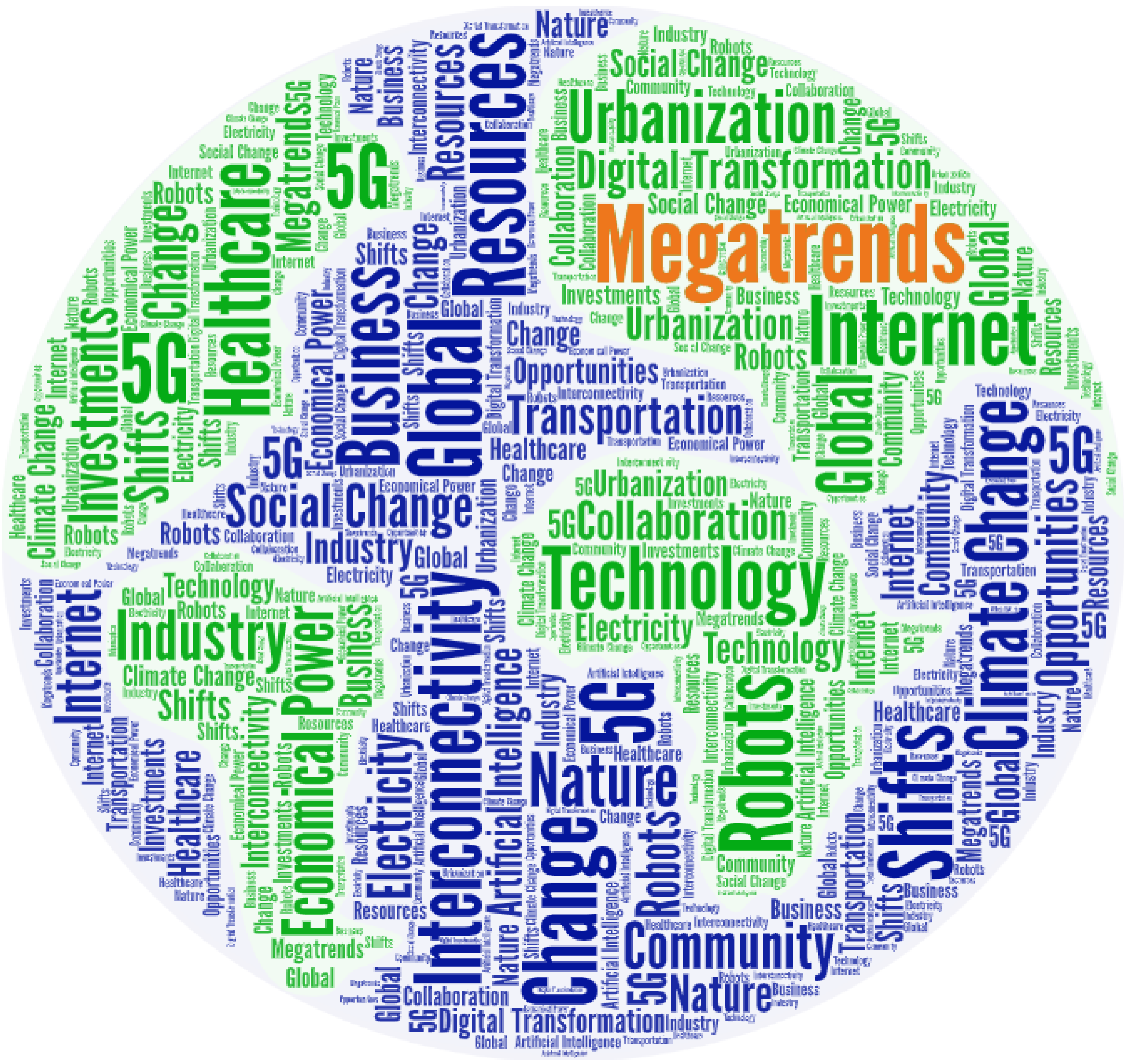
Megatrends for 2021-2030



Roberto Saracco - Digital Reality Initiative

This eBook has been produced as part of the Digital Reality Initiative of the IEEE Future Direction Committee. However, the content is of sole responsibility of the author. Segments of this ebook have been published on the FDC Blog in the November-December 2020 timeframe. Comments on the Megatrends have been submitted by several parties both on the blog, on Linkedin and as result of presentations that the author gave. These comments have been taken into account in the preparation of this ebook.

20 of the presented Megatrends have been inspired by the list of Megatrends for this decade written by Peter Diamandis. However, the discussion of all Megatrends has been done by the author.

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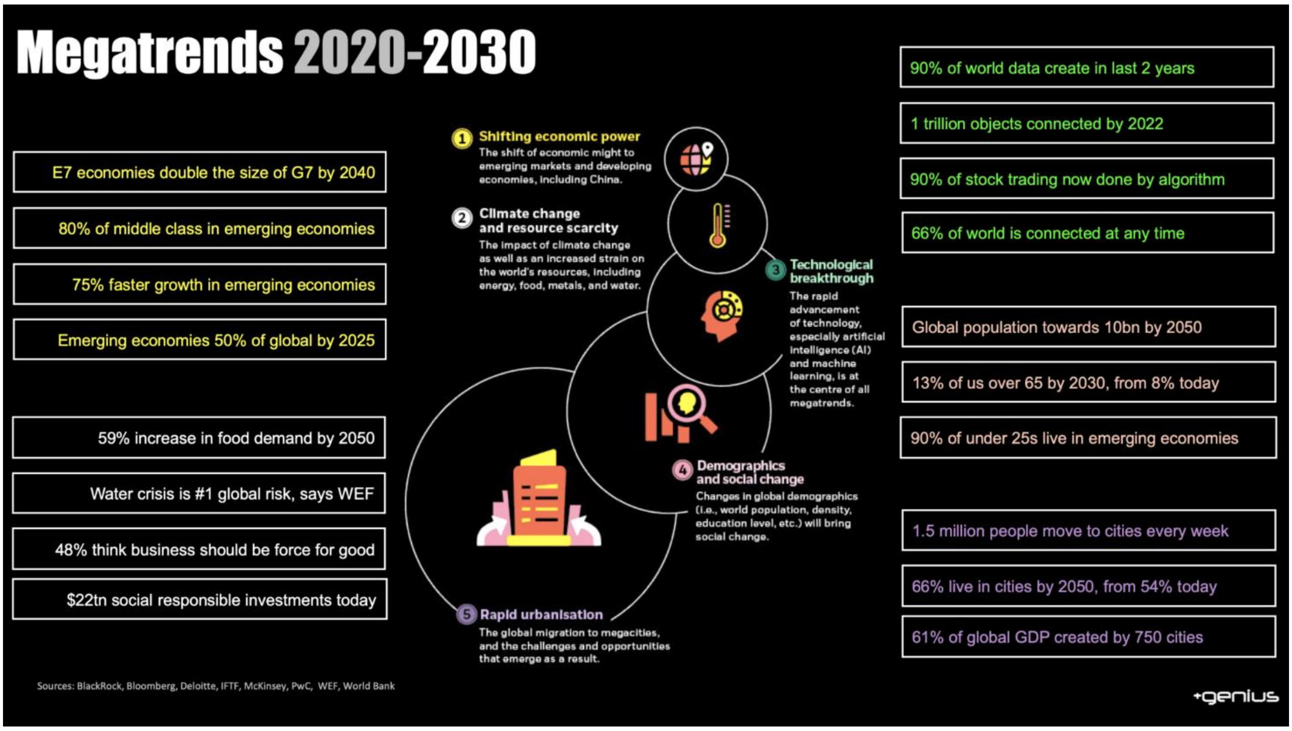


Fig. 1 Megatrends foresight for this decade with a special focus on economy. The prediction did not consider the upheaval created by Covid-19. Image credit: Genius, based on data from BlackRock, WorldBank, Bloomberg, Deloitte, WEF, IFTF, McKinsey

The ongoing pandemic was nowhere to be seen in 2019. However, throughout the past ten years, several researchers have been warning that a pandemic was due as, statistically, we get a major one every 100 years. Therefore, it was not considered in laying forecast for the incoming decade. The pandemic clearly disrupted short-term forecasts, but Megatrends spanning the next ten years may not have been affected significantly. Clearly some tuning is required, like considering acceleration or delays following the pandemic, and the countermeasures taken, but most of the forecasts can still be considered valid.

In this ebook, I will be looking at the optimistic Megatrends, proposed by Peter Diamandis.

Before looking at the proposed Megatrends, I plan to present and briefly discuss the ones resulting from the analyses of forecasts coming from the WorldBank, WEF, and a few Intelligence Agencies (see figure 1). They can help to set the scene for Peter's Megatrends, which are more focused on the expected impact of technology evolution.

1. the Emerging economies of the 7 Countries forming the E7, **China**, **India**, **Brazil**, **Mexico**, **Russia**, **Indonesia,** and **Turkey**, will double the size of the G7 economies (Canada, *France*, Germany, Italy, Japan, the United Kingdom, and the United States) by 2040. Notice that the classification of Emerging Economy needs some revision, given that China this year, according to the IMF, has already surpassed US as the largest economy in the world. Additionally, the pandemic has accelerated China's relative growth, since it has been the first major economy to recover after the pandemic, with an expected growth in 2020 of 2% (way lower than the usual growth, but a significant upswing from the 6.8% decrease marked in the first quarter of 2020);

2. Emerging economies will be experiencing a 75% faster growth than G7 economies. This is going to shift the established consumption of goods and influence the design of new products, also considering that the consumer market is driven by the middle class and, by the end of this decade, 80% of the middle class will be found in the E7. Also, consider that the E7 will represent 50% of the World GDP by 2025. Their markets will likely steer the evolution in the second part of this decade;
3. The global population keeps growing. The population is expected to reach 10 billion in 2050. There were 7.7 billion people at the end of 2019, and according to the world clock, there are 7.835 billion people as of 2020. By 2030, the population over 65 years old is expected to reach 13% of the total population (compare this with today's 8%), which is likely to put a strain on healthcare. Also, notice that the age range differs in various geographical areas with 90% of people under 25 years living in emerging countries. This is another factor creating strong imbalance across Countries;
4. The growing population will increase food demand by 59% in 2050, and there is a drinkable water looming crises. Water, food, and critical resources (raw materials) are a potential danger for the wellbeing and for a peaceful living. As shown in following sections, some feel we have the technology (or will have) to face and meet these challenges. The general consensus is that technology evolution will use artificial intelligence as a tool to accelerate progress.
5. The growth of population is not going to be evenly distributed. In addition, urbanization will continue at an accelerated pace. Every week, 1.5 million people move to cities, and in 2050, 66% of the total world population will live in cities (compared with 55% today). Additionally, it is expected that 61% of global GDP will be produced by 750 cities. This is leading to the creation of mega cities, with tremendous need for efficient infrastructures.

These economic/societal Megatrends are increasingly leveraging a digital economy and digitalization in its many forms. Ninety percent of world data has been created in the last two years, and this window is going to become shorter as we move into the future. Many activities are already completed in the cyberspace (90% of stock trading is now done by algorithms), and more and more objects are connected to the cyberspace (1,000 billion objects by 2022).

These trends are not just leveraging, they are also steering the technology evolution and changing the way we live.

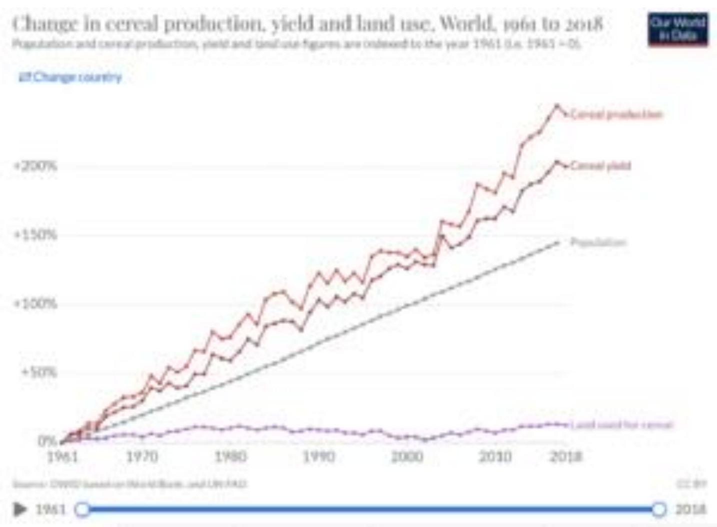


Fig. 2 Increase in yield of cereal production against a stable use of land. Image credit: WorldData

1. *Global Abundance*

Although we usually hear dark predictions on shortage of food for a world population that keeps increasing, production data tells a different story. As shown in Figure 2, productions are actually improving faster than the population growth (this is for cereal, and it is true for several other areas, with the exception of fishing and cattle). The big issues are related to climate change and to the transportation of products to the point of consumption.

Climate change may lead to sea level rising, flooding of densely populated areas, as well as agricultural areas that produce a significant amount of food. At the same time, the rise in temperature can turn areas that are not suitable for crops today into areas that can yield a good harvest. Notice that the shift, if it were to happen, would create huge problems as people will have to move from one place to another. The current flow of migration is nothing in comparison to what may happen if sea rise becomes significant. An example is given in figure 3, and more examples can be found here.

Fig. 3 Map showing the effect of a 1 m sea rise in Bangladesh, something that might happen by 2030. Notice that the impact is not contained to the sea rise (permanent flooded area), but also by the inundation caused by increased storm surges (monsoons and typhoons). The blue area is, today, home for 15 million people and a very fertile area. Image credit: UNEP/GRID-Arendal

Transportation of products is another huge hurdle. It does not help that we have abundant crop in a certain area if we are not able to distribute the surplus in areas that are experiencing a food shortage. Sub-Saharan Africa is a point in case.

Logistic chains have become very effective. Actually, this is one of the main significant evolutions in the past fifty years, and for sure one that has changed the well-being of people as well as the distribution of work (offshoring is dependent on the efficiency of the logistic infrastructure). Yet, reaching certain areas in an effective manner (low cost, short time) remains a challenge, and it may remain so in the foreseeable future.

This is why alternative, complementary solutions are needed, like moving crops closer to the consumer market. I'll address this in a following section.

Peter Diamandis, at the top of his Megatrends list in [his interesting blog](), placed the reduction of poverty as an indicator of the growing global abundance of resources, but I feel that affordable food availability (and water) is at the core of the reduction of extreme poverty, that is why I started this discussion on "Global Abundance" from the availability of food: this is one of the basic needs we face, along with availability of fresh, clean water—a topic I will address in conjunction to energy availability.

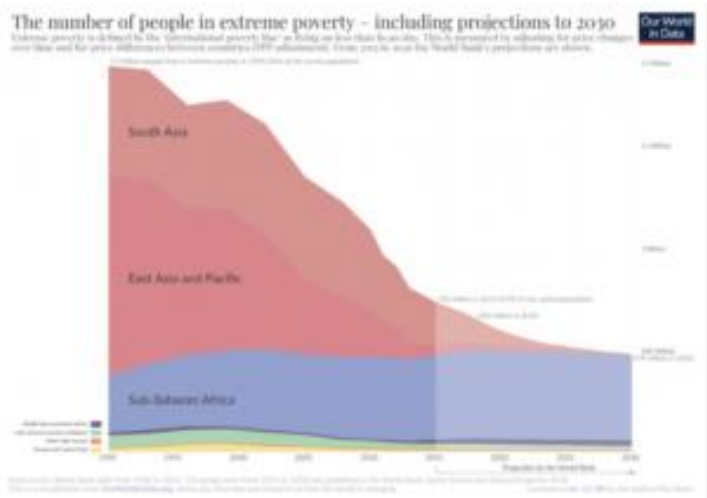


Fig. 4 Graphic showing the decrease of extreme poverty, defined as living with less than $1 a day per person. Significant progress has been made over the last 30 years worldwide, except for sub-Saharan Africa where the situation has actually worsened. Image credit: World Data base. Graphic rendering by Our World in Data

I do agree, of course, with him that the reduction of extreme poverty is a very important indicator.

As shown in figure 4, the progress made in the last 30 years has been significant, but the expectation is not rosy for this decade since the big sub-Saharan area is not expected to show significant progress. One of the reasons is the difficulty of having effective logistic chains there, the economic crises, and the political situation in the region (these three factors go hand-in-hand, and a solution can only come by addressing all of them in sync).

Apart from this (big problem), the expectation is that global abundance will be reflected by a generalized improvement of life and well-being in most parts of the world, with more and more people having access to better food, clean water, better education, and increased economic possibilities. That, in turn, will fuel the market as noted in the previous section forecasting the rapid uptake of E7.

Interestingly, Peter attributes this overall increase to:

- Low-cost communications (a trend we have already seen in the past decade) with affordable cell phones and very low internet rates. For example, now you can get a smartphone with a 6.5" screen in India for $85, and a brand new Nokia cell phone for $10. In India, the current lowest plan gives you 2GB of data and unlimited calls for $1.4 for four weeks!;
- Ubiquitous AI through the cloud, lowering the cost of AI (we are already seeing AI on-demand services that will be fueling more and more applications in this decade, for example, AAI as a Service, or AIaaS). Ubiquitous Internet access will bring AI within reach of every person in the world, which is a topic we are addressing in 2021 in the IEEE Digital Reality Initiative (DRI);
- Access to higher education and better healthcare, leveraging tele-services and AI in the cloud. This dramatically lowers cost, making advanced high-quality service accessible and affordable to people all over the world;
- The Digital Transformation, moving activities and value to the cyberspace, makes everything more affordable and easier for everyone to reach. More so than data, affordability plays a role on both the consumer and the producer/seller's side. This creates a virtuous cycle of

continuous, rapid innovation, and a continuous lowering of prices that, in turn, fuel demand and adoption as described in the "just published" Digital Transformation White Paper by DRI.

2. *Global Gigabit Connectivity at Ultra-low Cost*

Fig. 5 A rendering of CubeSat—deployed in orbit to provide high bandwidth communication coverage all over the planet. Image credit: Alén Space

This Megatrend is actually the convergence of three: "global," "gigabit," and "ultra-low cost." In fact, the quest for coverage and for performance is nothing new. The novelty is in the "quality" and "quantity" foreseen by this trend.

Connectivity has continued to improv over the last 150 years. However, it is only in the last 20 years, with the advent of low-cost, wireless technology (particularly on the handset side, the cellphone) that we have seen tremendous growth.

What used to take 50 years, in terms of usage adoption, has been squeezed into a few years. There are now 5.5 billion people connected via a cellphone, 90% of them with a smartphone.

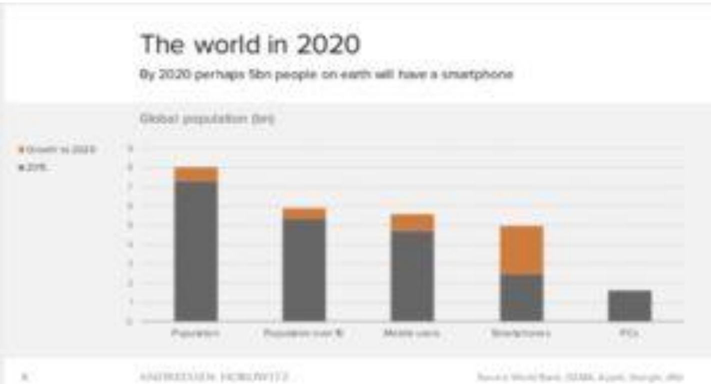


Fig. 6 An interesting representation of the world population vs the number of mobile users, smartphones, and PCs. Notice that if we compare the number of mobile users with the number of people age 10 and older (second bar), we get almost a one-to-one relation, 5.8 vs 5.5 billion. The increased mobile user's vs increases in population in 2015 (grey) and 2020 (orange) is also notable. The acceleration is clear. Image credit: World Bank

It is no longer just about the people. Actually, if we look at the numbers, object connectivity is already dwarfing people connectivity by a number of devices, and by a number of transactions, but not in terms of bandwidth. Our usage of bandwidth for movies keeps the bandwidth usage on our side, but this will also change in the coming years as more and more streaming videos from safety cameras will take the upper hand in bandwidth usage).

In this decade, connectivity is expected to increase further in two dimensions:

• Broader area of coverage, with expectation to have full planet coverage by 2035 accessible through normal consumer cellphones (today, to access satellite networks, which are the only ones providing full coverage, require a special, high-priced phone). This is expected to be achieved by new generations of satellites (like OneWeb planning to have 48,000 satellites in its constellation, and Starlink, already serving US and Canada with 540 satellites and expected to expand coverage in 2021/22 once 1,500 more satellites will be deployed) Both low orbit constellation and cube-satellites constellation, and the capabilities of cellphones to operate in the THz band, are expected to become reality with 6G;

- Higher bandwidth delivered through higher spectrum availability (because of higher frequencies, in the microwave range—above 300GHz in the next decade, and in the mm-wave range 30-300GHz in the second part of this decade) coupled with more dense networks (higher number of access points, 10 to 1,000 times the ones existing today, with the higher multiplier effective with the deployment of 6G and networks dynamically set up from the edges).

Fig. 7 Expected use of bandwidth by residential customers. Figures are expressed in Mbps. Image credit: Cisco

If "global" is easy to understand, the "gigabit" part is not so straightforward because it raises the question if "gigabit" connectivity will make a difference. There are then sub-questions like "for whom" and "who will be willing to pay for it," and "how much." However, the latter can be superseded by the third forecast, i.e. "at ultra-low cost."

As it happened in the past, we can assume that once increased bandwidth is available someone will find a way to exploit it, and eventually, many people will be using it.

The graphic in Figure 7 presents a forecast from Cisco on the possible bandwidth demand by future applications, in temporal order (from near to far down the line):

- Ultra-high-definition security cameras: 15 Mbps
- Ultra-high-definition streaming (4k): 15 Mbps
- Virtual Reality streaming: 17 Mbps
- Self-driving vehicle diagnostics: 20 Mbps
- Cloud Gaming: 30 Mbps
- Ultra-high-definition IP Video: 51 Mbps
- 8K wall television: 100 Mbps
- High-Definition Virtual Reality: 167 Mbps
- Ultra-high-Definition Virtual Reality: 500 Mbps

Some of the above applications may require low latency (<10ms), or very low latency (<2ms), and will therefore require edge computing and edge/peer-to-peer communication, hence a quite different network architecture that, in principle, is already possible with 5G, but then will surely be implemented for 6G.

Delivering Gigabit capacity to the single user (not to a single cell) requires very dense networks, and of course adequate technology. On the wireline side, the optical fiber can already deliver multiple Gbps today. On the wireless side, we need sufficient spectrum to funnel 1 Gbps. Considering 20 bits per Hz (an extremely high spectral efficiency, never reached in normal conditions where a 4-6 bit per Hz would be considered as a very good efficiency) to get 1 Gbps you need 50 MHz spectrum availability (today's 5G allocated spectrum in Italy has a maximum of 80 MHz, and that is for the whole cell, not for a single user!). Hence the need to use mm-waves and µm-waves (in the THz range). These allow allocation of a broad spectrum. The evolution of electronics will make this feasible in the last part of this decade.

Recapping: "global" and "gigabit" are reasonable targets. What about "ultra-low cost"?

Here is where I feel it gets really interesting!

If we look back, we can see that the shift from wireline to wireless has dramatically slashed the cost of delivering bits. This is a result of the following:

- First, the fact that wireless infrastructures can scale (almost) in synch with demand. When traffic demand grows you can deploy one more cell, and then another (right where it is needed). This makes investment much more effective.
- Second, to the shift of (part of) the infrastructure investment on the customer. In fact, the cell phone and smartphone are network equipment, they carry out actions that once were part of the infrastructure, like digitalization, access selection, ... Smartphones represent around 70% of the overall cost of the end-to-end wireless infrastructure. Hence, the telecom Operators are covering only 30% of the cost, whilst in a wireline infrastructure, they would have to sustain 100% of the cost!

This is decreasing the perception (and reality) of cost to the end-user. As the cost of smartphones decrease, so does the cost of connectivity.

This trend will continue in this decade, and it will have a further acceleration by the end of the decade, and beginning of the next, as communication will start to be provided by the edges (networks deployed by third parties that are not interested in charging for the access), and by objects themselves. 6G will be the first system designed to create edge networks, in part formed by meshing networks created by objects. This is what will lead to ultra-low-cost connectivity.

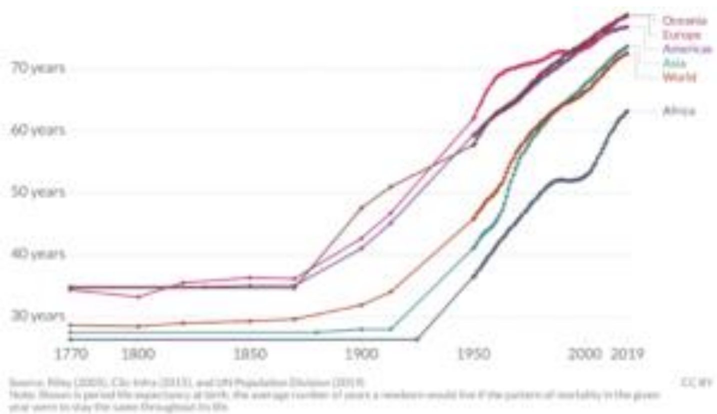


Fig. 8 Life span, on average, has been growing amazingly fast in the last century. This graphic shows the life expectancy at birth in the five continents, and the world average. Image credit: Our World in Data. Data sources: Riley, Clio Infra and UN

3. *Increased Life Span*

Human life span has been stable. Life expectancy was around 30 years for the most part of recorded history, probably less in the hundreds of thousands of years we have no written record for. This relatively short life span didn't mean that a few people couldn't live longer. We have credible written reports of people living into their 60's, and even 80's, but that was rare.

This changed in the middle of the XIX century in Europe and in the Americas, and at the beginning of the XX century in Asia, whilst Africa had to wait until the 1930s to see the beginning of an increased life span.

Although we often associate this increase with the progress in medicine, the reality is that the first increase in life span, until about 50-80 years ago, was the result of **clean water**. It is only in the last few decades that medicine has become a significant factor in the lengthening of humankind life span.

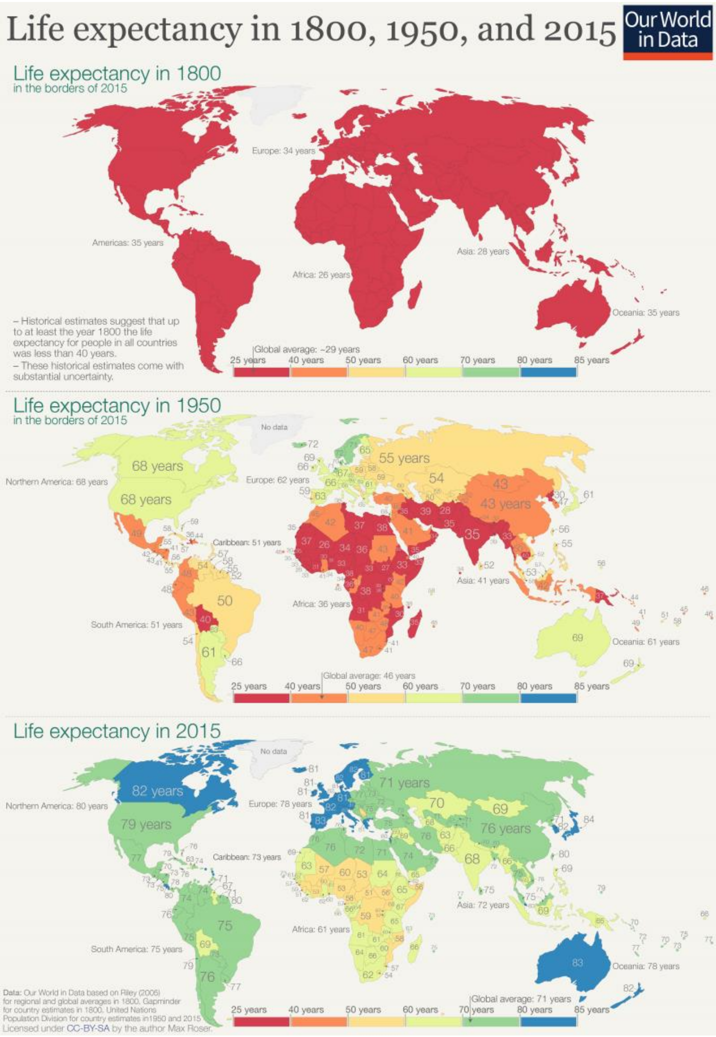


Fig. 9 Snapshots of the world in the 1800, 1950 and 2015 showing life expectancy. Image credit: Our World in Data

In figure 9, the world map rendering with color based on expected life span in 1800, 1950, and 2015: the redder/more yellow the color, the shorter the expected life span.

In the last few decades, medicine has become an important factor in extending our life span.

Peter Diamandis formulated this Megatrend because, in the coming years, medicine will be able to extend our life, and he predicts that by the end of this decade we will see a 10 year life expectancy increase. That is a daring prediction that might be difficult to achieve, particularly in areas where we have not reached an expected life span exceeding 80 years. I have no doubt that in Africa and in several developing Countries in Asia, where the life span is in the 60's and 70's, we will see a 10-year expectancy increase, but moving from 80 to 90, or 85 to 95 (on average!) is much trickier.

In his blog, Peter identifies the progress of technology applied to healthcare as the result of this outcome. In particular, he lists these technologies as the ones that will have a crucial impact in this decade:

- Stem cell supply restoration: These are cells that can be used to create any cell in our body. They are not differentiated and have the potential to replace cells that have been dying out without being replaced by cells of the same type—a cause of ageing.
- New drugs, including GDF-11, Senolytics, and NMD/NAD+, look promising, but one should be cautious since, so far, they have shown some age extending capabilities in the labs (on mice an extension of 10 to 15% of the life span has been demonstrated, but we do not know if that would replicate in humans, nor do we understand the possible side effects...).
- Machine Learning and AI, in general, are going to provide enhanced tools to pharmaceutical research, making it possible to test in cyberspace. Researchers can test the potential of new molecules and accelerate in-vitro testing using "organ and body on a chip." Digital Twins may play a crucial role in the acceleration and in the personalization of drugs.
- Genome sequencing, CRISPR technologies, AI, quantum computing, and cellular medicine are converging and accelerating the discovery process and evaluation of clinical trials.

In general, we are starting to see a flattening of the curve (see figure 8 and look at the curves representing the life span extension in Europe, Oceania, and America). It is obvious that something "new" is needed to further extend human life span. The technologies listed above may be the "new" that can change the rules of the game.

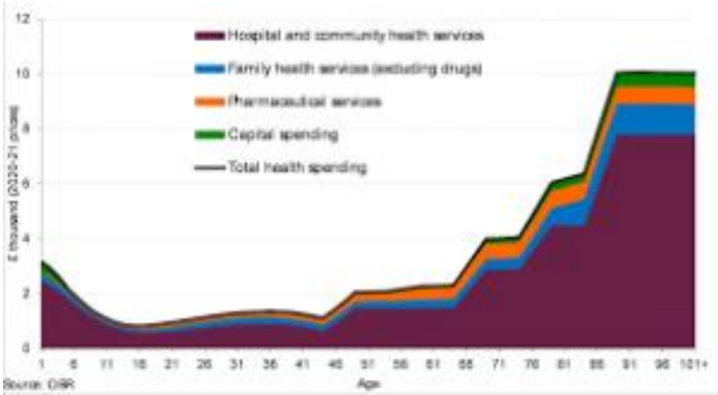


Fig. 10 Graphic shows the [increased expenditure per person as age increases](). Image credit: Office for Budget Responsibility, UK

At the same time, a word of caution should be taken. The ageing population and side effects on society and the economy should be considered.

As shown in Figure 10, the cost per person increases significantly with age. Regardless, it is important to notice that the highest expenditure is usually in the six months preceding death, so it is not necessarily a function of age (although as we get older we are more likely to suffer from multiple pathologies, adding to the cost of healthcare).

One of the goals of researchers involved in the quest for longer a life span is also the extension of good health, so that should take care, at least in part, of the increasing cost.

There are also societal implications for life span extension, such as the potential increase in world population, and the need to increase the working-life time. This, in turn, requires a re-thinking/re-planning of social security/retirement. Notice that I am not saying that extending our life (in good health) is bad, not at all. I am just pointing out that if this Megatrend gets real, we are going to face issues that need to be resolved in the next ten years and ten years in societal domain is a very short time.

4. *Age of Capital Abundance*

Fig. 11 Crowdfunding keeps rising at a 16% CAGR and it is expected to reach 28.3 B$ in 2025. Image credit: Valuates Reports

The global increase of wealth is creating a capital abundance that together with money dematerialization, online transactions, market accessibility and funding platforms facilitates access to capital. Crowdfunding, see figure 11, is an example of the power of access to distributed capital. Although this relatively new capital access is growing rapidly, and it is indicative of a new wave of funding, its global value is extremely small when compared to the overall money circulation. It is, nevertheless, important in showing the impact of Digital Transformation in Finance. Long gone are the times of the industrial revolution, when capital was concentrated in a few hands that, for the most part, controlled its investment.

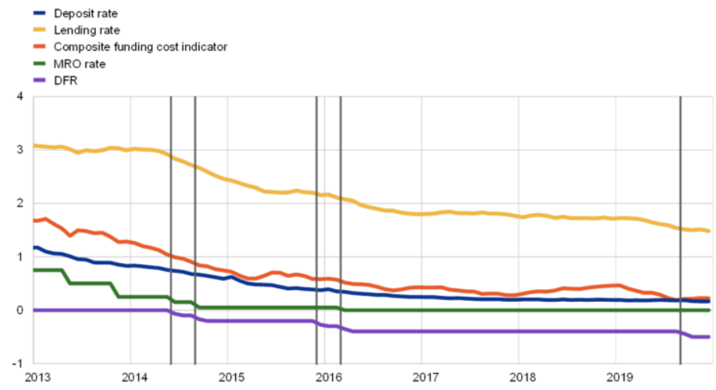


Fig. 12 The vertical black lines indicate the five cuts in the DFR into negative territory, from 0 to -0.1% in June 2014, from -0.1% to -0.2% in September 2014, from -0.2% to -0.3% in December 2015, from -0.3% to -0.4% in March 2016, and from -0.4% to -0.5% in September 2019. Latest observation: December 2019. Image credit: European Central Bank. Sources: ECB and ECB calculations.

The development of an effective banking system has put money within the reach of many more people (of course the system was and is far from perfect, with the funny but sadly true statement that banks tend to give money to those that already have money!).

In the latest years, we have seen the cost of borrowing money decrease to the point that, in some cases, (in banking transaction) it has actually <u>become a negative</u> (see figure 12).

The abundance of money is both a cause and a consequence of this situation. As more money becomes available, the interest rate goes down, and conversely as the interest goes down, money becomes more affordable.

The availability of "cheap" money clearly has an impact on borrowers and lenders:

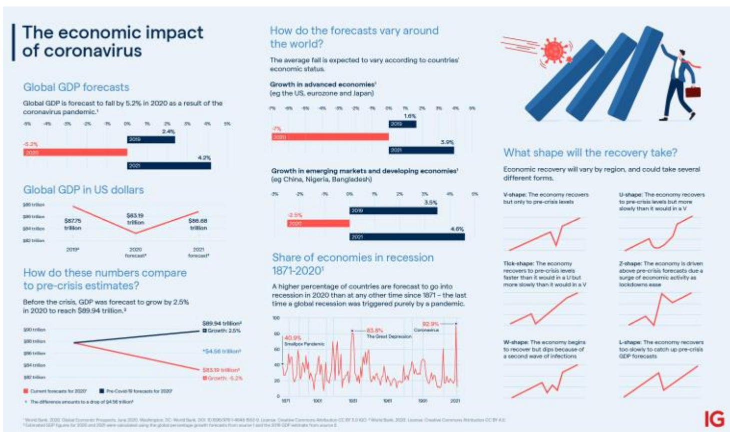


Fig. 13 An overview of *the* effect of the pandemic on the economy. Notice the slump in GDP (that is however different in different regions) that is clearly going to affect investment. Also notice the various possible types of recovery (the so-called V, U, W, Z and L shaped recovery). Image credit: IG.com

- Borrowers find quick and cheap availability of money to sustain investment, hence they tend to accelerate investment, and this, in turn, stimulates innovation. Small amounts of money can be found via crowdfunding (previously mentioned), or through specific Government sustained measures, whereas large investments take the form of more structural agreements, with long terms investors (banks and pension funds, for example);
- Lenders look for investments that can generate returns in the medium long-term, since short-term investments will lead to a "negative" return and tend to become part of the investment (i.e., buying shares rather than just lending money).

This money availability, coupled with long-term return, is particularly conducive in supporting infrastructure building (since these have a longer lifespan and can ensure returns over several years, even decades).

We are seeing this phenomenon in the growing interest in funding radio towers, a business that is seen by investors as long-term and likely to generate a steady return. This results in companies, within the network business, finding themselves with easy access to funds that can sustain a redesign of the tower market. They can then place more intelligence in the towers, thus accelerating the shift towards edge computing, smart antennas, and networks at the edges.

The overall situation has clearly changed as the pandemic keeps raging (watch this clip, from an interview with Daniel Lacalle, discussing possible recovery, and notice that the interview took place before the second wave of the pandemic). The impact is different across regions both because of the severity of the pandemic (and of the countermeasures), and because of the fundamental clock of the economy in a specific region. In the US, for example, technology is an important clock, whilst in Europe, the banking system plays a more significant role, and in Asia, the regional demand can serve as a throttle regulating consumption and recovery.

In Western Europe, the banking system has stepped in to provide low-cost money to counteract the working force (this was done in the US as well, but to a much lower extent). The problem with this is that a decrease of money availability in the long-term (you cannot keep printing fresh money to sustain spending), and the fact that a good portion of that money did not go to sustain production, but to sustain access to basic resources (food, rent, etc.). In other words, from a productivity standpoint, this is wasted money. However, that does not mean that it is not needed!

The long-term impacts of the pandemic are still under discussion. The general feeling is that a full economic recovery will not be seen until 2024, although a few sectors may see a rebound starting in 2021 (actually, companies developing a vaccine, if successful, are going to see sharp return and revenue increase early 2021). There will be a need to return the money that is printed in order to sustain the economy distress as this will decrease the amount available for quite a few years, particularly in Europe. However, in the long-term, this Megatrend of capital abundance should prove to be correct.

For sure the pandemic has accelerated (is accelerating) the Digital Transformation which, in turn, is enhancing efficiency in capital movement and management, freeing resources, and making it easier to access resources, including capital.

5. ***Augmented Reality and Spatial Web***

Augmented Reality has been around for several years now. Actually, Virtual Reality (VR), the possibility of immersing oneself in a virtual world, came first, but in the last few years the flanking of virtual and real has taken the upper hand in several business and, more recently, consumer applications. VR goggles have improved, but not as much as many thought they would. We are still facing a gap between the "reality" offered by these devices and the one we are experiencing every day, with the result that "virtual" remains "virtual" in terms of perception and often creates a sense of uneasiness, even dizziness. One of the reasons is that our brain integrates multi-sensorial flows of data, and if there is a mismatch (for example, the movement perceived through your eyes is not coherent with the data received by proprioceptors—in your ears and joints), something feels wrong. Although vision goggles have been improving (there are now untethered models, and the screen resolution has improved), we haven't been able (with a few exceptions like professional flight simulators that re-create movement and acceleration sensations) to re-create the flow of data that would normally occur in real life, and this is likely to remain unchanged in this decade.

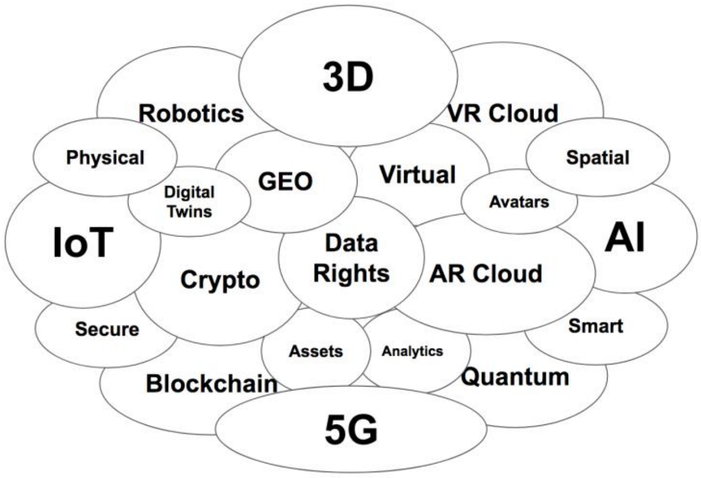


Fig. 14 The Spatial Web weaves together all of the digital and physical strands of our future world into the fabric of a new universe where next-gen computing technologies generate a unified reality. Image credit: Gabriel René, Book, *The Spatial Web*, 2019.

Fig. 15 Ikea lets you browse their catalogue and "see" how furniture will fit in your home. In this case, how a table would look in your living room using your smartphone to deliver augmented reality. Image credit: Ikea

On the other hand, seamless overlay of cyberspace data on the physical world does not create the issues we are facing with VR. Here, it is not about fooling our brain, rather it is adding an extra "sense" to our brain, or extending existing sensorial capabilities, like increasing our sight into the infrared spectrum, hearing in the ultra-sound frequencies ... Additionally, devices to extend our sensorial space are, usually less cumbersome than VR goggles. We can use our smartphone to access augmented reality!

We can expect to see a growing space for AR application. Industry is already a major user of AR for operation and maintenance, retail applications are growing, and, interestingly, AR in these areas is seen both as a way to incentivize buyers, and as a way to decrease returns of merchandise. The latter is becoming a major hurdle for online retailers. In the UK, the cost of returned merchandise has reached 60 B£ (30% of online orders are returned). Product return has been eased with no cost for the customer as a way to establish trust and grow sales. However, many customers are now routinely over-ordering to see and touch the merchandise in their home, keeping the one that fits best, and returning the others. During the lock down in UK, online retailers have seen a 40% increase of intentional returns (those that the customers knew they would return at the moment they placed the order). Augmented reality is viewed as a technology/service that could significantly decrease this problem.

Other present use cases of AR can be found in Education, field operation, healthcare, business logistics, and more. As an example of using AR in collaboration, watch this clip. The growth in AR is fueled by the Digital Transformation through the creation of data and the connectivity being established between products/products' users and service providers.

This Megatrend foresees a tremendous growth during this decade to the point where AR will become the normal way to access cyberspace. The point here is that we will reach a dimension ("digital reality" in the parlance of the Digital Reality Initiative) where cyberspace and physical space overlap in a seamless way. Everything we perceive as reality will actually be a mixture of bits and atoms. Interestingly, this does not restrict us to human perception—also "object" perception, which will be a mixture of bits and atoms. As Digital Twins move to stage 4 (we are now at stage 3 in most applications), an object will be made up by atoms, local bits (software enabled features), and its digital twin that operates in the cyberspace, but is also a fundamental part of the object and its behavior.

This is sometimes referred to as the "Spatial Web":

a pairing of real and virtual realities, enabled via billions of connected devices, and accessed through the interface of Virtual and Augmented Reality

As shown in figure 14, the Spatial Web results from the seamless integration of different technologies, part in the hardware side (like IoT, robotics), part in software (like AI, clouds), and part in connectivity (like 5G, digital twins, blockchain). By the way, the reason for the name "Spatial" is that the bits will be associated to a location (they will become visible and meaningful in a specific location). For more insights, watch this clip. A search on the web will return different results depending on where we are since the result will be materialized in the context we are in.

According to Deloitte, the shift towards the Spatial Web has already begun. Whether you feel it today or not, I have no doubt that the dividing line separating the physical from the cyberspace is becoming fuzzier and fuzzier and will completely vanish by the end of this decade.

