – Middle East, US, Russia, Australia – face huge challenges of realignment.

Automation and AI have a complex interaction with economic and geo-political power. China's investment in AI has seen leadership in AI become a major global battleground. Advances in this technology promise to give the edge in terms of military and economic strength. Forecasts of the impact on employment vary hugely: Frey and Osborne estimated that 47 per cent of total US employment was at risk from computerisation; by contrast, PWC argue that increase GDP growth from AI will create more jobs than it destroys. The US and UK suggest that employment can be brought back to old industrial areas and supply chains made more secure against future pandemics by "re-shoring" but many of these jobs are likely to be undermined by automation.
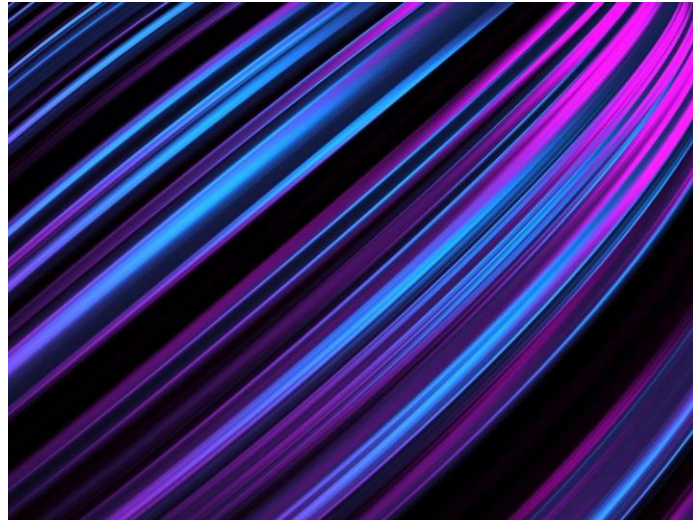
4. 4th Industrial Revolution

Image by 3D Animation Production Company from Pixabay

The increasing digitalisation of industry is bringing together advances in sensors, through the Internet of Things, other immersive technologies, Big Data analytical tools and machine learning/artificial intelligence. Together we regard these as part of the "4th Industrial Revolution".

At the simplest level, the pandemic has accelerated several digital technology trends, leading to more working from home and increased use of online collaboration tools such as Microsoft Teams and Zoom. A notable development has been the increase in virtual GP consultations, which can be expected to continue after the pandemic has passed (interestingly, text and telephone have been as useful as video). Online learning – and "blended" learning – is becoming the new norm.

The "Internet of Things", networks of connected devices, is dominated by applications in manufacturing (44%), followed by asset management, smart homes and freight management, with many innovative applications in health care, retail, energy, and agriculture. IoT sensors enable:

- remote control, predictive maintenance and energy management;
- "wearables" for health monitoring, in hospital or in the community – eg smart contact lenses can detect glucose levels and deliver insulin as necessary;
- precision farming, determining exact levels of water etc to be administered;
- smart cities, managing congestion and pollution.

Forecasts of the number of connected devices run into the tens of billions, even trillions, but most development effort is currently focused at the network level. Although many future applications are touted, the reality may be more mundane, with smart homes and smart cities being exaggerations of the actual benefits

delivered. <u>Intelligent chocolate dispensing machines</u> aren't a major societal development.

Challenges still facing IoT include latency, integration and especially cyber-security of the communications networks themselves, as well as user acceptance issues around privacy. Suggestions that the insurance industry could use sensors to help set premiums are experiencing pushback – Belgium has introduced a <u>law banning insurers</u> from using health monitor data.

IoT generates huge amounts of data, so has a natural link to "Big Data" analytics. A now-mainstream definition of big data is the three V's:

- **Volume**: from business transactions, smart (IoT) devices, industrial equipment, videos, social media and more.
- **Velocity**: the need to deal with very high volumes of data in near-real time.
- **Variety**: structured, numeric data; unstructured text documents, emails, videos, audios, etc.

But the benefits of Big Data come from analytical tools which enable users to identify statistical inferences and correlations. Traditional analytic techniques struggle to handle such vast amounts of data, so new parallel processing tools and techniques such as <u>Topological Data Analysis</u> are required to explore the "shape" of the data.