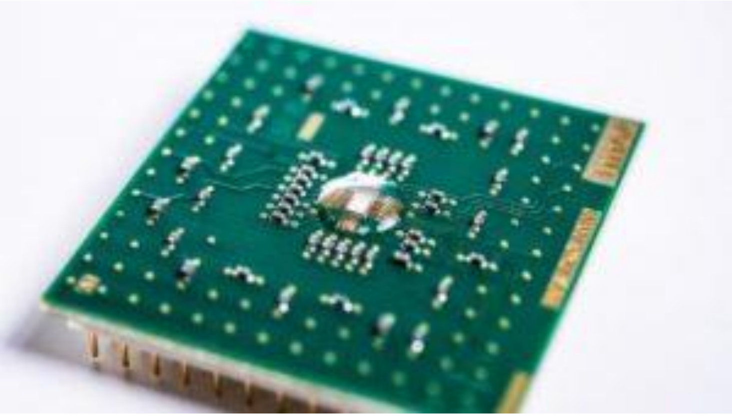


Fig. 16 The chip developed by Imec and Global Foundries using analog techniques for a low power machine learning engine for edge AI. Image credit: Imec

Of all the Megatrends proposed by Peter Diamandis, this is the one that I am most sure of!

6. ***Everything is Smart, Embedded Intelligence***

This Megatrend may appear "outdated". If you look around with an untrained eye, you'll see plenty of ads claiming "intelligence" of products, most of the time in a ridiculous way. The first "intelligent" toothbrush (that I know of) debuted at CES 2017 Now, you can find quite a few intelligent toothbrushes on Amazon starting at $24.99.

In figure 17 (a photo I took some time ago in a shop in Turin), selling an "intelligent" steak grill. The box stated that the grill was "intelligent," you just place the steak on it and it will determine the cooking temperature and the time needed. It most likely had a sensor to detect the temperature inside the steak, and based on your preference (raw, medium, or well done), it knew when to stop grilling. A chip provided the algorithm that I suppose would start with a high temp to broil the surface, and then a lower temperature for cooking until the inside of the steak reached a certain, predetermined temperature.

Fig. 17 - The packaging and the shop label claim this is an "intelligent" steak grill. You just place the steak, and it will decide how to best cook it! Photos taken by me at Kasanova shop in Turin

This is fine, and probably results in a grill that can cook a steak better than what I would be able to do but calling it “intelligent” is quite a stretch.

It is just one example of many you can see by just looking around. Sometimes an object is defined “smart” and this, in a way, is a prowess restricted to a very specific task, an assertion usually much more appropriate than claiming for intelligence. For sure, we have seen more products being defined as smart, but the term "artificial intelligence" has grown to the point of becoming a ubiquitous presence, and we are now seeing variations on the theme.

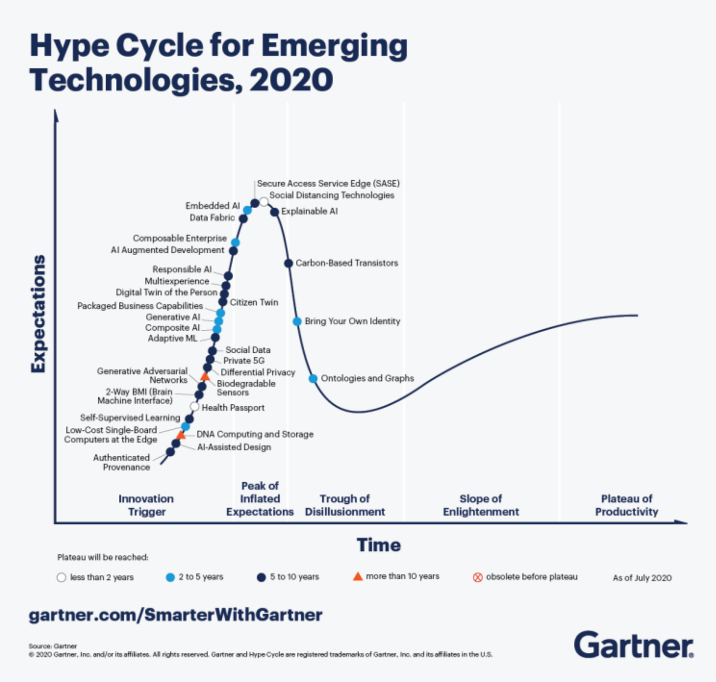


Fig. 18 The Hype Cycle for emerging technologies is out, and it is interesting to look at what changed since last year... Image credit: Gartner

Gartner, in its 2020 emerging technologies hype-cycle, identifies:

- Generative Adversarial Networks (a tech for self-learning by a machine)
- Self-Supervised Learning
- Adaptive Machine Learning
- Composite Artificial Intelligence
- Responsible Artificial Intelligence
- Generative Artificial Intelligence
- AI Augmented Development
- Embedded Artificial Intelligence
- Explainable Artificial Intelligence
- AI Assisted Design

One-third of the predicted emerging technologies are in the AI field (10 out of 30).

So, on one hand we have a pervasive perception of AI presence in our world today, on the other we see more and more research on different aspects of AI (as in the Gartner list) that will result in an expansion of capability and of application areas in this decade. There is more.

On November 18th, Halide, a company developing software for computational photography, published a review on the iPhone Pro Max 12 photo capabilities.

In that review, they discovered an amazing, although hidden feature of this phone. As you may know, the iPhone Pro Max 12 has three lenses, i.e., three cameras/three sensors. The wide-angle lens/camera has the biggest photo sites (the buckets gathering the incoming photons)—1.7µm versus the 1.4µm of the other two cameras (yes I know 1.7µm may not seem something to call "big," but it is 20% bigger than the others. Meaning it can harvest 20% more incoming light, and that makes a difference when you are dealing with very low light, such as in nighttime photography).

Here comes the amazing part. When you take a photo in a low-light condition and select the telephoto camera, you'll see as you would expect in the iPhone screen the "zoomed in" image. However, the phone will not use the telephoto camera since the software has detected a low-light situation and switched to the wide-angle camera. Then, in real time, it crops the image frame to match the frame size you would get if it were using the telephoto lens. Well, you might say: "that is a trick, that really does not require any intelligence!" and you would be right to expect that you are not!

When you take a wide-angle photo and then a telephoto, you get a zoom-in effect that can be obtained by cropping the photo taken with the wide-angle lens. However, that cropped image will not be like the one taken by a telephoto lens: the perspective changes (using a tele depth, distances are squeezed) and the bokeh is dramatically different so that our eyes (brain) will spot the difference. Not so much with this iPhone. The software (computational photography) will look at the scene, "understand" the image, and reshape it to match the result that would have been produced by a telephoto lens. Now, this is what I call "intelligence"! And yet, it is not advertised as such (I guess for marketing reasons: Apple might feel it is better to hide this little cheat, letting you think that you have control on the selection of the camera...).

Hence, we are seeing:

- hype (often just pure hype and no substance),
- ongoing research effort in bettering AI and extending its application, and
- AI becoming a tool in a growing number of industries, both as part of a product and as part of industrial processes, although we may not be perceiving it.

The latter two are obviously the most important and are the ones that are sustaining this "everything is smart, embedded intelligence" Megatrend.

A significant evolution that is happening in these last years, and that will be in full swing in this decade, is the capability to embed intelligence (at least a little bit) inside more and more objects leveraging on the evolution of electronics "designed" to support ML.

An example is shown in figure 16: a chip developed by Imec and Global Foundries using analog techniques for a low power machine-learning engine for edge AI. Here, the crucial point (taking for granted, the lower and lower cost) is the low power demand, allowing its embedding in a variety of products. Notice that the chip on its own would not be enough: it needs to be fed by data, and these are provided by embedded sensors–IoT, an integral part of the Industry 4.0 evolution—*AND*, it needs to become part of a network of local intelligence leading to an emerging "ambient intelligence".

The latter is what is probably going to characterize the next decade (2030-2039) with 6G playing a major role.

Digital Twins may also play a significant role in this distributed smartness and embedded intelligence, creating a bridge between an object and the cyberspace, and stage IV contributing to the object functionality (and behavior). A Digital Twin can embed a local (object) intelligence and can be part of a shared/emerging intelligence (once they move at stage V–cooperative Digital Twins).

Fig. 19 The roadmap for AI to take the pilot seat on commercial airplanes. Full replacement targeted for 2035. Image credit: EASA

6. *AI au pair with Human Intelligence*

1956. This is the official starting point of the race to create an artificial intelligence that could match the human one.

Some 20 mathematicians and scientists brainstormed for 8 weeks to outline a path forward. The hope was to be able to create a machine that would demonstrate a level of intelligence "au pair" with human intelligence.

Overall, the mood was optimistic, and that optimism pervaded the following 15 years as better and better programs were written. However, after the initial burst of results, it seemed that AI work has met a roadblock. New approaches are needed, and AI faded away from mainstream "news." In these 65 years, we have seen waves of renewed interest followed by neglect. Each new wave, however, brought forward a bit more clarity on what should be tried, as well as what kind of intelligence should be expected. Even though the goal of an AI au-pair with Human Intelligence, as expressed in this Megatrend, still fascinates imagination, we are now looking at something different.

In fact, when we say that we want to match human intelligence, the starting point should be an understanding of what "human intelligence" is, and the picture of human intelligence is quite fuzzy!

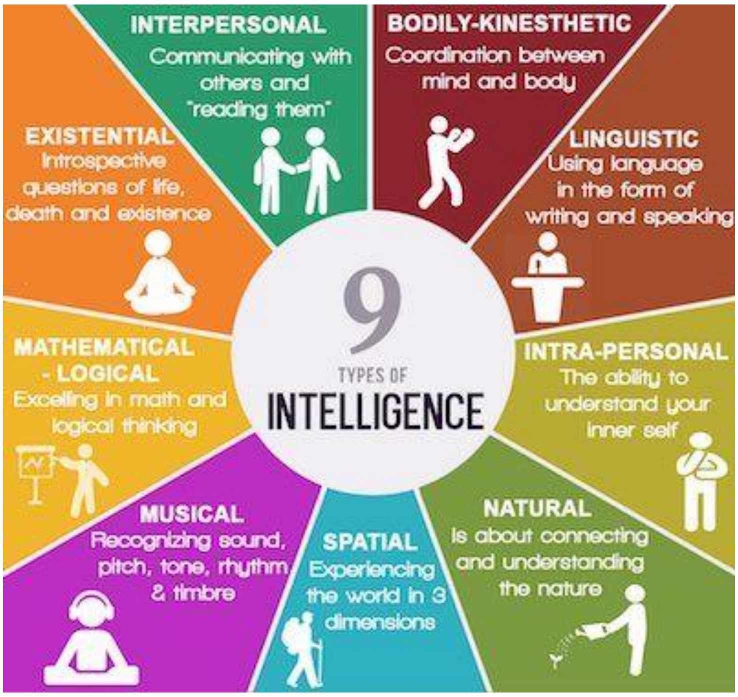


Fig. 20 The nine types of human intelligence that are usually accepted as classification. Image credit: communicatorzdev

There are several types of human intelligence that have been identified (or classified, since it is not a partitioning based on some objective facts). Most experts in the field classify them into 9 types:

- Mathematical/logical
- Spatial
- Interpersonal
- Linguistic
- Interpersonal/social
- Intra-personal
- Natural
- Musical
- Existential

If we look at this list we can easily find types that are fitting a machine (software), like mathematical and logical capabilities, where we have several demonstrations of capabilities to prove theorems (so going beyond pure calculus...). We have some theorems that have been proven by computers (and some mathematicians refuse to acknowledge the proof!). If you are interested in this area, you may like this paper discussing "superhuman mathematics".

Other areas, like "Spatial" involving the perception of 3D space and its implication, are now addressable by machines in a very effective way, although leveraging on very little "intelligence." For example, self-driving cars use a variety of sensors (LIDAR and image sensors), and a lot of number crunching to create a 3D model of the surrounding ambient. The 3D models use some form of AI to make sense of data (like identifying objects and then deriving the probability of behavior. For example, a pole is unlikely to cross the road, but this is not the same for a stroller that may be pushed from a sidewalk into the roadway as a car is approaching, although unlikely, whereas higher risk exists for a kid chasing a ball). This sort of "machine intelligence" does not exactly map onto human spatial intelligence, which includes characteristics like orientation, something difficult for us (in principle - imagine being stranded in the middle of nowhere...), but quite straightforward for a machine having access to a GPS.

Other areas, like "Musical or Linguistics," have been considered "out of reach" for machines, but we have seen in these last few years examples of machines (software) that can create "music," paintings, and poetry to a level that can fool people (including experts). The difference with people, of course, is that a composer would enjoy what they are doing and be proud of the result, sensations that are not present in a machine (as far as we can tell).

Other areas, like "Social Intelligence," would seem to be a far-fetched machine trait. However, we have seen significant progress in social robotics ending up in machines that can establish an empathic relation with people. Again, a machine has been programmed to be empathetic, or it has been programmed to learn certain behaviors; it does not feel empathy.

For sure the areas of "intra-personal" and Existential" intelligence do not make sense for a machine (at least so far, unless you are interested in science fiction).

So what is this Megatrend about? It is not about the essence of Intelligence (assuming we can reach an agreement in defining what it is), it is about "performance." If a machine can perform as well as a human being in a broad variety of contexts and situations, that would require "being smart." Thus, allowing the replacement of a human with a machine, we can say that AI is "au pair" with human intelligence, such as:

- Can we replace a poker partner with AI?
- Can we replace a pilot with AI?
- Can we replace a medical doctor with AI?
- Can we replace a financial advisor with AI?
- Can we replace a teacher with AI?
- Can we replace a journalist with AI?
- Can we replace a discussant with AI?
- ...

This list can go on and on. If you'd like to explore a bit more, click on the links and you'll see what it is already possible today in using AI to replace people.

However, here the crucial point may seem to be in the words: "a broad variety of contexts and situations." All of the above examples, and many more, seem to point to the fact that we have, today, the capability to replace a person with AI in a specific domain. It may not be done in practice, because of cost or because of some shortcomings, but it is obvious that in the near future the cost will go down, and many of the shortcomings will be overcome. Therefore, we can say that performance achieved in a specific sector is not a proof of having reached a human-like intelligence, only that we are able to develop expert systems in that domain.

This is not a satisfactory objection. Computer software is additive and can scale graciously (at a cost, of course). In other words, if you have an AI system able to impersonate a pilot, you can extend that (if you want to) to impersonate a musician by adding the required software (or asking the self-learning engine to dedicate a day to become a proficient musician). Provided sufficient computer power (either centralized or distributed) and having AI software capable of delivering intelligence in each sector, you can pick up that capability and add it to another set of capabilities.

This Megatrend is not about a philosophical discussion on the equality of machine and human intelligence. It is about the availability, by the end of this decade, of artificial intelligence able to perform as well as humans in a broad variety of fields. It is not suggesting that AI creating music will "enjoy" the piece it has created, nor that an AI pilot will feel proud after a particularly tricky landing, just that AI did the job.

Considering that we are now moving towards open AI (the possibility to access AI functionality from any object), thus spreading out the intelligence in any ambient and, conversely, to have any object contributing to an emerging AI (by harvesting / sharing data and creating local intelligence). I am confident that this Megatrend is a concrete possibility that will be implemented, step-by-step, within the next few years.

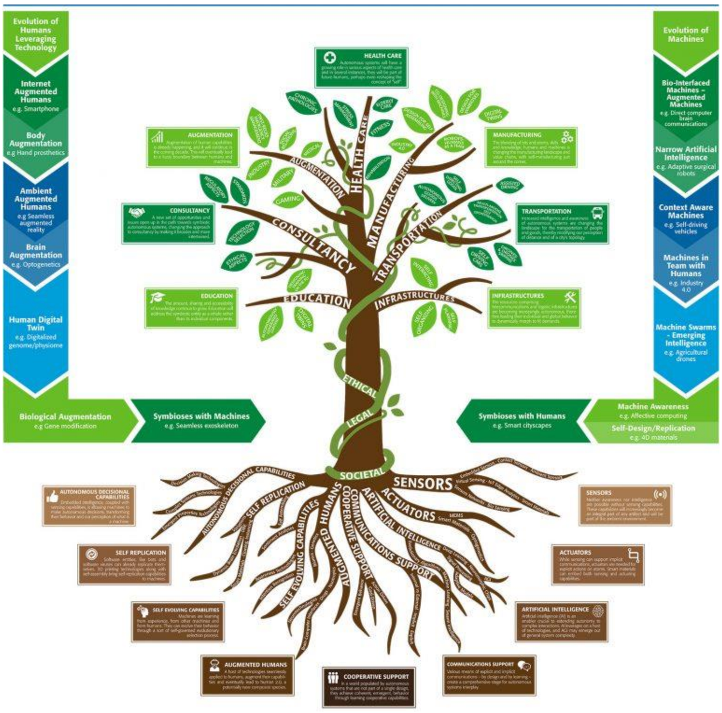


Fig. 21. The expected convergence of the evolution of machines (right hand side) and human (left hand side) augmentation. The augmentation is fuelled by the set of technology areas depicted as roots of the tree, whilst the leaves indicate application areas.

Fig. 22 AI as a Service (AIaaS) is expected to grow in the next few years at a CAGR of 48%, reaching a market value of 15+B$ by 2023, with the lion's share taken by the US. Image credit: TechNavio

*7. **The coming age of AI-Human Collaboration***

This Megatrend is already affecting our lives in many ways, as well as affecting businesses. Think about talking to Alexa or Siri: you are actually bringing AI into your everyday life. Pick up your phone and take a picture: AI is at work when you allow the device to determine the correct exposure given the type of image, detect smiles... Are you turning to Google translator to help that Japanese tourist that has asked you a question? That's, again, AI at work.

In a factory, plant robots are starting to interact with blue-collars, and AI is supporting the interaction and collaboration. Are you on the trading floor of a stock exchange? You are most likely using AI to support your decisions. Are you a doctor looking at a CAT and reading the report? Most likely AI had a lot to do with that report content.

The technology we see today (and most of the time predict) is the harbingers of the next few years. By the end of this decade (and what this Megatrend is all about), AI will be an omnipresent companion. We have seen the starting of the market of AI on demand (AIaaS—AI as a Service—see figure 22), and we have seen the announcement by Google offering access to an AI Cloud through public APIs (Application Programming Interfaces) that turns AI into, basically, an infrastructure that can be used everywhere and in any type of application.

A similar offer is available through Amazon AWS. For example:

- Amazon Polly offers up to 5 million characters text to speech capabilities per month (equivalent to 1,500+ pages of text translated into voice);
- Amazon SageMaker offers 250 hours per month of processing capacity used to train AI models;
- Amazon Lex allows you to create Chatbots that can process 10,000 text requests, or 5,000 voice requests, per month;
- Amazon Rekognition supports the analysis of 5,000 pictures and stores metadata for 1,000 faces per month;
- Amazon Comprehend lets you develop natural language understanding of up to 50,000 phrases per month, and
- Amazon Transcribe lets you add voice-to-text capabilities to your application for up to 60 minutes per month.

All of this for FREE! Amazing!

Notice that, particularly in areas where training is needed to create AI, the process is very computationally intensive and only the big ones, with their huge computation capabilities, can support this. This explains the value to be able to access services like Amazon SageMaker. Access to these resources is going to multiply the development of AI and widen its areas of application.

The Symbiotic Autonomous Systems Initiative (now Digital Reality Initiative) came up with a roadmap leading to a symbiotic relation among humans and machines (see figure 21). This roadmap foresees a parallel evolution of capabilities in machines (getting smarter) and in humans (becoming seamlessly connected with machines) which is leading, by the end of this decade, to a symbiotic life. This is where humans will benefit from the seamless augmentation that machines can provide (better sensing, faster processing, specific augmentation in some areas of intelligence), and at the same time, machines will be leveraging on human intelligence in a shared environment. For an in-depth discussion on these topics, you can take a look at the eBook "**Augmented Machines and Augmented Humans Converging on Transhumanism.**"

Fig. 23 Baxter, the collaborative robot, is shaking hands with a little kid. It was designed to work along with humans and to learn from them. Image credit: Rethinking Robotics

Collaborative robots, or cobots like Baxter in Figure 23 (no longer in production, but it marked the starting point of a human-robot collaboration), are already a well-defined area of research and, more importantly, are becoming industrial products.

Interestingly, these cobots were designed to be safe when operating in conjunction with humans. Then they evolved, through AI (machine learning), and became capable of "learning" from their interaction with humans, learning to take the lead when needed, and learning to teach human coworkers so that teamwork can become more effective.

*8. **Living in a Software "Cocoon"***

Some of us have already achieved a familiarity with AI assistants like Alexa, GoogleHome, and Apple HomePod. The obvious evolution is towards an increased intelligence of these assistants and, in turn, this will be leading to a "personalization" of the interactions. Think about it: as you talk to the assistant in your home, the assistant will know more and more about you —it will remember what you asked yesterday, and it will start guessing what you interested in, anticipating your needs. Progress in emotion detection (and affective computing, see figure 23) will enable an "understanding" of your emotional status that, in turn, will provide the assistant with clues on what you need. It will become a real "personal assistant." Of course, a home assistant can double and triple up as a personal assistant to each of the home dwellers...

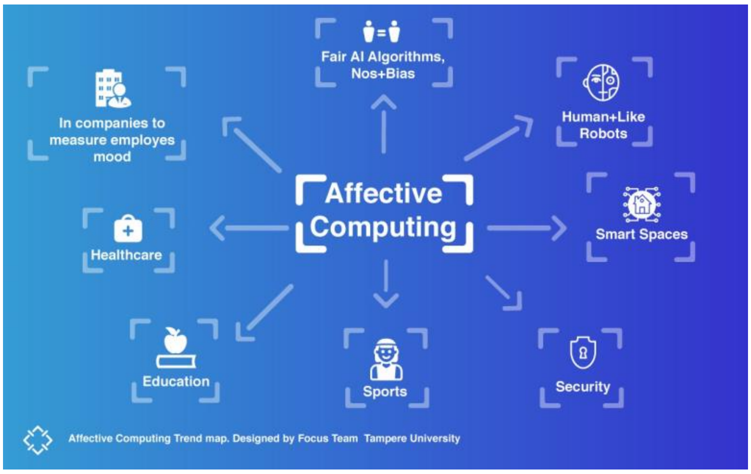


Fig. 24 Affective computing is a relatively new area mixing sociology, psychology, IoT, AI and computer science to create systems (software) that can become aware of emotions and interact with human beings, taking their emotions into account. It can be applied, as shown in the graphic, in many areas, including personal assistant (smart spaces). Image credit: Valentina Ramírez

Now, let's take a step forward. Why not take that "personal" home assistant along with you, through the day?

That is basically what this Megatrend is all about: the creation of cognitive prosthetics that will become commonplace by the end of this decade, augmenting people's intelligence (at least that kind of intelligence based on information and decision making through information processing).

The growing work on Digital Twins, particularly the one carried out in academia and research environments (extending to people the concept of Digital Twin, now widely adopted by industry, to create a copy of a physical object, such as a city, and be able to digitalize cities' processes and infrastructures), is contributing to this Megatrend. So, is the work carried out in Knowledge as a Service (KaaS), part of the Digital Reality Initiative, aiming at creating Cognitive Digital Twins to capture the knowledge of a person, or an organization?

By the end of this decade, it is reasonable to expect that our lives will be lived in a context that is no longer just made of the physical entities around us., rather it will be a context resulting by the overlapping of the cyberspace and the physical space we are living in.

This assertion, supported by the evolution of technology that provides a seamless connection of physical and virtual (like IoT, ambient awareness, AI, VR and AR), is much trickier than it might seem at first glance.

One of the tricky points is related to the presence, and mediation, of personal assistants/Personal Digital Twins. Think about it: today as we talk with one another sipping a coffee, we are in the *same* physical context. We might have slightly different interpretations of this context, like it might be perfectly ok for you whilst I find this ambient pretty noisy and uncomfortable, but it is not that difficult to agree on the perceived reality. On the other hand, in a Digital Reality situation, my perceived reality depends on the perception of the physical space (similar to yours) compounded by the perception of the virtual space, provided by my Personal Digital Twin, that will differ from the one provided by your Personal Digital Twin. The problem arises from the seamless perception of those two "realities" as a single "true" reality. As we lose the separation between the two, it will be more and more difficult to compare my perceived reality with yours!

Yes, in the next few years we will probably access the virtual part of reality, the one contained in the cyberspace and mediated by the Personal Digital Twin through a device such as AR glasses, that, in case of mismatch, can be removed and the user will go back to the physical context. However, in the longer term, the Personal Assistant might become an extension of our senses, embedded in our body, it may be in the form of an electronic contact lens and aural stimulation. At that point, it might be much more difficult to separate the two.

It looks like science fiction, but it is already on industry roadmaps. If you are puzzled by this, take a step back: look at how much influence television and, more recently, social media have on people. Depending on the type of information you are exposed to, your mindset evolves in specific directions, and your way of perceiving the world diverges from the one of people exposed to different sets of information stimuli. The shift towards Digital Reality will just aggravate the social issues that we are already experiencing today in our exposure to artefacts, like television and social media. It will multiply the effect since it will be shaping our context continuously.

9. ***Globally Abundant, Cheap Renewable Energy***

The use of energy has been a trademark of humankind, from the taming of fire to the invention of ways to harvest hydropower and wind-power (mills). Yet, for most part of human history, the amount of energy used has been negligible.

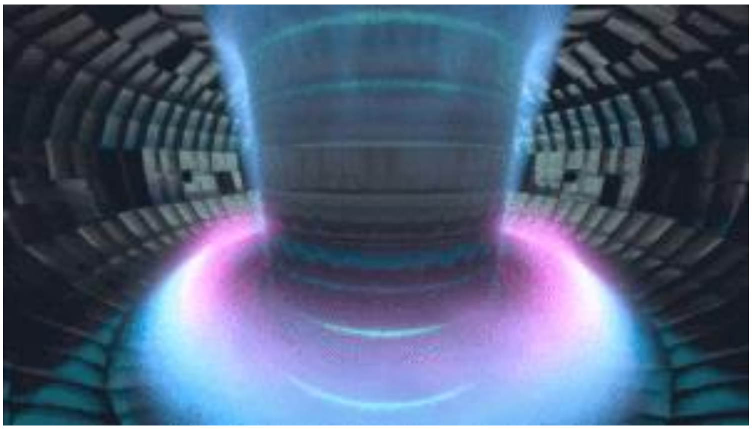


Fig. 25 Rendering of a fusion reactor where the hydrogen is heated until it becomes a cloud-like ionized plasma. Credit: ITER

The industrial revolution can be considered the dividing line in the harvest and use of energy. There is not a single date, it is spread out in the XVIII and XIX centuries. Coal was the first energy source, and the first steam machines were used in coalmines: the very low efficiency of those first engines was not a big issue in places where coal was cheap! For a captivating history of humankind use of energy, you can look here.

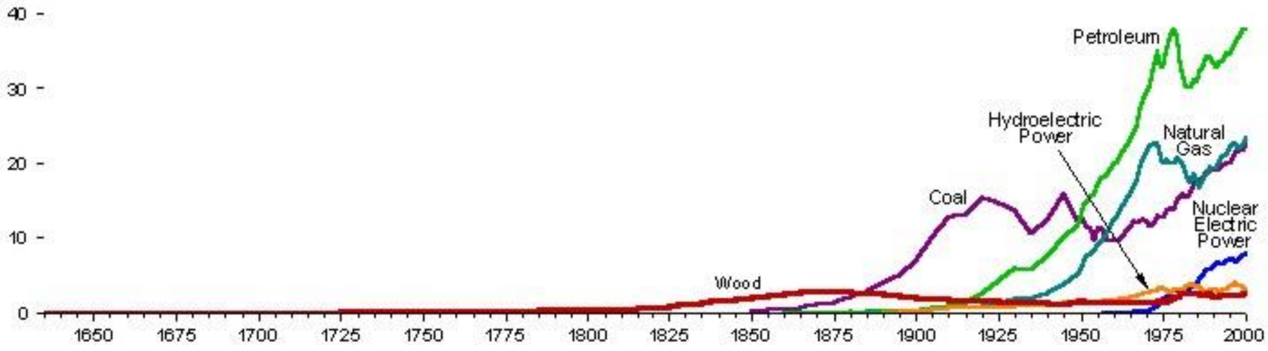


Fig 26. The use of energy in the US over the last 5 centuries. Notice how flat the use remained until the industrial revolution and the sharp increase in the last century. Image credit: Arlene Courtney

As there is not a single date for the uptake of energy use, the usage of energy has been, and still is to a significant extent, quite different in different geographical areas (countries).

Looking at energy usage is important from the point of view of wellbeing (measured in pro-capita GDP: yes it does not necessarily correlate with happiness, but it is a fairly good indicator of access to education, healthcare, food and so on), and data shows a clear correlation between energy availability and GDP (as shown in figure 27 created by the European Environment Agency). As shown, the relation falls (almost) onto a straight line indicating a linear correlation: the more energy used, the higher the GDP.

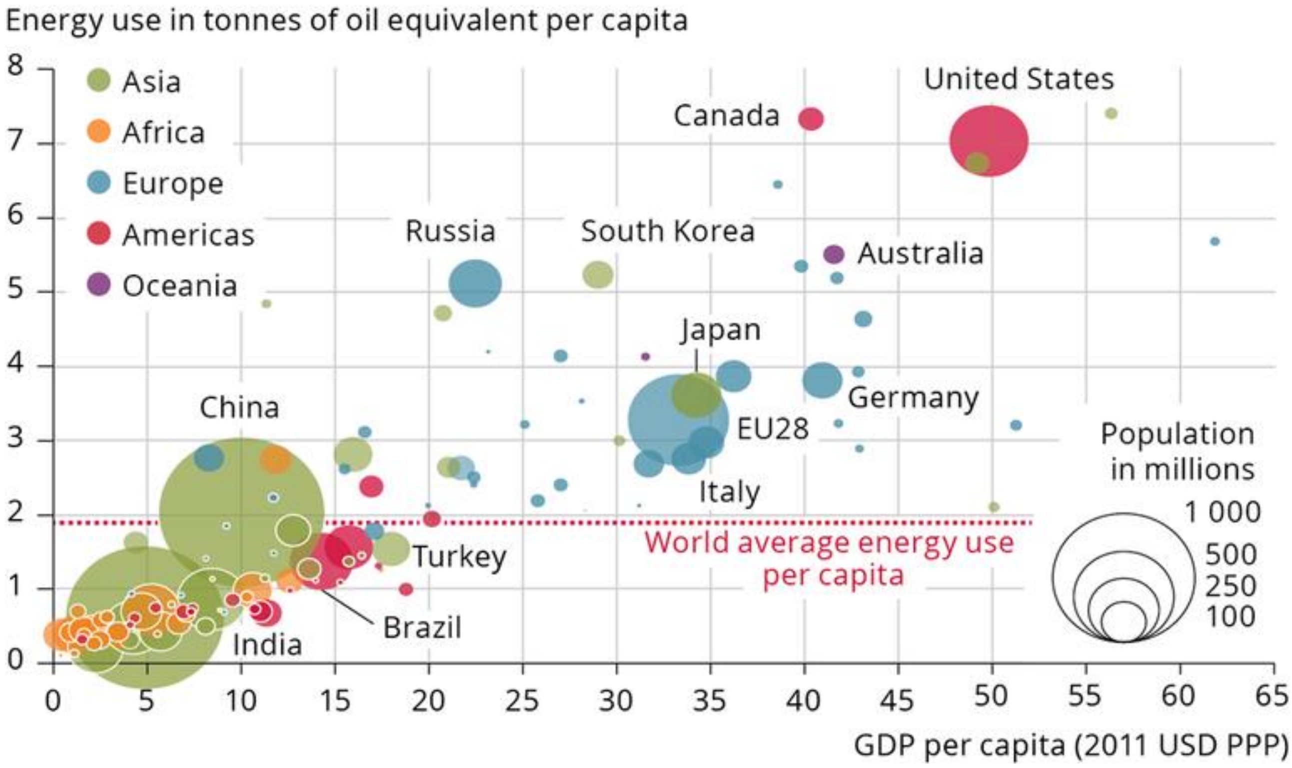


Fig. 27 Representation of energy use (expressed in tons of oil equivalent per capita) versus the GDP per capita. This graphic is based on 2011 data, so quite a bit has changed in these last 10 years, but the point made is still valid: more energy use relates to more GDP.
Image credit: European Environment Agency

Notice in the graphics the "bubbles"(circles) represent the size of the population in each Country — India and China having, obviously, bigger circles (the tiny dot at the top of pro-capita energy use is Saudi Arabia).

Of course, access to energy is a matter of availability and affordability (the two are related). Hence, any progress towards more abundant and more affordable energy would result in an increase of the GDP, and a parallel increase of wellbeing. Again, with the caveat expressed above and noticing that distribution of GDP may be quite uneven, it is generally true that a significant increase of GDP results in a generalized increase for all that Country's citizens).

This Megatrend is about the forecast of an abundant energy at a low cost, available everywhere and based on renewable energy. The latter has been the focus of research for many years, and we already have plenty of renewable energy from a variety of sources (hydro, solar, geothermal, etc.). The main issues are about continuity of energy availability (solar is only good as far as the Sun is shining, wind powered turbines need the wind to blow...), and its cost. This Megatrend envisages ubiquitous availability at a cost of 0.01$ (1 cent) per kilowatt hour by the end of this decade.

In fact, what would have seemed like wishful thinking ten years ago is now within reach.

Figure 28 shows the amazing decline in the cost of solar power over the last ten years, a decrease that was previously foreseen to happen over a 30 to 40 year-span. It should be noted, however, that this amazing decrease applies only to those areas that are enjoying plenty of sun majority of the year.

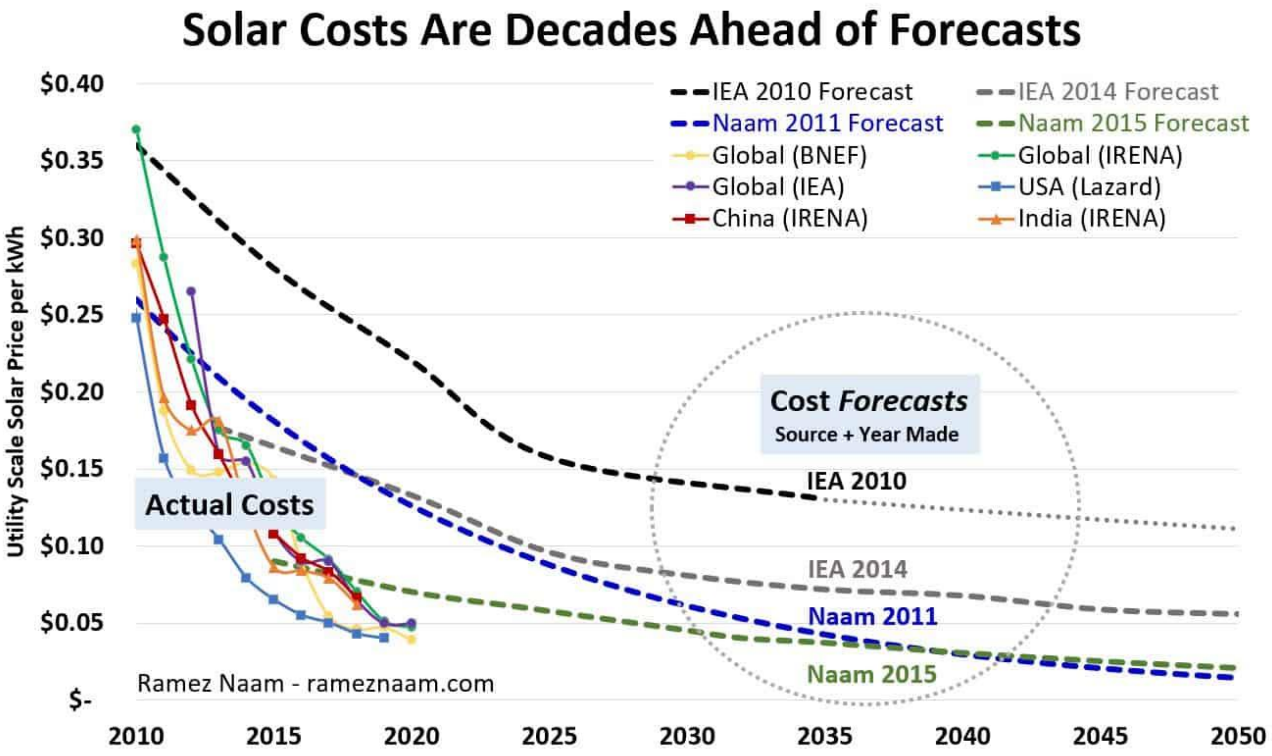


Fig. 28 The cost of solar power, measured in $ per kWh, has decreased much more in the last 5 years than it was expected, reaching values that were expected to be reached in 2040/2050.
Image credit: Ramez Naam

This trend is in synch with the forecast of this Megatrend to have a kilowatt hour cost in the range of 0.01 $ by the end of this decade.

Also, notice that to meet this Megatrend prediction, we need a variety of energy sources, solar is not enough. The reason is not that we are lacking solar energy (most of the energy we harvest on Earth is originated by the Sun), rather the fact that there are only so many places that are suitable to harvest solar energy. Placing photovoltaic panels in the Sahara Desert (an ideal place from the point of view of sunlight) would not do: the cost of transporting that energy to the point where it is used would be too high (evolution in superconductivity may eventually change the landscape, but so far it is a no go).

By the end of this decade, the exploitation of fusion power should be within reach (if not by the end of this decade shortly thereafter). The ITER program is now involving over 60 Countries, and the expectation is to have a functioning fusion reactor able to support large scale production of power in the next decade.

It will take few more years before fusion power will progress from feasibility to affordability, but the path is clear.

By the end of this decade, I am not expecting that we will be able to get one kWh at just 1 cent, that would be some 25 times cheaper than today. I am expecting, in particular, that such low-cost energy will become ubiquitous. However, I do believe that the price will keep going down and that the shift towards renewable will continue. This will also require availability of cost-effective batteries, and that is also an evolution that we might expect by the end of this decade. Notice that as battery use increases, the issue of recycling them becomes more and more pressing.

*10. **Insurance: from "recovery after risk" to "prevention of risk"***

Today we insure our home, our cars, and ourselves from accidents, and insurers evaluate the risk of such an accident occurring. To do this, they are using statistics, and are increasingly trying to customize the risk evaluations to be as accurate as possible. It makes sense, of course.

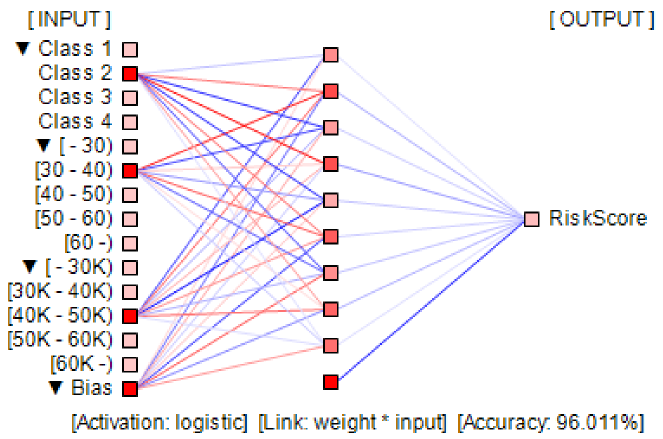


Fig. 29 The use of Artificial Intelligence is growing in the Insurance domain to provide better accuracy on risk estimates. Image credit: Rosella Machine Intelligence and Data Mining

However, technology evolution (read IoT/Internet of Things), pervasive communications, and massive amounts of data makes it possible to use this prediction of risk to ... avoid it.

Hence, why not pay for a service aiming at reducing my risk? Think about sensors at home that can detect any increase in temperature, or a tiny whirl of smoke, and some actuators that can sprinkle the area to extinguish an incipient fire. Or car sensors that can step in to avoid a collision, or immediately report a theft attempt, sending a drone to record the thieves (and possibly scaring them to the point of giving up). Think about having a virtual doctor monitoring your vitals and stepping in in the case of a red flag.

We are already starting to see these kinds of services, today provided by specific companies. In the future, however, it makes sense to imagine them provided by insurance companies as an integral part of the package. It is usually cheaper to be proactive rather than stepping in once the damage has been done. This is a very strong incentive for insurance companies to take advantage of new technologies and move into the area of risk prevention!

Artificial intelligence, coupled with sensors, will be able to create awareness, evaluate risk in real-time, and activate contrasting actions to decrease it (at the very minimum to decrease the damage). Gone will be the time of a statistical evaluation of risk, and the detection of risk here and now, and the implementation of avoidance measures, will become exceptionally important.

This is basically what this Megatrend is all about. It is important because it fosters a change of paradigm. It is not a given that present insurance companies will move into this new setting: it might be difficult for companies that have been growing on a lay back approach (see what happened, take notice to calculate future insurance premiums, delay payouts as much as possible, and thrive on the capital you keep harvesting... some insurers may object, but I can tell you it is rooted in experience) to take a lean forward approach, interact with the customers' lives and assets, and provide guidance/step in with actions in real-time. Insurers don't have organizations nor systems designed for real-time action.

Therefore, I tend to favor a scenario in which companies that are providing real-time support/monitoring today will be in a better position to become the insurers of tomorrow. There will be exceptions, of course, but if I have to bet, I will bet on a fading away of current insurers, and the rise of new players.

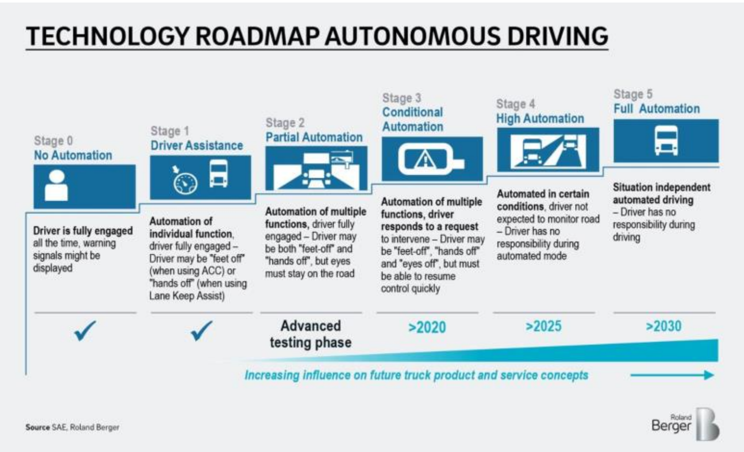


Fig. 30 Roadmap for autonomous vehicles. Full autonomous vehicles are not expected to become the "norm" in this decade. We shall wait for the next one, and possibly they will not take the upper hand until 2040. Image credit: SAE - Roland Berger

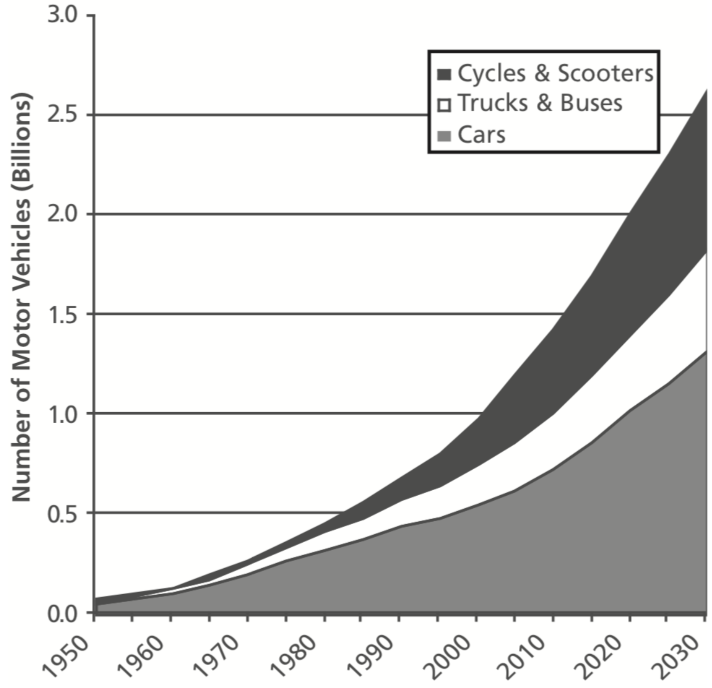


Fig. 31 Graphic representing the growth of vehicles, cars, trucks and motorcycles, in the last 70 years with projection up to 2030. Notice that the growth in this decade is fueled by developing countries whilst the market in developed countries is flat or declining. Image credit: Sperling, D., and D. Gordon, Oxford Press

11. Autonomous Vehicles and Flying Cars

There are already several autonomous vehicles, both self-driving cars and autonomous trucks. Additionally, there are several fully autonomous drones, and a few airplanes flying in the sky.

However, if we compare those numbers with the numbers of vehicles/planes, we can see that the former fall in the curiosity domain. There are an estimated 1.4 billion cars in the world (in case you were wondering, as of 2017 China has the most (with 300+ million cars), having surpassed the US).

As shown in figure 31, the number of vehicles is almost twice as much the number of cars, if you take into account motorcycles and trucks.

We have already seen an autonomous motorcycle, courtesy of BMW, but the point there was to show the progress of technology (and expertise) rather than paving the way to a real product.

If we look at flying objects, we have autonomous drones (in the military but now also becoming available for commercial applications, like inspection of infrastructures). Very recently, Garmin got approval for its devices to self-land planes.

All of the above is telling us that the technology used to create autonomous vehicles is available. So, the real question when looking at this Megatrend is "what stands in the way between technology and its exploitation?"

The biggest hurdles are regulatory. Of course, it is not about tardy regulators not doing their job and adopting/accepting technology evolution. It is about the principle of caution: before approving something, be double sure that there are no (hidden) issues. If a self-driving car has an accident, it will make newspaper headlines. The few thousand autonomous cars driving around today have had very few accidents, and the fatal ones can be counted on a single hand. On the other hand, 3,700 fatalities from car crashes occur every day—a staggering total of 1.35 million people die every year, and an additional 20-50 million suffer from non-fatal injuries.

However, we need to factor in the "billions" of normal vehicles on the road, a million times more than self-driving cars. According to Tesla statistics (and their interpretation), Tesla cars are safer when in autonomous drive mode than when driven by a human driver, but it remains to be seen what may happen as more and more autonomous vehicles hit the road. Are they really safer, or are the current statistics biased by the fact that many drivers are actually finding this type of vehicle more predictable, hence contribute to avoid accidents? The questions on the table are many, and this explains the reservation of regulators.

Throughout this decade, it is obvious that more data, and more autonomous vehicles (foreseen to reach 10 million in the next decade), will become available. That will provide both better interpretation of statistics and allow autonomous vehicles manufacturers to fine-tune them for increased safety.

In parallel, we will be seeing progress in technology (sensors, AI in particular) and lower cost that, in turn, will make it possible to increase the functionality (and safety), and increase the market demand.

What is most interesting about this Megatrend is that the path forward consists of many little steps, both in terms of fields of application and in terms of growing autonomy. Looking at them provides us with information on the evolution roadmap.

In terms of application (in order of deployment):

- Autonomous industrial vehicles (inside a factory/warehouse)
- Autonomous taxis
- Autonomous trucks
- Autonomous ships
- Autonomous cars

Autonomy is progressing every day. New cars are offering advanced features:

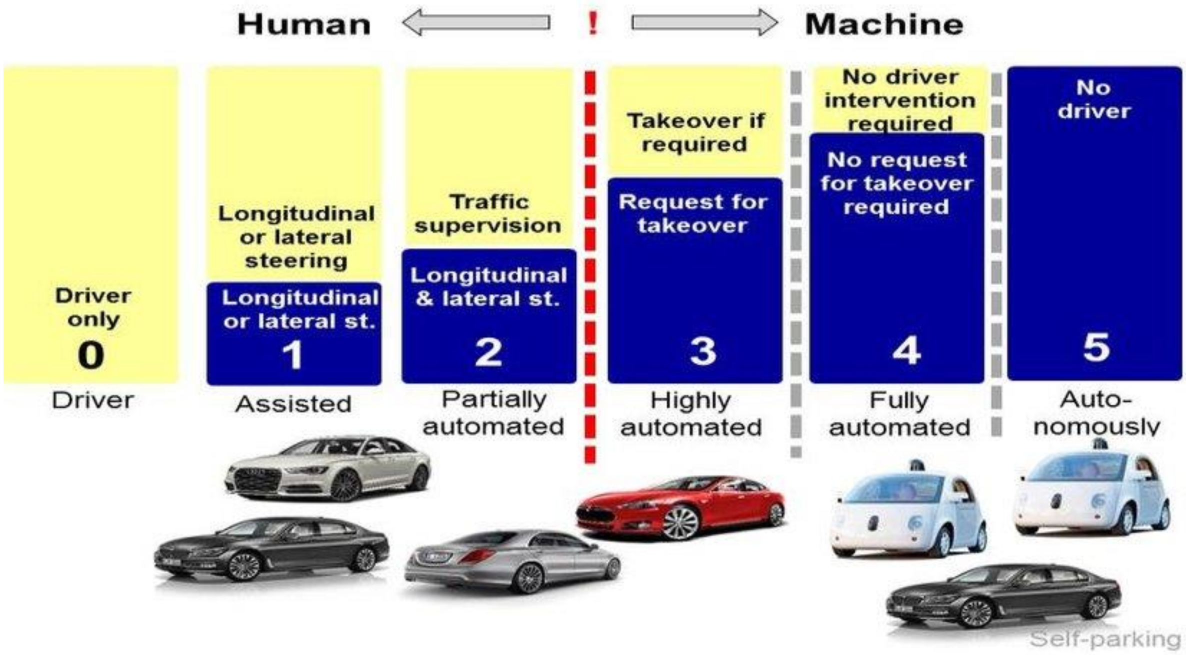


Fig. 32 Levels of autonomous driving according to SAE J3016. Image posted by Mario Hirz

- Detection of obstacles when parking (many cars have it)
-
- Detection of obstacles that require quick actions, and the ability to act in order to prevent accidents (For example, breaking automatically when nearing a car at a lower speed).
- Cruise control and automatic braking to slow down
- Autonomous parallel parking
- Autonomous vertical parking
- Autonomous parking without the driver in the car, and pick-up of the driver at a later point in time (autonomous valet parking)
- Autonomous driving with the ability to hand-over control in case of problems
- Autonomous driving on highways
- Autonomous driving in traffic jams, queue

As you can see from this list, it is a sequence of tiny steps that require, on one hand, better awareness on the car side, and on the other, an increased trust (on the "human" side). Likewise, on the flying vehicle side:

- Autonomous hover
- Autonomous navigation and return to base
- Autonomous landing
- Autonomous obstacle avoidance
- Autonomous tracking (of a person, a face, an object, etc.)

There are now a few prototypes that are close to commercialization (watch the clip), and it is reasonable to expect that by the end of this decade flying cars will be part of the landscape. Here, again, regulatory issues are a continuous roadblock. There is a need for a control infrastructure, and it is well understood that the one in place today for controlling commercial aircrafts does not scale to manage thousands of flying objects in a city. Today's aircraft management involves vertical and horizontal separation that simply cannot be applied in an urban situation of flying cars (with present rules, you can only have a few, perhaps 3/4 cars, flying over a city to maintain separation). We will need to shift to an autonomous flight control, with each flying car coordinating with those in proximity for right of way. 5G, and even more so 6G, will be crucial to ensure communications.

Fig. 33 Dubai has started to test autonomous flying taxis, and it is expecting to have them in service by 2021. Image credit: BBC

Flying cars are seen as a way to reduce congestion in megalopolis and as a way to save on fuel (a flying car uses about 15% more power than a rolling car, but by flying over a shorter distance and not having to stop on the way, it ends up consuming less power).

We should also note that flying cars were already among the "forecast" 50 years ago (I remember newspapers predicting them as a side effect of the emotional state we had seeing men landing on the Moon). Yet nothing happened in those 50 years. However, technology has now matured, and it is reasonable to expect quite a few of them by the end of this decade, starting in cities like Dubai where a desert is conveniently available to support flying over an empty space, thus avoiding safety issues for those walking below…

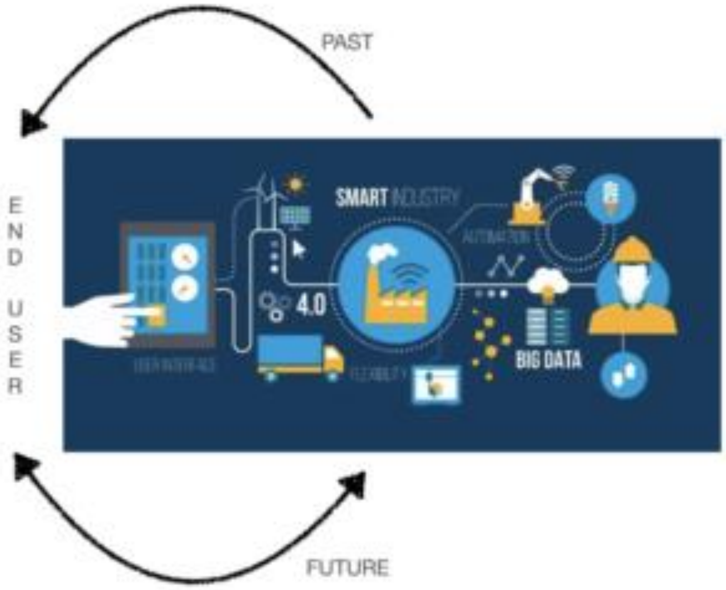


Fig. 34 Up until now, with very few exceptions, the factory produced a product and the end user bought it. In the future, we will experience a much higher level of customization, and in several instances, the factory will produce "on-demand" and based on the end user specification. Image credit: modified image from Proto3000.com

*12. **Instant Economy of Things***

The great change brought by the Industrial Revolution was the production of goods for an unknown customer. Think about it, before the industrial revolution, production was handled by artisans, and they worked on demand. Their wares were manufactured based on a customer's specifications be it a piece of furniture, a sword, or a cart. The Industrial Revolution changed the paradigm and changed the overall business landscape.

It was the Industrial Revolution that "invented" marketing, since it needed to push products produced "in absence" of a specific demand from the market, stimulating people to buy them!

We take all of this for granted, since we have lived all of our lives in an economic framework—goods are on a shelf and we have the possibility to choose one among them, and that's that. In his biography, Ford mentioned saying the following to his sales dealers:

"*Any customer can have a car painted any color that he wants so long as it is black.*"

However, market competition and flexibility in production have created an enormous variety of products, offering us an amazing choice, something that was unthinkable 100 years ago. Yet the

Fig. 35 The Ford model T. The first batch came in black color only. This was a way to create economy of scale and keep the cost down (hence the price down to reach a broader market). Image credit: Ford

paradigm is the same as it was in the XVIII century: the factory manufactures products that go on a shelf where customers may decide to buy them. However, over the last few decades, the variety of choices and the preference of market has sent clear signals to producers: if customers prefer a certain shape/function, the industry takes note and starts investing more on that, which leads to products that are more in synch with the market (differentiation and fine-tuning go together in mass market production).

In addition to that, in this last decade, we have started to see the first signs of a paradigm shift, taking us back to the pre-industrial era, but still preserving all the advantages from the industrial revolution (abundance, low cost):

- We can create our own photo book and have it delivered to our home in a matter of days.
- We can customize our next PC by selecting the types of chip, RAM, storage capacity, the interface, and even the keyboard... and have it assembled on-demand!
- We can customize our new car by choosing amongst numerous "options" and our car can turn out to be unique, manufactured just for us.

These are just a few examples of a paradigm shift, as shown in figure 33. We are moving from being a "buyer" to becoming a "builder." Of course, it is much easier to be a buyer (all you need is money) than a builder. However, technology is progressing at an amazing pace. Think about creating an app.

Writing software was a very specialized form of technical art (it still is), but now there are tools that can make simplify these tasks. I am using one right now to write this ebook. There is a major software supporting me, although I may not appreciate it. What has been done in the last ten years, on the production of software, will likely happen in this decade (and the following ones) to hard products.

This is what this Megatrend is all about: on-demand production and delivery. Initiatives like EIT Manufacturing (watch the clip) are paving the way towards this paradigm shift.

Industry 4.0 is a big part of it, but there is more:

- Design of raw material
- Design through Digital Twins
- On-demand production
- Software-as-a-Service (Servitization)
- Instant delivery
- Build/customize as you desire

- Recycling/circular economy

a) *Design of raw material*

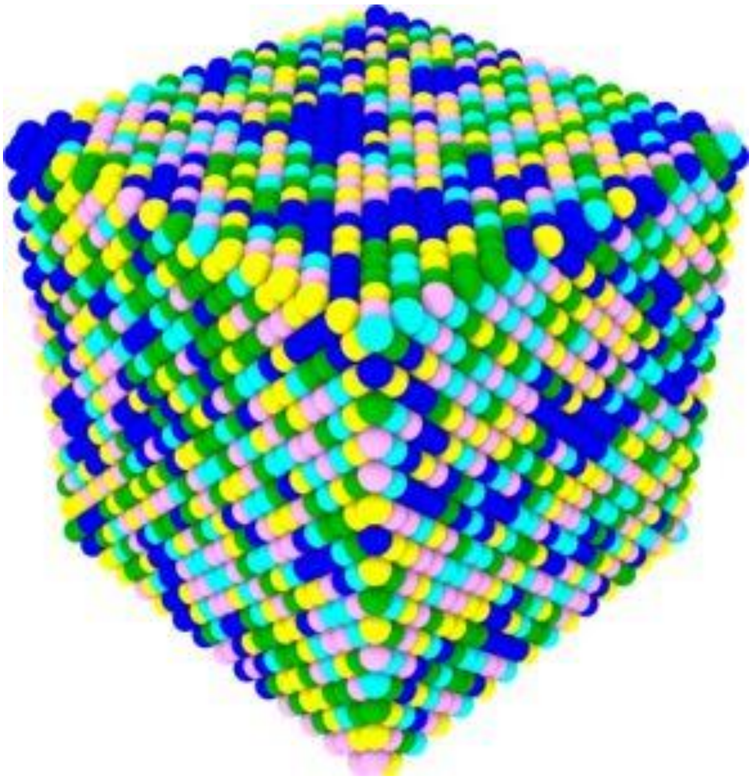


Fig. 36 Schematic illustration of the new palladium—containing high entropy alloy shows how new alloy contains large palladium clusters (blue atoms). Credit: Ting Zhu

Humankind discovered the first alloy a long, long time ago. Historians place the date somewhere between 5,000 and 6,000 years ago. In the current Iran/India area, our ancestors were using copper. They discovered that smelting certain copper ore, such as Olivenite and Tennantite, resulted in a stronger metal. Some went further and discovered that smelting copper and adding a pinch of arsenic led to the same result. Indeed, those ores contained arsenic mixed with copper. That was, based on historical records, the first alloy: bronze (arsenical bronze). Over the following centuries, it was discovered that mixing copper with other substances during the smelting led to even better results, and didn't provoke poisoning of the smelters (you don't want to breathe/ingest arsenic). Better results were discovered by mixing in tin, in a percentage around 10 to 12.5%. It took two millennia to get the right recipe for bronze, and it is still good today (for casting bells).

Over the centuries, humankind has learned to create several other alloys; the most important one, that fueled the Industrial Revolution, was "steel." The British found a good recipe for steel and were able to guard the secret for a few decades, then France and Germany (the latter was able to "invent" the recipe by themselves, and the French found it more convenient to use spies and to obtain knowledge ...).

There are basically an unlimited number of alloys just waiting to be discovered. The problem is that there are "potentially" so many. Researchers are fascinated by alloys because each one has specific characteristics (see in the chart, on the side, the differences for various types of steel).

Their discovery has accelerated in the last two centuries, and now we have thousands of alloys fitting different needs (racing cars would not perform as they do without the progress in the alloy department, leading to lighter material, yet much greater strength).

The quest for new alloys is not over, quite the contrary. In this Megatrend, new ways of exploring the "virtual" world of alloys plays a major role.

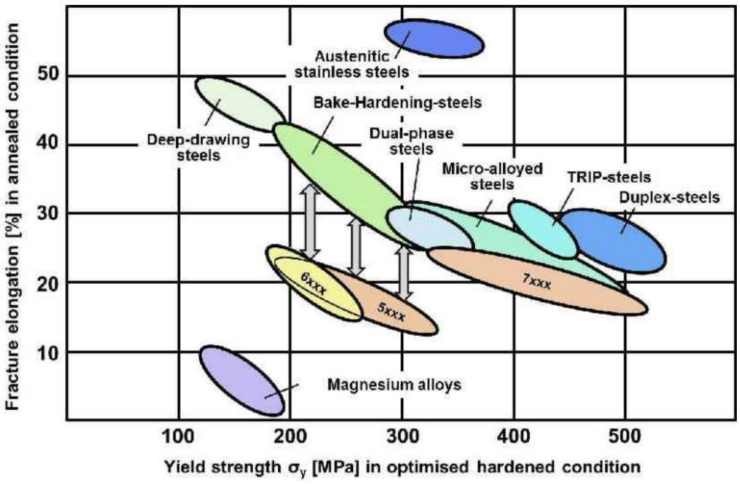


Fig. 37 Different characteristics of steel alloys. Image credit: Dierk Raabe

The word "virtual" is used for a reason. We know that an alloy is the combination of different materials, and this combination can go down to an atomic level. This means that, in principle, we can create two different alloys, composed of the same percentage of atoms, but placing the atoms in different ways (this is the case of chalk used to write on a blackboard, and seashells—they are both composed of calcium carbonate, but their consistency is quite different!). This can give you an idea of the, basically, unlimited number of possibilities. In addition, with a bunch of elements in the periodic table, we have, again, basically an unlimited combination of possibilities. Proceeding by blind experiments, as our ancestors did, is time and resource consuming. Hence, the new approach: let's build these alloys in the cyberspace (>>> virtual).

Machine learning algorithms are being applied to identify possible alloys that would deliver specific characteristics. An example is Intelligens, a US based company that has developed AI software that can help companies dramatically reduce time and investment in the search of new alloys (they claim a compression of 15 years into one month, with savings up to $10 million in the quest of a specific alloy). An example of composition at the atomic level is given in figure 35, and further details can be found here.

The ultimate goal is to use additive manufacturing to create material that is needed in terms of performance, while containing characteristics from the one used for manufacturing the product (or a component). Ideally, rather than looking for a material that would be fitting the requirements and then finding ways of using it in an industrial manufacturing process, a designer will specify the required characteristics, and an AI based software will create the material in the cyberspace, and then through additive manufacturing, the desired object will be created—directly driven from the cyberspace. This would support, as this Megatrend is predicting, an on-demand production.

I do not think that this will become commonplace by the end of this decade, but several "pieces of the puzzle" will start to become available. Economy of scale is a big obstacle in the way. We might be seeing this approach for specialized applications with stringent constraints, where price is not the point.

b) *Design through Digital Twins*

Digital Twins have become an integral part of the manufacturing process, used both as a tool and as a mirror of the product manufactured. Actually, several companies are now starting to use digital twins in the design phase, and in doing so, they also create the digital twin of the virtual product.

The use of CAD —Computer Aided Design— has become increasingly sophisticated. Born as a drawing tool for engineers, they have become platforms for product design. As such, they embed all features/resources and constraints that characterize a given manufacturing process. In this sense, the designer "cannot" design a product that would not be possible to manufacture by the present manufacturing processes/resources. In the case a designer wants to enforce a characteristic that cannot be implemented in the current framework, a red flag is raised and will need to be resolved before the design can reach the approval stage. Interestingly, some of these "platforms" allow simulation on the go, meaning that as a product characteristic/feature is being designed, it can be emulated against a context (like existing components or part of the operation environment) simulating the interactions, the use of shared resources, the overall impact, thus providing immediate feedback on what it would look like. The "under-construction" digital twin of the virtual product creates this emulation.

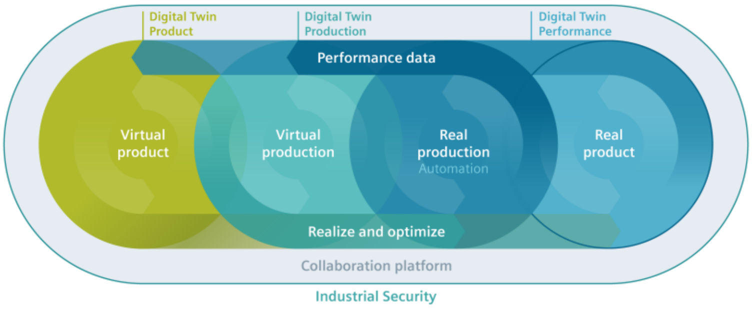


Fig. 38 Digital Twins are being used across the value chain. In the design phase, a digital twin represents the virtual product, and, in most instances, the design of the Digital Twin is the design of the product. Image credit: Siemens

An interesting example is provided by the Municipality of Singapore: since 2019, they have created the Singapore Digital Twin. When a company wants to build something, such as a new mall or deploying a self-driving taxi service, it is required to present the project in terms of a digital twin. This digital twin is embedded into the Singapore framework, interacting with the Singapore Digital Twin. Out of this interaction, the Municipality is able to spot potential issues and request changes to the presented project.

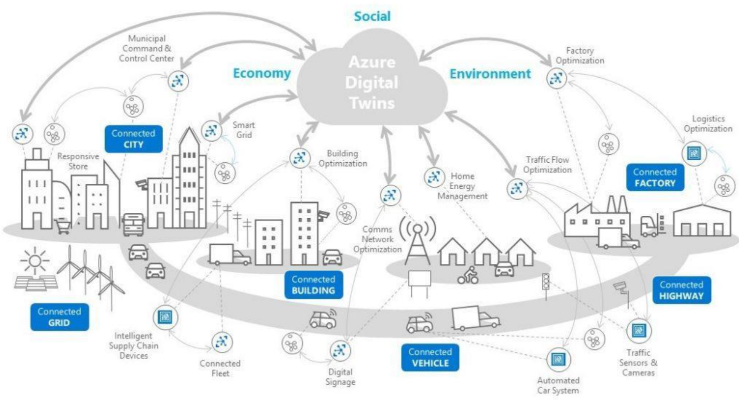


Fig. 39 IoTs in a city generate plenty of data streams that effectively provide a shadowing, making it possible to keep the Digital Twin of the city in sync with the status of the city in quasi real-time. The data is recorded, creating a Digital Thread, and the whole is used through machine learning to [create an emerging intelligence](). Image credit: Microsoft

More incredible than that, a city Digital Twin can be used to provide a living snapshot of a city. As such, it can be used by citizens for better awareness on what is going on. That same Digital Twin can be used by a service developer to interact with the city in the cyberspace in the crafting of the service (in the previous paragraph it was the Municipality that used the service Digital Twin to assess its operation vs the city, here it is the reverse, the use of the DT to develop a service).

By the end of this decade, we can expect a cyberspace populated by Digital Twins, mirroring both artefacts and people. They will provide a dynamic backdrop usable for the development of products and services. Furthermore, Personal Digital Twins may be used as an interface component by several services (and for the soft part of products), in the same way that your smartphone is often used as an interface to products and services.

c) *On-demand production*

The efficiency of distribution chains and flexibility of production lines resulted in an amazing change in production processes and in the relation between the market (and with the end customer). Just two decades ago, when buying a car you, would have been offered what was available in the physical lot, and what the dealership was expecting to arrive. Options were limited, and usually "pre-packaged" by the manufacturer. It was no longer "whatever color as long as it is black," however, it was a choice among a very limited pallet. Now, you either go to a dealership and select from numerous possibilities and features in the car you want, or you create your car “online” using the manufacturer customization tool. The number of possible "versions" is in the hundreds of thousands. Just for fun, I checked how many different versions are possible for the car I recently bought: 307, 584!

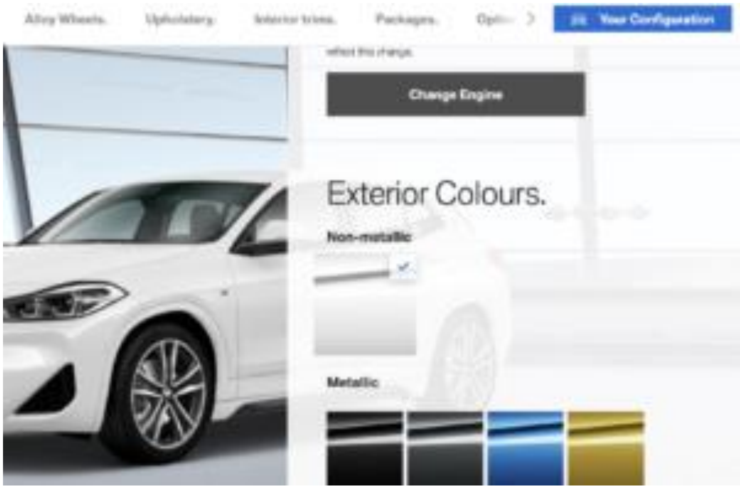


Fig. 40 Flexibility in present manufacturing systems make it possible to create "on-demand," personalized products. In this image, the BMW configurator lets you customize your car in ways that can make it "unique." Screenshot of the BMW configurator

It is not quite an on-demand production market yes, but it is getting close. Notice that this variety is all provided in "hardware," products that are manufactured to specifications requested from the customer. In my case it was via the dealership, but it is possible, as noted, to customize the car yourself using software on your laptop or smartphone —Imagine creating your own car specs on your smartphone and "pushing" them to the robots on the assembly line for manufacturing! Now, think about software customization: that is something that, in principle, could be done as you are using the product, in the same way that you load new apps on your smartphone to do something specific.

The trend is quite clear; hence, this Megatrend is not surprising at all.

In this decade, 3D printing and additive manufacturing will become more effective, i.e., more affordable, and flexible. I do not envisage a 3D printer in my home, what I expect is to have the possibility of creating 3D models of objects, be it my foot or a gasket that wore out on the kitchen faucet. The new (top of the line) smartphones are starting to embed a Lidar sensor, something that can allow the creation of very accurate 3D models. Once created, an app will let me tweak it to fit my specific needs, and then its production will be just a click away. The 3D printer that will "manufacture" perfectly fitting shoes, or the new gasket, can reside at a manufacturing plant (most likely in the case of shoes ...), or at the hardware store close to my house. One way or another, I should be able to get what I want by the end of the day.

Big factories were the engines of the Industrial Revolution, as well as its consequence (huge capital to pay for the manufacturing machines/assembly lines). Over time, those machines have become increasingly flexible and can, in principle, produce different artefacts. The reason why this has not happened is the parallel amazing evolution of the delivery chains. These have become so effective that it is irrelevant where production occurs from the point of view of the customer, so production is happening where conditions are best, leveraging economy of scale. I just had a first-hand example: ten days ago, I ordered the printing of 3 photo albums, each one of its own size. I received the first one 5 days later and discovered (from the tracking number) that it was printed near London, UK (it was an unusually large format). The second photo album was printed in Germany (and arrived to me in Turin, Italy, one week after ordering it). The third one arrived ten days later, and guess what: it was printed in Italy! One would have expected that the printed in a closer location would have arrived sooner, but that was not the case (by the way, I remember ordering a laptop and receiving it after 2 days: looking at the tracking number I discovered it was sent from Shenzhen, China).

The effectiveness of the delivery chain might improve even further in this decade as new tech for last mile delivery will become available (watch for the upcoming Instant delivery).

On-demand production/manufacturing is a reality in the high-cost item, like haute-couture fashion. The order triggers the manufacturing process, and the factory will deliver the product directly to your home, skipping all intermediaries (known as drop shipping). The textile industry is also moving towards on-demand production: In November, Kornit announced the creation of a new biz line focusing on digital, on-demand production management.

This will become more common and pervade several sectors. One that is going to be significant for its broader implications is the Pharma industry. By the end of this decade, personalized medicine will become mainstream and that will go hand in hand with the on-demand production of medications, since each one will have to be custom-made. The 2020 Researchers Night theme (November 2020) focused on the evolution towards tailor-made drugs! For an overview of enabling technologies for personalized /precision medicine, read this article.

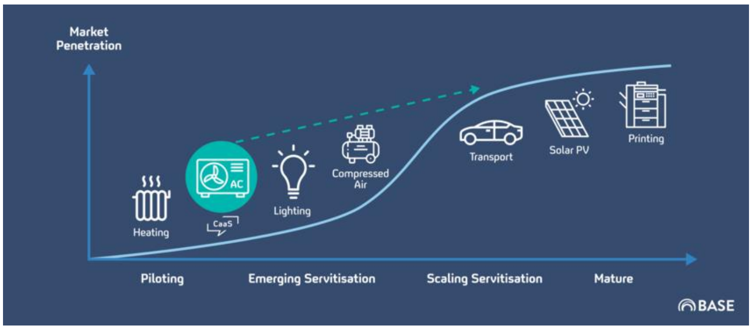


Fig. 41 The shift from product to services is increasing at a quick pace. The figure, from a World Economic Forum article, displays the maturity of servitization in the energy sector. Image credit: Basel Agency for Sustainable Energy

d) *Servitization*

The transformation of products into services is not new. Several verticals have experimented new biz models aiming at generating continuous revenues by delivering services rather than selling a product. Digitalization creates data, the orchestration of an ecosystem exploits the information, which often leads to the creation of more data. In addition, direct and indirect connectivity make it possible to keep the image of a product in cyberspace, resulting in a direct link between the product's manufacturer and the customer. More than that, if the product is designed to support open connectivity, ecosystem players may access and get feedback from the use of the product delivering data (read functionality/services).

During this decade, we can expect several products to have a digital twin, their counterpart in cyberspace. Today, the digital twin is a mirror of a product, but in the coming years, the digital twin will become an integral part of the product with some functionality offered through the digital twin (DT at stage IV). This means that by adding functionality to the DT, one is actually adding functionality to the product. It is, obviously, easier to add functionality in cyberspace than in the physical product, and this will stimulate the shift towards a service paradigm. In a longer timeframe, I expect DT (at stage V) collaborating in a mesh network, and each one relating the relevant results to its physical twin - see figure 42. This will also be a way to create a multitude of services in cyberspace (with very low transaction cost) in representation of the physical twin and based on relevance and needs.

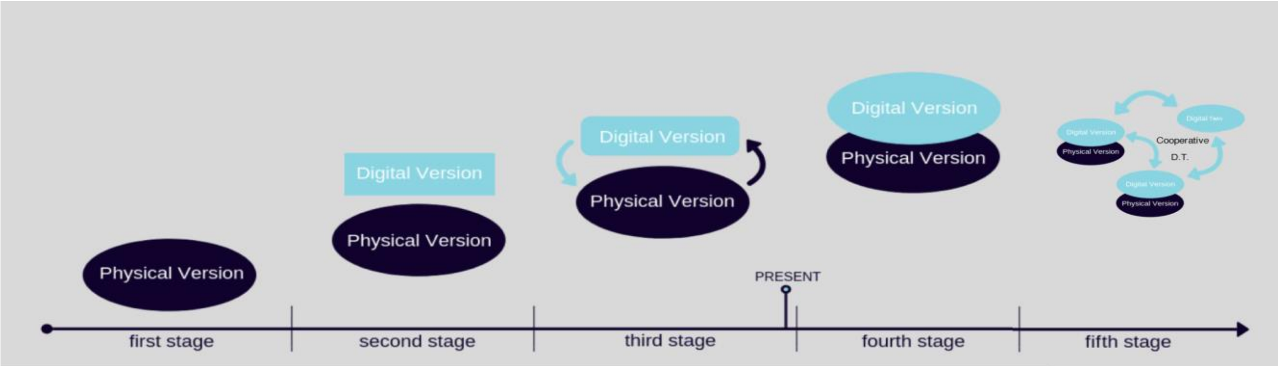


Fig. 42 The five stages of evolution of a Digital Twin. At present, most of them are at stage III, with a few examples at stage IV

Notice that servitization is not restricted to the use of software over hardware. It is also about managing hardware "with software": think about the shift from "owning" a car to renting it as you need (such as with a driver, like Uber, or a service without, like Car-to-Go). Our cars are, basically, sitting idle most of the time, parked somewhere. By having an effective way of "summoning" a method of transport when needed, and wherever we are, can cause the ownership of cars to become obsolete (MaaS - Mobility as a Service). This would significantly reduce the number of cars (some estimate that New Yorkers could get the same level of service with just 40% of the cars present in New York).

In the MaaS area, we are expecting an increase in sharing mobility, as shown in the graphic, and an integration of sharing resources. This is possible by using supporting platforms and by a growing intelligence (machine learning and data analytics) that can pre-plan resource allocation at the macro scale, plus interaction with personal agents (in the future, personal digital twins) at the micro scale. By the middle of this decade, we can expect an uptake in sharing integration (it was supposed to happen in the first part of this decade, but the ongoing pandemic and social distancing requirements are slowing the uptake as people feel more comfortable using their private vehicles. For interesting analyses on the shift on transportation's preferences look: here , here , here , here and here. Each of the linked reports address a different aspect, but all agree that the general public is less inclined to use public/shared transportation for fear of contagion. Clearly, the attitude will change once the epidemic is over, but that will take a few years).

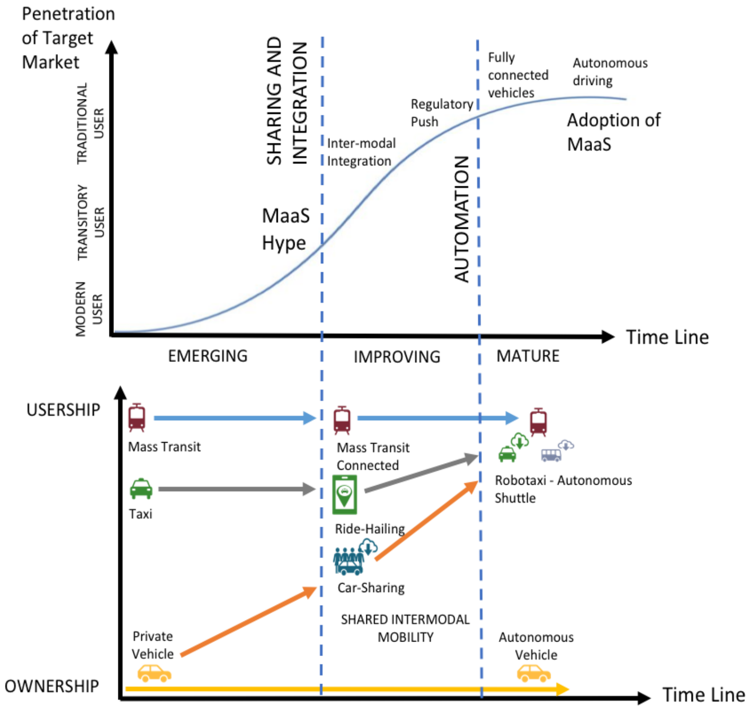


Fig. 43 Two interesting graphics indicating the evolution in the adoption of MaaS, from an emergent to a mature landscape (full maturing in the following decade), and the corresponding decreasing level of ownership. Notice the two big enablers/accelerators: first, the software based sharing integration, and second, the automation of vehicles. Image credit: Bax&Company

The second big shift towards MaaS to happen in the following decade is expected to be fueled by the advent of fully autonomous vehicles. At that point, any vehicle will be perceived similarly to a public bus, and you "use" a bus when needed, you don't buy one just in case you need it!

The Digital Transformation is at the core of both aspects of servitization: for the first one (delivering services by flanking a product), we are seeing the impact at the micro-level, the shifting perception of the end consumer on the value of a product. For the second one (sharing of resources through a software orchestration), we are seeing the impact at the macro-level, the shifting perception of needs.

The servitization is progressing in several areas, increasing in depth, value, and breadth (I used MaaS as an example, but we have similar examples in many verticals). It is also driven by the need to decrease impact on environmental resources: using cyberspace and moving atoms to bits decreases the footprint. This, at the same time increases the focus on services. For more on the specific aspects, read the article from the World Economic Forum.

Selling a service is quite different from selling a product, and it requires a different organization. Therefore, it is complicated for a company to make the shift.

When selling a product, the "manufacturer" relies on a delivery chain and on resellers. It is basically decoupled from the end customer. This is not the case when selling a service which involves a direct relationship with the end customer (and with the users). Also, when you sell a product you are unlikely to see that customer for an extended period (depends on the product life cycle, but it is usually measured in years), which is another crucial fact. For example, when you sell a washing machine, that customer will not come back to buy a new washing machine until it has worn out (and if it wears out too rapidly, the customer will look for a different brand!). However, your revenues are made at the time of the sale. On the other hand, if you are in the service business you are going to interact with your customer frequently. In fact, the more frequent the better since you are generating revenues out of repeated use of the service.

The reason for the "decoupling" of the value chain (the separation of the manufacturer from the end users/customers) is the consequence of the high transaction cost occurring as you interface one player with another. The digital transformation, by shifting processes in the cyberspace and using data, slashes transaction cost, thus making it possible to directly connect the players (most of the time this connection is mediated by machines/software). Industry 4.0, among other things, makes connection across the value chain “cheap" and "effective." This possibility can be leveraged as a potential revenue generator. In turn, this stimulates the flanking of services to products.

Hence, to wrap up, there is a continuous growth of service offerings, including services that are associated to products, and, of course, service delivery can be instantaneous (on-demand) and can be easily customized, fueling this Megatrend.

e) *Instant delivery*

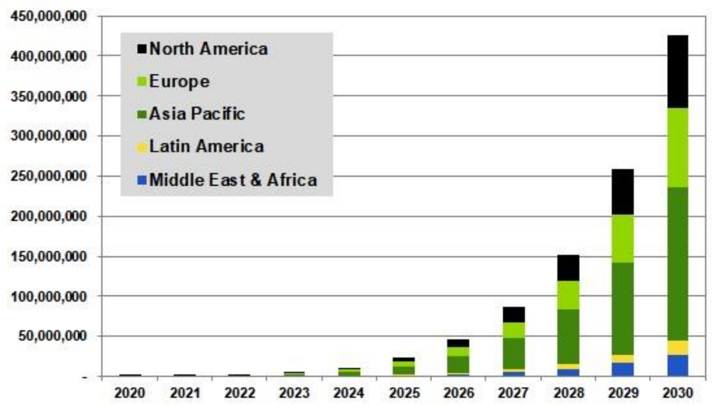


Fig. 44 Estimated growth of drone delivered packages, worldwide. Image credit: Guidehouse Insights

Logistic chains are a marvel in today's world. They work (most of the time) seamlessly and are so effective that you can get your delivery within a single working day (it does not work for any place and for any type of product, but I can vouch that I can get a number of Amazon items within 24 hours most of the time).

This Megatrend foresees an immediate delivery, let’s say within a few hours and even within an hour, for most types of goods and for most locations. I don't think this will be feasible in general, but it is reasonable to expect that "instant" delivery will become part of daily life for many people in many situations by the end of this decade.

First, consider that 68% of the entire population will be living in an urban environment by 2030, and 730 million people will be living in one of the 31 megalopolis (more than 10 million inhabitants) by the same date. This high concentration of people in urban environments creates poles of attraction for markets and allows the creation of effective hubs for the logistic chain in the last (few) miles.

Second, consider that robotic delivery, including drone delivery, is progressing rapidly with the big guns (Amazon, Fedex, UPS, ...) all running trials.

It is not just the big guns experimenting with autonomous delivery. Big retailer chains are also interested, and a few have started trials. As shown in figure 46, a delivery using a Boston made Deuce Drone by Rouses Markets in Alabama (a store chain with 64 stores employing 7,000 people).

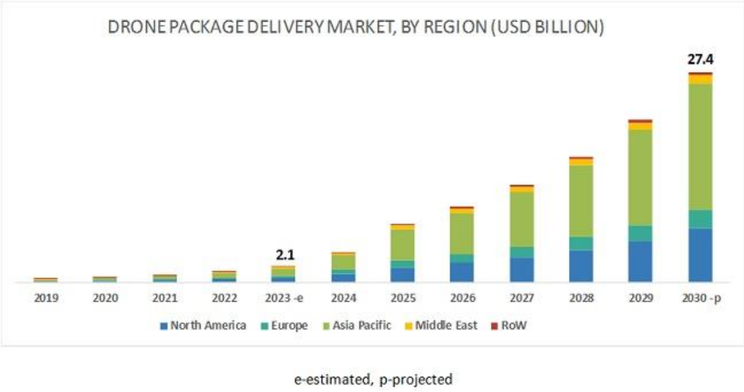


Fig. 45 Estimated market growth for drone delivery worldwide, expected to reach $27.4 Billion USD by the end of this decade. Notice the lion's share taken by Asia/Pacific region, followed by US as a distant second. Image credit: Markets and Markets

Emergency services are also using drones to deliver first aid kits, drugs and food to areas that are isolated. All of this is fostering technology evolution and we can expect to have more affordable and effective drones as time goes by.

As shown in figure 45, the market for drone based delivery is expected to grow significantly, basically increasing from $2.3 in 2023, up to $27.4 billion USD in 2030. Most of the market is related to delivery of packages under 2kg of weight (above that, bigger drones are needed to carry the increased load). Also, projections indicate that longer range deliveries (over 25km) are expected to accelerate.

Fig. 46 Drone delivery has entered into a trial phase in several market segments. In the photo, a drone delivery by Deuce Drone on behalf of Rouses Markets. Image credit: PYMNTS

Autonomous delivery robots are widely used in warehouses, hospitals, and are now being used in factories. Trials are running for using autonomous “carts” as freight delivery in urban environments, and the pandemic has increased the interest towards contact-less delivery such as the one provided by autonomous freight vehicles designed for the last mile. Supermarkets and big stores are the prime focus for their deployment.

I am not sure that both drone delivery and autonomous freight delivery will become the norm by the end of the decade everywhere. Most likely, there will be some areas that will make use of this delivery type (mostly because of geographical location and a lay of the land that is conducive to this type of autonomous delivery), whilst others will see autonomous delivery more as an exception.

f) Build/Customize as you use

The flexibility of manufacturing and the softwarization of functionalities result in a broad range of adaptations for most products. For example, think of something you already own, like your laptop. You chose the chip type (how many cores, the clock frequency), graphic board, storage capacity, the screen size, etc. It might not seem a lot, but when I bought my first PC, I had no choice at all! Now, think about the software: here the choices are so broad that it is highly unlikely that you will find a laptop that is identical to yours (I am talking about applications, not about the data). In the case of your smartphone, the choices are much more limited on the hardware side, but they are practically limitless on the software side, with a pool of 2+ million apps to choose from.

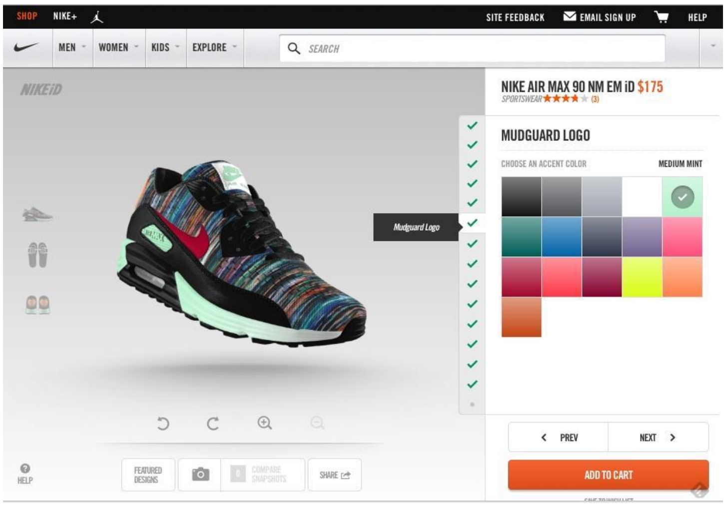


Fig. 47 Customization is becoming increasingly possible for more and more products. Manufacturers and retailers are using it as a competitive advantage. Visibility on users' data transforms customization into personalization through the life cycle of the product. Image credit: Nike

The trend towards customizing products as you buy them will continue, as already noted in the section "on demand production." Furthermore, several products will provide the ability to further customize as you use them. Customization through usage is obviously happening today for your smartphone (and several other devices embedding a computer, like televisions). You tweak your devices to better suit your needs and way of using them. For example, go to YouTube and search "customize iPhone 12" and you'll see plenty of videos to guide you through the unlimited possibilities for customization that are worth exploring a bit (I discovered many "things" I can do with an iPhone I was not aware of ...).