This brings us on to Machine Learning and Artificial Intelligence. Sectors where AI is particularly beneficial include:

- Law: many areas of law require relatively straightforward analysis of a large number of documents – planning applications, personal injury fraud;
- Medicine: similarly AI has found many applications in medicine, in cancer detection, drug development, predictive diagnosis and triaging, as well as more general clinical decision support systems . The pandemic has stimulated many developments in this field, however a recent review suggested that few systems are currently matureenough yet to show operational impact.
- Retail: covering a range of areas such as sales and CRM applications, customer recommendations, logistics and delivery and Payment Services

AI is penetrating <u>journalism</u> – though sometimes with <u>unfortunate mistakes</u>, publishing a photo of the wrong Little Mix singer. Thomas Frey (one of the authors of the <u>report on AI and jobs</u>) identifies areas of the <u>arts and entertainment</u> that AI will transform. AI creating "deep fakes" – manipulated or entirely manufactured images and recordings of people that are very hard to detect – will create a further challenge in an era of "fake news".

A related application is facial recognition, though its use in policing has been challenged because of interference with human rights and its inaccuracy, especially with ethnic minority faces. Russia is developing a "Minority Report"-style system for identifying people behaving aggressively: "pre-crimes". The Chinese government is accused of using facial recognition to commit atrocities against Uyghur Muslims.

These last examples indicate the ethical issues associated with AI. AI-driven weaponry is a major area of concern. And if China is investing more in AI than any other country, then its ethical principles will implicitly become the dominant ones.

AI also underpins developments in Automated Vehicles: driverless cars, robotaxis. Again, despite ambitious claims from Tesla and Baidu, reality may more challenging as regulators take a hard line on accidents. Some suggest that driverless would still have as many as two-thirds as many crashes, and "safety drivers" in such cars may still be prosecuted.

At the top end of advances in the field of AI robotics is Popper, a semi-humanoid robot designed with the ability to read emotions based on detection and analysis of facial expressions and voice tones. The pandemic stimulated the use of telemedical robots as a way of reducing physical contact.

As we observed in our blogpost on geo-political trends, there are a range of views on what AI does to employment. Susskind and Susskind in their book The Future of the Professions: How Technology Will Transform the Work of Human Experts, predict the decline of today's professions (doctors, teachers, accountants, architects, the clergy, consultants, lawyers, and many others), not just clerical jobs. Others argue the reduction in routine tasks is to be welcomed, leaving roles requiring empathy and relationship-building to humans – but AI is moving into these areas too with mood detection.

In the area of technological advances, it is important to maintain a degree of scepticism. The Gartner Hype Cycle illustrates how often, after a burst of enthusiastic promotion, innovations can settle down to a specialised but lucrative niche – the "plateau of productivity". Nonetheless, the more dramatic claims can be a useful way of shocking people out of their current comfort zones and encouraging them to explore alternative scenarios.

5. Biotechnology

Image by Pete Linforth from Pixabay

As well as the technological developments of digitalisation that characterise the "4th Industrial Revolution", the field of biotechnology is shaping up to be just as dramatic.

In our 2018 set of Drivers of Change, we identified Crispr-Cas9, a gene-editing technique, as a break-through technology. The technique has now won the Nobel prize for its discoverers, Jennifer Doudna and Emmanuelle Charpentier. In their 2012 paper, they described how this bacterial system could be used as "DNA scissors". CRISPR is faster, cheaper, and more accurate than previous gene-editing systems and has since become ubiquitous in labs around the world.

Applications are envisaged in several fields. There are significant medical initiatives in curing genetic diseases, such as inherited blindness, blood disorders (e.g. sickle-cell anaemia) and lung cancer. Agricultural applications include increased grain weight and protein content in wheat, bacterial blight resistance in rice and herbicide resistance in several plants. There are also applications that promise higher quality meats or disease-resistant livestock. CRISPR can also help the environment as it can be used to produce biofuels from landfill and reducing methane emissions from cows. Within industrial biotech, a start-up company founded by Doudna is using CRISPR-based to improve the industrial fermentation process that is critical for the production of chemicals and enzymes. Bio-engineers have also introduced mutations into an enzyme from the leaf compost bug making it break down the PET plastic from which drinks bottles are made. The material can then be used to create new food-grade plastic bottles.

Biotechnology is also being employed in the battle against Covid-19. CRISPR's ability to rapidly and accurately diagnose a wide range of diseases is being brought to bear; RNA vaccines are being developed rapidly.