Even more interesting, in the future your device will learn the way you are using it and will self-customize to better fit your habits (for example, your new iPhone learns your charging habits and will self-regulate the charging to decelerate the wearing out of the battery ...). This is already capable in some devices today, but in a limited way. As artificial intelligence is embedded into a device, it will allow the device to learn habits and activities and will therefore finely tune the interaction to better fit that type of use. This kind of customization, based on the understanding of a persons usage and context, is often called "personalization," and is distinguished from customization, which does not require knowledge of the unique user. Interestingly, the possibility to connect a product through its usage phase to the manufacturer (or to a service provider) enables the personalization of the product, increasing the perceived value. The more you use it and share data with the producer/service provider, the better the product will meet your needs.

The shift towards voice interaction, and within voice interaction towards natural language interaction, provides a further boost to device intelligence and to its adaptation. By the end of this decade, you can expect to be able to talk to most of your devices, directly or via an orchestrator (like Alexa), the same way you would be talking to a friend or a colleague. You will start expecting the device to keep a memory of previous interactions, and you can start the next one from where you left off, without repeating yourself. Also, we can expect that the use of voice interaction will allow the device to capture our moods–annoyed, bored, happy, stressed, etc. –and tune the interaction accordingly (sentiment analysis).

The presence of a device in terms of functionality, both in the physical space as well as in the cyberspace, will greatly increase flexibility and customization potential. Additionally, the existence of a personal digital twin that can interact with the digital twin of the device will enable a backstage customization even before we start using the device.

What is true for products will be true for services, and this might happen sooner. It is already happening: our profile, created by entertainment service providers, becomes a sort of personal digital twin (in the entertainment sector), and this is used any time we access entertainment services with our identity. This, as an example, will allow me to find customized (personalized) recommendations on what to watch both when I am sitting on the couch at home, and when I am in a hotel room thousands of miles away (the offer may differ based on location for copyright reasons, but the service will still customize the offer to my tastes).

g) recycling/circular economy

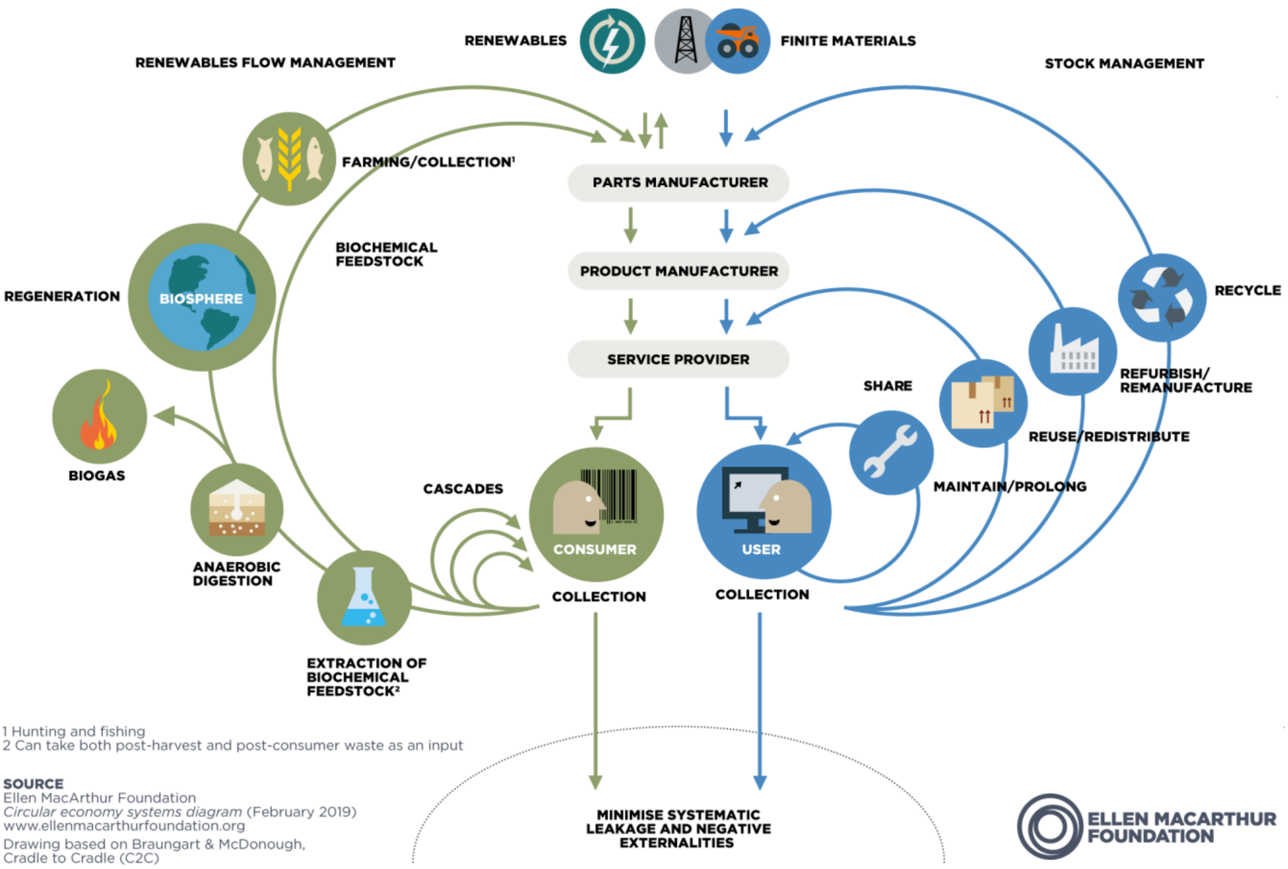


Fig. 48 A circular economy representation having, in the central part, the value adding chain (component production, final product manufacturing/assembling and service creation), on the right side, the usage part (including all life extending activity and eventually the parts recycling). On the left-hand side, the use of waste and its reprocessing by nature to contribute back to the production chain. Image credit: Ellen Macarthur Foundation

We have been talking about recycling for a few decades, and we have been taking action to implement recycling, at least in part (differentiated waste collection and processing is surely part of it). More recently, we have been discussing the possibility of a circular economy where the cost of managing the end life cycle of a product can generate value. This Megatrend, on instant availability, is deeply intertwined with recycling and circular economy, and it foresees a much broader uptake of these paradigms throughout this decade.

From a physical-mathematical point of view, a circular economy would be impossible since it would go against the second law of thermodynamics. However, from an engineering point of view (approximation), it can be done. Besides, there is a trick: we look at circular economy on our planet, but this is not a closed system as we get "input" from the sun (energy) and we can use that energy to satisfy the second law.

Anyway, when we talk about recycling and circular economy, we take an engineering standpoint and an economist standpoint, which lets us do what is possible and make the most of it!

As shown in figure 47, production of value - products and services leads to use (user) and consumption (consumer) (interestingly, the representation of steps where you see services following the product: this is in line with the trend of flanking a product with services and enriching the product functionality and user experience through services).

Usage is addressed by several actions that maximize the use, and more specifically:

- Sharing economy: using the product by several parties, maximizing its benefit, AND reducing the need for duplication. An obvious example is car sharing. Rather than having several cars, one per user, we can share the use of a single car across several users. This is under the (true) assumption that a user is using a car for only a fraction time (on average. our cars are sitting idle over 90% of the time, parked somewhere). By using software and platforms we can make a car available to several users. Several studies have been made modelling different usage scenarios (a very nice one can be found here), and they all show that there is not a single solution fitting all use cases, but all car sharing approaches lead to a significant decrease in the number of cars required. This is good if you look at it from the point of view of raw material usage—producing fewer cars requires less raw materials. It is also good in terms of economic efficiency from the point of the user—spending less to move from A to B. It is good in terms of urban space occupied by cars—fewer cars being parked around. BUT, it is bad for car manufacturers who will see their market volume squeezed to the point that present manufacturing processes and competition environments would collapse since they have been finely tuned for a market buying (some 70+ million vehicles per year, and difficult to sustain when market will shrink to less than 40 million per year). It is bad for the many companies maintaining the cars, it is bad for those selling gasoline, it is bad for car-wash businesses…;
- Proactive maintenance and continuous improvement/extension of functionalities: think about the new features you get as a new OS becomes available: you still have the same computer, but it gets better with the new OS. This extends the life of products, and again it is good for the environment and for the user, but it decreases the substitution market, leading to decreased sales. In software, this has become a major issue that has led several software companies to shift to a subscription model, since the sale of a perpetual license would result in a shrinking market;
- Reuse and redistribution: we have seen this happening in areas like wedding dresses, with companies that are offering customized rentals (they take care of modifying a wedding gown to fit the bride). A bride to be can rent a perfectly fitting dress out of a very large selection for as little as 150$ (compare this to the $2,000+ needed to buy one). That dress will most likely only be used only once by the bride, and upon return to the renting company, it will be cleaned and restored to pristine condition waiting for another bride to be. Notice that this is different from car-sharing. Here, after each use, the dress is reconditioned and before being used again, it will likely be modified to fit the new bride. However, the bride that uses such a wedding gown is a bride that does not "buy" a wedding gown, thus shrinking the potential market;

- Refurbishing/remanufacturing: the refurbishing of a product is nothing new—the big department stores have been doing that for decades. However, it will be extended further. Several companies are now advertising a service-like contract —you buy a smartphone and every year you can return it and get the new model for a minimal yearly fee. The old device (one year old on average, so, still young) will be refurbished and placed on the market once more (at a lower price). I have gotten several refurbished items (like Nikon lenses, tablets...), and they all work flawlessly at a fraction of the original cost. Again, we are basically extending the life cycle of a product, hence decreasing the total market;
- Component and raw material reuse: for certain products, it is possible to disassemble them once they are returned, and in some cases to extract the basic raw materials (like copper, gold...) for their reuse in the manufacturing of other products. In this case, we are not seeing a decrease in the potential users' market, but of course we are decreasing the market of some parts (like raw materials) of the supply chain.

By the end of the decade, this Megatrend predicts a significant increase in all the above aspects of recycling and as pointed out, this is good in many aspects, BUT it is bad in terms of market space (fewer products will be sold). However, it is also true that all processes involved result in value creation, and thus in revenue opportunities, although these opportunities are usually not harvested by the original producers.

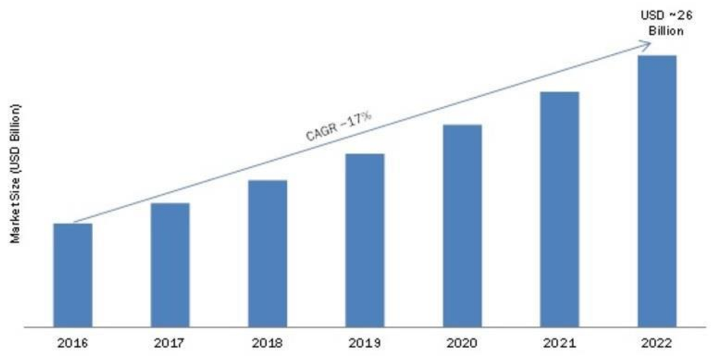


Fig. 49 Global Market value growth of recycling in electronic waste. As shown in the graphic, it is expected to grow at at 17% CAGR, reaching $26 billion in 2022. The growth is a result of evolving recycling technologies that decrease recycling cost and foster reuse of materials, thus creating revenues. The growing awareness of the impact of electronic waste on the planet and a more environment conscious culture all over the world is another important factor. Image credit: MENAFN

On the consumer side (left part of the graphic in figure 48), we see products that are transformed by use into "waste." In this case, the challenge is how to make use of the waste to feed different value chains (like using waste as fuel or to create fuel). We already have a variety of thermo-valorization plants, and you can expect to see many more of them and with a higher efficiency in this decade. The trick is to exploit waste in such a way to generate value (like heating city buildings or providing electricity), and for the residual material to be regenerated by natural processes (using sun-light) to return to a state of natural materials that are present in the environment. All of this is feasible, from a technical point of view. The real challenge is to make it affordable from an economic point of view (that is, it should be cheaper to dispose waste through thermo-valorization than dumping it into a landfill).

This Megatrend promises that by the end of this decade we will be able to do this, and that would be an amazing result!

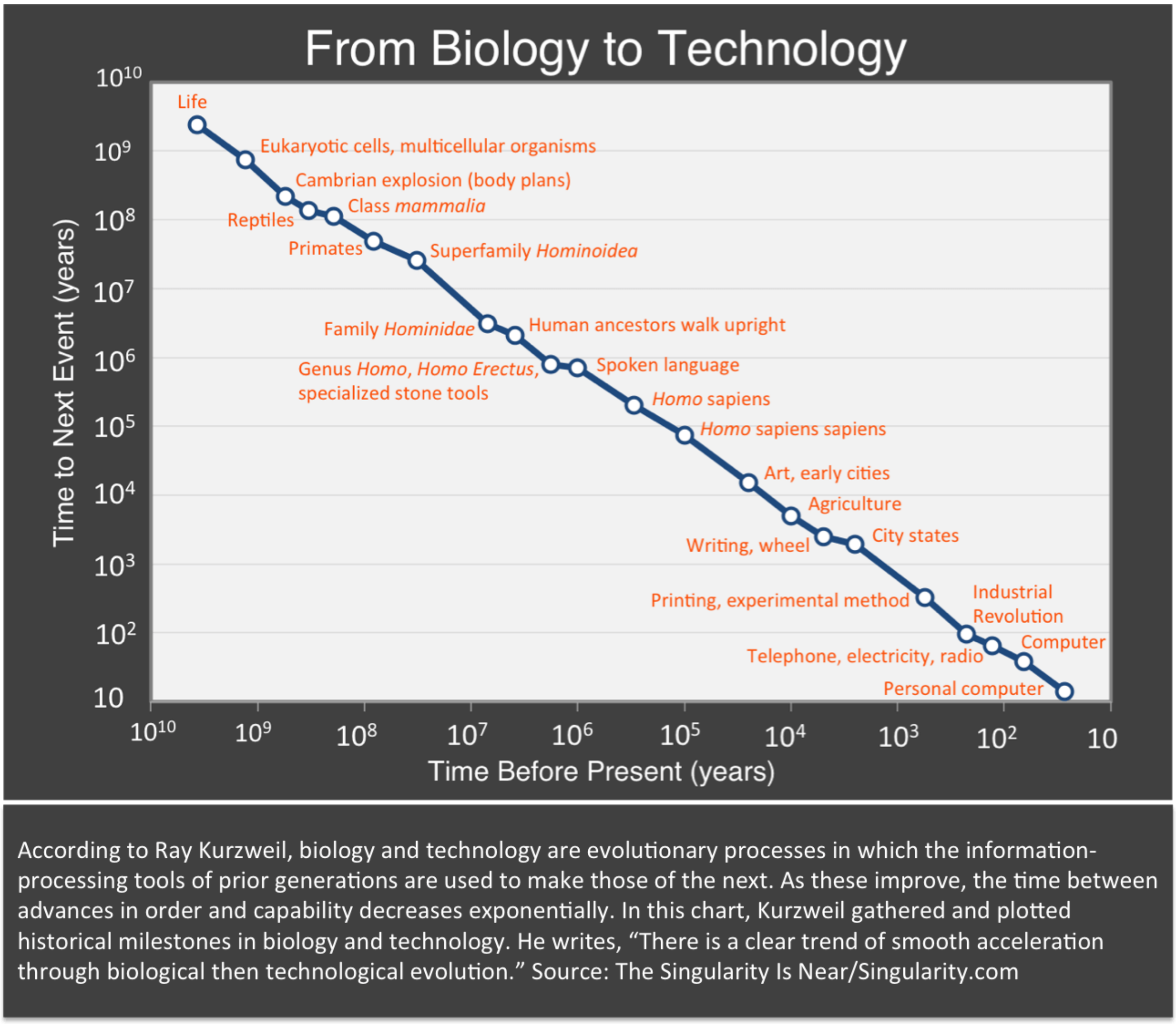


Fig. 50 A very intriguing graphic where biology and technology are seen as forces of evolution, with technology pushing the envelope in the last fragment of Earth's history. The graph, conceived by Ray Kurzweil, demonstrates how each "generation" builds up on the results achieved by the previous one, both in biology and technology, leading to an acceleration. Image credit: The Singularity is near. Singularity University

*13. **Sense and Know Anything, Anytime, Anywhere***

This Megatrend is about the never-ending explosion of knowledge. This looks like a very recent phenomenon, however, if we go back in time and take a broad view, we'll see that the growth of knowledge has not only characterized our history on the planet, but the whole "history/evolution of life on the planet" as it has been observed by Ray Kurzweil in his book, *The Singularity is near*. I would go even further by saying that knowledge of some sort was predating life. Of course, you would need to stretch the meaning of knowledge a bit, but weren't primeval molecules learning how to assemble in different ways? Exploring the huge possibilities of chemical reactions and finding the ones that would lead to an advantage over others? You may object to this stretching of the concept of knowledge, but I feel that the path of evolution, starting with artificial intelligence, self-learning machines, and cognitive digital twins, requires a re-thinking of the concept of knowledge.

Let's go back for a moment to Ray's graphic shown in figure 50:

In the graphic, you see a plot of milestones that characterized quantum leaps from one stage of knowledge to the next one, spaced in time. Notice that the measuring criteria is in order of magnitude, i.e., it is exponential. Therefore, what seems to be the same spacing is representing a compression of one order of magnitude (ten times faster). Also, you may notice that the knowledge steps included for most of the graph (between 4 billion year ago to some hundreds of thousands of years ago) are resulting from an evolution that has been driven solely by biology –chemistry and natural selection. Since thousands of years ago, technology (agriculture, the invention of the wheel and lever, the invention of writing) has started to flank the biological evolution. Notice also that biological evolution requires plenty of time, and although some biological evolution happened in the last hundreds of thousands of years, it is technology evolution that has made a difference. For example, most scientists would agree that if you could pick up one of our ancestors from 10,000 years ago as a baby, him as a contemporary baby. he will be indistinguishable from our contemporary fellows. However, if you pick a grown-up aborigine that has not experienced modern civilization, the difference would be huge, especially in terms of capability to understand the world. Technology makes a deep imprint on our mindset and on our capabilities to acquire knowledge.

What is most interesting in this graph is the underlying thesis:

Technology is extending, and accelerating, the evolutionary path set in motion by biology

The acceleration (exponential growth of technology) is perceived as linear when you use a logarithmic scale (as it is the case in Figure 30), and since we are sensing our world through senses that are logarithmic in terms of sensitivity, we are not experiencing an exponential increase but a linear one. For example, a sound must be 10 times stronger to be perceived twice as strong, light intensity needs to be 10 times greater in order to be perceived as twice as bright. Yesterday was not that much different from today, and tomorrow will look pretty much the same as today. It is only by taking a step back that we can perceive the exponential growth.

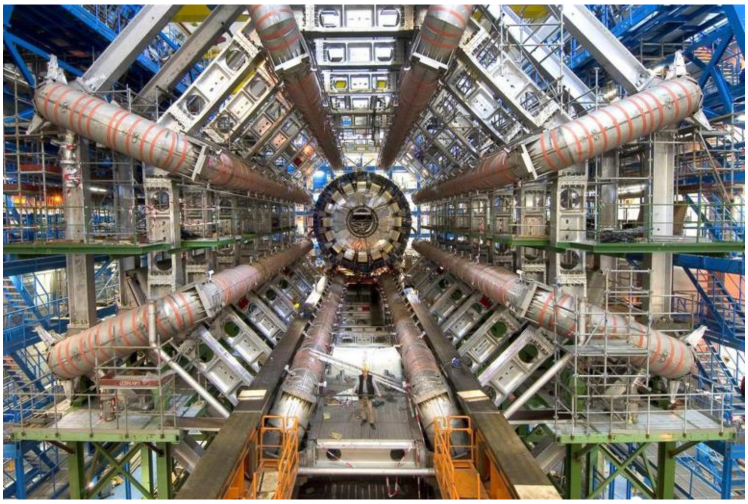


Fig. 51 The Large Hadron Collider, LHC, in Geneva lets scientists study the effect of particles collision at high energy. In the process, it generates a huge amount of data, some 90 PB per year – a volume that is beyond human brain capability to process. Image credit: CERN

What is important is the association of "sense" (what we can sense) and knowledge, and this is exactly what this megatrend does. As we can sense more, our knowledge horizon expands. The invention of the telescope and microscope have expanded our senses capability, and our knowledge consequently. Today's IoT –Internet of Things –along with pervasive communications networks and huge processing capabilities, multiply the capability of our senses. Interestingly, I am naming "processing" as a fundamental component of both senses (to capture data) and knowledge (to make sense out of data). Think about the Large Hadron Collider at CERN: it generates some 90 PB of data per year in addition to 25 PB generated by correlated experiments (a PB is a million GB). CERN opened 300 TB of LHC experiments' data in

2016, and at the end of 2019, the EOS storage system of CERN makes over 3 billion files of data available through open interfaces. The processing cloud for CERN processes 1 PB of data every day. It is clear that without this kind of computer power we could never extract knowledge out of the LHC. Opening the data without computer processing power will not increase our knowledge by one iota.

Now, this is interesting because, basically, we are acknowledging that our technology (sensors in particular) is providing us with plenty of data. Therefore, with a greater awareness of the world around us, there is, consequently, greater knowledge. However, without relying on technology to process this data, we would not increase our perception of the world, nor our knowledge. The consequence is that in the evolution of knowledge we are forced to rely more and more on technology (and this goes well with what the graphic is showing, an evolution steered by technology).

However, we have reached an inflection point: we are now transferring the creation of knowledge to machines. Artificial intelligence is no longer mimicking (or trying to mimic) our intelligence, it is achieving a status of its own —it is becoming a complementary intelligence. Some people are scared by the idea of artificial intelligence that we do not understand, but I can see many parallels with "things" that we are perfectly at ease with. Think about having a nice meal: have you ever stopped enjoying the meal to reflect that you are eating it with a fork and knife? Both tools that you would not be able to manufacture by your own and that, at the micro scale, you don't even understand how they can possibly work. If you beg to differ, send me an explanation of why the atoms that make up a fork result in a solid tool that does not bend, whereas the atoms that are in the spaghetti you are eating results in something that bends and wraps around the fork! The point I am making is that we take many things for granted, and we build what we call knowledge upon very shaky understandings of the deep reasons: you can pull a box with rope, but you cannot push that box using a rope…. What we call "common sense" makes up a big chunk of our knowledge.

I bet that in the future we will become more and more familiar with artificial intelligence to the point that it will become part of our knowledge. We already use AI hidden within our devices, like when talking to Alexa or to your television. For example, I know how to calculate a cube root: I just pick up my smartphone and press a few keystrokes: voila!

If you think this is reasonable, let me move one-step further and introduce Cognitive Digital Twins (CDT). A CDT is mirroring a certain set of knowledge, be it the one of an enterprise or of a person. For example, suppose you have your own Personal CDT. This digital representation will mirror your knowledge and can come handy in several situations, even to impersonate you at a meeting... or, even better, to deliver knowledge services on your behalf and generate revenue (for you). Think about your expertise in using a photo editor: you could lend (at a price) this expertise to an agent that will be using your CDT to offer consultations on-demand to people seeking your expertise.

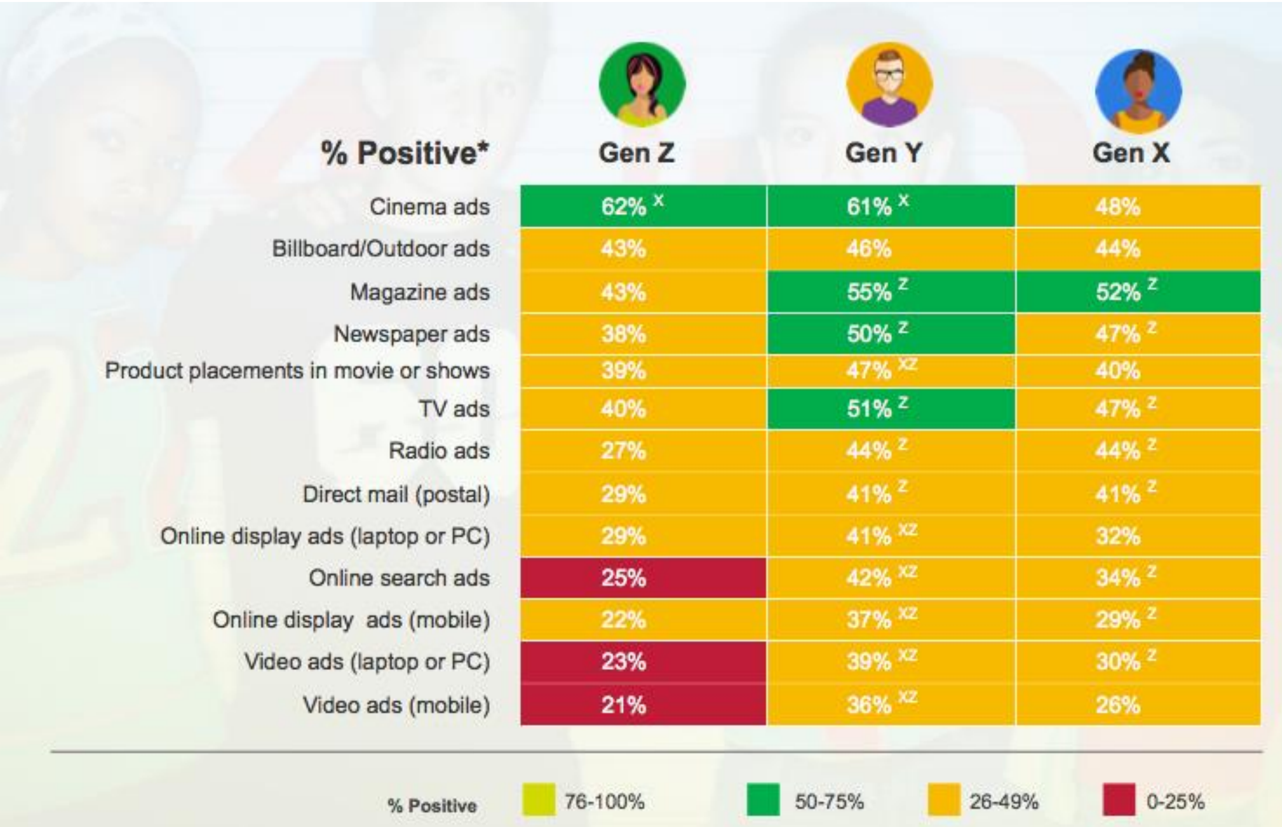
Now, if you have a CDT you might also be interested in using it to remember things that are somewhere in your brain, but that seem out of reach —they are on the tip of your tongue, and the CDT may turn them into vivid thoughts. Also, think about using your CDT to increase your knowledge. It may roam the web, connect with other people's CDT's, and consider what would be useful for you to know at a certain point in time and space, and teach you what you need to know accordingly.

Wait a moment. Why couldn't I use my CDT as an extra knowledge "bank" so that I don't need to acquire a certain knowledge (as long as I can seamlessly access that knowledge through my CDT, whether it is already embedded in my CDT or it can be summoned as need is irrelevant for this discussion). Am I not using my smartphone today when I need to calculate a cubic root of a number without any idea how to do that manually? To me, the result is what matters, and of course the knowledge I need to get the result, not the manner I need to produce the result on my own. A CDT at stage IV (autonomous CDT) and, even better, at stage V (cooperating CDT) would be able to flank my knowledge with all knowledge that I might need here and now.

Here comes the real, impressive power, of this Megatrend: Sense and knowledge of anything, anytime, anywhere. A CDT seamlessly in synch with my brain would be able to deliver on this promise.

Personally, I do not think that we will get there by the end of this decade, but I have no doubt that we can make significant steps in that direction.

Can we still call that knowledge? I would say so. At the same time, this direction is a direction towards a further evolution of our species, towards a symbiosis with machines. The problem is not only about the upsides and downsides of this evolution at personal and societal level, but also about a potential digital gap between those having a CDT and those not having it that makes the one we are talking about today child's play.



% Positive*	Gen Z	Gen Y	Gen X
Cinema ads	62% X	61% X	48%
Billboard/Outdoor ads	43%	46%	44%
Magazine ads	43%	55% Z	52% Z
Newspaper ads	38%	50% Z	47% Z
Product placements in movie or shows	39%	47% XZ	40%
TV ads	40%	51% Z	47% Z
Radio ads	27%	44% Z	44% Z
Direct mail (postal)	29%	41% Z	41% Z
Online display ads (laptop or PC)	29%	41% XZ	32%
Online search ads	25%	42% XZ	34% Z
Online display ads (mobile)	22%	37% XZ	29% Z
Video ads (laptop or PC)	23%	39% XZ	30% Z
Video ads (mobile)	21%	36% XZ	26%

% Positive: 76-100% | 50-75% | 26-49% | 0-25%

Fig. 52 Advertisements target specific market audiences, and the way to reach them changes as technology and social framework advance. This chart displays the result of a poll on generations Z (born between 1997-2012), Y, and X (parents of Gen Z kids, born 1965-1980), and their sensitivity to various forms of advertisement. Notice the differences of Gen Z with previous generations. Image credit: Kantar Millward Brown

14. Disruption of Advertising

As offer variety exploded, customers got the upper-hand—they had a choice. Hence, product and service offers had to compete to get customer interest. Whilst it is true that advertisements can be traced back in millennia, the modern advertisement goes back less than 200 years when two factors came into play: growth in variety, and presence of media to support advertisements (printed newspapers). The variety stimulates the need to advertise, the latter provides the means. Both have kept "growing."

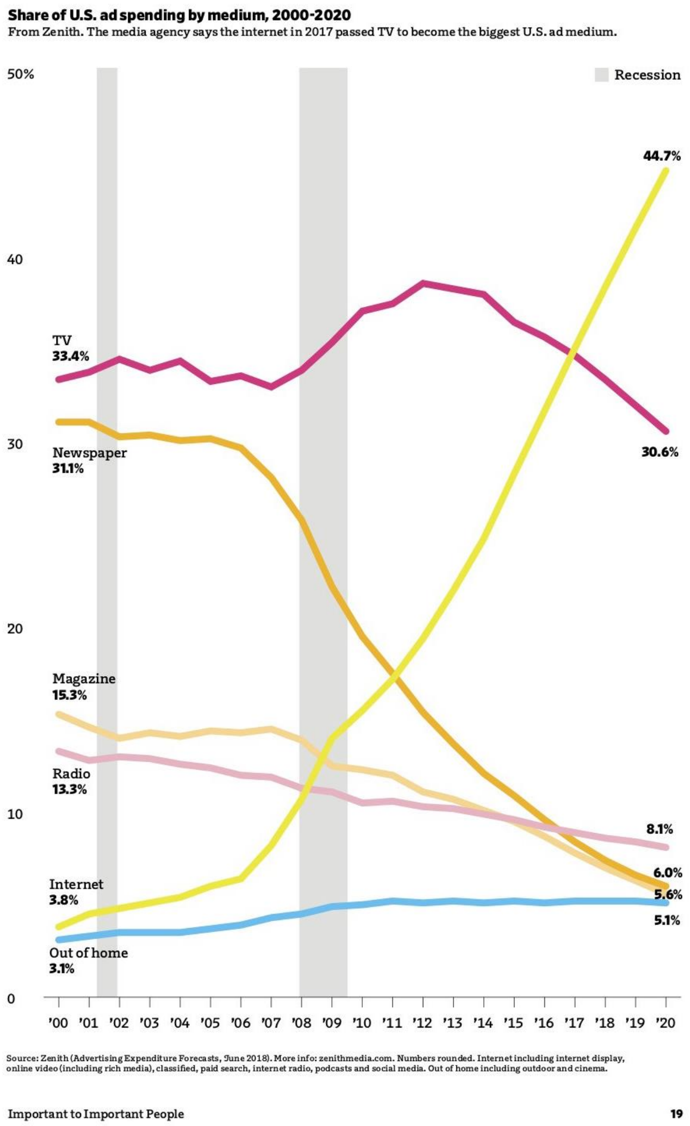


Fig. 53 Spending on different media for advertisement in the US. The yellow line, you guessed it, is the spending on digital advertisement. It exceeded spending for ads on the radio in 2008, magazines in 2009, newspapers in 2012, on television in 2017, and in 2020 it represents 50% of the overall spending in advertisements (in the US). Image credit: Zenith, Advertising Expenditure Forecast, June 2018

The variety of products that we can "reach" today would have been unimaginable fifty years ago: Amazon sells over 12 million products, and on its virtual shelves, it displays over 350 million variations of the products (sold by third parties). These numbers are mind-boggling.

The number of products and variations as well as the advertisement opportunities have also grown immensely. Ads are still in newspapers, but we get them through radio, television, movies (as products being used by celebrities, which further increases the appeal), public screen displays, shop windows and banners around the city, leaflets ... However, today, most exposure to advertisements is via the web, or in what is typically referred to as Digital Media (as opposed to Traditional Media). A completely new "marketing science" has flourished, and many companies are working to make digital marketing effective (in reach, cost, measurement) with Google heading the pack by far.

However, it is not a one-way street: you have a product, and you have a variety of means to advertise that product, but it is more about the kind of people you need to reach. Unfortunately, people are rapidly changing their habits and their perception of advertisement channels and messages. For example, figure 52 represents the result of a study on how different generations (Gen. X, Gen. Y, and Gen. Z) perceive different communication channels and the ways of using them.

This is what this Megatrend is all about: changes that will lead to a disruption by the end of this decade.

It is important that a new played enters the game this decade: Artificial Intelligence (AI). AI has been used for several years to profile viewers, leverage and analyze statistical data (where you are, how much time you spend on a page, how many times you come back to that page, what else you look at, how you interact with ads and posts on social media, how involved you are in social media, and so much more). In fact, today's AI is providing more insight into your tastes and whims than you may even be aware of. Based on this emerging intelligence about consumers and users, sellers can customize ads to make them more effective, and even change the price to meet your spending willingness (which, by the way, does not mean decreasing the price. For example, when an airline observes your interest of a particular destination, the ticket price is likely to increase! A good rule of thumb is to use one device computer to search, and a different one that doesn't have your identity/personal information to make the actual purchase).

The point is that AI has been used on the advertiser's side, to provide insight about you (and me), and to increase the effectiveness of the advertisement. However, by the end of this decade, the use of AI to improve accuracy of product/service selection for the user/buyer is expected to increase. This is where the "disruption of advertisement" occurs.

Personal AI, embedded in our personal digital twin or in our devices, will know even more than advertisers. It will be able to collect more data, and it will continuously refine this knowledge, and even intercept our moods, fine-tuning advice. The advertiser's "power" will be greatly reduced, and they will have to find new strategies to "push" the offer to the market.

15. *Cellular Agriculture*

Carnivore diets are more nutritious than a vegetarian diet—this is somehow "coded" into our brains to steer us towards a meat-based diet. However, meat is more expensive and a bigger threat to the environment (since it is at the end of the food chain, as per the second law of thermodynamics, every step in the chain adds a cost). This, in turn, makes market-prices of meat more expensive, and hence affordable only to those that have a higher income. In the interesting graph, figure 53 (produced by the IMF and FAO), it is clear there is a shift towards a meat-based diet as pro-capita GDP grows. In China, the increase of pro-capita meat consumption has increased from 4kg of meat per person a year in 1961, to 62kg eaten in 2013—a 1,450% increase within 50 years.

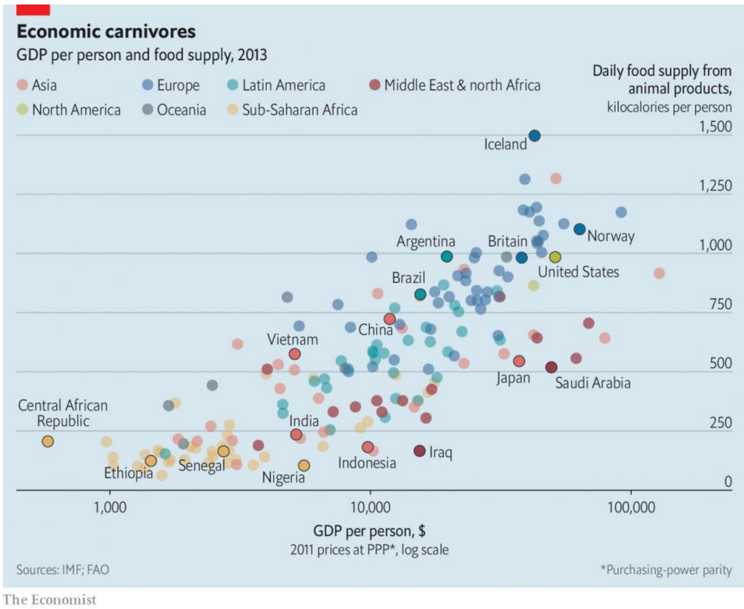


Fig. 54 An interesting graphic showing the relation between the GDP per person and the use of meet as food supply. It is obvious the correlation between higher pro-capita GDP with higher meat consumption. Image credit: IMF, FAO

To "produce" a 170g steak (6 ounces, a standard serving), you need 2,500 liters of water (674 gallons - it may actually requires ten times as much if you factor in the water needed in all parts and processing of the food chain). A serving of salad (including tomato and cucumber), on the other hand, requires only 80 liters of water (21 gallons). Interestingly, a tiny cup of coffee requires around 130 liters of water (34 gallons) to grow and process the beans...

Clearly, more than just water needs to be considered when evaluating the environmental cost of food, but it definitely provides a rough estimate. On the other hand, you need to gauge the yield and you can use, again as a rough approximation, calories. That 170g steak delivers 459 calories, the salad delivers around 160 calories—1/3 of the steak, yet its "environmental" cost is 1/30! To reiterate, these are back of the napkin calculations. I devised them to help readers better understand what I am talking about. The actual numbers, once you consider all aspects fertilizers, antibiotics, land usage, machinery) may differ, but I feel that they will further increase the unbalance).

Fig. 55 Artificial beef lab grown meat in retail supermarket emerging field of food production with label. Future trend of biotechnology, artificial food 4.0 concept. Image credit: iStock, Getty Images

Therefore, we have the basic craving for meat (and fish...) that, as wealth increases globally, becomes more in-demand, and simultaneously, we have the low environmental efficiency of a meat- based diet. The challenge is to identify tactics that will dramatically slash the cost of meat production to meet that challenge.

This Megatrend is predicting cellular agriculture will be used a solution by the end of this decade.

Cellular agriculture is an emerging field aiming at producing meat without the animal! The process entails in vitro growth of cells, and the goal is to be able to create a steak equivalent at a much lower cost, both in terms of environmental impact and production cost.

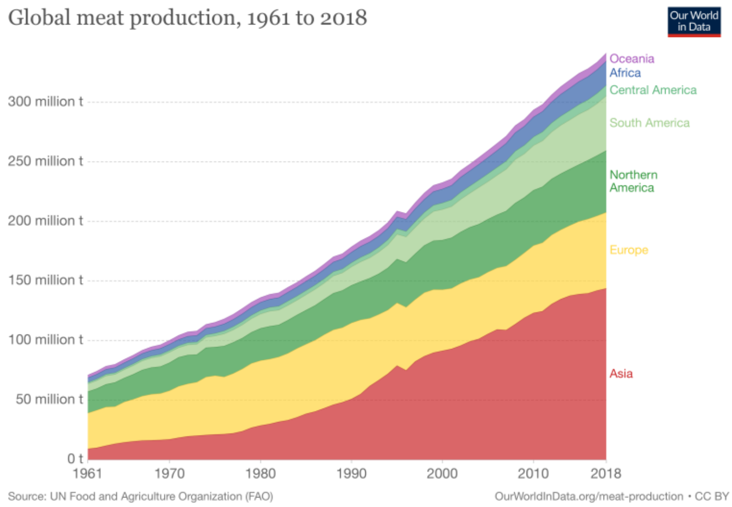


Fig. 56 The increasing growth of meat production is not going to satisfy the growing demand as more people turn to a meat diet (because they can afford it economically). Image credit: data from FAO, graphic by Our World in Data

The first artificial/cultured hamburger meat was made as early as 2013, by Mark Post, professor at the University of Maastricht (you may want to watch this clip). However, in 2018 the US Federal Food Administration put a high-demand on large-scale production, and this defined the regulatory framework.

There are already a few companies working to make this possible and, as shown in figure 55, products are already available on market shelves. So far, the production has resulted in ground meat and hamburgers, not steaks.

One of the problems is the scale of production and its cost (in 2018, the cost for a “steak equivalent” was $50 USD). By the second part of this decade, cellular agriculture is expected to deliver alternatives at a cost in-line with that of current "natural meat." However, it will probably take quite some time for industrial production to scale up anywhere near the current output of natural farming. More optimistic visions foresee an equal cost existing as soon as 2022.

Even in the eyes of the most optimistic observers, this Megatrend is not going to have a big impact in this decade. The production volume that we can expect by the end of the decade will represent a tiny fraction of the overall meat consumption. Current world meat production (2019) is 340 million tons per year, the manufacturing plants that Aleph, an Israeli start up, is planning to build starting in 2021 are targeting a production equivalent to that of hundreds to a thousand tons of cultured meat. It would take a million of them to match the current world meat production.

Regardless, it is a sure bet that cellular agriculture and alternative (veggie-based meat) will both play a growing role in the next decade.

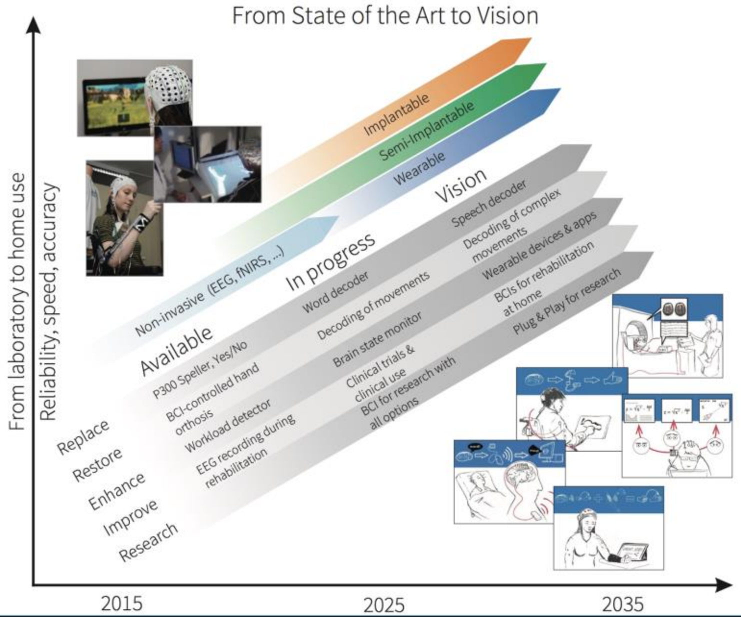


Fig. 57 An interesting roadmap for the coming two decades on the evolution of brain-computer interfaces. Notice the categorization of interfaces in wearable, semi-implantable, and implantable, and the expected evolution according to the goals: replace, restore, enhance, improve, and research. Image credit: BNCI Horizon 2020

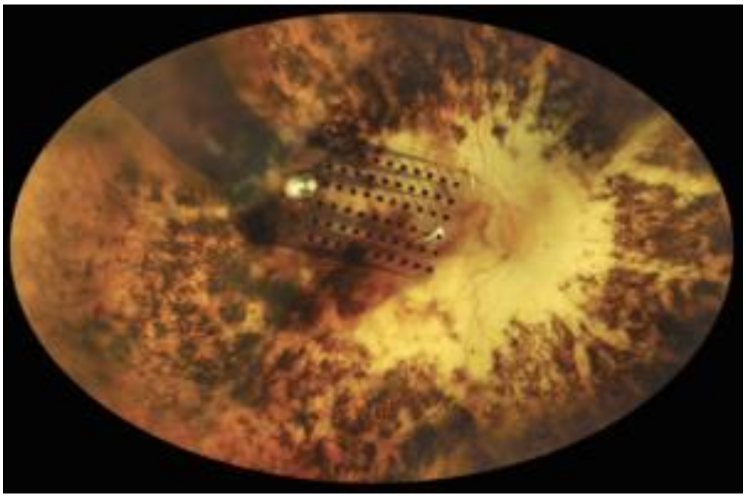


Fig. 58 An example of computer-to-brain connection via nerves. Argus II implanted on a "blind" retina stimulates the optical nerve, allowing the brain to perceive the light that hits the sensors on the implant. Image credit: University of Michigan/Second Sight Medical Products

16. Brain Computer Interfaces (BCI's)

The connecting of our brain to a computer was, in a way, imprinted in the name that many gave to the earlier ideas of computers: "Electronic Brains." If they are both "brains," it makes sense to look for a connection among them: easier said than done. An "electronic brain" is a fixed thing with some hooks you can use as Input/Output gateways. This is what we use to connect a keyboard, printer, and other "electronic brains"(computer hardware). Software then analyses the signals received through the gateways and will make sure that the signals sent out in response can be understood by the receiving party.

Similarly, our brain connects to a variety of peripherals through "nerves," and one approach would be to establish a connection with these nerves as entry/exit points. However, although this is done in some cases (like the artificial retina (see figure 58), or the artificial ear in the computer-to-brain direction, and in the case of limb/hand prosthetics in the brain-to-computer direction, BCI's aim at direct connections from the brain to a computer and vice versa.

This is quite tricky since there is no connector "inside the brain." One needs to monitor the brain activity, in terms of neuronal activation, to extract a signal (in the brain to computer direction) and influence the activation of neurons in the computer-to-brain direction. There is no single neuron that can be associated to a signal, nor a single neuron that can be activated to influence the brain in each way. More than that: the variety of neurons whose activities define a "signal" (or that must be triggered for creating a signal) may be in different parts of the brain. To add complexity to complexity, the set of neurons involved in an activity may (and do) change over time.

Therefore, a connectivity like the one established between a computer and its peripherals is simply not possible. To get a signal from the brain, we have to "look" at its global activity and "guess" what is going on. It is a bit like operating a car—to determine a driver's intention to turn in a particular direction, the driver is required to indicate via the steering wheel, otherwise we would have to rely on observing how the driver moves his eyes and other tell-tale signs from the look on his face and reading his lips (assuming that he is saying something relevant at that point). Wouldn't that be a desperate endeavor?

Yet, this is exactly what researchers have been doing to extract a signal from the brain to be used by a computer. The amazing thing is that they are succeeding!

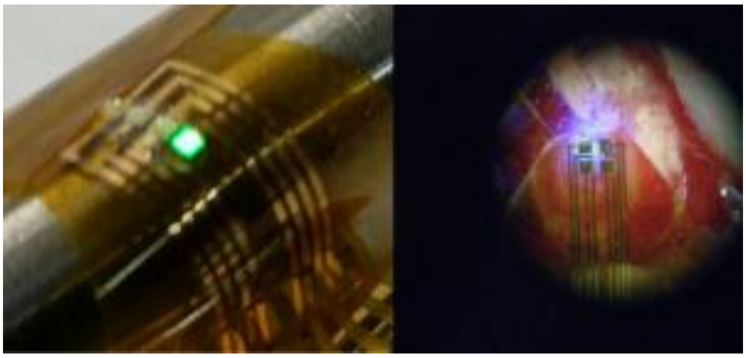


Fig. 59 Micro LEDs were used to optically detect seizures. The flexible optical device is shown on the left with a green-emitting LED. The photo on the right shows the device performing seizure detection on a rat's brain. Image credit: FindLight

The brain's electrical activity can be captured through sensors placed on the skull (non-invasive sensing), the cortex, or in the brain (in either case, surgery is required). Recent technological advances are enabling the placement of multiple sensing points and transmission of detected activity using a wireless connection. Obviously, the closer the sensor is to the area generating an electrical activity, the less noise in the signal, and the more precise the measurement. However, no-one would be looking forward to an invasive procedure, so this is done only when strong medical reasons are present, like in the case shown in figure 59 of a patient suffering from epileptic attacks. Detecting the insurgence of a condition with higher precision and sensitivity to predict an epileptic attack allows the establishment of counteractions that prevent the attack.

In pursuing the tackling of disabilities (not just epilepsy, also Parkinson's, dementia, etc...), researchers are perfecting existing technologies and exploring/creating new ones. The convergence of science material is expected to lead to significant progress in this decade, supporting the claim of this Megatrend for much better BCI. For example, graphene seems like a compatible material to use (it is smaller and bio-compatible with multi sensing capabilities) for technologies leveraging artificial intelligence, in particular machine learning, for better signal processing and even for robotics. Accurate placement of sensors in the brain is expected to make significant progress in this decade, supporting the claim of this Megatrend for much better BCI. Progress in signal processing and machine learning will compensate for the lower-signal precision provided by non-invasive BCI's, and this will expand the trials (today, as noted, it is limited to persons having serious medical conditions that require brain surgery).

There is still a long way to go, and the path is full of obstacles: today, when we hear of computers (robots) that can be controlled by the "mind" of an operator, we are implicitly led to believe that the computer can read a person's mind (such as a situation in which a paralyzed person using a BCI can control a robotic arm or a wheel-chair -watch the clip). This is not the case. What actually happens is that the person has been training their brain to generate a specific electrical activity that can be interpreted by a computer, and thus results in a specific action controlled by the computer. It is true that there are sensors picking up this electrical activity, but it is the person that, through training, learns to generate that activity. On the computer side, signal processing and machine learning identify that specific electrical activity among many others that are running in parallel, and they use that as the input to start an action. In a way it is more the human brain learning how to control a computer than the computer learning what the human brain is thinking!

According to this Megatrend, the possibility of having a computer starting to understand some basic "intention" of a brain through machine learning and training (of the computer) is expected in this decade, but this is nowhere near having a computer that can read our mind!

There is also another big hurdle to overcome —every brain is unique in terms of electrical activity (to the point that this can be used to identify a person, a digital signature of that person), and even more, this changes over time. Therefore, a computer that can understand a person's intention to move a wheelchair will not be able to understand a different person that has the same intention. BCI's are, and will remain for the foreseeable future, person specific. You can move the software from a computer to another so that a new computer can interface with that person, but you cannot have that computer understand a different person (unless you start the training from scratch on the new person).

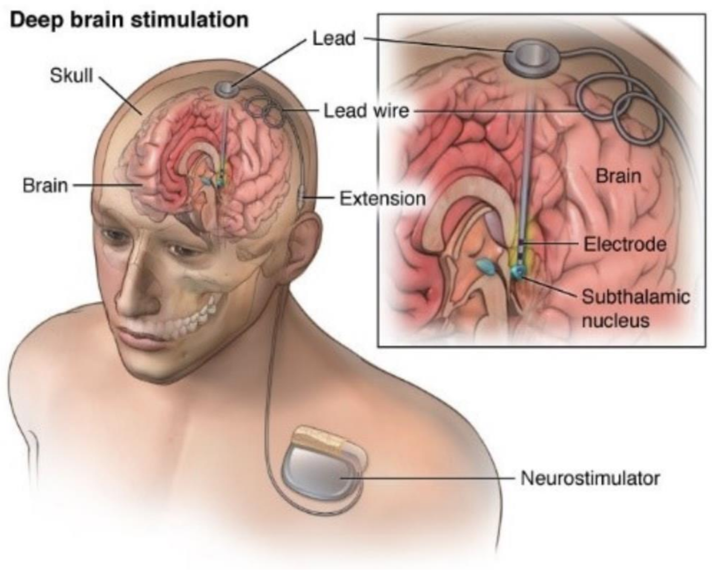


Fig. 60 Schematics of a Deep Brain Stimulation system using implanted electrodes controlled by a computer implanted under skin. Image credit: National Institute of Neurological Disorders

It will remain easier for a computer to read our "mind" in terms of mood and feelings by looking at our face, analyzing our voice, and interpreting our speech than by analyzing the electrical activity of the brain.

So far, I've considered the brain to computer interface. If this direction is difficult, the other is close to impossible given today's knowledge and technology.

Computer to brain communications today result in a coarse induction of physiological response, such as the already mentioned blocking of an epileptic attack. Here, an electrical current is sent to some areas of the brain where anomalous electrical activity has been detected, and this artificial current overwhelms the ones generated by the brain and lead to a reset (it is not that different from the use of a defibrillator to block anomalous heart electrical currents: the ones generated by the defibrillator are stronger and leads to a reset of the hearts own currents). More recently, Deep Brain Stimulation (the insertion of electrodes into the brain, or by focusing beams of wireless energy in a certain spot in the brain) has been tested to resolve and relieve certain symptoms of neurological disorders.

Technology evolution is making it possible to send signals to single neurons or to group of neurons using optogenetics, but so far this has only been used on animals, and the goal is to identify a way to study how neurons operate to express a given brain function, i.e., they are not used to transfer information to the brain.

In this decade, by some called the decade of the brain, there is a strong expectation to break the code of the brain (or to understand the way it works), and that might lead to better cures and preventative methods of neurological disorders in the future. Personally, I think the dream of downloading information on a brain (who hasn't dreamt to learn by plugging in a flash memory rather than spending long hours studying...) will remain a dream for the foreseeable future.

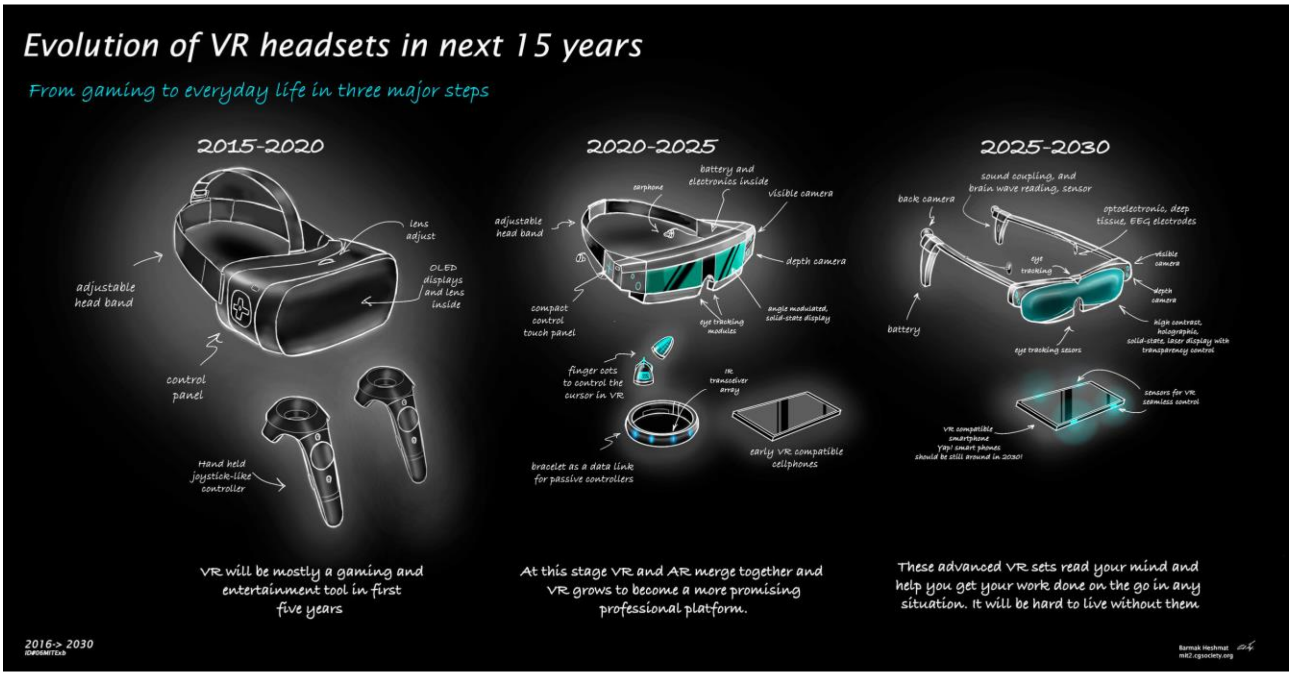


Fig. 61 Expected evolution of VR goggles in this decade. The graphic was drawn at MIT five years ago to cover a 15-year span. It is still valid today, although, in a way, we are lagging a bit behind the foreseen roadmap, but it may pick up steam in the coming years and deliver as expected by 2030. Image credit: Barmak Heshmat

*17. **Hi-Res VR in Retail***

Virtual Reality (VR) and Augmented Reality (AR) have been the talk of the town for quite a while. In the beginning, the focus was on VR and the possibilities of exploring virtual worlds with our senses in an immersive manner to enhance our experience and feel like a part of those worlds.

Technology was not mature enough to deliver due to:

- Bulky devices that require you to be tethered to a machine
- Grainy resolution delivering images different from the visuals we experience in the real world
- Insufficient processing power resulting in a low frame rate

As we look at this decade, we can be sure that processing power will no longer be a roadblock. The new chips, like the most recent ones from Qualcomm Snapdragon 888, will become available in 2021, and the ones powering top of the line smartphones like the Apple (A14 Bionics —faster than the 888 in early benchmarks), promise sufficient power to drive high frame rate and high resolution, plus local computation for local processing of sensors data. Notice that these chips, when inserted into a headset, can use cooling fans so they are not constrained in extended peak performance as they are when used in a smartphone. Is current processing power sufficient for VR? Not yet, but in a few years it will be.

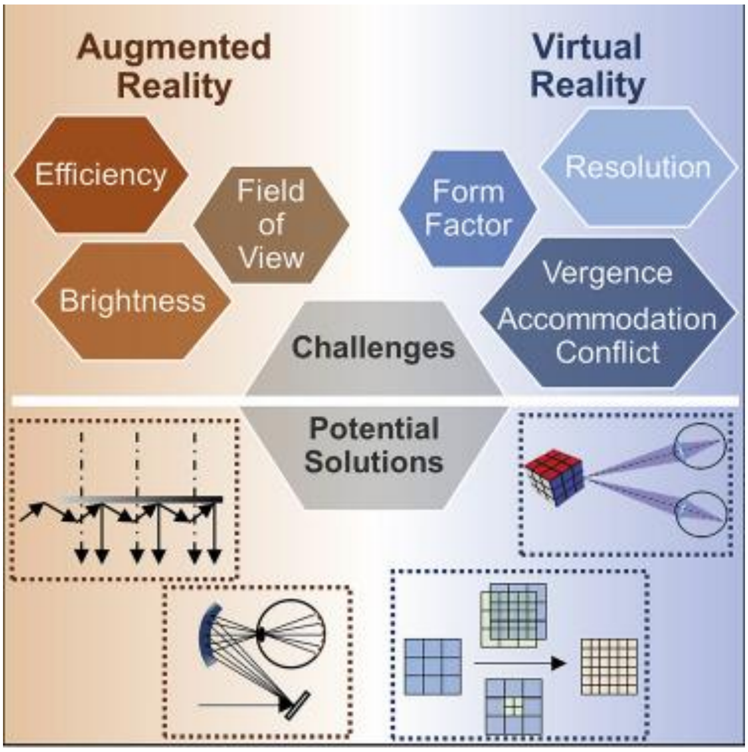


Fig. 62 A graphical representation of the challenges faced in VR and AR devices and the areas of research looking for solutions. Notice on the upper part the VR issues of form factor, of resolution and the problem of vergence -the attempt by the eyes to focus and manage near vision, whilst on the AR side the ones of brightness, efficiency and field of vision - the form factor is also crucial for AR. Image credit: Tao Zhan and others, iScience Volume 23 Issue 8

In terms of resolution, we have plenty of 4K screens and a few 8K are now available. However, it is one thing to have a 70" 8K screen, but quite a different story to have that kind of resolution within a very small screen, such as those that must fit in a headset. Here, what really matters is the pixel density (like in a smartphone), and top of the line smartphones have exceeded 400ppi, orpixels per inch. The newest iPhone 12 mini, for example, has 476 ppi, the one with the highest pixel quality is the Sony Experia with 643 ppi. This kind of density is great (possibly already an overshooting for what is perceivable by our eyes in a smartphone), but it is not sufficient for a headset considering the very short distance of the eye to the screen. There are, however, concrete promises for technologies delivering much higher densities, like the one spearheaded by MojoVision, a Californian start up focusing on ultra-high density displays for augmented reality devices. Their latest screen is the size of a grain of rice and has a density of 14,000 ppi! Therefore, on the resolution/density side, we can be confident that technology meeting the requirements will become available in this decade. However, the perceived quality of an image involves more than resolution. It is also about brightness, contrast, ... Most important is the ability to auto focus, and this remains a significant problem. The fact is that with television/computers, and even smartphone screens, it is our eyes that take care of focusing, but when the screen is just a few cm (less than one inch) away from your eyes, as in the case of a headset, focus is very difficult.

New approaches are needed where the screen takes care of focusing the images on our retina. As shown in the clips (if you are interested in this subject, they are worth the 20 minutes it takes to watch them), there are a few technologies that might be used, but it is still a research area. So far, no silver bullet has been found, yet this area is crucially important because it is the bridge between the resolution/density problem and the form factor problem.

Indeed, the form factor problem remains, and will remain, the main hurdle to meet the requirements for seamless VR in this decade. Notice that, in addition to the issues I mentioned, there are more fundamental aspects of perception that are difficult to resolve given the current technologies and the ones we can foresee in the coming decades. Our perception of reality has been chiseled into our brain through evolution as a species and in the first years of our life. For example, we expect a small bead to be and feel lighter than a bigger one. When this is not the case, a red flag is raised to draw our attention to the issue. If you pick up a hollow bead that looks like it is made of steel, and a smaller one made with lead, the smaller one will feel much heavier, and this would seem strange. This is just to emphasize that our perception of reality is derived from a multi-sensorial experience coupled with expectation. VR will eventually be able to deliver credible sensorial experience in terms of vision and hearing, but it will fall short in terms of those sensations derived from proprioceptors (the sense that tells our position in space and acceleration—perception of movements). Pilots training with professional flight simulators enter a simulated space that provides, to a certain extent, movement, and acceleration sensations, but this uses very complex machinery that clearly cannot be part of an everyday VR experience.

BCI might, in the very distant future, trick the brain into a full sensorial virtual reality, but so far it is still in the science fiction domain.

Fig. 63 AR and VR are already been "tested" in shopping malls as a new way to have offer meet demand and as a tool for customisation of the offer. Image credit: Hackernoon

A different case-study involves analyzing the specific applications of VR across industries, for example, the claim in this Megatrend pertaining to a revolution in Retail and real-estate businesses.

In this market segment, both VR and AR have already carved a dent in the marketing of products (and estates). It is now common to explore a space in 3D to shop for a new house or an apartment. Similarly, AR is being used by some department stores to give you a better idea of how a given product would look in your home (the Ikea app for example).

The pandemic has accelerated this shift. We have become familiar using QR codes (a very old hat) for exploring menus and catalogues to avoid interaction with physical objects. Most importantly, we have learned to explore "reality" using augmented reality and virtual reality. This is a crucial paradigm change in terms of perception.

According to this Megatrend, AR and VR will become an integral part of our daily life when buying online. Thinking about buying a new dress online? This is not unusual today. What if it doesn't fit, and even if it does, how will it look on me? This is where VR and AR come into play. Your avatar, embedded in and shared by your personal digital twin, will connect to the retailer and, through virtual reality, you'll be able to look at yourself as you do in a mirror. You'll even be able to turn around and see how the dress fits and looks from different viewpoints and angles. Your size and shape are exactly mirrored in your personal Digital Twin; therefore, the rendering will be accurate. Want to check how a tie you bought will go along with that dress you are (virtually) donning? No problem. A quick selfie of you wearing the tie, or a snapshot of the tie, and you can see it through virtual reality (along with the dress you are "virtually" trying on).

Likewise, if you are considering buying a new house, you may want to see how your current furniture would fit and look in the new house. Let the digital twin of your current house interact with the prospective house, and through virtual reality, take a walk around the prospective house to get a better idea.

The convergence of new devices with artificial intelligence (with the smartphone probably taking the lion share), digital twins and the digitalization of products and environments makes this Megatrend credible. Do not expect, however, that by the end of this decade virtual reality will feel like the physical reality. I don't think we will be there for quite a while.

*18. **Focus on sustainability and environment***

Natural resources have been out there to grab, and once they were no longer needed (nor their corresponding crafts), they were discarded in the least costly way. The emergence of an environmental awareness, and of sustainable use of resources, is relatively recent. Notice that our ancestors ran into resource shortages several times and they moved, looking for a place of plenty (or at least of some!).

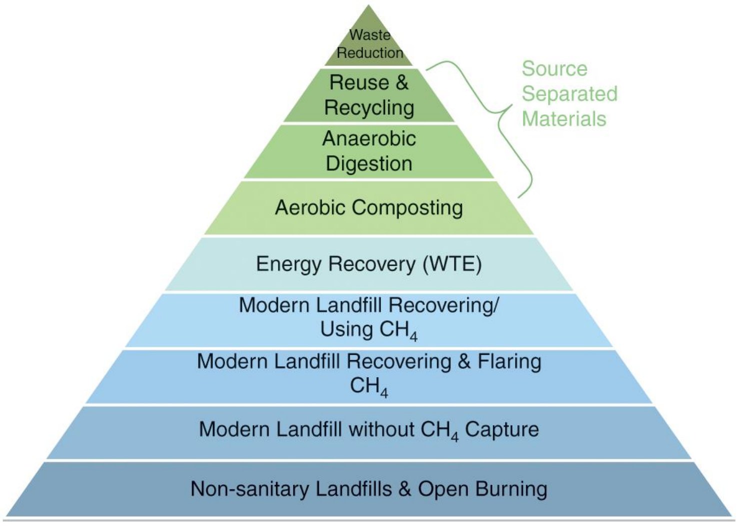


Fig. 64 The pyramid of solid waste management from the bottom, where waste is disposed in the environment without any precaution, to the top towards reuse/recycle and decrease of waste. Image credit: Stelios Grafakos

It should also be noted that only 200 years ago there were one billion people on the planet, one seventh of today. For comparison, the human population was estimated between 200-300 million 2,000 years ago, and it remained stable for thousands of years (310 million estimated in the year 1000, tripling in the following 800 years, duplicating in the following one-hundred years, and tripling in the last 100 years).

However, what really impresses me is that, looking at the pro-capita use of energy, we get an astounding fact: 1,000 years ago, at the beginning of the industrial revolution, people used the same amount of energy, on average, that we use today! It seems impossible, doesn't it? Think about cars, electronics, food packaging ... it really seems unbelievable. Yet, that is the case.

A thousand years ago the energy used (for a physicist, the power used) derived from (percentages are an approximation, hence total is not 100):

- 50% animal traction (like ox pulling a plow);
- 25% wood;
- 12.5% water;
- 5% human;
- 2% windmill;
- 1% sail.

One thing that is evident is that up until 300 years ago, people were using renewable energy! However, using renewable energy does not mean that it is sustainable. Many islands in the Pacific Ocean were abandoned after the depletion of forests, the source of wood energy.

How can we explain the fact that our ancestors were using, pro-capita, as much energy as we use today, yet doing a fraction of what we do? The key is efficiency, or if you want, "inefficiency." Using an ox to plow a patch of land is much more energy consuming than using a tractor! You have to feed the ox, and you have to feed it whether it is plowing or not. Heating a house using a fireplace and a chimney is not energy efficient at all (most of the heat rises into the sky). Pre-Industrial Revolution Europe is estimated to have used some 15GWh of power, and if you scale it up for population and GDP, you get at pro-capita that is equal (if not greater) than today's use of energy.

Fig. 65 A distorted map of our planet where each region size is proportional to the pro-capita emission of CO2, a good yardstick measuring the use of power (in 2016). Image credit: World Mapper

The point is, when talking about sustainability and environment, we need to look at the big picture, and in the big picture, the use of renewable energy does not necessarily result in sustainable processes, nor is it resourceful environment wise. Efficient use of power is as important as the source of power.

Indeed, humans in the past systematically destroyed local resources and had to move somewhere else because of that. Today, humankind has occupied the whole planet, and if we deplete our resources, we will have no place left to go! Additionally, today we are significantly relying on non-renewable energy sources (at least not renewable in the short term– knowing that there will be brand new oil available 400 million years from now does not help!). However, today resource use is more challenging as rather than 300 million people, there are now over 7 billion people (25 times as much) that are transforming resources into waste. Hence, we have problems both on the resource side (provisioning), and on the waste side (disposal).

The environment is affected on both sides: the provisioning of resources impacts the environment (mining is one of the most polluting industries), and waste is obviously impacting the environment.

Technology has been a double edged sword: on one hand it has greatly improved the efficiency of power use (as mentioned, we do so much more today than a thousand years ago, yet we are using, pro-capita, the same amount of power), but on the other hand, technology is directly and indirectly power hungry: directly because we need a huge amount of power to "manufacture" our luxuries (like building a car), and a huge amount of power to enjoy our wellbeing (like using the car). For the record, producing a car requires an equivalent of 1,000 liters (260 gallons) of gasoline (manufacturing an electric car requires 1,250 liters– that's 25% more because of the batteries); using the car ... well it depends how you use it. In my case, I use about 500 per year, over the 10 years of the car life, that is 5,000 liters, 5 times more than manufacturing it. Interestingly, in terms of carbon footprint (CO2 emissions) the production is equivalent to the use of the car throughout its lifetime. The carbon footprint of an electric car is about 25% higher than a combustion engine car for manufacturing **and** disposal, whilst the carbon footprint of its usage depends on the way the electricity used to recharge the batteries is produced. Unless this comes from renewable and zero footprint sources, an electric car has a higher environmental impact in terms of CO2.

This Megatrend is foreseeing a strong increase in general awareness on the importance of sustainability and environment protection, together with technology evolution, decreasing the cost of managing sustainability along the value chain (from design to recycle/disposal). Last, but not least, this Megatrend foresees growing business opportunities for an ecosystem that can transform waste into revenues (at least part of it). This is not that different from what happens in Nature where the waste in a food chain becomes the thriving ambient of an ecosystem of smaller animals, plants and, most importantly, bacteria. How could this be? Isn't this against the second law of thermodynamics? Well, there is a trick, and that is tapping energy outside of the system (the Earth) to decrease, locally, the entropy: tapping Solar energy. We are probably going to do the same, using Solar energy for low-cost tech to power the sustainable value chain.

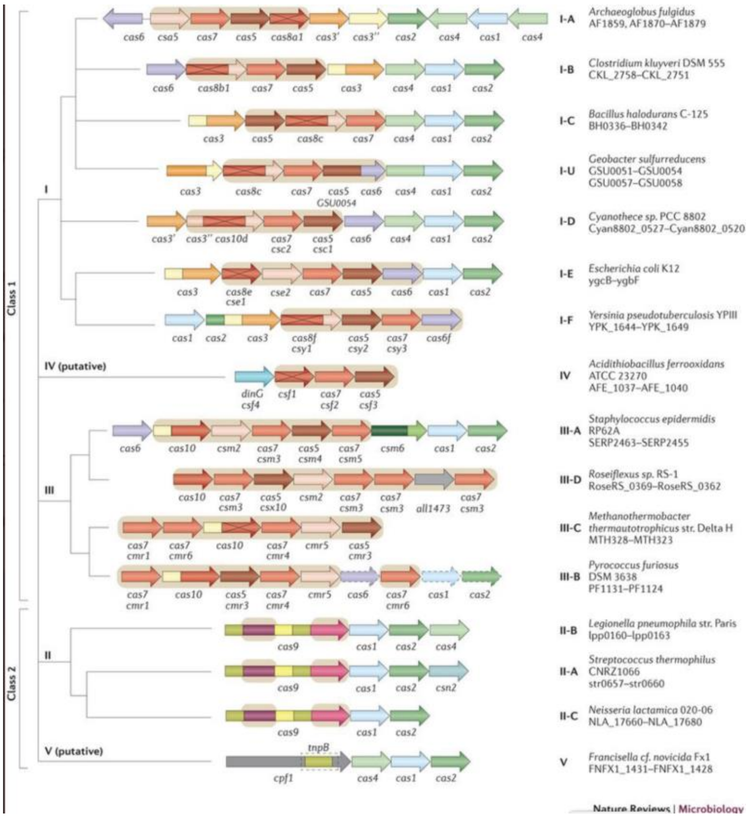


Fig. 66 Class 1 and class 2 CRISPR-Cas systems. The growing varieties of CRISPR-CasX are providing more specific tools to researchers, and in the latest part of this decade, will provide tools to practitioners, for manipulating DNA and RNA.
Image credit: Eugene Koonin, NatureEcoEvo, feb.2019

*19. **CRISPR and gene therapy to fight diseases***

CRISPR (Clustered Regularly Interspaced Short Palindromic Repeats) is a series of DNA chunks discovered in bacteria in the last decade of the XX century. Researchers found out (a bit later) that these were remnants from bacteria of fagi (nasty bits that eat bacteria from the inside, even bacteria get sick!). This infected bacteria, and they were killed by the bacteria reaction. The killing resulted in a sort of immunity (the bacteria got vaccinated). So if another fagi invaded the bacteria, it was recognized and simultaneously killed using a protein associated to the DNA sequence Cas (a CRISPR associated protein). The “killing” is done by breaking the DNA of the fagi, basically it works like a scissor). There are quite a few proteins that can be associated, and scientists decided to call them by a number.

They also discovered that a particular protein, Cas9, was pretty good in the editing of a DNA string in vitro, so they and started experimenting. After a while, they realized that CRISPR-Cas9 can be used as a tool for gene editing, and a whole new slate of possibilities opened up (the 2020 Nobel Prize in chemistry was awarded to Charpentier and Doudna for their contribution in establishing this technique).

As shown in the graphic in figure 66 (click on the link to get a readable size), CRISPR-Cas9 can be used as bacteria are–to kill a “gene” by chopping the DNA strand at the point where that gene is

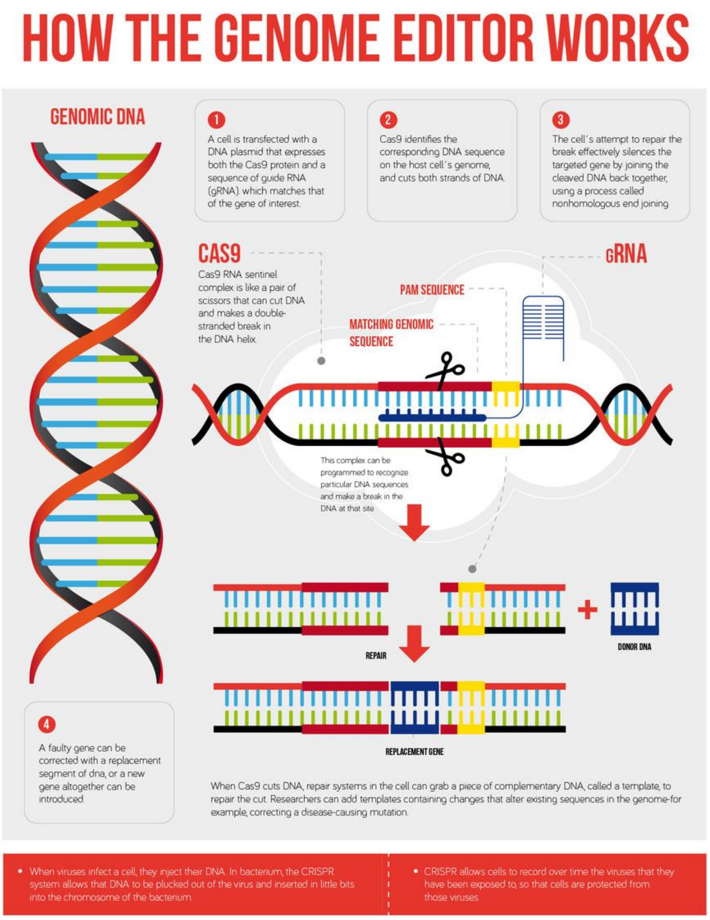


Fig. 67 Schematics showing how CRISPR-Cas 9 work in silencing a gene (by cutting the DNA location storing that gene - the cell repairs the break but the gene is not restored so it remains inactive) or in inserting a new code -a new gene- in the DNA strand. Image credit: Freelancer

contained. The cell will patch it up, stitching the broken strands together, but in doing so it will lose some parts of the original gene, thus disabling it. However, CRISPR-Cas9 can also be used to insert a new chunk of DNA as a replacement of the disabled gene. In the previous case, the cell will no longer be able to produce a certain protein (and that may be good if that protein was creating problems, as is the case in some genetic disorders). Whereas, in the latter, the new gene can provide instructions the cell needs to produce protein (again, some genetic disorders derive from the inability of cells to produce a certain protein).

In practice, scientists now have a tool (CRISPR-Cas9) allowing them to manipulate DNA to get a specific result. As with anything having to do with biology (differently from mechanics), the process has a statistical flavor. On average, you get the result you are looking for, but there are cases where this is not the case. For example, when the cut does not occur where it was planned, or the insertion does not work out the way you wanted. However, as long as the majority of operations have a positive result, you are good (not all cells, for example, will have the capability of manufacturing that protein, but if a sufficient number do, the genetic disorder can disappear).

This lack of absolute precision is also the ground for several scientists and ethicists to object on the procedure. By altering the DNA of a living being, you may set up a ticking bomb that could lead to unexpected consequences. One of the issues here is that we don't know how genotypes–the instructions contained in DNA strands–result in phenotypes, the actual living being and its behaviour. A single gene is often involved in many traits of a living being, and conversely, a given trait may involve several genes, and the truth is that at today's level of knowledge, we do not know the relationship (or better, we understand just a tiny fraction). Hence the opposition to modify the code of life–better be safe than sorry.

On the other hand, the potential advantages that this technology may offer is evident, starting with, obviously, the cure to genetic disorders (there are some 6,000 known today). Once perfected (i.e., becoming more accurate and predictable), this could also be used to improve a living being (this is something that occurs in Nature over millions of years of selection process, and that science can make possible within a few weeks...). We have already seen this technology applied to create bacteria with specific characteristics (like the capability to adsorb heavy metals to clean up a polluted area). Here, again, we are faced with a Pandora's box: once we open the lid of genetic modifications, the possibilities are endless, but are we sure we want to live with all the consequences (and who is going to decide what is right or wrong)?

The CRISPR-Cas9 has proven to be a practical tool, the first technology available for genetic modification. However, in the last ten years, several others have been found, each one having specific characteristics that would be useful in a given application. Also, scientists have discovered a way to apply the genetic modification to the RNA, rather than the DNA. This is somehow better since the modifications will not propagate to the offspring, therefore limiting the concerns (although not completely clearing them). A person with a genetic disorder may be cured through RNA modification, but that would require continuous intervention since the new cells (and we keep changing our cells) will be affected by the disorder (since their DNA has not been changed/fixed). Additionally, a baby born from that person will have a chance of inheriting the disorder. Hence in case of genetic disorders, a DNA modification is the way to go. In case of "augmentation," using the RNA path would probably be better.

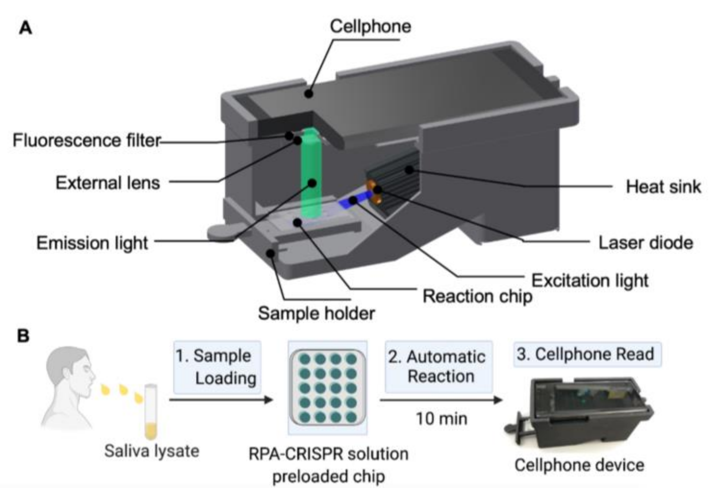


Fig. 68–A smartphone-based COVID-19 test developed at Tulane University's School of Medicine uses CRISPR to detect coronavirus RNA in a saliva sample within 15 minutes. Image credit: Bo Ning et al

CRISPR can also be used as a sensor, and a team of researchers at the Gladstone Institute of Virology have developed a test (awaiting for FDA approval) that uses it to detect, with high precision, the presence of the Covid-19 virus. Interestingly, the test has been designed as a do-it-yourself test so that people can run it at home by collecting a saliva sample from their mouth. Interestingly, as shown in figure 68, part of the processing takes place in a micro-fluidic chip connected to a smartphone, in charge of the heavy computation and display of result.

It is foreseen that progress of this megatrend will continue at a fast pace throughout this decade and will result in cures for hundreds of genetic diseases by the end of the decade.

*20. **The vanishing Babel tower***

This Megatrend, and the following ones, are mine, and they expand on the list of Megatrends discussed in the previous sections (as proposed by Peter Diamandis). This one is about technology overcoming the language barrier.

There are roughly 6,500 languages spoken in the world today, although most of them are "local" and likely to become extinct soon. Although in the past there were fewer people, more languages were spoken. Communicating was more difficult, and the language within smaller communities shifted over time, differentiating their languages from the ones of surrounding communities. Of course, there were some common languages. For example, in Europe 2000 years ago it was Latin and (ancient) Greek.

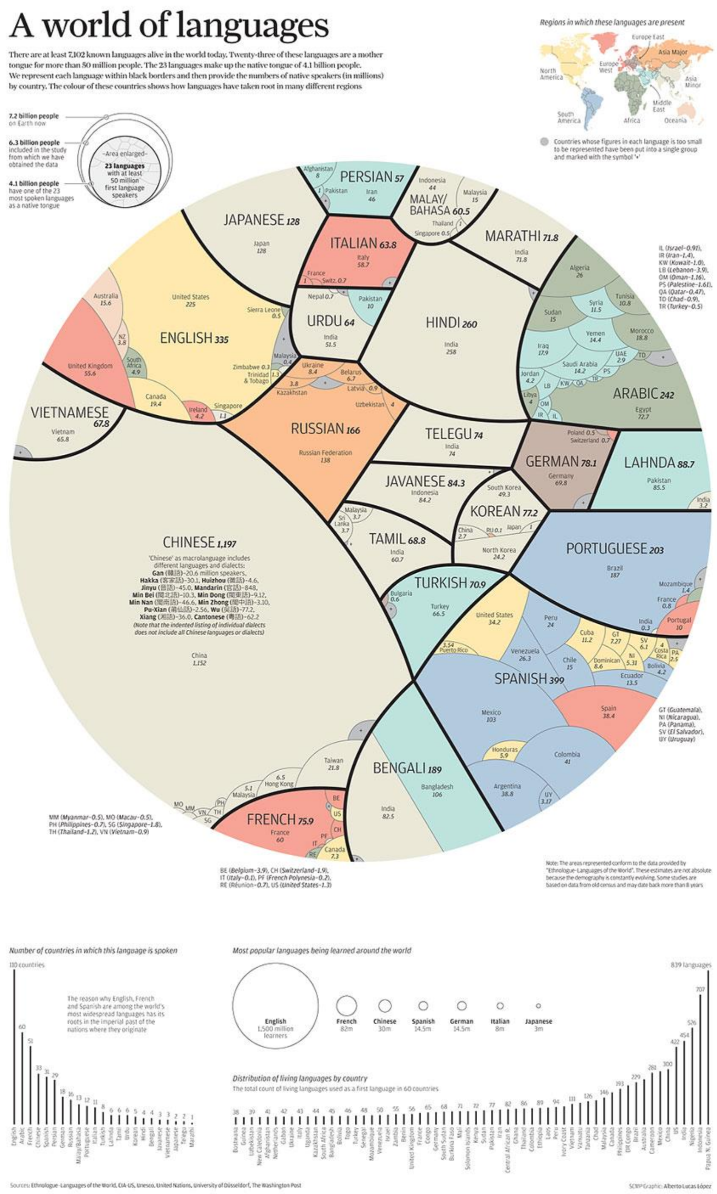


Fig. 69 The top 23 most spoken languages in today's world. Notice that English, for example, is counted as a single language, although there are several variants. Image credit: InLingua, data source: Ethnologue Languages of the World - Click for the [expanded - readable map].

Marco Polo, in his famous report of his voyages to the Cathay, tells us that he learned new languages on his way to meet the Kublai Khan: Turkish, Arabic, Persian, and Mongolian. He didn't speak or learn Chinese since the Kublai Khan spoke Mongolian, but it took him 4 years to travel from Venice to Beijing, plenty of time to learn a new language. A Marco Polo voyage today would only take about 10 hours, and it would be tricky to learn 4 languages in such a short time frame.

It is the quick pace of modern life, the presence of literature written in different languages, and frequent travelling of people that has created a real Babel Tower: for ancient civilians, the difference in language was not a big deal (at least for the great majority of people).

I remember when I was a kid (a long time ago), my father would tell me that knowing a foreign language would give me a competitive edge in today's world (and he sent me to study German in Switzerland...).

Now, foreign language has become part of the high school curriculum in most countries, and in quite a few it is even part of primary school. Unfortunately, we learn different "second languages" in different parts of the world, and I am usually lost when I want to communicate with local folks on the other side of the planet.

However, the situation is changing, and this is the point of this Megatrend. Earlier this year I was in Laos, in the Laotian countryside, and their language was quite a different piece of cake from Italian. Some of the elderly people spoke French, several young people spoke Chinese, but that was it (and the latter dod not help me). We did manage to establish some form of communication through our smartphones. For example, I typed in an Italian sentence and showed the other party the translation in Laotian (courtesy of Google). I am unsure of the accuracy of the translation, but I can tell that it worked as we were able to communicate.

That was amazing, but it is nothing compared to what I think will be possible by the end of this decade: talking in one language, and having the other party listening in their language (and vice versa).

Real-time translation is becoming state of the art. Google is now offering free translation to < > from 108 languages, a tiny fraction of the 6,500 languages spoken, but covering most of the world. The latest additions were:

- Kinyarwanda,
- Odia,
- Tatar,
- Turkmen, and
- Uyghur.

I must confess, I didn't even know those languages existed, yet Google stated that they are spoken (in total) by approximately 75 million people. I routinely read articles in Chinese, by cutting and pasting the text into Google Translator and reading the English version, and I know many people do the same daily. Therefore, language differences are no longer a barrier.

I find this amazing, and I bet that, by the end of this decade, I will be listening through my wireless headphones to the other party with their language converted, seamlessly, to my language. That would be a game changer.

Think about what this would mean for tourism. Not just to you as a tourist, but, even more importantly, to local people in faraway places that will be able to offer new services and experiences, and we know that tourism is evolving in this direction. There are now many Local Guides and the web is connecting them to the world.

In addition, by the end of this decade, virtual reality will enable people to experience many places from their living rooms: we will be able to experience walking through a souk in Istanbul and talking to local people in Turkish. We can then flip to a souk in Marrakesh and talk to the spice sellers in Arabic. The possibilities are endless, and they will completely change the ideas and possibilities regarding tourism.

I am not at all saying that we will be staying home rather than travelling (I hope the pandemic will be over!!!), it is just that from home, I will be able to get a taste of the experiences that I will have, can have, or that I already have had.

When travelling we will be using this possibility even more, through augmented reality, where the augmentation takes the form of sound, hearing people speaking our language in spite of the fact that the origin of the sound was in a different tongue.

To me this Megatrend is the one that is most likely to become reality, and it is also one that will have most impact on feeling part of a single planet.