CRISPR is not without its controversies. A European court ruling made gene-edited crops subject to the same stringent regulations as other genetically modified organisms (GMOs), despite the CRISPR editing being small enough that the crops are indistinguishable from naturally occurring organisms. More dramatically, there was uproar at a Chinese scientist gene-editing embryos which were then used to produce babies – potentially rewriting the gene pool of future generations by altering the human germ line. That incident has at least served to energise the scientific community to greater ethical control.

Bio-engineering mosquitoes could produce males that have been modified to produce only sterile offspring, thereby limiting the spread of malaria. When released into the wild to create a "gene drive", they could mutate, spreading genes that researchers never planned for and find difficult to control once they spread outside the lab. In any event, the role of mosquitoes in the wider ecosystem may not be fully understood, and could create unintended consequences. The balance of risk and reward here is hard to calculate.

More generally, Cambridge University's Centre for Existential Risk has a full research project on Global Catastrophic Biological Risks looking into bio-safety and bio-security.

Further advances are expected from greater understanding of the genetic code. "Precision medicine" is an innovative approach to care that takes into account an individual's genes, environment, and lifestyle. Combining an analysis of the specific genome with sensors monitoring behaviour, AI systems can predict outcomes and design interventions. Many people have been concerned that sequencing individual's genomes (and hence predicting probabilities of various diseases) might affect one's insurance. The UK Government has agreed a voluntary Code of Conduct with the Association of British Insurers that restricts this, but whether that can be maintained permanently is open to question.

A separate field is nanomedicine – a branch of medicine that applies the knowledge and tools of nanotechnology to the prevention and treatment of disease. Nanomedicine involves the use of nanoscale materials, such as biocompatible nanoparticles and nanobots, for diagnosis, delivery, sensing or actuation purposes in a living organism. Main applications are

- Target specification: attaching nanoparticles onto drugs or liposomes to increase specific localisation. Since different cell types have unique properties, nanotechnology can be used to "recognise" cells of interest. This allows associated drugs and therapeutics to reach diseased tissue while avoiding healthy cells.

- Controlled drug release: research efforts are focused on trying to understand how to release diagnostic molecules and drugs from liposomes with heat, and microbubbles using ultrasound.

- Understanding different populations: tailoring nanomedicine behaviour to different physiological characteristics of patients and their disease states.

Biotech is also being utilised to grow artificial meat in the laboratory. "Cultured meat" is produced by taking a cell, preferably a stem-cell, from an animal, introducing a sample into a bioreactor (a vat of culture medium) where the cells proliferate exponentially and can be harvested. The resulting meat cell mush can be formed into a plethora of unstructured items, from patties to sausages – with or without other ingredients added for texture. Adding an edible "scaffolding" enables the production of more realistic, textured meat.   However, as yet there remain many challenges in producing meat at scale and an attractive cost. There are also several ethical issues.

A similar technique is applied to lab-grown organs, notably livers. Initially used to research liver disease treatments, the technology is advancing towards the point where liver transplants might be possible. An advantage here is that if the stem-cell is taken from the patient themselves there is far less chance of the body rejecting the transplant. After decades of research, clinical trials of artificially made blood are getting underway, offering hope of a backup to human donors.

Biotechnology can also interact with the digital world. CRISPR screening combined with machine learning can identify anti-viral compounds that may prevent viral infection. The focus is now on treating coronaviruses, including COVID-19.

Conversely, DNA is in effect an information storage mechanism – it can be sequenced ("read") and synthesised ("written to"), and is resilient and long-lasting. Its great advantage though is its capacity. E.Coli has a storage density of about 10^{19} bits per cubic centimetre – all the world's current storage needs for a year could be met by a one-metre cube of DNA. Recent advances work at room temperature, making it much more feasible to develop DNA data management technologies that are viable in real-world scenarios.

Biotechnology may not have had the hype that AI has received, but it looks to be just as likely to reach a viable plateau of profitable applications. Like AI, there remain several ethical and public acceptance issues and serious risks to mitigate, which could delay its implementation, but which if tackled early enough should be possible to overcome.

6. Social attitudes

Image by [Gerd Altmann](#) from [Pixabay](#)

We've seen how demographics, various macro-economic forces, climate breakdown and technology will cause change. The last of SAMI's six drivers of change is ***changing social attitudes***, a critical underpinning force. This discussion primarily addresses attitudes in advanced economies, but important changes are happening in developing countries too.