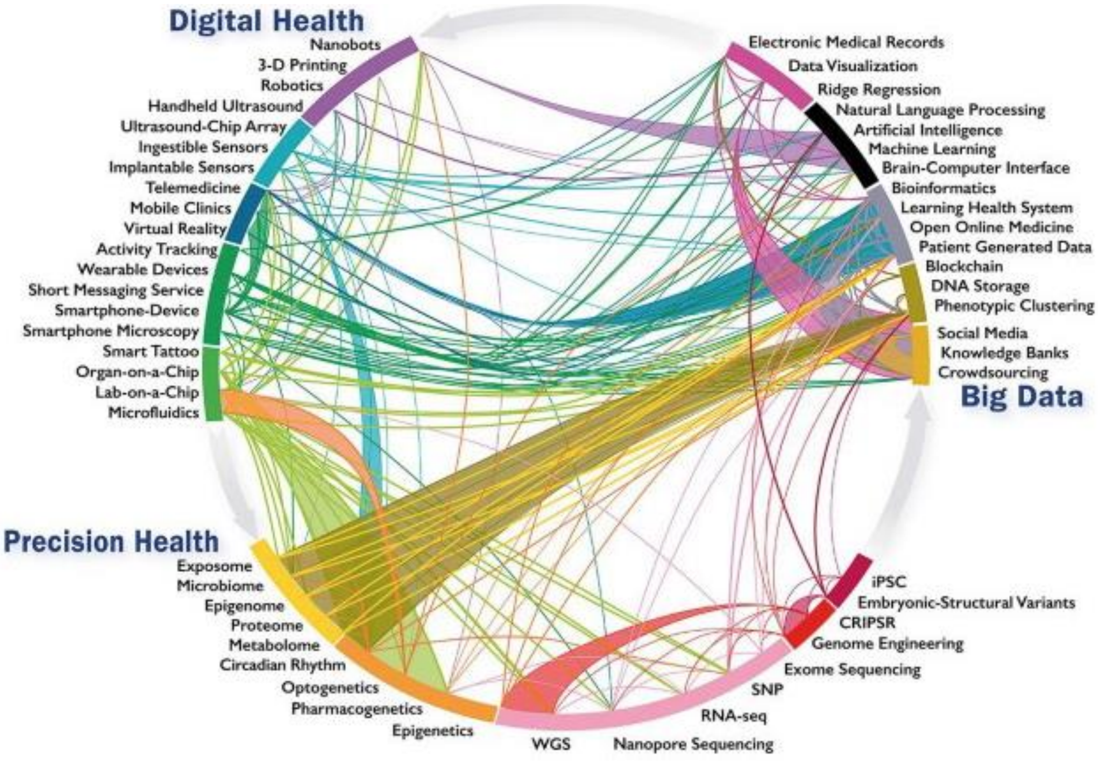


Fig. 70 A representation of the three main pillars for future innovation in healthcare: Digital Health, Precision Health and Big Data. The graphics shows pretty well the correlation among these three pillars. Image credit: ACC - American College of Cardiology

*21. **Healthcare in the Cyberspace***

This Megatrend is likely to land in slightly different ways, and at a different pace in different Countries (and regions within a Country), but I consider this unavoidable under the pressure of:

- Steady increase of per-capita healthcare costs
- Availability of better cures/preventative treatments that are considered basic human rights
- Change in paradigm: from exams for diagnosis to exams for curing

as well as sustained by:

- Ambient, wearable, and implanted sensors
- EHR - Electronic Health Records
- Personal digital twins (PDTs)
- Chip implantation into the body
- Artificial intelligence
- Chatbots

All the above is being accelerated by the 2020 pandemic. In fact, the shift towards a digitalization of Healthcare goes back at least a decade, and potentially could have found broad application in the last 5 years, but bureaucracy and siloed systems have decelerated implementation. The pandemic has put healthcare institutions under severe stress and sometimes, such as in Italy, the cyberspace has been used as a digital crutch. For example, all Italians have suddenly shifted to the electronic prescription in the prescription originates from the family doctor upon remote consultancy, and then goes directly to the pharmacy where patients can pick up the medicine. The machinery and capabilities were already in place, but not utilized. What had been attempted for at least 3 years was put into play within about a week because of the pandemic. At the same time, special support centers have been set up to evaluate Covid-19 symptoms and risks. In addition, many areas were provided with at home testing and tele-support opportunities. Furthermore, the data harvested from individuals and from institutions is being used to drive Government policy almost in real-time. The changes to the containment measures have been changed so frequently that they generated sarcasm and opposition: why do they keep chainging their minds? Culture is still rooted in the past when it took ages to decide, and even more time to modify it. I believe that these changes are here to stay and will become the new norm by the end of this decade.

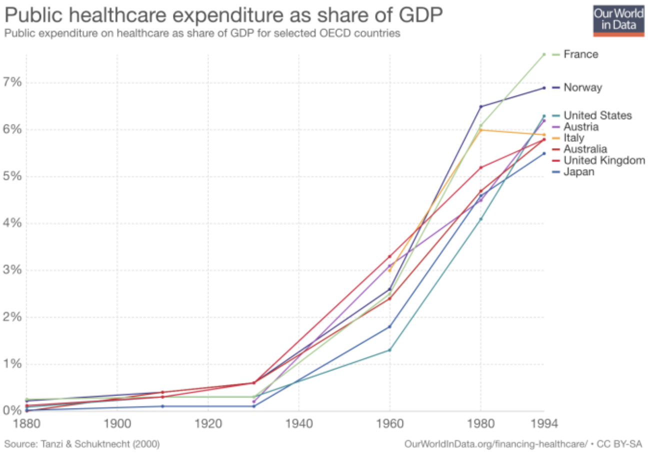


Fig. 71 Public health costs have increased everywhere, as shown in this graphic, both in absolute value and as % of a Country GDP. Image credit: Our World in data

a) Steady increase of healthcare costs

Healthcare costs have increased dramatically in developed Countries over the last 50 years, as shown in figure 71, both in absolute value and as percentage of the GDP, and this trend continues today. As reported by Our World in Data, healthcare spending in the US was a meager 0.5% in the 1900s, and the percentage was quite similar in many other countries. It reached 8.5% in 2014, and an astounding 17.7% in 2019 (3.3 trillion dollars, or $11,582 per person)—and that was before the pandemic! The total cost (including GDP decrease, job loss, countermeasures) is estimated to be about 16 trillion dollars for the US. The average cost for in-patient care for Covid-19 ranges between $51,000 and $78,000 depending on the patient's age. Vaccination for a Country like the US costs well into the ten-billions. Even without consideration of Covid-19, the graphic is quite clear on this —healthcare costs have been on an accelerated rise in the last five decades and have reached a critical level where both Countries and single citizens can no longer afford further increases.

Fig. 72 Various measures of preventative healthcare services for women. A similar graphic can be made for men. Image credit: Aeroflow Healthcare

b) Availability of better treatment / preventative care

Medicine has significantly progressed in the last twenty years, thanks to both science and technology (with technology in the driver seat since science has progressed thanks to technology).

The portfolio of available drugs has increased, resulting in more efficient drugs, and drugs that are able to fight a broader slate of ailments. In parallel, surgery and other medical procedures are able to address situations that, just 10 years ago, would have been impossible.

Prosthetics are becoming increasingly effective in addressing disabilities, but they are not cheap. An Argus II retinal implant (bionic eye) may cost well over US $500,000, and a liver transplant also costs more than that.

We have the possibility of mass screening, and focused personal screening (the "check-up"), and it is often said that the cost of preventative measures is much lower than the cost of a cure. Hence the interest of healthcare institutions to move towards preventative measures. To maximize the effectiveness and minimize cost, preventative measures (such as mammogram screenings, colonoscopies, and other cancer tests) target the higher-risk population, leveraging on statistical data.

c) Change in paradigm

In the coming years of this decade, we are going to see an increase in personalized treatments. We already see this approach in preventing the recurrence of breast cancer in the treatment of lung cancer. Exams identify specific genes that can make the patient at a higher risk of recurrence, or other genes that can indicate if a specific therapy will be more effective. Doctors are now prescribing exams to determine the best prevention and treatments rather than conducting exams to make diagnoses. This is a change in paradigm, and we are going to see this becoming the norm by the end of this decade. Precision Healthcare is the name of this new approach. Rather than using the "one fits all" approach, doctors are looking for a therapy for that specific person. By the end of this decade, we will have medicines that are so person-specific that they will not be effective on a different person, and because of that, these medicines may not be used for other people. This completely changes the approach to the approval of medicine since we can no longer trust statistical data. If a medicine has been designed for a specific person, there is no data on its effectiveness (nor on its side effects!). This will call for a completely new way of monitoring the patient.

The evolution of healthcare in this decade will be sustained by the convergence of several technology areas, each progressing independently from one another under the pressure of demand from several markets. Therefore, these technologies are not healthcare specific.

Fig. 73 The global wearable medical devices market is expected to grow to $67.2 billion by 2030, at a CAGR of 18.3% during 2020–2030. This forecast was made before the pandemic, so it is probably underestimating the growth. Image credit: Prescient Strategic Intelligence

d) Ambient, wearable and implantable sensors

There are already millions of wearables in use that monitor basic physiological parameters. The starting point was fitness, but in the last three years, data generated by wearable sensors has been processed to predict health indications. For example, the Apple Watch has been the first mass market product to be certified for detecting a medical condition (atrial fibrillation), and the latest version can provide a simplified ECG that can be sent to the doctor for analysis. Additionally, there are ongoing trials to detect movement disorders and get insights on Parkinson's disease. Wearable blood pressure sensors, position sensors, and bio-sensors are becoming mainstream, and they will be a common sight by the end of this decade.

In addition to wearable sensors, ambient sensors will become an important source of health data in hospitals, offices, and most importantly, at home. In addition to the issues that need to be addressed with wearables when applied to healthcare, ambient sensors raise privacy concerns that need to be managed, particularly when used in public spaces like hospitals and offices. As for any other healthcare-related data security, ownership and privacy are crucial (see next point), and it is obvious that data gathered in a public ambient, often with people unaware of what is going on, create even more problems.

Fig. 74 A self-adhesive biosensor that automatically and continuously measures vital signs, body posture and step count, and detects falls. Image credit: Philips

In the second part of this decade, we can expect the rise of implantable sensors. While the growth of health-related wearables was driven by fitness that expanded into health, for implantable sensors, the adoption will be driven by a specific "need to have," such as glucose monitoring for diabetic patients. Implantable sensors are, obviously, invasive and require (minor) surgery. On the positive side, they are fading away from perception, and unlike wearables they cannot be forgotten. Technology evolution promises an extended life cycle through self-charging, as well as creating sensors that, when implanted into the body, will work for a pre-defined period of time, and then fade away by biodegrading in the body.

In all cases, data communication from the sensors to the monitoring applications take place via local wireless networks that connect to the service provider. Some of the data processing usually takes place locally, with the smartphone playing an important role (also as gateway), although most processing will take place in the cloud, managed by a healthcare service provider.

We can also expect that some medicine will embed IoT sensors to signal the "swallowing," while other biosensors will monitor the effect.

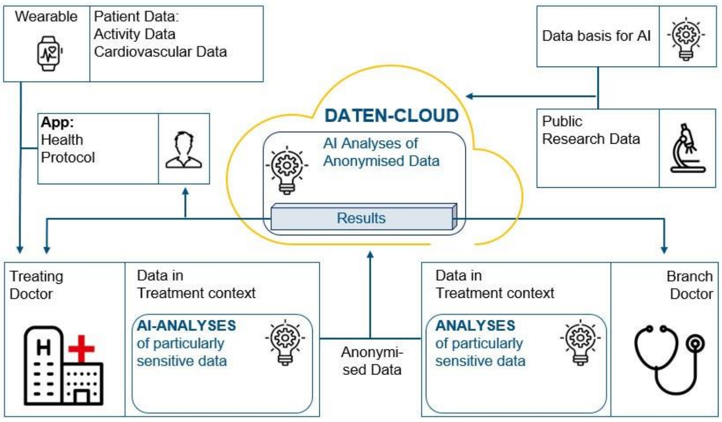


Fig. 75 Gaia X use case in the Healthcare domain. The diagram shows the management of data in the European Cloud. This data is generated by wearables, hospitals, and medical testing, and they are used by the citizens via apps, by healthcare providers, and by researchers. Image credit: Christian Lawerenz and Prof. Dr. Roland Eils, University Medicine Berlin

e) EHR - Electronic Health Records

Electronic Health Records are becoming widespread in terms of concept, and even in terms of regulatory framework. However, actual implementation and interoperability are still an open matter. The European Union has an agreed framework for the her, and member states are required to implement it. The recent Gaia-X initiative should support this data framework and provide the required security measures. There are now numerous use cases in the Gaia X framework (see figure 75) to apply the EU framework to the healthcare area. Different frameworks, although having the same objective, are being implemented in the US, China, Japan, Singapore, and many more Countries. While some Countries are well on the way to full deployment and use of EHR, others are still in the early deployment phase (or haven't started yet). By the end of this decade, the penetration in the G20 Countries should be completed, and interoperability shall be achieved. These Countries will steer the application in the other parts of the world, although it is unlikely that a full deployment can take place within this decade. Based on a recent report from the World Health Organization (WHO)-derived from 2016 data, there is still a long way to go to achieve full-coverage. At the same time, the pandemic has put a lot of pressure on accelerating the deployment and revising the framework for EHRs.

The key point is the need to ensure an effective (accurate and prompt) flow of data across healthcare institutions (hospitals) and across borders to detect early signs of an epidemic and provide effective control. This extends to the personal data sphere, since a healthcare "passport" is becoming key to enable safe travel across borders.

The EHR is also seen as an important tool to support research and to monitor drug effects. By having a large data set, it enables the use of the machine learning and data analytics techniques to extract information from the global EHR. This clearly has important societal implications, but it is also having huge business implications, hence the need to tackle data ownership issues.

f) Personal digital twin

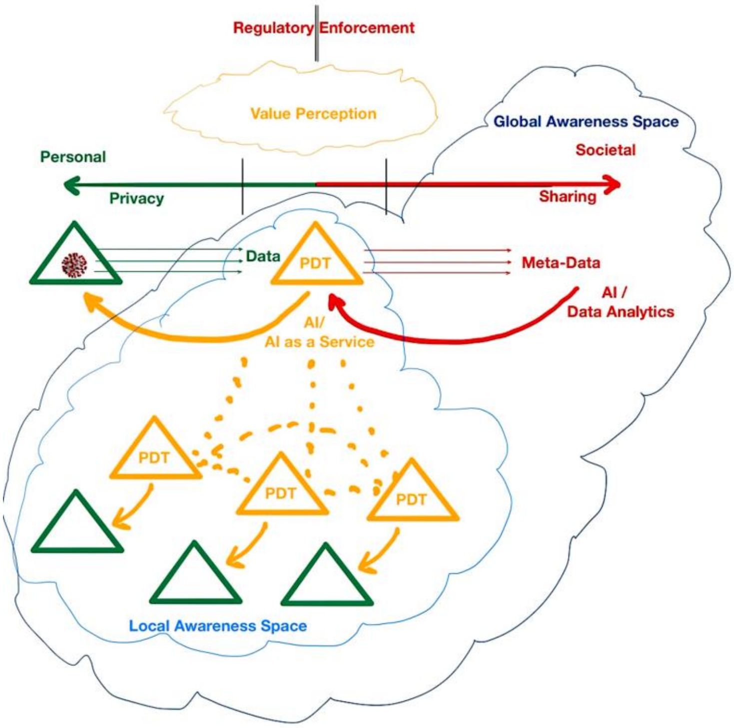


Fig. 76 Framework for using PDT in the context of the monitoring and control of an epidemic. A PDT acts as a gateway separating the person from the context, thus preserving privacy whilst ensuring awareness on societal obligations. A PDT can autonomously interact with other PDTs, representing persons that are within an epidemic risk radius, as shown in the lower part of the graphic. The local intelligence can therefore extend to a cluster of local intelligences, and the emerging information is shared with the relevant institutions.

The data mirroring and recording of the healthcare status/history of a person are part of the EHR of that person. New studies are ongoing to extract local intelligence from this data, giving rise to Personal Digital Twins (PDTs) serving the healthcare space.

A PDT in the Healthcare space is connected to its physical twin in a variety of ways. First, a framework can be defined (a regulatory framework could be used as background) and made available through a healthcare service provider. Insurance companies may have a role if state-owned or private-owned healthcare institutions are not stepping in. Personally, I think that in Western Countries, private companies are the ones most likely to set in motion the adoption of PDTs in the healthcare space. A company that is providing healthcare insurance or healthcare services may start by requesting access to the EHR of that person and then add specific information that is collected at the initial service subscription time. Furthermore, the first set of data mirroring the person's healthcare data is going to be extracted as new data from exams, visits, prescriptions, and monitoring devices that are becoming available. This mirrored image of the person is used to customize services, and it is made accessible, for the relevant parts, to any medical doctor / healthcare provider interacting with that person (duly authorized by the person that remains the owner of the data). By the end of this decade we can expect genome sequencing to become part of the PDT. Monitoring devices, wearables, implants, etc. will continuously provide data that enrich the model and keep it in synch with the physical twin.

Applications embedded in the PDT leverage data, creating a local intelligence. Additionally, these apps (or others) interact with the environment through API (this is important to keep the PDT data separated from the environment, private, and to allow the interoperability of a PDT with its environment, including other PDTs, independently of the model / framework used in the PDT itself). Data values are shared on a need-to-know basis (hence a doctor can access certain sets and certain attributes, whereas a researcher may access a different subset, and a healthcare institution a different one. For example, a researcher does not need to know my identity, a doctor does not need to know where I have been (only if I have been somewhere that a given risk exists), a public institution in general does not need my identity if the point is correlating proximity data, etc.).

A crucial role of the PDT, as a bridge between its physical twin and the context, is to create "context awareness," —to inform the physical twin of threats and of the appropriate countermeasures (behavior). It is also the PDT that has to inform its physical twin in real-time of the regulatory framework (for example, "since you have been diagnosed with Covid-19, you cannot go out), and in case that the physical twin does not comply, a red flag should be raised. Notice that this is not a violation of privacy, nor a Big Brother incarnation. The PDT is actually preserving the privacy of its physical twin provided the latter conforms to the regulation. It is like the blackbox in car rentals that do not disclose locations, wandering, behavior, etc. as long as I stay within the allowed framework. Or, for example, a speed trap that will not release information on cars unless they exceed the speed limit.

We have already seen (partial) implementation of PDTs in China and other Far East Countries where, during the pandemic, each citizen had to have a digital passport to move around, a passport that was recording data, symptoms, test results, etc.

PDTs at stage V will be able to act proactively by analyzing the context in cooperation with other PDTs and Digital Twins of healthcare services. Resources will shift, as foreseen in this Megatrend, a significant portion of Healthcare processes to the cyberspace.

*g) Body-on-a-chip*s

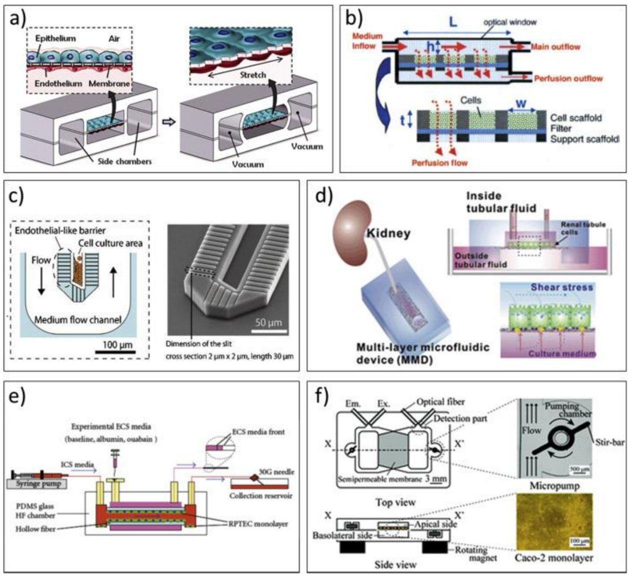


Fig. 77 Using electronic and micro-fluidic to replicate human organs functionality. In this schematic, replication of a) lung, b/c) liver, d/e) kidney, f) gut. Image credit: Hiroshi Kimura et al, Elsevier

The development of micro-fluidic has made it possible to duplicate the functionality of living beings by organizing living cells on a chip and subjecting them to conditions that replicate one of those cells in an organ. Once the functionality (and structure) is replicated, it becomes possible to change the conditions (like varying nutrients, altering oxygen perfusion, introducing bacteria and drugs, etc.). By observing the reaction of the cells, and the change in functionality, it becomes possible to simulate the behavior of an organ, in vitro, under different conditions. The progress in this area has been focused on the replication of a broader set of organs (we now have chips for the lung, liver, kidney, gut, skin, heart, pancreas), and to include more functionalities. For simulating some organs' functionality, cells have to be organized in very specific structures, mimicking the one in the real organ, and for this, bio 3D-printing is used.

Lately, researchers have started to connect various organs to a chip to create more complex systems, with the objective of creating a "body-on-a-chip" that can represent the complex interactions among the various body systems. Notice that this is not creating a "body," only a lab system to mimic specific functionality (besides, a brain on a chip is still in the science-fiction domain, although neurons are studied in vitro and have been integrated in bio-chips).

A first, obvious, use of this technology is for drug discovery/ testing. As a matter of fact, the process leading to the commercialization of a drug is a lengthy and costly one (a drug development may cost

$2 billion, considering all the dead alleys that have to be discarded). Microfluidic evolution, along with data processing, is expected to shorten the time to market and significantly decrease the number of dead alleys by the end of this decade.
A further expected evolution is the support to personalized treatments, where a body-on-a-chip can be created using the patient cells to test a therapy in vitro. Here, again, as previously mentioned, the availability of a personal digital twin may become important since part of the testing could be performed in the cyberspace.

Finally, by the end of this decade and early in the next one, technology of organ-on-a-chip can become so effective that (in some cases, like in the pancreas), the chip can be used to replace/flank the natural organ.

h) Artificial intelligence

Artificial Intelligence is already used in the medical field (applied AI), particularly as a support to diagnoses and predictions (data analytics). Predictive technology has become an important sector of AI in healthcare, looking at improving clinical decision making, managing, and leveraging on EHR for risk assessment, monitoring data generated by wearables to raise red flags, and augmenting medical devices. The latter will prove particularly important as we will shift more in this decade towards increased home care and preventative/personalized medicine.

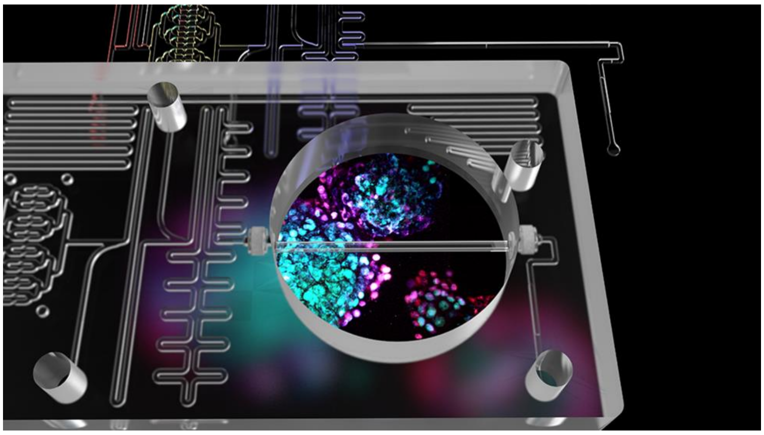


Fig. 78 The fully integrated, thermoplastic islet-on-a-chip (pancreas on a chip) was designed for scalable manufacturing, automated loading of islets into parallel channels, synchronized nutrient stimulation, and continuous insulin sensing. Image credit: Michael Rosnach/SEAS.

Interestingly, it is also starting to be used to detect patterns, pointing to processes resulting in better outcomes (shorter hospitalization, prompter recovery, fewer side effects/complications). The point is to use AI to find questions, not to find "answers"! In fact, there are so much data and data-streams available in a hospital environment, or in a medical practice, that it is possible to apply data analytics to derive answers to questions such as "why are there patterns leading to certain patients experiencing better outcomes than others?"

In this decade we can expect increased pervasiveness and use of AI in healthcare, as shown in the market forecast by Markets and Markets (figure 79) along the whole value chain:

- New drug design;
- Assisted diagnoses, data rendering, automatic EHR updating;
- Early diagnostics based on multiple data streams (ALS, cancer, dementia, etc.)
- Assisted surgery;
- Therapy identification and monitoring;
- Assessing/predicting risks in specific populations and at individual levels;
- Home healthcare and rehab;

- Tele-care through virtual doctors;
- Robotic/chatbot-assisted healthcare, including natural language interaction and virtual nurses;
- Continuous education for medicines and best practices for current and future doctors;
- Identification of pathogens, incipient epidemics, noxious substances;
- Genotype to phenotype correlation, diseases related to genetic predisposition and ambient factors.

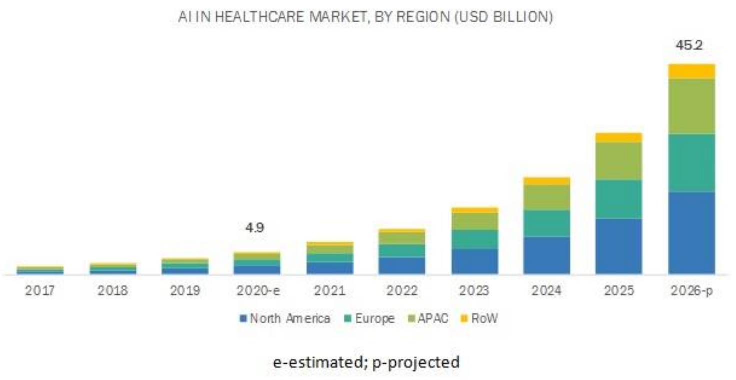


Fig. 79 Expected worldwide market for AI in the healthcare area. The shift towards tele-health, accelerated by the pandemic, is likely to further increase market demand for AI. Image credit: Markets and

By the end of this decade, AI will be pervasive in every healthcare area, giving a fundamental contribution to personalization, monitoring, and cost reduction. We can expect AI to be embedded in services and medical devices and to be provided both at a centralized and local level. In particular, we can expect the embedding of AI in personal digital twins to enhance the local intelligence over time and to enable cooperation with centralized intelligence. PDTs are also expected to play the role of advisors, steering the physical twin towards healthier behavior as well as raising the physical twins' awareness of potential risks.

The growing pervasiveness of AI in this sector raises questions on privacy, accountability, transparency, as well as on the digital divide that is created among the ones that will have access to this support and those that will not be able / allowed to access it.

Moreover, there are deep ethical questions in the use of AI. As mentioned, cost is an important factor, often a driving deciding factor in the selection of cures. Cost aspects are part of the AI systems supporting healthcare. Who will oversee the creation of the ethical framework and of checking that it is being followed? This clearly connects to the transparency aspect.

i) Chatbots

Chatbots are seen as the ultimate interface between a person and the healthcare system assuring continuous access, any time and place, to healthcare consultancy.

There are already several chatbots on the market, and more will become available. Some will be provided by independent third-parties, others by insurance companies, or as a fringe benefit by the company you are working for, and others by the official healthcare institutions.

Of all the innovations, novelty, in healthcare, Chatbots are likely to become the signature of this decade in terms of their impact on habits and the way people deal with their own health. In a way, it will have the same impact the cellular phone had on our way of looking at "communication." Before the "cellphone," we had to look for a "phone," and when on the move we looked for a "telephone booth." It required a conscious search that created awareness of increased use in "telecommunications." However, today, telecommunications has lost the "tele" in terms of perception–we simply communicate when we want, wherever we are. Picking up the smartphone from the pocket, or the purse, is so natural that we no longer give it a second thought. Add this to the fact that we no longer must dial a number (most of the time we just pronounce the name of the person we want to talk to), and only then you realize how seamless communication has become. A third subtle, but not less important, aspect to create this seamless flow: we no longer perceive communication as a "cost." Most people today have some sort of "all you can eat" data plan, with the consequence that a single call, or access to the internet, is perceived as costless (a telephone booth reminded us every single time that making a call had a cost!).

Now, consider the chatbot in healthcare. At any time of day, doesn't matter where you are, you can call *your* chatbot and talk to it (him/her?), to report that your throat feels sore. Ten minutes after that,

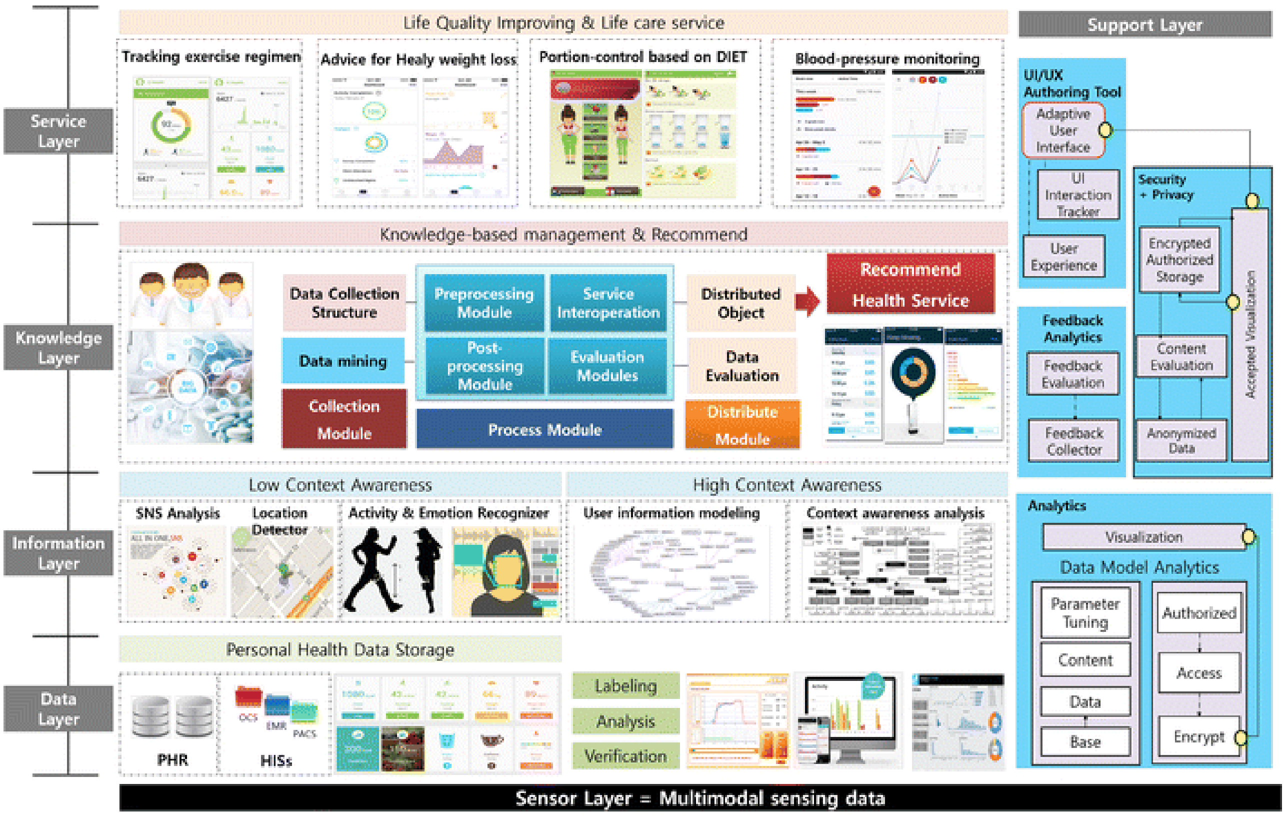


Fig. 80 Chatbots interface every value layer in healthcare, from access to data to information and up to knowledge and services, as shown in this graphic. Image credit: Kyungyong Chung, Research Gate - Cluster Computing

looking at the menu at a restaurant, you call it again asking it if a certain item on the menu would be ok to consume while taking a specific medication... So, here you see the same "continuity" of service that the smartphone is providing. You also see that you are not talking to a chatbot, rather to *your* chatbot, something that knows you! For example, asking a virtual assistant (Siri, Alexa, etc.) to call your mother only works if you are using your smartphone, because it is *your* smartphone. Thirdly, your chatbot will come as part of the healthcare service–you are not paying for its consultancy (at least that is the most likely situation in the future).

Today's chatbots have a limited set of "functionalities" and interact through natural language. In the coming years, they will want to look at you and will be asking, -as needed, to use videoconference. Our face can tell quite a bit to a keen observer, and chatbots in the future will most likely be using signal processing to check our heart beat, respiratory frequency, blood pressure, and more (all of this just by looking at our face with the smartphone camera), and will possibly get additional data collected by our smartphone (like our physical activity in the last few days, hours and minutes), or by some wearables (smartwatch, fitness bands, etc.).

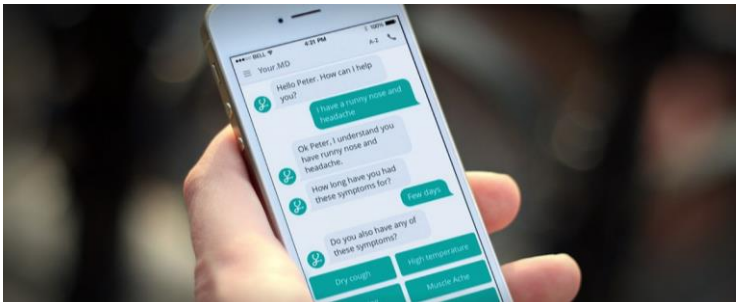


Fig. 81 An implementation of a chatbot (interface) on a smartphone. Using the smartphone as an interface has the additional benefit of leveraging on a familiar platform/User Interface. This is reflected by a recent poll showing that 96% of healthcare chatbot users (patients) find the interaction useful. Image credit:

Like your family doctor, but better, your chatbot will know more and more about you as time goes on. The more you use it, the more it will be in synch with you. It will be the chatbot that, should you need it, will contact the appropriate doctor, sharing the relevant data, setting up an appointment, or just providing feedback depending on the situation.

This will be a profound change in the healthcare world, for us as users and for all healthcare providers. Doctors will have to learn to interface with people's chatbots (and some biz models will need to be invented for these types of consultation), as well as to see their patient as a set consisting of a physical and digital persona (the digital reality we are addressing in the DRI). Insurance companies will be competing to implement the kind of chatbot that can provide specified data, and their efficiency will depend on the way the chatbot manages the consultancies with the client (person/patient). A scary scenario arises from the business role of the chatbot in the insurance world as described in the thriller *Cell* by Robin Cook (I would advise you to read it).

There will not necessarily be one chatbot for accessing all healthcare services. Actually, I am pretty sure that doctors will start to offer their own chatbot to interface with their clients, and they will be able to transfer part of their knowledge (and the specific knowledge related to that client) to the chatbot. Interestingly, the transfer of the chatbot-acquired knowledge to the doctor will become an important issue, not just in terms of a notebook reporting symptoms, time of the call, prescriptions taken... rather in terms of general knowledge deriving from those interactions (a doctor learns every day by interacting with their patients, and with the mediation of a chatbot, they would be losing quite a bit!).

Chatbots and Personal Digital Twins will be intertwined, but I do not think they will be the same, mostly because of the need to keep separate ownership. The PDT will connect to the chatbot (possibly to several of them, since there will be others outside of the healthcare domain), but it will be owned by its physical twin. However, the chatbot may be owned by an insurance company (for example). Also, we can expect our PDT to take initiative and interact with the chatbot in the event it detects some anomaly in our physiology or behavior, and if needed, have the chatbot call us or prompt us to call the chatbot.

In addition to the above, the evolution of genetic-based diagnostics and treatments (see the CRISPR Megatrend) will characterize healthcare in this and in the following decades. It is obvious that progress in genetic understanding will lead to more personalized diagnoses and cures. The challenges that we have today in correlating a given syndrome to a genetic map will be overcome through data analytics and artificial intelligence: the availability of hundreds of billions of sequenced genomes creates a vast pool of data that can support machine learning.

All in all, we can expect this Megatrend to lead to new and better healthcare, supporting the change in paradigm, emphasizing proactive and personalized support, and aiming at keeping healthy rather than stepping in once people have become sick.

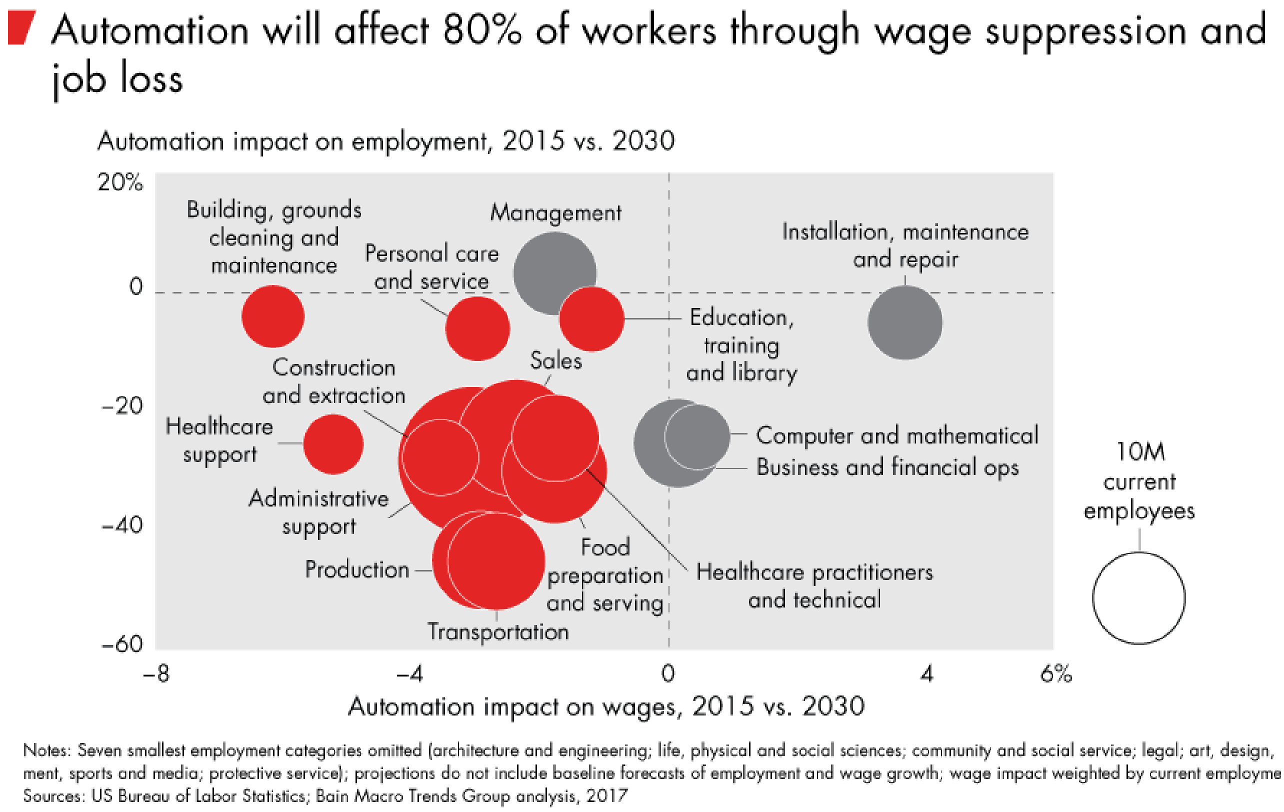


Fig. 82 Is a graphic representation of the expected impact in the US of automation in different sectors, measured as percentage of job losses/increase (vertical axis) and wage loss/increase (horizontal axis) taking 2015 as a reference for the 2030 forecast. The size of each bubbles relates to the number of people involved – red represents losses and grey gains in one dimension.
Image credit: US Bureau of Labor Statistics

22. The Future of work

This Megatrend, on the future of work, is possibly the most complex one to analyze, and this is the reason I left it at the end of this foresight exercise. “Work” is different in so many areas that drawing a global view is basically impossible. There are significant variations in different Countries and Regions, but this is mostly affecting the timeline of evolution. In some areas, transformation may already be ongoing and will complete within this decade, but in others it has not started yet and may be far from completion, even by the end of the decade. However, it is mostly a matter of time (although, local policies may have a significant impact). Eventually, the transformation will affect all Countries because they are all part of the same market and tick to the same economic rules.

When looking at the future of work, we can do that from several points of view (pov). The most important pov is surely the one of “who” is doing “what,” and in particular, assessing the impact of automation (work delegated to machines). Figure 82 summarizes the conclusion of a study by the US Bureau of Labor and Statistics as discussed in an interesting report by Bain, published in February

2018: "Labor 2030: the Collision of Demographics, Automation and Inequality." Although the data and forecasts are US specific, the factors leading to the trends are applicable in a global context (sooner or later).

Even at first glance, the impact of automation is clear in the 15 sectors considered, resulting in lower wages and loss of jobs (11 red bubbles signaling a loss, versus 4 grey bubbles showing a gain). Since, on the surface, each bubble is proportional to the number of people involved, it may seem evident that many more people are going to lose than to gain.

Gains are expected in Science, Technology, Engineering, and Mathematics (STEM) related jobs and in installation and repair jobs in terms of wages, but these areas will see an overall job loss. Comparatively, the Management area is expected to see an increased number of jobs, but at lower wages (no area seems to be gaining in the number of job opportunity *and* in wage). We can expect a (slight) wage increase in STEM jobs since they require very skilled (and smart) people, and this is a scarce resource. However, the number of jobs is expected to decrease as computers (and artificial intelligence) take care of more activities. The same reasoning goes for business and financial operations. In the case of installation, mmaintenance, and repair, we expect automation to take care of some of the activities involved, but most of them will still require actual human intervention, and more skilled and specialized intervention, hence the expected increase of wages and the very limited decrease in job opportunities. As more activities increase in complexity, and the processes shift from value chains to ecosystems, direct human management is expected to grow, but the abundance of related- skills will result in a continuous decline in wages.

In terms of job loss, it is expected that around 20-25% of jobs will be lost (1 out of every 4/5 jobs will disappear) by the end of the decade, and low-income workers are expected to be hit the hardest. The new wave of automation is based on two main pillars: Digital Transformation and Artificial Intelligence:

- The Digital Transformation moves a number of activities and processes to the cyberspace, with the consequence being a disappearance of jobs previously needed to complete these same tasks in the physical space (think about travel agencies being hit by online autonomous reservations and ticketing). Notice that DX is killing jobs, but not by substituting them with a machine, by removing them from the value chain (unlike automation on the assembly line where a robot steals the job of a blue collar, in the DX, the job disappears). DX is going to hit most (in terms of jobs) in the areas of healthcare and production (production already suffered from the first wave of automation with robots replacing blue-collar workers, and now it will suffer from the softwarization of production);
- The Artificial Intelligence augments machine capabilities, making it possible to replace humans, including white-collar workers, with machines. Administrative support jobs and sales are the ones suffering the most, as shown in figure 82. Automation in the transportation

sector, construction/extraction, food preparation and service, and personal care and services will require a broad mix of technologies, but artificial intelligence will be the crucial enabler.

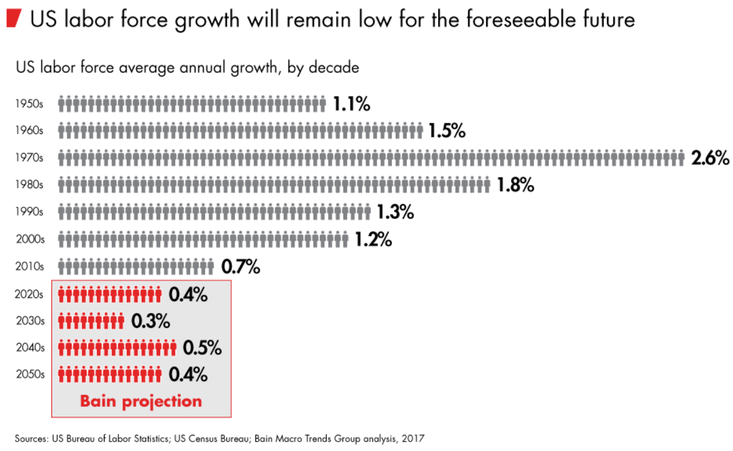


Fig. 83 Labor force growth in the last 6 decades and projection over the next 4. Image credit: Bain

It is important to notice that the drive towards increased automation (hence higher capital investment and job losses) is fueled by the decreasing availability of a work force, in particular, of a skilled work force. In turn, this is bound to fuel inequality since the economic benefit of automation will go, mostly, to those having capitals (the rich), and to those with crucial skills in high-demand areas (estimated to be about 20% of the workforce).

The two biggest economies, China and the US, are already suffering from inequality, and this decade is likely to increase it. Also, the speed of automation uptake can have a significant impact on inequality since a fast speed will create loss of jobs without providing time for re-qualification (historical data shows that the workers' re-absorption rate in the US was 0.7 million per year, and in the next decade, the expectation is a job loss of around 2.5 million per year, thus generating 1.8 million people that lose their job and cannot find a replacement). This would increase the demand for investment capitals, thus increasing the power of rich people.

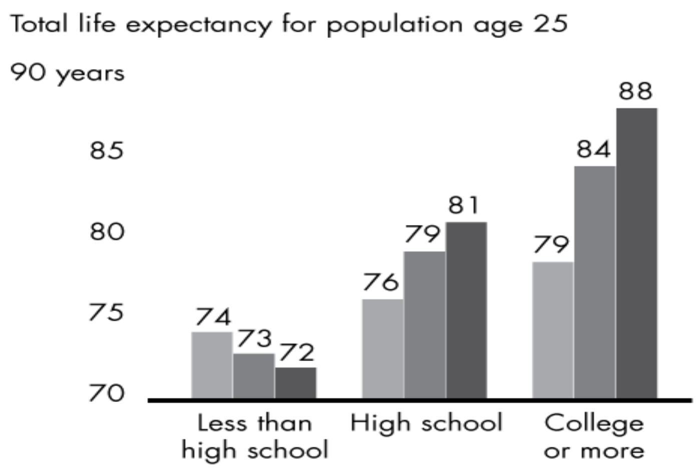


Fig. 84 Life expectancy is expected to increase in this decade with the exception of less educated people, whose life expectancy will continue to decline.
Image credit: Bain

The access to resources, including healthy food, preventive healthcare, and adequate medical treatments is clearly influenced by wealth, and the rising inequality will have a significant impact on life expectancy. According to Bain forecast, see figure 84, a significant impact derives from the education level, and this of course correlates to inequality and fosters inequality, to the point that the education level can be taken as the measuring stick for life expectancy in young people.

Rising inequality is also likely to increase intervention from Governments, thus

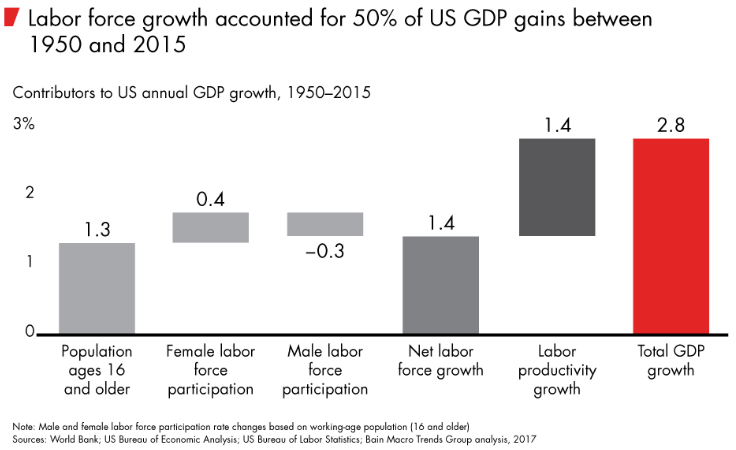


Fig. 85 From 1950 to 2015, GDP growth has been generated in equal part by the increase of productivity and increase in the workforce. As the workforce increase slows, more investments are required to increase productivity to keep the rate of GDP growth. Image credit: World Bank

changing the balance between private and public in several markets. We are already starting to see this happening in Europe and other areas as result of pandemic-related stress on the economy.

GDP growth in the last 65 years (1950-2015, see figure 85) was fueled in equal parts by workforce increase and productivity increase. In this decade, the workforce (the ones with high-skill levels) is bound to decrease in several areas (for example, in Europe, by 0.5% per year), or not be in synch with the growth in previous decades (in the US, the expected growth for this decade is 0.4% less than half the ones of the previous decades). To keep the GDP trend, productivity must increase, and automation is expected to result in a 30% productivity increase by the end of this decade.

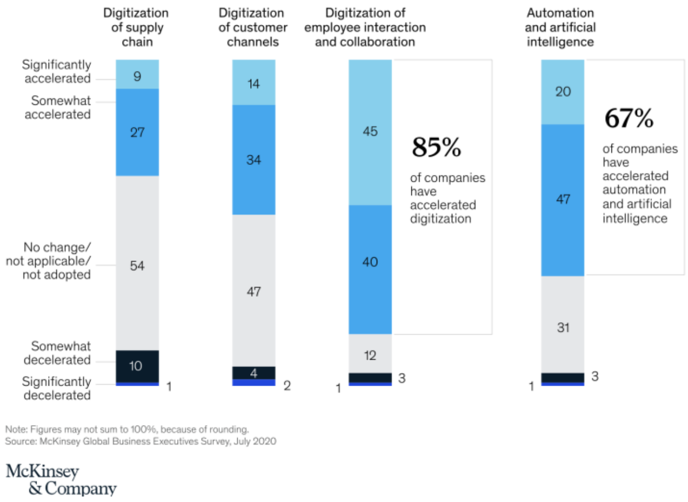


Fig. 86 Measures of digitization and automation taken to counteract the impact of the pandemic. It is clear the acceleration towards a digital transformation (blue shades) of the various processes. Image credit: McKinsey&Company

a) The Future of Work is now... isn't it?

In the past year, we have seen, and possibly contributed to, a momentous shift in the way of doing business, courtesy of the pandemic and of related countermeasures taken by governments all over the world. Even the world wars of the last century had less of a dramatic change in such a short time and involving so many countries.

One of the most amazing things was the resilience of businesses that, in the space of a few days, managed to find ways to ensure operation continuity.

Clearly, not every business was able to reinvent operation processes, or keep them operational by moving to the cyberspace. Think about the tourism industry–movement restrictions imposed by authorities led to a screeching halt of travel and tourism, affecting airlines, airports, catering, tourist attraction, hotels, etc...

Other businesses, such as healthcare and telecommunications, faced a surge of demand, and others had to move (part or all of) their operation to the cyberspace, such as retail, banking, etc. In some cases, businesses invented new channels to reach their market.

All of this is well represented in the previously mentioned study by McKinsey, involving some 800 executives on the post pandemic lingering effect on business and on workforce (see figure 86). As shown, close to 50% indicated changes in the supply chain (36% foresee an increased digitalization, and 11% a decreased one), and similarly, a change in the customer channels (although here the foreseen changes were overwhelmingly in the direction of increased digitalization). More interestingly, with respect to this trend, are the expected changes in operation (employee interaction/collaboration and automation/artificial intelligence).

85% of companies that were surveyed indicated an acceleration towards digitalization in the area of employee interaction and collaboration (remote working and all that is encompassed, for example, video conferencing software), and 67% foresee an increase of automation and use of artificial intelligence (AI).

Teleworking was adopted wherever feasible, for example for administrative work, education, software production and testing, power plant control, etc. This shift affected and involved a significant portion of the workforce. In Italy, for example, TIM (one of the major telecom Operators), had 85% of its workforce working remotely for over a year (since the lockdown started in March 2020).

The experience was a mixed bag in terms of productivity and employee/customer satisfaction. Overall, customer perceptions of the services did not change (remote customer assistance and interaction was already in play before the pandemic) and productivity did not change significantly (at least in the short-term). However, employee satisfaction ranged. Some appreciated the convenience of working from home, and others became concerned about losing the human connection that is possible with face-to-face interactions at the office or in stores. Quite a few found that the convenience of tele-working was (at least partially) offset by cramped working conditions at home as many were forced to share their remote workspace with kids, pets, a spouse, roommate, etc., and as a result, many tele-workers long to return to the office and revert back to previous lifestyles. This, for many companies, is unlikely to happen. In the cited example of TIM, the company has taken advantage of the forced lockdown and remote work requirements to change their office space into shared desks. Workers were asked to remove all personal stuff from their desks, since the concept of a personal desk is over. From now on, when on-site working is resumed, only a fraction of the workforce will operate on- site, and about 30 to 50% (the remaining part) will keep working remotely. Office space will become available on a first come, first served basis, and many companies will require employees to reserve a workspace in advance. This has led to the release of office space, and a decrease in real-estate costs/profits.

On the one hand, it is obvious that the pandemic has changed the way of working for a significant portion of the global workforce, but this raises several questions. For example, are these changes here to stay (as in the afore mentioned example of TIM)? Or will people revert back to the previous "normal"? If the adaptations do stay in place, what kind of consolidation will take place, and how will work look by the end of this decade? In addition, what other changes may occur as result of the changes induced (or accelerated) by the pandemic?

Let's consider the first question: are the changes brought on by the pandemic going to become the new “normal”?

My guess is that there is not one answer that would fit all businesses and countries. However, in general, I would say that NO, the changes brought by the pandemic are not the new "normal." Let's consider a few examples:

- In some cases, we are going to see a full revert back to the previous situation. For example, restaurants that have been forced to offer take-out or other "take away services" will likely want to go back to serving customers on-premises. A small number of these restaurants may keep take-out options, as an additional revenue stream, since they had to implement new services during lockdown to generate (some) revenue. The extent to which this may happen will largely depend on the demand side. Will customers (at least a significant portion of them) be interested in take-away services from restaurants that used to be dine-in only (usually up-scale restaurants)? I personally think that, at least in the first post-pandemic period, most

Fig. 87 Flippy, a kitchen robot for fast food restaurant can prepare burghers and salads. Demand is expected to grow as restaurants face Covid-19 restrictions. Image credit: Miso Robotics, California

people will want to forget the pandemic experience and go back to previous habits Therefore, I don't think people will be interested in take-out as they are eager to enjoy an evening out. The behavior of demand is, obviously, very much culture-based, and in Countries where take-out is common, people may see expanded offerings that enhance satisfaction and expectations. However, other Countries, such as Italy, may want to forget about the past and resume activities as they did pre-covid. In places where take-out is going to flank, the on-site services will likely require significant reorganization of work in order to manage the two types of services. In fact, delivering take-away food, particularly for an up- scale restaurant, requires a fine tuning of the menu as not all dishes are suitable for take-out given the time lag between the kitchen and the table. In addition, many restaurants will need to re-evaluate their order and delivery processes. During the lock down, restaurants did not have customers on-site, so they could focus on take-out. However, with on-site customers, there will be two different processes to be managed concurrently. Automation can surely help although, so far, restaurant automation has served mostly low-scale restaurants. Luckily, in the future, enhanced robots may be able to enter up-scale restaurants to take orders and coordinate with the delivery chain. I do not see this happening (not on a massive scale, anyway), during this decade, although I think there may be a few trial runs.

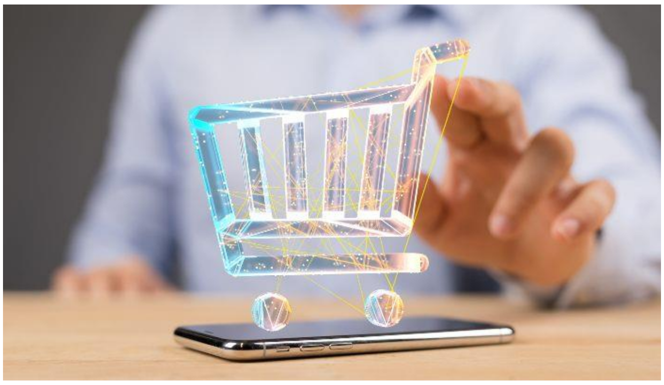


Fig. 88 The integration of physical and digital shopping is most likely the future of shopping and there's a new word for this: Phygital. Image credit: WAM

- Retail stores have strength in their location and in the physical interaction with customers. Many retailers have invented a new way of interacting with customers using a type of video conferencing in which a prospective customer calls the shop, and an assistant moves around the shop, showcasing the merchandise using a smartphone camera. This was only a temporary solution in response to COVID, but retails are eager to get back to the old normal. In a way, managing the customer relationship via smartphone camera was an expensive way of doing business (it takes the continuous presence of a shop assistant to be with the client...), and yet the physical experience still could not be delivered. On the other hand, hardworking shop assistants had the opportunity of continuous engagement with particular clients, and this provided them with an opportunity to establish trust among the consumers, and to steer the client towards certain products, resulting in a better revenue stream. They also probably obtained the customers contact information (their telephone

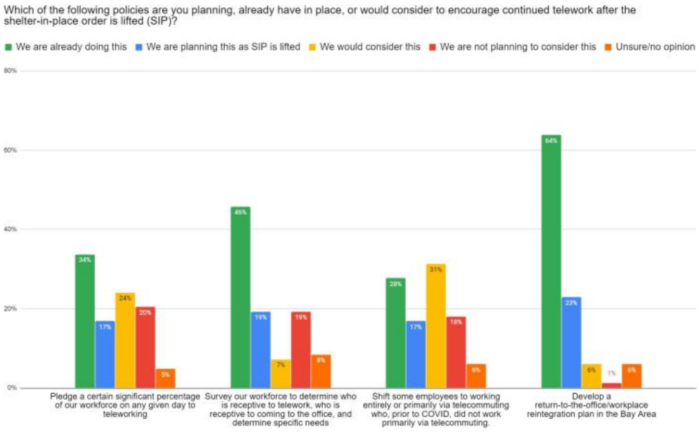


Fig. 89 Results of polling 83 CEOs from innovative companies in Silicon Valley on their plans towards teleworking in a post-Covid landscape. 51% are planning to keep teleworking for a significant percentage of their workforce, over 60% will survey their workforce to see who is willing to telework, 45% will impose teleworking to a part of their workforce, and 89% will develop a plan for returning to work on premises in a different way. Image credit: The Silicon Valley Leadership Group

number), and this can be leveraged as an excuse to profile a customers' shopping habits and a better indicator of when to call them if certain products become available. As in any crisis, some retailers patched up a dire situation, others might have found an alternative way of doing business that can complement the old one once the old one can be restored. Overall, I think retail stores will go back to the old normal, but a few have learned to create personal, remote relationships with customers, and these businesses will be able to create a new, complementary revenue stream that eventually may become essential as the competitive pressure from on-line retailers accelerates. Actually, the pandemic has increased this pressure, creating a habit in consumers to use online retailers. Notice, additionally, how this form of retail, let's call it click and mortar, requires shop assistants to have advanced interpersonal skills due to the need of establishing a lasting relationship with the client, and to highlight the value of a product using a virtual channel. Technology must become an integral part of the assistants interaction, sometimes having to cover shortcomings in technology management from the client side. There is even talk of integrating virtual reality with haptic interfaces (to make you feel like you are physically in the shop), and this in-the-shop experience flanked by an online presence can be referred to as phygital. Take a look at this (entertaining) video, and take a look into the future.

- Companies that are working in the "cyberspace," such as software companies, are clearly in a different position than restaurants or retail stores in which the physical space is a must. This demonstrates the relative ease of their shift to teleworking, and most importantly, in the minimal impact resulting from the pandemic. The production part of their business has been mostly unaffected by the lockdown. The sales part, on the other hand, has suffered both directly and indirectly. For example, the loss of personal contact with prospective clients has made selling more difficult, and in addition, a significant portion of their customer- base has likely been affected economically by the pandemic, leading to decreased investment in innovation. In some cases, a smaller percentage have experienced an increased demand from companies that needed their product/services to shift their biz to the cyberspace). Part of these companies were already operating with a remote workforce, either working from home, or located in different places/Countries. What Covid-19 did was increase the number of workers operating remotely (from home) to the point that several companies closed their main offices. From a productivity point of view, in the short term, there have been no losses. Actually, a number of companies are reporting increased productivity as commuting time is often converted, at least partially, into productivity time. The occasional chit-chat typical in an office setting has disappeared, also increasing productivity. However, this is a mixed bag since part of that chit-chat is inconsequential, however, part may result in spreading knowledge, creative thinking, and serendipitous discovery. Furthermore, the chit-chat is perceived by several workers as bonding, something that is sorely missed when working from home.

The latter highlights the importance of how workers are adapting to telework, and their desire to resume working remotely once the pandemic is no longer a threat. Commuting time is perceived as wasted time by most, and as a cost by all. Therefore, working from home is better in that respect.

However, in addition to the loss of human touch deriving from on-premises interaction, there are several negative perceptions playing against teleworking:

- Home ambience may not be ideal for work (kids, pets, spouse, dedicated workspace not available/unsuitable).
- Presence of distractions and lack of focus (difficult to separate home chores from work).
- Fear that one's work contribution is not perceivable by the "boss."
- Fear of being monitored by "big brother."
- Fear of losing the "big picture" (a side-effect of not sharing physical space and not having in-person/group interactions)
- Losing the sense of being part of a team—small talks and physical co-presence are crucial.
- Inadequate collaborative tools (video conferencing is ok for short meetings, but it can become unnerving if using throughout the entire day).
- Video fatigue.

It is also important how managers feel about teleworking. The loss of direct, physical co-presence is felt as a loss of control for many managers. Notice that control taking place at the office as a passing glance is not perceived as inquisitive, whereas control taking place in cyberspace is felt as a loss of privacy and strongly unfavored.

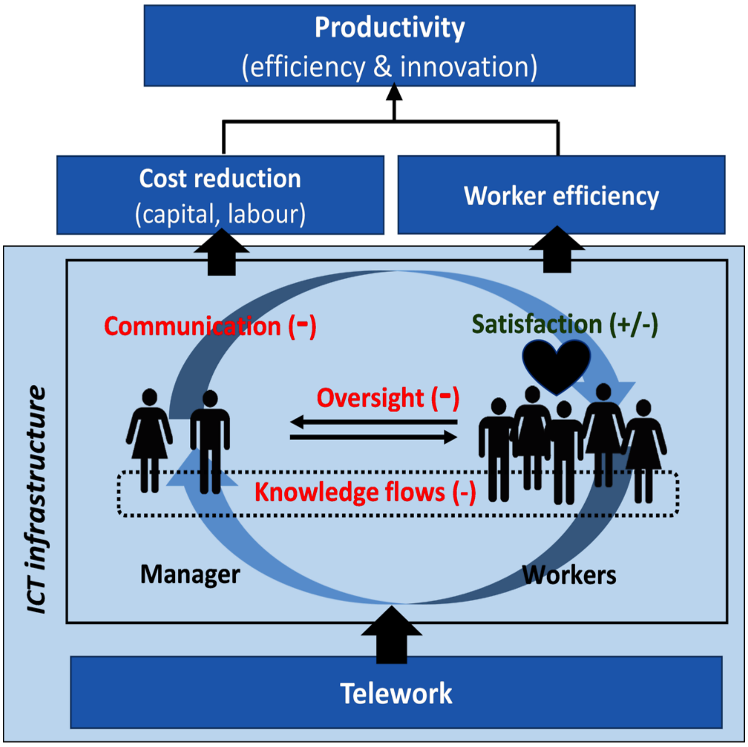


Fig. 90 Pros and cons of telework, as seen from workers and managers. Worker satisfaction is a mixed bag, with a prevalence of positive aspects. The communication, knowledge exchange, and oversight effectiveness are all suffering from teleworking. Image credit: OECD

It goes beyond the loss of control, it is also about loss of serendipity. It is about the casual opportunity to point out something in the middle of a conversation, of motivating colleagues by using body language (such as a handshake or smile). All of this is true in the short-term, but what about in the long run? Will productivity remain constant, or will it start decreasing? Will people adapt to the point where negative perceptions of remote work will fade away? There are, obviously, statistics on telecommuting since millions of people have been doing it for years now. However, this is about people, and jobs, that have only operated in a physical space. The pandemic has imposed certain necessities, such as remote work, which brought to light structural issues because of businesses not being able to predict, plan, and prepare in advance. Hence, the current working processes used, the ones deemed effective when working on-premises, may not be ideal when applied to teleworking. As a matter of fact, this was a recurring theme when I spoke with a number of CEOs a few months ago to discuss the new working landscape deriving from the Covid-19 countermeasures —there is a need to re-think processes. This is not a minor issue, particularly for big companies that operate on an infrastructure made up of processes. This is also a reason why several companies will find the process of re-engineering costly and will go back to the "old" normal as soon as possible.

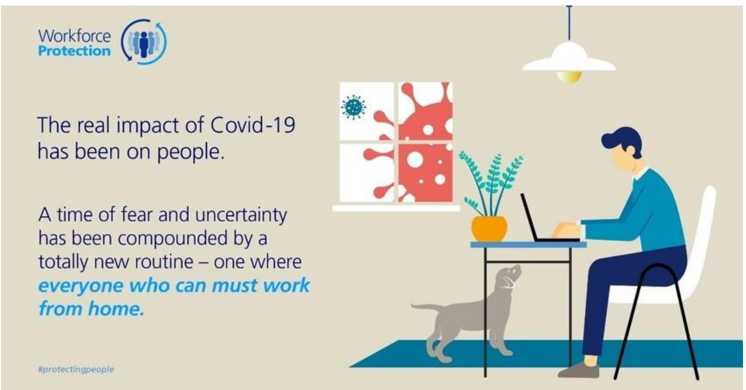


Fig. 91 Everyone who can must work from home. This has been the main message to workforce during COVID-19, with effects that will be lingering throughout this decade. Image credit: WEF - Zurich

- Between businesses that are rooted in the physical space (retail stores, restaurants, transport, hotels, etc.), and those that are already living in the cyberspace (addressed in the previous post), there are plenty of other businesses (such as the entire manufacturing sector) that are rooted in the physical space (the factory). However, a significant portion of the workforce within factories can operate in the cyberspace (administrative processes, customer relations, monitoring processes, etc.). In most of these businesses, the workforce operating such processes have been using computer- assisted tools and, as a matter of fact, we have seen that in response to the pandemic, this workforce shifted to remote working. This is what the WEF calls: Everyone who can must work from home.

However, many companies undertook this shift with numerous reservations— security consideration being an important factor. The physical presence of workers on company premise has provided a protected environment for work in-line with security procedures. Processes have been finely tuned over time to adapt to this working environment. Changing a company's policies and allowing employees to work from remote creates an uncontrollable circumstance, and in turn, resulted in increased stress and anxiety for many CEOs and security heads. On the workers side, working from home eliminated the in-person, real-time technical support that they were accustomed to when in an office. Unlike the technical (software) workforce, the administrative workforce has very little familiarity with the inner workings of the tools they are using. All technical problems are rerouted to a support team which, obviously, is not available in one's personal home. This has brought to the problem of re-skilling the workforce to light, and as a result, several companies have engaged in a retraining program. This ensures employees have a minimum skill-level which will, in turn, increase the overall success and productivity within a company leveraging remote work opportunities. Even something as basic as video conferencing software had to be taught.

Additionally, considering working remotely a stable situation (which turned out to be the case as the pandemic stretched over a year) required companies to recreate a sort of “virtual” company premise— “decentralized cocoons” at the homes of their employees, providing fast, secure, and stable Internet connections. The high-speed internet capabilities were not really dependent on the company, they depended on current network availability. In several cases, there were several options to ensure adequate connectivity, such as using a wireless/VPN network. Numerous companies provided wireless connectivity access via dedicated company smartphone tethering—leveraging private virtual networks to provide secure access to company servers (applications and data—assigning the required devices to employees, such as laptops, smartphones, etc., and then training those workers on security aspects.

Fig. 92 Real-estate in cyberspace is a growing business. A company may use a virtual/cyber "location" to create their office space with the same support that would be available in a physical location (the ones that still makes sense, no heating/air-conditioning needed) ... Image credit: eXpRealty

Beyond providing this basic infrastructural set, companies had to revise processes and identify proper digital channels to leverage for each task (for example, when to use an instant messenger, a common communication area, a videoconference, etc.). In addition, they had to re-evaluate the management of document flow (sharing documents for simultaneous editing capabilities vs generating a process to define ownership for each one), creating mailing lists, authorization check points...

Working on a company premises is regulated by context. For example, most employees arrive at 9 AM every weekday. Working from home provides more flexibility by allowing employees to work, potentially, at odd hours. However, in certain situations a team may need to be on the same schedule, therefore, rules pertaining to working hours will need to be enforced.

To make up for the physical separation, companies have discovered and tested alternative ways to create a team "spirit". For example, setting up specific conference calls for socialization purposes, mediated by digital channels, and one-on-one interactions with supervisors. Increased flexibility in work organization must be complemented by very clear objectives, KPI's, and milestones. This may be easier for certain roles and tasks than others. All of the above are useful guidelines, however, in the long term, companies need to realize that a massively distributed workforce, operating remotely, requires a significantly different work organization and a different set of tools, leading to a new way of working and a new workforce landscape.

In this decade, we are going to see an increased use of virtual office space. This concept has root in the ideas proposed and tested by SecondLife at the turn of the century (SecondLife was launched in 2003). These tests generated a strong interest from the business sector. One of the problems with the SecondLife study was the perception of a "fake" world that eventually discouraged people and businesses after the first wave of enthusiasm. However, we now have enhanced technologies (better in terms of performance, capabilities, and availability of widespread connectivity), and a growing shift from application to data. In other words, rather than having applications to generate and manipulate data, we have data that stimulates the creation of applications. The pandemic, as previously noted, has forced a shift to cyberspace for many industries, wherever possible. This framework highlights the need for development of offices in the cyberspace. The real estate company, eXpRealty, may be a good example as they have several hundred people and need to provide them with offices, meeting rooms, auditoriums, and more, all in cyberspace (take a look at this clip).

I am sure there will be many business opportunities for companies to provide different packages of services for companies to enable them to set up offices in the cyberspace, and this will likely become a very profitable market by the end of this decade.

b) Forces Reshaping Work in this Decade

Fig. 93 The changing relevance of knowledge, the ways knowledge keeps its value, and how this knowledge can be accessed is a major factor in shaping the future of work in this decade. This graphic shows the decreasing half-life of knowledge, from an average of 30 years in the last century to an average of 6 years today. Furthermore, knowledge gained in schools today is not the same knowledge that may be needed in the workplace. As shown in the graphic, 65% of children entering primary school will end up working jobs that do not exist today, and it is difficult to predict what knowledge will be needed for these roles.
Image credit: CNBC - Future of Work Report

The acceleration of the Digital Transformation and the shift in ways of working, in response to the pandemic, cannot be used as a measuring stick for what may happen to work and the workforce in this decade. It is obvious that the pandemic has had a huge impact and will continue to in the short term. However, over a longer period, the changes will depend on other forces. Quite a few companies are waiting for the pandemic to end and plan to rewind the clock and go back to business as usual.

The pandemic has taught us a lesson that companies should change their way of doing business to be prepared for future pandemics. Unfortunately, I do not think this is the way businesses work, nor how humans behave. To put that in perspective, we are quite sure that an eruption of the Vesuvius volcano will happen, yet people are still building houses on its slopes... Likewise for pandemics: we know from historical data that humans have experienced new pandemics, on average, every 100 years (the present one hit right on time!), but a hundred years for a business is a long period of time. If we change the way we work to achieve an advantage that can't be reaped until one-hundred years time, changed that may have some disadvantages in the short term, that will not happen (unless regulation is being enforced, but this is also unlikely since regulators take into account the business landscape. If a regulation will put companies at a competitive disadvantage, they will think twice before enforcing it).

Hence, in discussing this decade Megatrend on the future of work, we should consider the driving forces reshaping the work landscape. We need to take the pandemic into account for impacting and accelerating change, and identify which changes are in-line with previously identified driving forces, and disregard changes that are likely temporary measures in response to COVID-19.

In my opinion, some of the driving forces are:

Distributed knowledge—Human Cloud

- Gig Economy
- Artificial Intelligence Driving Automation
- Distributed knowledge shared by humans and machines

It is obvious that to take effect, these forces need to leverage technology (features, availability, and affordability), and the opposite, that tech evolution strengthen these forces, is also true. Hence the reinforcing cycle that has already started to take shape.

I already addressed the economic, demographic, and environmental (ecological awareness) factors that are shaping, fostering, and constraining the evolution of work in this decade in the first part of the discussion of this Megatrend. Now, I am going to focus on the tech-related forces.

c) Distributed Knowledge - Human Cloud

It is obvious that knowledge is more widely disseminated, and we now have plenty of tools to foster the growth of this knowledge., This starts by recording and sharing the history of improvements (the internet and web made this possible in an efficient way), as well as by making sense out of the distributed knowledge (we are just starting in this area).

Clearly, the "location" of knowledge matters, since it relates to accessibility, credibility, ownership ... and there are many efforts focusing on protection and encapsulation rather than on access and sharing.

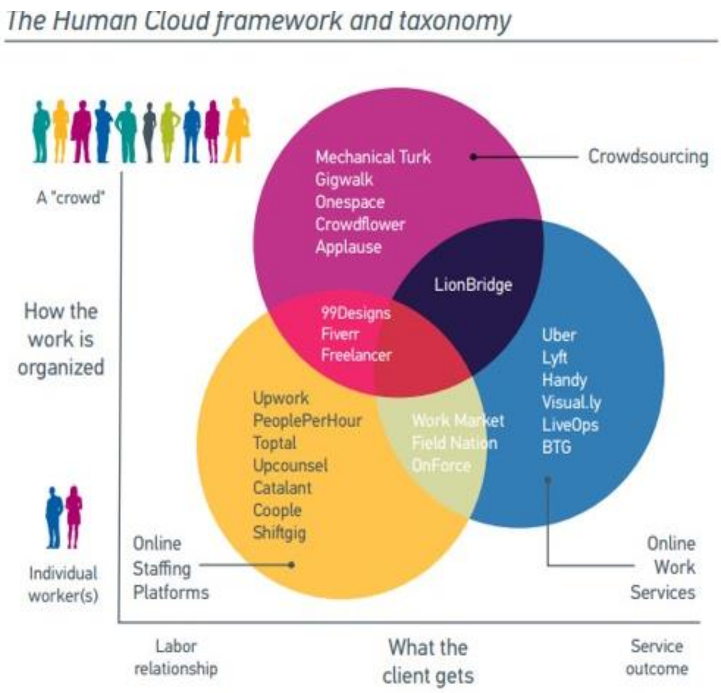


Fig. 94 A nice graphic placing in relation the organization of work, from being based on individuals to being based on a "crowd", with the client relation, from interacting with the labor provider to interacting with a service. Each bubble lists a number of companies in that space. Image credit: Staffing Industry Analysts

Actually, this is nothing new. Human beings as knowledge repositories have been the platform of distributed knowledge for millennia. What has changed more recently is that human distributed knowledge, also addressed more recently with respect to leveraging knowledge such as "the human cloud," has become increasingly accessible as communication among humans has increased its effectiveness (you can connect two "minds" in a matter of seconds, independently from where their "brain container" is located). The adoption of a standard language, such as English, has further improved communication.

The Human Cloud is seen both as an ensemble of distributed knowledge (and skills that sometimes are more important for industry) provided by humans, and as the infrastructure connecting this distributed human knowledge/ensuring access to it. The yearly investment on this infrastructure has reached 80B$, and it is expected to keep growing in the coming years.

Part of the "story" when looking at the human cloud is about mobility of humans (both physically and virtually). Companies are accustomed to determining salaries based on an assumption that employees will work on (their) premise, and in the process, typically take the cost of life in that area into consideration. This approach does not work when considering the human cloud. People keep moving around, so it does not make sense to correlate salary to a specific location. You may have heard of a few companies that are allowing remote work during the pandemic, but that are also imposing wage cuts on the assumption that if you no longer need to live in a particular city/area where an office is located, you can live with a lower salary by moving to an area with lower expenses.

The existence of an accessible Human Cloud will increase competition among workers (at least certain types of workers, particularly in the technical sectors and for all activities that can be delivered "spot"), but will also make competition to access these resources much more intense. Therefore, the need for an effective human cloud infrastructure support is crucial. Another challenge is the ability to sift through and analyzes the Human Cloud of knowledge (and skills) to identify the one that fits best for the need at hand. You don't want to overshoot, and you may not be able to rely on previous choices since knowledge obsolescence is accelerating, as shown in Figure 93.

It is reasonable to expect that Distributed Knowledge and the creation of effective Human Clouds are going to reshape work processes and the workforce, fueling an extended Gig Economy.

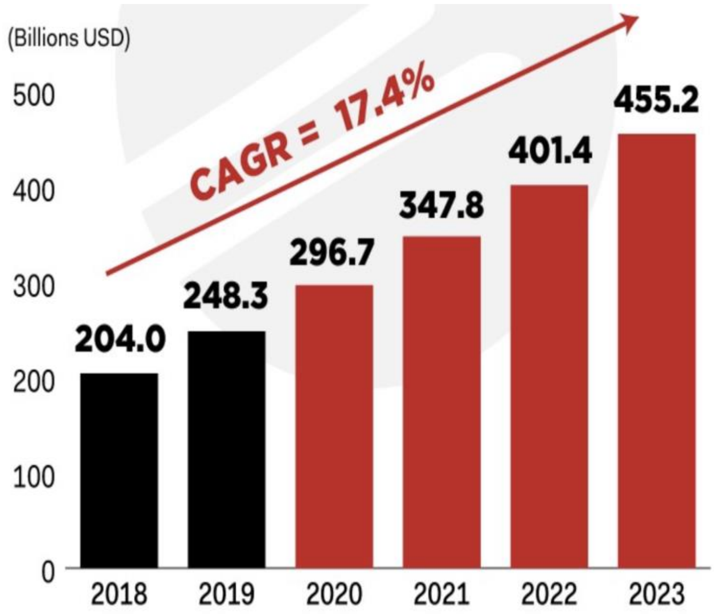


Fig. 95 Gig Economy is expected to grow 17.4% CAGR over the next 3 years, reaching 455 billion dollars in the US. Image credit: Nasscom Insight, data from Statista 2021

d) Gig Economy

The Gig Economy started out as little tasks (often referred to as gigs) and jobs that required very limited skills, such as delivering food in the neighborhood, which also requires very little resources (a bike would suffice), or fixing a rusty bannister ... The person offering the services would complete the task when convenient for their schedule, and can do one thing today, and nothing tomorrow. No obligations beyond that specific task/time require little to no commitment.

Compare this to the (mutual) contractual obligations between an employer and an employee and you immediately perceive the difference. The contractual obligation allows the employer to ensure they can deliver a service by securing the availability of the needed resources (the employees), and in turn, they provide the employee with a continuous wage.

Technology can bridge the two approaches and create platforms that decrease the costs for offering services, help meet demands, and provide access to a pool of resources that, statistically, would ensure continuity of service: all of those with the skill of fixing a rusting bannister can always provide their availability and services, and those in need of a person capable of fixing a rusty bannister, or another task, can connect with someone willing to complete the job. These platforms are the engines of the Gig Economy and each one is usuallyrun by an independent company.

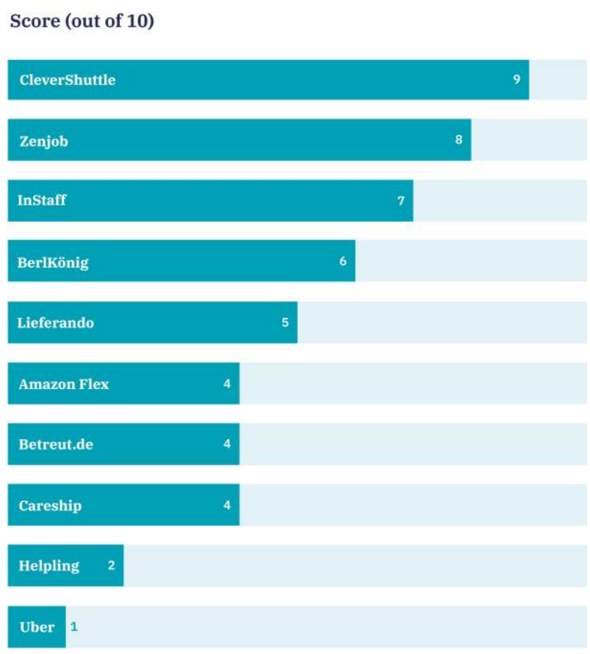


Fig. 96 A list of gig economy platforms/companies operating in Germany ranked according to fairness principles (pay, conditions, obligations, management, representation). Image credit: Fairwork Foundation

Platforms decrease transaction costsand enhance the process for efficiently delivering services. However, this may not be as great as it seems at a first glance! The company creating, operating, and maintaining such a platform can reduce the cost of business, resulting in an increase of qualified candidates offering overlapping services, and decreasing the number of potential customers. In addition, as in any competitive system, the prices for the services are going to decrease, favoring the end-customer. At the same time, alternative opportunities to offer a service (not using the aforementioned platforms) will be extremely limited due to the efficiency provided by the platform (i.e., it will cost much more for the offered service to meet demand). This creates an asymmetrical situation between the company owning/operating the platform and the people using it to offer their services. The company holds all the cards and can end up exploiting the ones that are actually delivering the services. We have witnessed protests claiming (with good reasons in general) exploitation, unfair pay, and being forced to work even when unwell... This is the result of the asymmetry and efficiency provided by the platform. The presence of such an opportunity exceeds demand and leads to a compression of values (wages). This issue has become a sensitive one and organizations such as Fairwork have identified a set of principles and standards to evaluate these platforms (or the sponsoring companies) using parameters such as:

- Fair pay: decent pay, based on the service provided, that should be paid on-time, compensate for all tasks completed, and cover all associated costs;
- Fair conditions: appropriate work conditions should be enforced, decreasing occupational risks (the high competition often enforced by platforms push workers to cut corners and take risks);
- Fair contracts: although there may not be a specific labor contract, access to the platfom and the manner of which the work process is managed (distribution of demand, monitoring of activity, etc.) should be transparent;
- Fair management: decisions affecting workers (method of ranking and assessing performance) should be transparent;
- Fair representation: although the relationship is between the gig worker and the platfom, workers should have the right to self-organize and appeal to decisions taken by the "platform/company."

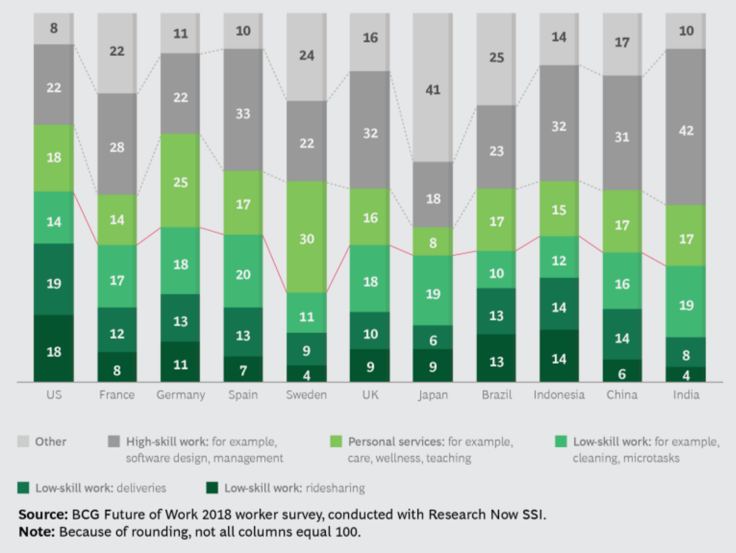


Fig. 97 Growth of freelance work. The Gig Economy is expanding towards higher skill markets and more and more workers are looking into this as a different way of micro-entrepreneurship, providing flexibility and independence. Image credit: BCG Henderson Institute

Working conditions have worsened in several cases, as should be expected when the offer is high and the competition enables increased efficiency at the expense of the "offer", i.e., the gig workers. This is a result of basic economic rules—in every competitive system, the price of a product/service tends to the marginal cost, and in this case, the marginal cost is approaching zero (it costs nothing, but time and energy, to ride a bike and make deliveries). Therefore, some sort of regulation is urgently needed.

The problem is not felt in situations where demand is high, and offer is low. In these cases, the gig workers are the ones that have the upper hand, such as in consultancy areas. Consider how much a company pays for a consulting service provided by a specialized firm— quite a lot, and the more skills required for the consultant, (if there are a limited number of qualified candidates) the more the consulting firm will charge. By leveraging the platforms that were developed, consultants can access the demand directly, and because the connection takes place in the cyberspace, consultants will experience an increased demand, therefore allowing them to increase their rates! This is not the case for pizza deliveries since this service is constrained by a physical location (a gig worker in LA cannot benefit from a demand in San Diego…), thus having a limited demand and a larger number of "riders."

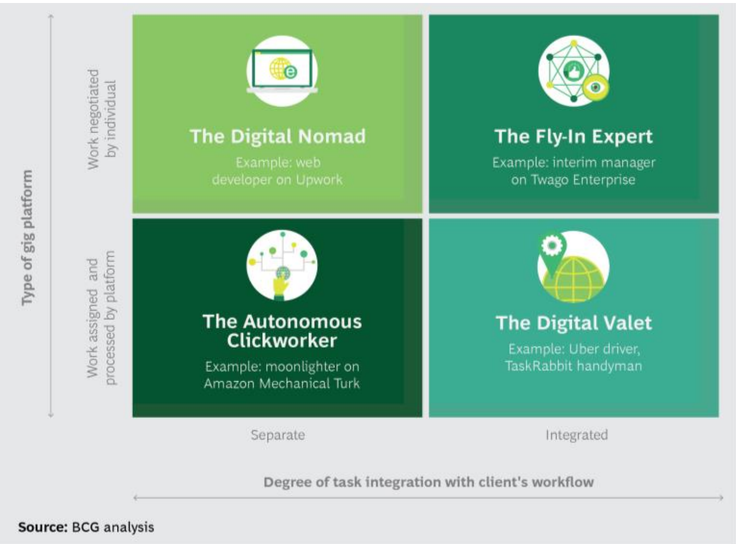


Fig. 98 The four different types of freelance work, identified by the type of platform (platform assigns job versus job negotiated by the individual) and by the relation with the client (separated vs integrated). Image credit: BCG Henderson Institute

Due to the efficiency introduced by the platform, both the consultant and the company servicing the consultant are benefitting: a consultant that would make $200,000 a year as an employee of a consulting firm gets paid around $100 per hour. As a freelance consultant, a person can make at least 3 times as much per hour. From the perspective of the one seeking the consulting service, it will seem like their cost is slashed. For example, rather than paying the consulting firm around $1,500to identify and provide a candidate, they will pay the consultant $300 directly. These numbers are based on Roberto Saracco's actual experience in providing consultancy as freelance over several platforms. Figures change quite a bit depending on the type of consulting, but the concept is clear. Therefore, both the freelance consultant and those using their services are gaining. Who is losing? —The old- style consulting companies that are seeing their way of doing business superseded by the shift to the Gig Economy. As a matter of fact, most consulting companies have started offering platform-based services as a new business proposition, causing the "old" ways to become inefficient and obsolete.

There is now a broad spectrum of working types in the gig economy as shown in figure 98, and this trend will continue throughout the next decade.

There are and will be platforms that manage demand and, based on policies and resource availability, connect demand to offer. In other words, sending demands to one of the available resources (a freelance worker). The worker may have no visibility on the demand landscape, they just respond to a request. This is the case of the Amazon Mechanical Turk, a platform that manages, in principle, any type of offer connecting it to any type of demand (a work marketplace). It looks similar to the Amazon marketplace where companies offer their product and have no control over the demand. They are just told that someone is asking for their product and then they will deliver. Uber and ride-sharing platforms create a similar situation in which a service (transportation) is allocated by the platform to provide a specific demand (based on the platform's criteria including the shortest pick-up time and the rating of the drivers in the area). In the second case, like in the previous one, the connection between offer and demand is still decided by the platform, however, it is fully integrated whereas in the former case of the Mechanical Turk, each connection is self-standing (no need for coordinating the offer).