Attitudes of different generations likely vary in large part because of different experiences in their formative years. It used to be assumed that people's attitudes changed as they got older, becoming less radical and more pragmatic. But it is beginning to appear that the views of different cohorts are now remaining distinct as they age.

Typically, discussion of different generations uses something like the following definitions (many of the comments in this blogpost are taken from Pew Research Centre research). The descriptions of "Attitudes" are of course generalisations – no generation has uniform attitudes. Indeed, greater individualism and less conformity and deference has been a trend over the years.

Label	Birth	Adult	Formative events	Attitudes
Silent Generation	1928 – 1945	1952	WW2; post-war austerity; NHS, Welfare State; Festival of Britain	Fortitude
Baby Boomers	1946 - 1964	1969	"Swinging sixties"; hippies, *Les evenements;* Vietnam and anti-Vietnam; Equal pay, legalising	Optimism and progressivism; some becoming anti-migration and feeling left behind.

			homosexuality, Open University; winter of discontent	
Gen X	1965 – 1980	1992	Thatcher – Falklands, miners' strike; Cold War, fall of Berlin Wall; Mandela	Materialism, consumerism
Millennials	1981 – 1996	2008	War on terror; Blair: minimum wage, Iraq war; Financial crash, recession	Grim, retrenchment; ethical, life not defined by work
Gen Z	1997 - 2012	2020 +	Brexit, Trump; Covid-19; climate emergency; digital world	WTF?? Boomers stole our future; gender fluid

Money and work

Successive generations have become better educated (on average) – a factor tied to employment and financial well-being – but there is a sharp divide between the economic fortunes of those who have a college education and those who don't. Millennials have brought more racial and ethnic diversity to society. And Millennial women, like Generation X women, are more likely to participate in the nation's workforce than prior generations.

Britain's millennials earned £8,000 less during their 20s than their predecessors and are at risk of being the first cadre of workers in modern times to see their lifetime earnings fall.

Home ownership is considerably lower amongst young people than it used to be. The phenomenon of "boomerang children", returning to live with their parents is increasing: six-in-10 single 20 to 34-year-olds (3.5 million) without children now live with their parents; the proportion has risen from 55% to 63% over the last 10 years .

In 2018, a BBC documentary explored the views of millennials. They see themselves as hardworking, entrepreneurial and about to change the world for the better.

Gen X saw the rise of portfolio careers; millennials are increasingly entrepreneurial. A combination of different generations in the workforce has significant implications for incentive and reward schemes of larger organisations. Compared with earlier generations, millennials value greater flexibility, appreciation, team collaboration, progression and career opportunities, and, above all, a healthy work/life balance. Gen Z, however, is likely to value security and stability more highly.

Health

Depression is on the rise among millennials, many of whom suffer from loneliness, money stress, and burnout in the workplace. Since 2013, millennials have seen a

47% increase in major-depression diagnoses. The overall rate increased from 3% to 4.4% among 18- to 34-year-olds. This can be ascribed to the work and finance issues described above, but some commentators also identify social media as a factor because of the greater pressures it brings to compare one's life with others. Close to half (48%) of Gen Z and 44% of millennial respondents in a Deloitte survey said they're stressed all or most of the time.

On the positive side, the younger generations are being more open about their issues and destigmatizing therapy, with high profile individuals admitting mental health challenges.

Millennials and Gen X drink less alcohol than their predecessors – causing a rise in sales of "nolo" drinks of 30% since 2016. The pandemic is apparently reinforcing this trend. This group also smokes less than before. Although younger age groups smoke more than older ones, the prevalence of smoking since 2011 has fallen most in those groups; down by 8 percentage points among 18-24 year olds (from 26% to 18%).

Marriage
Millennials are less likely to be married than previous generations at the same age. Three-in-ten Millennials live with a spouse and child compared with 40% of Gen Xers at a comparable age. Again, this may be related to housing and finance.

Gender
Gen Z is becoming ever more gender fluid. According to Pew Research data released earlier this year, 35 percent of people in Gen Z know someone who uses "they/them" pronouns.

Research from VICE found 41% of Gen Z respondents from western countries identify themselves in the middle of the masculine to feminine scale, while half identify themselves as something other than heterosexual.

There is even the concept of "sologamy". More and more people around the world are choosing to "marry" themselves in symbolic ceremonies.

Digital technology
Millennials onward are digital natives who have little or no memory of the world as it existed before smartphones. Gen Z may even not be able to function without the internet or smartphones.

For this demographic, social media outweighs email for communicating: on an average day, Millennials share roughly six pieces of content through social media, and only five through email.

With that comes an increasing attraction to visual content (video, photos, infographics) over text. <u>Specifically, 66% of Millennials post photos</u> or comments about products, retailers, brands, etc. on social media sites (compared to 58% of Gen X and 40% of Boomers), and 69% of Millennials pin products and product information on Pinterest (compared to 56% of Gen X and 34% of Boomers).

Gen Z is reputed to have <u>shorter attention spans</u> – 8 seconds. <u>They are multi-device user</u>s – 66% of Gen Z often uses more than one device at the same time.

Inter-generational Politics
The boomers were lucky to receive the fruits earned for them by their parents' and grandparents' generations ,eg:

- bigger access to education, funded by the State;
- health care, free at the point of delivery or covered by European social insurance schemes (and the conquest of most infectious diseases);
- rising living standards and career expectations;
- home ownership as a luxury in itself and a vehicle of capital growth;
- occupational pensions linked to career earnings.

The consequences have been harmful to the next generation(s), eg:

- cuts to education and social services + student fees and loans – dumping the costs on the young;
- obesity and comorbidity among older people;
- collapse in career expectations and career paths for the young;
- unaffordable housing (driven in part by NIMBY boomers and buy-to-let rentiers) leading to the rise of "Generation Rent", people living on canal boats etc;
- poor pension prospects (even when younger people can find the money to pay for them after their student debt repayments, exorbitant rents etc);
- a legacy of debt equivalent to World War 1 or the Napoleonic Wars, which will fall on the next generations.

Ethics
Millennials are twice as likely as the overall investor population to <u>invest in companies</u> targeting social or environmental goals. They're also twice as likely to check product packaging <u>to ensure sustainability</u> and similarly as likely to purchase from a brand because of the company's social and/or environmental impact. They want their work to refclect their values: a resounding 87% of those born between 1990 and 2015 also believe that "the success of a business should be measured in terms that go further than its financial results".

Climate change

Climate change tops the list of <u>vital challenges</u> of our time, say young people. Amnesty International's survey of over 10,000 18-25-year olds across 22 countries reveals that 41% of respondents cited global warming as the most important issue facing the world. 36% identified pollution as a key issue.

Covid-19

The pandemic has affected age groups differently. Death rates are significantly higher the older one is. But <u>younger people have suffered more economically</u>, being more likely to work in most severely affected sectors such as hospitality (60% compared with 28% of boomers), less likely to be able to work from home. Surprisingly, Boomers are just as likely to have been furloughed or made redundant, with Gen X being the least affected.

There are signs that the oldest Gen Zers have been particularly hard hit in the early weeks and months of the coronavirus crisis. In a March 2020 <u>Pew Research Center survey</u>, half of the oldest Gen Zers (ages 18 to 23) reported that they or someone in their household had lost a job or taken a cut in pay because of the outbreak.

Millennials and Gen Z'ers both said they will make a special effort to more actively patronize and support businesses — especially <u>smaller, local sellers</u> — after the pandemic. But they won't hesitate to penalize companies whose stated and practiced values conflict with their own. The pandemic has brought about an even stronger sense of social responsibility: nearly three-quarters said the pandemic has made them more sympathetic toward others' needs and that they intend to take actions to have a positive impact on their communities.

7. Summary of key pandemic effects

The pandemic has affected each of our 6 fundamental drivers of change, but not changed their basic importance. The key effects have been:

- ***Population dynamics:*** Negligible effect on global population levels; some regional impacts

- ***Climate emergency and renewable energy sources:*** dip in carbon emissions was transient; increased interest in "build back greener".

- ***Geo-political dynamics:*** "vaccination diplomacy" as major powers curry favour by distributing vaccines to rest of the world.

- ***Fourth Industrial Revolution:*** working from home and online shopping trends were accelerated, though a hybrid version is most likely outcome.

- ***Bio-technology:*** rapid vaccine development demonstrated what was possible and is stimulating new advances.

- ***Changing social attitudes***: some indication of greater social co-operation, but this too may be transient.

For further information, please contact the author at huw.williams@samiconsulting.co.uk, or visit our website at www.samiconsulting.co.uk.