Other platforms support negotiations of the work by those who are controlling the offers. Hence, these platforms aggregate the demand side and provide the offer side visibility on the demand. This allows them to establish the connection and negotiate the deal. An example of a "separate" offer is the one provided by Upwork—the offer side can "show" their wares (skills and services that can be provided), and the demand side can contact candidates to start a negotiation. Other platforms support negotiations, but do so in an integrated way, such as Twago. In this case, the demand (the customer) explains their needs, and the platform identifies possible offers that will then be negotiated directly by the customers and freelancers involved.

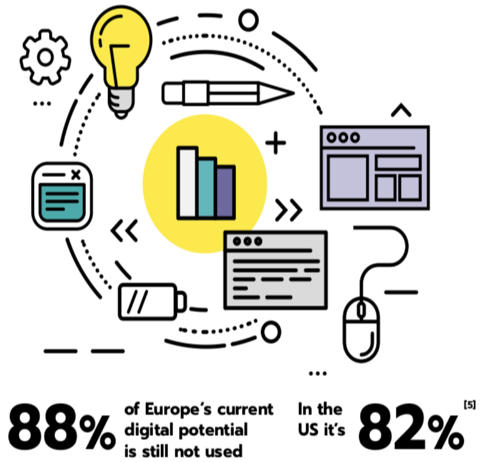


Fig. 99 demonstrates the multitude of unexploited opportunities in the digital space. Image credit: Talent Alpha

As explained, the Gig Economy is undergoing a significant evolution, and this is expected to characterize the work landscape in this decade (and the following ones). The dramatic effects on work processes, the workforce, and on work environments from this evolution are evident.

In addition, it is important to note that the expansion of the Gig Economy is providing a multitude of people access to services provided by people that may otherwise have had no way to offer their skills. This is true both for the ones that are using the cyberspace to offer their skills locally/physically, and for those that can provide a digital service. For example, a software developer in India can their skills to companies all around the world based on spot-demand, and for people offering their services locally, companies such as Go-Jek, with a team of over 200 engineers, provide, maintain, and operates platforms managing 100 million orders per month and coordinating over 2 million drivers (in Indonesia). The amazing thing is that it has basically created 2,000,000 + new jobs within 10 years (the company was founded in 2009). By slashing transition cost, these platforms enable a very effective connection for offers and demands and increases marketplace use, a crucial aspect in emerging economies.

At the same time, the evolution of the Gig Economy to a high skill market molded single individuals into entrepreneurs. This is a very important evolution that is going to change, in a dramatic way, the work landscape in developed countries, which corresponds to the aforementioned evolution in distributed knowledge and human cloud. In a way, we could say that the present evolution of the Gig Economy is a response (enabled by technology) to the increasing knowledge distribution, rapid obsolescence, and human specialization requiring access to a dynamically evolving human cloud.

e) Artificial intelligence Driving Automation

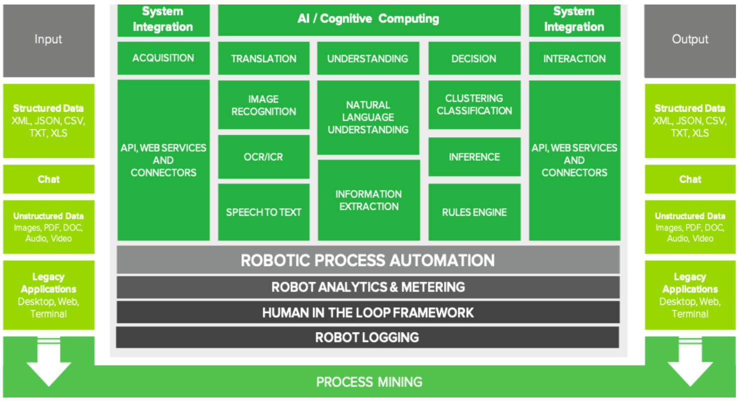


Fig. 100 provides a general framework for Intelligent Process Automation layered on Robotic Process Automation. Artificial Intelligence (AI) supports specific functionalities and creates an emerging, cognitive intelligence. This image outlines a comprehensive architecture identifying the various components that are embedded in AI. Image credit: Reply

Many industries have adopted production and process automation using robots—Robot Process Automation (RPA), and document flow (process automation). This has had a significant impact on the workforce, both in terms of downsizing and in terms of required skills. Activities shifted from blue collars to robots, and from white collars , or clerks, to computers and data bases. There is an increased need for those with skills interacting with robots and computers which require specific experience and training).

Within the last decade, AI became a service located in specific AI service providers/data-service centers or embedded into the tools used by industries (smart robots, smart applications...). In this decade, AI is expected to take a seat in the control room of companies, being updated and capable of learning by leveraging multiple data streams, most of which are internally generated by employees, machines, and/or processes. This is known as IPA: Intelligent Process Automation.

The reality of today's business world, and even more so tomorrow, is an unmanageable abundance of data. Everything is either creating data or being "substituted" by data (digitally mirrored and operated through both the physical and digital objects). Digital Transformation is at the core of this trend. However, analyses show that only a fraction of the digital potential offered by this world of data is actually being exploited. According to "7 drivers shaping the future of work", report by Talent Alpha,88% of the digital potential in Europe is not used, and the US, with 82% of their digital potential unused, is not much better.

One fundamental issue is that there is just too much data, and the sheer volume is beyond human capabilities. Hence the need to turn to AI, not for replacing "human intelligence," but to do something that humans cannot do and provide intelligence that can be combined with human intelligence. This is addressed in the next section.

By using AI to continuously explore the data landscape, it is possible to extract and contextualize meaning in ways that have not been possible before (also due to the amount of data available today that was previously inaccessible).

For example. consider a self-driving car. The car must harvest internal and external data and make sense of information and to take action/make decisions.

In cases like this, there are plenty of sensors as demonstrated in figure 102:

- Radar, for obstacle detection
- LIDAR and Cameras, for creating a map of the surrounding environment
- Ultrasonic, for near field obstacle detection
- GNSS (Global Navigation Satellite System) and IMU (Inertial Measurement Unit) to pinpoint the position of the vehicle.

Fig. 101 is a snapshot on the amount of data produced by the sensors in a self-driving car. The total amount is impressive (with the lion's share played by the video cameras): a one-hour drive produces between 1.4 and 19 TB of data. Image credit: Tuxera

CAR AUTOMATION SENSORS & DATA VOLUMES

Sensor type	Quantity	Data generated
Radar	4–6	0.1–15 Mbit/s
LIDAR	1–5	20–100 Mbit/s
Camera	6–12	500–3,500 Mbit/s
Ultrasonic	8–16	<0.01 Mbit/s
Vehicle motion, GNSS, IMU	-	<0.1 Mbit/s
TOTAL ESTIMATED BANDWIDTH		
3 Gbit/s (~1.4TB/h) to 40 Gbit/s (~19 TB/h)		

The above sensors are just for providing context awareness. In addition, the self-driving car control unit needs to have a digital model of the car describing its shape, volume, and performances, and it needs to receive data from the various active parts (such as the engine, wheels, brakes, suspensions, etc.) to understand the slate of possible actions and outcomes.

As indicated in figure 101, the amount of data is huge. Most of this data is time-sensitive and will lose value overtime (once the car has left an area, all the relative data previously collected is no longer of use). However, combining the acquired data with the resulting actions taken by the car can provide further data to enhance the experience, hence allowing the car, in particular the auto-drive system, to learn. This learning can be shared with other cars, thus increasing the speed of learning and preventing hazards actions in the event a car faces a similar situation for the first time.

What goes for self-driving cars goes for airplanes, trains, ... and of course it goes for robots in a manufacturing plan.

In the case of self-driving cars, most of the decisions are local—taken by the car, in the car. As a result, there is a very limited number of shared decisions between vehicles and also because a self-driving car cannot assume, otherwise it would be wrong! Cars would need to communicate with other cars, share data and decisions, and be notified of actions taken. More importantly, there are parameters that are completely unobtainable from a system of wide analysis possibility such as pedestrians, bikers, dogs, etc. It is obvious that a car cannot communicate with many of the potential obstacles, therefore it needs to make some assumptions in a manner to play it safe. In the case of airplanes, the overall system is much more controllable (with the exception of taxiing, but here there are some studies to do that), and there are systems for autonomous aircraft to aircraft communications such as the collision avoidance system (TCAS).

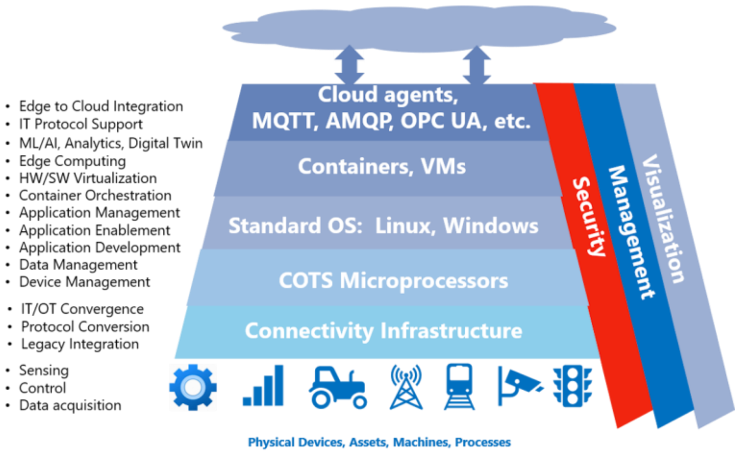


Fig. 102 Schematics showing a layered architecture for automation in a factory/industry environment based on IIOT. At the lowest layer is the connectivity infrastructure, LTE or (private) 5G, then data processing and integration through commercial off-the-shelf computers (COTS), operating systems, Virtual Machines and Containers. The upper layer is connected through a variety of protocols to the Cloud/Edge where AI takes over the data analysis and learning. Image credit: ARC Advisory Group

In an industrial environment—on the shop floor, in assembly lines, in warehouses —there is a growing flow of data, courtesy of Industrial IoT (IIoT), which can easily exceed the ones produced by self-driving cars.
This data is being used for:

- *descriptive analysis:* providing info on what is happening and what happened (inventory, failures, output demand, etc.)

- *predictive analysis*: providing info on possible malfunctions, output requests by single machines over the coming weeks, resources including workforce needed in the coming weeks...

- *prescriptive analysis*: providing info on when to activate procurement, and where to procure, activation of pre-emptive maintenance, different allocation of resources, fine tuning of processes...

In all three areas, there is a growing use of Artificial Intelligence to support automation of the various processes involved.

Notice that the trend on the shop floor (and in manufacturing in general, along with the Industry 4.0 paradigm) is to analyze the whole picture and act directly or indirectly accordingly. This sometimes involves suppliers and dealers (up to the user).
The intelligence needed is not the one localized in a machine (robot), in a plant, in a supplier... rather it is the emerging intelligence deriving from the cooperation of all "intelligent components." This is the big challenge ahead for the industry (what Industry 4.0 is all about), and in this decade, we can expect increased automation at the global level and throughout the entire value chain. The starting point, obviously, is the emerging intelligence on the shop floor, in warehouses, and in the supply and delivery chain. These separate intelligences (each one with a specific "owner") will cooperate, resulting in a global emerging intelligence.

This clearly has an impact on the workforce since automation is shifting control activity from humans to machines (to the Cloud and Edge). In the past decade, we have seen affects from automation at the micro scale—a robot replacing a worker/a team of workers. Now, we are facing process automation which will simply render several activities unnecessary. The use of Digital Twins is further accelerating the shift to the cyberspace and accelerating process automation.

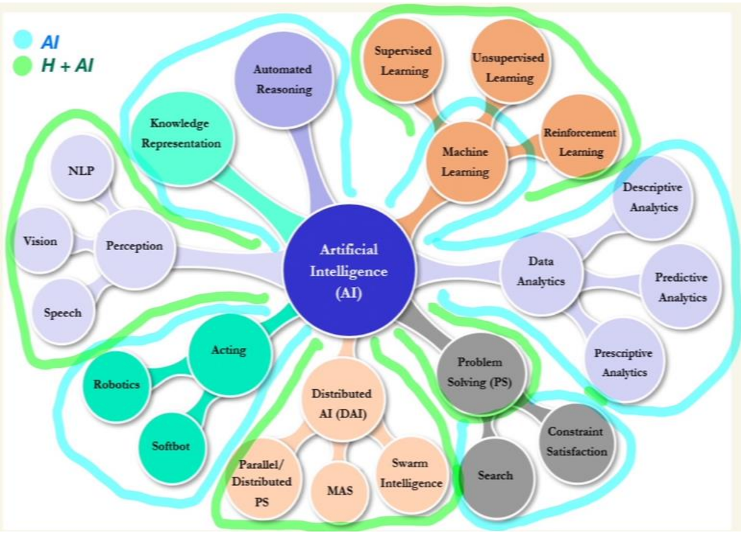


Fig. 103 shows the broad spectrum covered by AI. Marked in blue are the areas where AI is most likely to take the upper hand in this decade in the workplace, and items in green highlight where cooperation between human and AI would result in human augmentation. Loss of jobs due to AI adoption can be expected in the blue areas and increased productivity through human-AI cooperation in the green areas. Image credit: LaptrinhX, marks by me

f) Distributed Knowledge Shared by Humans and Machines

Artificial intelligence is becoming increasingly pervasive and able to pick up a number of activities that, until this point, have been carried out by us (humans). This is the "automation" part of the story, and automation is no longer restricted to manual activities. AI is expanding to soft, mental activities. In other words, we are moving from muscle automation to intelligence automation.

As shown in figure 104, AI covers many areas: in some, the prevalence of AI over human intelligence is evident, in others, we see an advantage in a cooperation among the two.

Prevalence:

- Machine control: The speed required in controlling the operation of robots or for softbots is impossible using human intelligence. The human may define the operation framework and impose boundaries that impose a stop to the machine if reached, but in normal operations, AI is at work.
- Searching and evaluating is beyond human capability once the data set exceeds a certain volume, and this is more and more the case. In these situations, humans can provide the search criteria and the boundary conditions, but the actual search can only be performed through AI. A "human-google" is simply impossible.
- Data analytics (descriptive, predictive, and prescriptive) are also beyond human capabilities due to the large volumes involved. Again, humans can define targets (such as the goal of the analytics) but must rely on AI for actual data crunching.
- Machine Learning (ML), by definition, is in the realm of AI. However, as noted in the graphic, ML can be leveraged to contribute to human learning and vice versa. Humans, by identifying contexts and data sets, can steer the machine learning. Notice that the recent use of GAN's is decreasing the human role in steering ML. However, the definitions of "what should be learned" remain as a role of humans.

- Automated reasoning and knowledge representation (in machine readable form) are clearly in the specific field of AI.

Cooperation:

- Natural Language Processing (NPL): Vision (image and context recognition) and Speech (voice recognition) are contributing to context perception (meaning, emotion detection, feelings, etc.). These are areas where humans show greater capability "in the small." In other words, in single instances humans are far better in converting the flow of "data" into a perception of "what is going on." However, “in the large," humans are limited in their ability of processing. For example, a single person can only understand a few languages whereas AI can process hundreds of them. A human can follow a very limited number of parallel conversations whereas signal processing can separate a flow of voices into streams, and a NPL application can be instantiated as many times as needed to process all streams in parallel. In addition, vision acuity of humans is limited whereas the one of machines can be expanded over the human limits. In this decade, at least, cooperation of human and machines (with machines performing bulk work and humans finely tuning results) lead to the most optimal and accurate results. Furthermore, the capabilities of machines to learn voice-based and visual communication cues improve the possibility of collaboration with humans. Chatbots are an example of such an application.
- Problem solving is an area that often requires stepping out of the box and leveraging creative thinking—something that human (experts) are usually better at than machines. At the same time, the evaluation of potential solutions and of all the implications/requirements may depend on in-depth analyses and a lot of data crunching (such as cost evaluation, supply chain re-engineering, weak effects impacts, etc.), which are tasks that machines handle better and faster. Hence a tight collaboration between humans exploring the big picture and machines working out the details and performing simulation is likely to be the way to go for this decade (and the following ones). However, humans will need to learn to use "machine intelligence."
- Learning (supervised, unsupervised, reinforced) is a human characteristic, but AI has made huge progress in this area, becoming faster and faster. For example, it takes years for a human to become a chess master, and only very few can/will, whereas a machine can become as proficient as a master in 24 hours. However, AI can be used by humans to accelerate their learning processes and most definitely can be used to flank and complement their knowledge. Learning knowledge is increasingly associated with learning how to access (and make sense of) knowledge. This, and future decades, will be characterized by the augmentation of human knowledge through machine.
- Distributed Intelligence (or DAI—Distributed AI), Parallel/Distributed Parameter Servers, Multi Agent Systems, and Swarm Intelligence are technologies in rapid evolution to deliver enhanced AI. Distributed Intelligence is also a characteristic of human societies and communication infrastructures, digitalization of knowledge, and knowledge organizations (such as Universities, IEEE, research centers, Open research frameworks, etc.) have increasingly leveraged distributed intelligence. The difference from the past is that now, and in the future, it becomes possible to have a distribution of intelligence involving machines and humans (as intelligent nodes). Up until a few years ago, machines were "repository" (not active) nodes of intelligence. Technology has always played a role in growth and leveraging distributed intelligence (for example, think about the invention of writing, books, printed press, mail services, telecommunications, internet, etc.)

In assessing the impact on work and workforces of distributed knowledge (and intelligence) shared by humans and machines, we should also consider the differences between the two (the idea that artificial intelligence is a replica of the human one has lost appeal, we are now looking at two different, although valuable, forms of intelligence):

- Creativity, serendipity: on the human side, these characteristics are not just important, they seem to be an integral component of human intelligence. For example, the capability of imagination and thinking outside of the box. A machines' intelligence is lacking such characteristics, although we see results of AI that are similar results of human creativity, such as music composition, paintings, and even poetry.
- Creativity as self-fulfillment, self-motivation: on the human side, we see that creativity is leading to more creativity through a process of self-appreciation (pleasure of having done something). This is completely missing in machines (an algorithm is not "happy" nor does it feel good after having achieved a result).
- Cost: intelligence is engrained in humans from birth and keeps "growing," but it does not cost anything. On the other hand, the costs associated with the growth of intelligence include time, investment in learning, and exposure to specific experiences. Human intelligence tends to grow asymptotically, but after a while, each further tiny increase requires more and more effort. On the machine side, AI incurs high upstart costs, but then it runs basically for free. Creating an artificial intelligent algorithm is quite complex and the cost can vary significantly, depending on the quality of data available and several other factors. In this decade, the cost is likely to decrease, and more and more companies will be able to develop their own "local" intelligence. Bringing together and aggregating several intelligences will remain a research endeavor for a while, something that has been being addressed in the FDC Digital Reality Initiative throughout 2021.

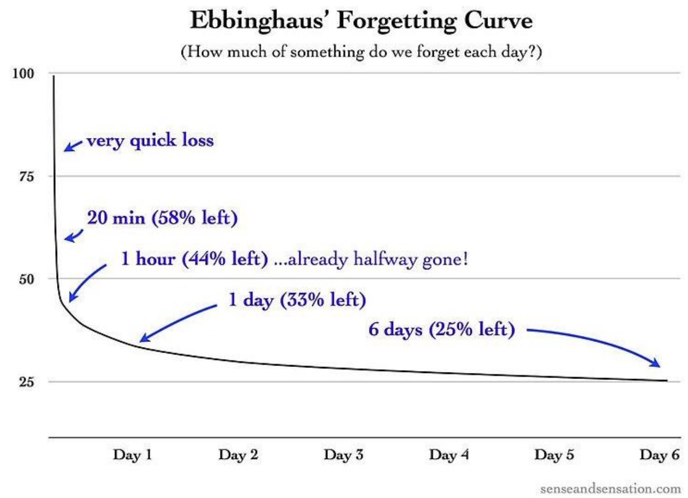


Fig. 104 Represents the Ebbinghaus "forgetting curve." We tend to quickly forget what we are and have learned, halving the retention after an hour, and retaining just one-fourth after a week. Image credit: senseandsensation.com

- Permanence of knowledge and intelligence: human intelligence is tied to a specific person. Moving it from that person to another one takes a lot of time, and the results are not guaranteed. On the contrary, moving intelligence from one machine to another is quite straightforward. Transferring human knowledge is time-consuming if attempted directly, from one person to another. It depends on the existing gap of knowledge between the persons and on how receptive the receiving people can be), much more effective if it is done through a medium (the first person writes down the knowledge in a book, and other people can read that book to acquire the knowledge), but still quite time consuming (both in writing and reading/learning). Also, notice that not all knowledge can be transferred through a medium. You can read an entire encyclopedia on how to ride a bike, but you will discover that you cannot actually learn to ride a bike unless you try it over and over.
- Another aspect of human knowledge is that over time we forget ... In the case of machines, the transfer of knowledge is easy, and machines don't forget… The distribution of intelligence

and knowledge among human and machines can also be used as a continuous refresher of a human's memory, increasing intellectual performances, and, in a way, augmenting human memory.

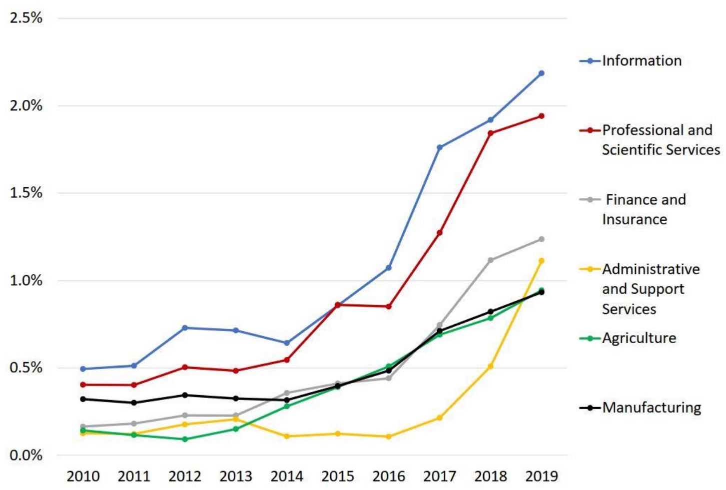


Fig. 105 Demand for AI skills across industries. Notice the increased growth of demand and how it is accelerating. Notable the acceleration in the administrative/support services sector. Image credit: Liudmila Alekseeva et al. The demand for AI skills in the labour market. VoxEU

g) Working with Smart Machines

From what I have discussed, it is obvious that in this decade work will be intertwined more and more with intelligent machines (Machines used to include both hard and soft robot-like applications).

As pointed out in previous sections, AI extends the applicability of automation, and in doing so, some jobs are lost. At the same time, the growing use of AI stimulates growth of jobs in companies providing AI-based systems, and companies using them are on the quest for AI skills (see figure 105 demonstrating the increasing demand for AI skills in several industry sectors within the US).

However, most of the impacts from AI will be felt in the way work is performed, and mostly by high-skill jobs (the ones that, so far, have not been affected by automation).

First, look at the way work changed because of AI and the Digital Transformation. Digital Transformation fuels AI and the integration of AI into work processes. For example, consider the evolution of work in the manufacturing industry.

Today, we have plenty of robots on the shop floor (in warehouses and in the supply/delivery chain). Each robot has a certain level of autonomy that will increase over the coming years. Interaction with blue collars is taking place at the "machine level." There are meters to be read, levers to be pulled, buttons to be pushed, dials to be turned… (figure 106-1)

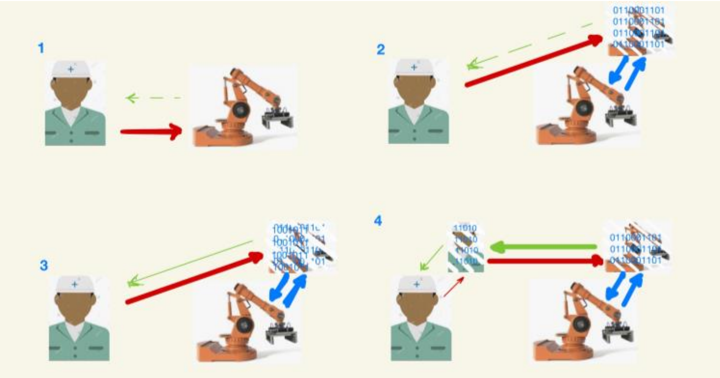


Fig. 106 Expected evolution of automation involving Digital Twins. 1. The human worker controls the machine and looks at how the machine operates (dashed green line). 2. The machine has a Digital Twin (DT), and the human workers interact with the machine via the DT. Using AR, the human can explore the DT. 3. The machine's DT is an active component of the machine and manages the interaction with the human worker (solid green line). 4. The human worker is also associated with a DT, and this DT interacts with the machine's DT

What we are seeing is that machines are progressively equipped with a Digital Twin that models their behavior, mirrors their status (DT at stage III), and progressively participates in the delivery of functionality (DT at stage IV). By the end of this decade, we will likely see the DT cooperating with other DTs on the shop floor and beyond (DT at stage V).

Blue collars can interact with the DT, since this can provide more information on the status of the machine. The data provided by the machine (through shadowing, ensuring a real-time mirroring of the status of the machine) can be interpreted using AI to create a meaningful interpretation of what is going on. For example, a meter indicating the temperature inside a component of the machine (that was read by the blue collar in case 1) can now be correlated by AI to other parameters, resulting in a situation awareness that can be much more meaningful to the blue collar operating the machine. The interaction with the DT can occur via normal screen reporting images and text messages, or, even better, it can be provided via AR goggles that let the blue-collar look "inside" the machine to "see" both the temperature and the potential impact on other components. This is represented as case 2 in the drawing. Notice the green dashed line indicates that the initiative relies on the blue collar and there is not an interaction from the machine (nor DT), but this results from the proactivity on the human side. Also, the same digital twin can be inspected by a white collar, like a designer, to verify the actual behavior of a product using VR (since the white collar will not be co-located with the machine).

A more advanced situation occurs when, as in case 3, the DT reaches stage IV. At this point some of the functionality of the machine can actually be implemented (co-implemented) by the DT, which will now autonomously interact with the blue (or white) collar (solid green line) when the need arises.

Further down the line, by the end of this decade, many workers will have their own Personal Digital Twin (PDT). In this case (case 4 in the graphic), the interaction may occur between the machine DT and the worker PDT, which in turn will convert the information into a personalized manner to maximize the effectiveness of the interaction. As a trivial example, two workers accessing the same machine could get the information in two different languages if one is an Italian worker and the other a Korean one. For example, if the machine is being used in an Italian factory but was produced by a South Korean company. The same event may require the notification to both the user (Italian) and producer (Korean) for different purposes. For example, the user will need to be notified of ongoing fine tunings that will increase the yield so that more pieces will be produced in the next 24 hours, and the producer is notified of the increasing yield resulting from that fine tuning. The fine tuning, and the decision on who should be informed, is driven by AI. The actual flow of information is the result of adaptation taking place in the PDTs.

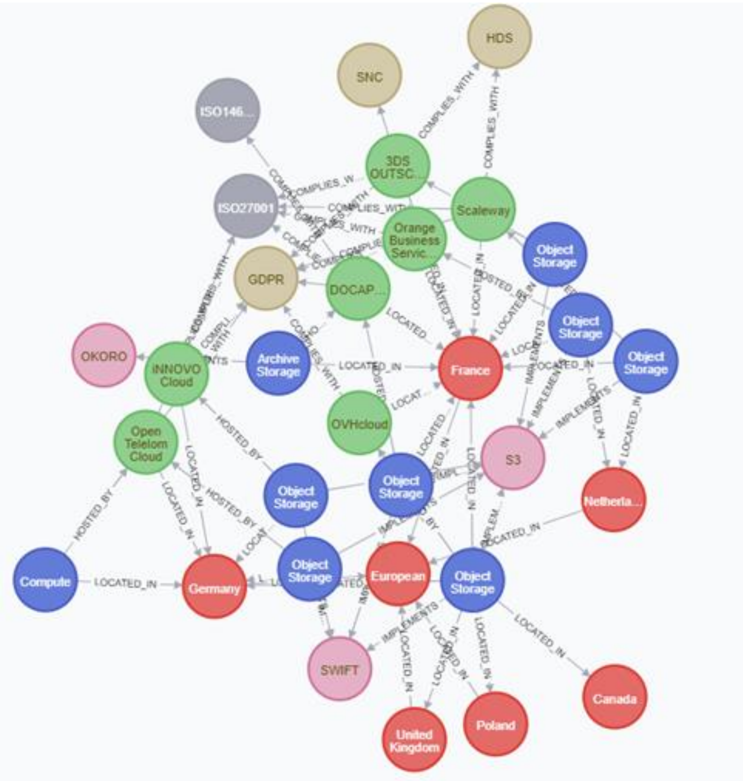


Fig. 107 A schematic representation of a multi-cloud system, with locations in several Countries, offering object-storage services in line with [Gaia-X architecture](). Image credit: Pierre Gronlier, OVH Cloud

Although this example is a trivial one, it helps in imaging how much the working environment will change in this decade, and how much more interconnected the various players will be. This introduces the concept of open data, which is a double-edge sword. On one hand, open data increases the value of data by bringing in more players that can invest and create services, but on the other hand, the protection of data becomes trickier.

Whereas today a factory is a closed environment (controlled, with well-defined processes), and it is clear who has access (and responsibility) to what, in the future, machines and humans will be sharing responsibility through data, and this data can be visible to third parties, such as the manufacturer. Notice that today we are seeing this happening (but may not be perceiving it) when using an app on our smartphone or PC. The producer of that app most likely will gain information on the way we are using it and possible problems. This is (I hope) for improving the app performances and fixing bugs, yet it opens the door to unexpected side effects.

Industry 4.0 is facing these kinds of issues, such as healthcare with personal data (often shared with a number of players such as doctors, hospitals, pharma, health institutions, etc.) is another point in case. Workers will need to understand the broader implications of their activities.

Work is going on within the European Union to define a comprehensive architecture for data management (sharing, protection, ownership, etc.) based on a distributed cloud and a federated data infrastructure—Gaia-X. It now involves hundreds of European and non-European companies and is being "tested" through a number of use cases, including manufacturing and healthcare.

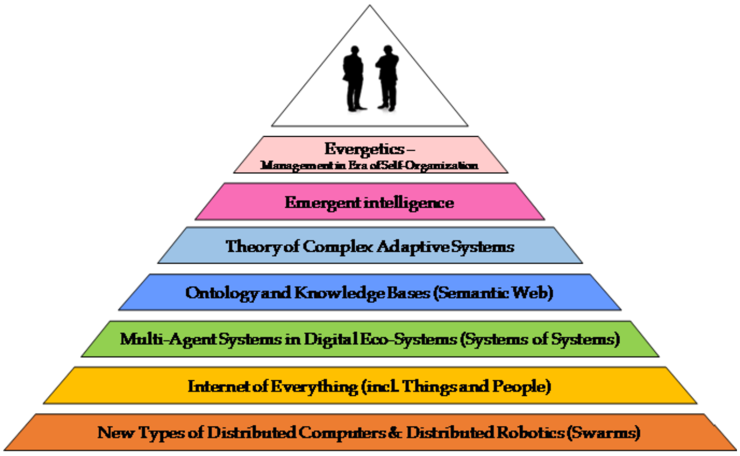


Fig. 108 From Digital Manufacturing to Digital Society—The various layers composing a Digital Society. At the bottom, enabling infrastructure, distributed computing and Robotic Swarms, Internet of everything to include Things and People, Digital Ecosystems (whose players interact with one another via Agents), a reference model for data (ontology and semantics), organization through theory of complex systems giving rise to an emerging global intelligence, and at the top, a self-organizing management. Image credit: P. Skobelev and Borovik S. Yu.

h) Working in a Smart Environment

It is well known that human societies progress through a continuous interaction among minds (people) and resources. Increasing one or the other, or both, without an effective interaction leads nowhere.

Therefore, humans are more than used to exploiting distributed intelligence—the one present in other humans in the group. Actually, people were/are used to "harvesting" intelligence from animals. For example: by looking at their behavior, they could infer possible dangers ahead.

Over the past century, we have learned to get information from a variety of sensors, and by processing the data, we have been able to become smarter. As these sensors become more sophisticated, they provide better data (covering more and more aspects of the real world), but they also have become increasingly difficult to interpret (think about the data provided by sensors in a car, or in an airplane: it would be impossible to make use of the data they provide in real-time—we rely on computers to harvest and process them). This has opened the door to interaction with computers to retrieve and make sense of information/knowledge. We have moved from using computers because they are fast and can react in real-time, to using computers since they can correlate a huge quantity of data and make sense of the data. We are becoming increasingly reliant on computers (AI) because they can make sense out of data and evaluate the best course of action in each situation. In other words, because they have become "intelligent," more and more computers (and devices embedding computers) are becoming autonomous and making decisions based on their perception of the context (context-aware) and on the goals that have been defined.

Now, when you have several autonomous systems and each system is context- aware, you have a situation where the action of one system affects the context, and therefore influences the actions of the other systems in that context (not necessarily by direct interaction, but through change in the context). Humans are autonomous systems, and as such, we use context awareness (quite often) to tune our behavior. In my opinion, most of our lives are based on context awareness and adaptation—only a minimal part is based on explicit interactions.

Fig. 109 People walking in a crowd automatically adjust their movement based on the context. Most people will tend to occupy the central space so that in a station, as shown in this photo, people getting out of the train will walk in the central part of the corridor, forcing people moving towards trains to walk on the sides. This is an example of a swarm behavior/intelligence. Image credit: DNYUZ

Think about walking on a pedestrian road. You are among hundreds of other people, moving in a seemingly random direction (at least this is what I feel sometimes...). You never stop to ask the other person what their plans are so that you can avoid bumping into each other. Nor are others asking you, yet, seamlessly, we manage to go our way without colliding into others (well, most of the time…). This is what is known as swarm intelligence. The behavior of each participant in the swarm affects the behaviors of others, and in turn, this creates an emergent behavior (intelligence) of the swarm. This also applies to knowledge (and culture): by living in a certain environment, you absorb the knowledge and culture at the core of that environment's societal behavior (by living side-to-side with a mathematician, you are not going to "learn" differential equation by proximity, but over time, you learn to "think" in a certain way...). This is also one of the reasons why remote work is not the same as operating in the same physical space, and both companies and workers pointed this out during the lockdown we have experienced during the Covid-19 pandemic. The smart of the crowd, of the swarm, is lost when proximity is lost.

Fig. 110 The Baxter co-bot has been designed with some anthropomorphic traits —a screen is used as a head to convey a sense of attention, emotion, etc. Image credit: Rethink Robotics

In this decade, workers are going to make higher use of telework, but companies will need to find ways to restore the swarm intelligence. The evolution of collaborative tools has increased rapidly in response to the pandemic, and quite a few have tried virtual spaces. So far, nothing has emerged as being capable of restoring the benefits of proximity, but we should get closer by the end of this decade. VR, for example, can potentially play a significant role providing more credible virtual presence in a community, but we are not there yet (not even close).

This seamless influence in a crowd/team so far is not available among people and machines. People today experience a gap between themselves and machines. Co-bots are being designed to operate seamlessly with workers, some are even providing anthropomorphic traits to robots (like Baxter in figure 110). The use of voice interaction is surely going to increase the effectiveness of interactions. The use of AI and

NLP, along with the capability of distinguishing various streams of speech (as humans do, focusing on a specific conversation out of many), will further improve seamless interactions.

The availability of a pervasive, high-bandwidth communication infrastructure is enabling seamless connections. Local intelligence (both machines and humans) has created a swarm in the cyberspace and are providing local intelligence with the option to become augmented by accessing the emerging intelligence of the swarm. "Seamless" is the keyword for an effective smart ambient: people should not perceive an interface, they should just "live and act" in a context, and the smartness of the context is increasing intelligence to each person (and machine). An example of "swarm intelligence" is provided by Unanimous AI. Through software, integrated with AI, Unanimous AI is leveraging the distributed intelligence of a crowd and complementing it with the intelligence of machines.

Fig. 111 A screenshot of the Swarm Intelligence interface. Each participant contributes to the total intelligence, including the ones generated by machines or autonomously by the system.
Image credit: Unanimous AI

For example, general practitioners can interact with Unanimous AI Swarm Intelligence and share their experience or formulate questions. They can interact via voice or through a screen (see figure 111), and the system is customized to fit the needs of different healthcare practitioners. The long-term view would include a presence of tendrils of the swarm, in the doctor's office, to pick up all conversations, record all exams and their results, pick up the voice of the patient, etc. None of this is currently done as connection to the system requires an explicit action by the doctor, which also creates and highlights privacy issues. The Swarms collect and cross-checks all of the data and autonomously peruses the thousands of medical articles in medical journals to cross reference drugs and their effects as tested in labs and experienced in the field. This knowledge, and intelligence, is made available to doctors.

The approach to emerging intelligence via a swarm can be applied in many different scenarios. I feel we are going to see plenty of it in many areas, transforming the workplace and the way of working by the end of this decade.

23. Conclusions

The future has not been written yet—it will happen day by day. Hence, all these Megatrends are to be taken with a grain of salt. Some of these may prove to be too ambitious, or quite simply the cultural and economical landscape will no longer be conducive to their realization. The economic resources that will be needed to recover from the pandemic losses may limit the resources available for innovation in certain areas, but may increase innovation efforts in others. Others may actually be implemented well before the end of this decade. The current pandemic has created a disruption that has shifted focus, needs, and funds in ways that were unexpected in 2019. It may turn out that the pandemic effects will be transient and life, and roadmaps, will be restored as if nothing happened (I don't think so).

The aim in presenting these Megatrends is to stimulate discussion. Quite a bit occurred when I presented the various chunks in a series of posts on the FDC website. I hope that having collected them all into a single document may help in reasoning about the forecasts and stimulate new ideas.

In the Digital Reality Initiative, we are going to address a number of the topics mentioned in this ebook, particularly the ones related, or influenced by, artificial intelligence. Others are being addressed in the many IEEE Societies that, every single day, bring together thousands of engineers from academia and industry that are building the future, for all of us—a future that each one of us has the responsibility of shaping.

The first step is imagining what it could be.

Appendix - Technological Legacies From the Last Decade

To put the discussed Megatrends into a perspective of the legacy they can leave to the subsequent decades, it might be worth looking back at the last decade to consider what happened, from a technology point of view, that left a lasting imprint on the current decade:

- The first iPad was released on April 3rd, 2010. I still remember Steve Jobs' presentation promising that "it will feel like holding the Internet in your hand and it will change the way we will look at the web from there on". It turned out he was right;
- Last decade was the one that saw the shift from 3G to 4G. It took ten years to complete (it is not yet fully completed, but we can say that 4G is now the "norm"). That increased the download speed from 1.5Mbps to 15Mbps, 10 times the previous speed. In other words, what took 5 hours to download could now be done in less than one minute. Who benefitted from this shift? Clearly all of us, as users, as well as industries in the areas of content delivery, eCommerce, social media, and smartphone manufacturers. Strange enough, Telecom Operators did not benefit from the increased performances *they* provided—as a matter of fact, all of them saw their revenues shrinking, courtesy of the digital transformation;
- Smartphones took over plain vanilla cellphones. In 2010, 296 million smartphones were sold worldwide—this number increased to 1.5 billion in 2015. In the last 6 years, the number of units sold has remained constant—between 1.5 and 1.6 billion units. Interestingly, the top-of-the-line smartphone costs keep increasing, doubling in the last 5 years, but at the same time, the price for a basic smartphone has gone down to under $100 USD (the cheapest smartphone in India in 2021 was selling for $60). This is making smartphones affordable for third-world countries, and leading to people replacing their cellphones with smartphones. By the end of 2020, 63.6% of people in the world (that includes everyone, newborns as well) had a mobile phone, and 48.5% are using a smartphone In other words, almost 78% of all mobile phones are smartphones;
- Smartphones, tablets, and the availability of 4G has increased the time spent on mobile devices from an average 32 minutes in 2011 to 132 minutes (daily) in 2019 (worldwide average). In 2019, people in the US spent more time using a mobile device than watching TV (for the first time ever);
- Point and shoot digital cameras peaked in market volume at the beginning of the last decade, and have now basically become obsolete — killed by the digital cameras integrated in smartphones. They disappeared in just a few years—between 2013 and 2016;
- Smart home assistants were basically non-existent at the beginning of the last decade. Alexa was released on November 6th, 2014. Voice controlled devices were born in the last decade, nowhere to be seen in the previous one. Today, we control our television, appliances, car entertainment system, and more via voice;
- In 2016, Google released Google Neural Machine Translator (GMNT). Today, GNMT provides translation among 109 languages. This has changed the world, although not many people have realized it. In this decade, most people will experience this change which will enable real-time communications regardless of language barriers;
- In October 2009, an article on Fortune discussed the possibility of using smartphones as GPS navigators, pointing out that it seemed like a crazy idea. Today, it is normal to use your smartphone as a GPS navigator —it is actually better than the one we have in cars (because it is updated in real-time, it has new and enhanced features (such as searching by the name of a place rather than by address, you can see where your friends are, customize the voice,

etc.. In the last ten years, car rental services stopped offering navigation services as an add-on(or no one is buying them if they are offered...);

- Televisions have shifted from analogue to digital in the last decade, and they are now digital almost everywhere. 4K arrived in 2015, and 8K is now becoming the "standard" . Netflix started its international expansion on 22 Sept. 2010 in Canada, and now it has become one of the largest worldwide players with over 182 million subscribers;
- Social media brought our lives on-line and affects everyone, as individuals and as part of a society. The influence social media has in regards to politics and business can no longer be ignored. In addition, the power of those controlling main social media platforms cannot be ignored. For example, the recent ban of President Trump from Twitter and Facebook is both a testimony of the power that can be exerted through social media, and the power these platforms must decide what is right and what is wrong...;
- CRISPR-Cas9 was "discovered" in 2012 and opened the door to genomics and precision medicine—stimulating both research and application. From zero papers published on this technology in 2012, to over 3500 papers being published every year to-date (3000 in 2018). In fact, the Covid-19 Moderna and Pfizer vaccines have been using this technology;
- In 2011, there were basically zero electric cars on the road. At the end of 2020, there are approximately 8 million electric cars worldwide today, which is just a tiny fraction of cars, but we are starting to notice them. 2.1 million electric cars were sold in 2019, versus a total of 70 million in 2020. As stated, this is just the beginning—it is going to reshape the industry in this decade. Interestingly, in the last ten years, the price of the battery pack fell by one order of magnitude at a CAGR of -22% (from $1,120 per kwh to $120 per kwh);

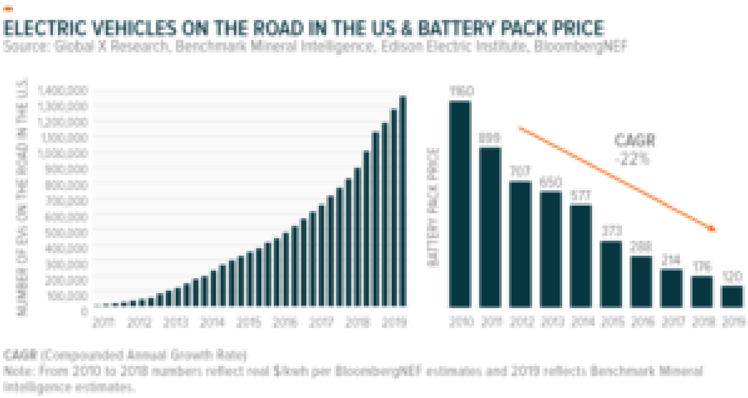


Fig. 112 The growth of electric cars in the last decade, and the corresponding decrease of the price (expressed in $ per kwh) from $1120 to $120. Image credit: Global X Research

- Big data has become even bigger moving from 2ZB produced in 2010 to 41 ZB in 2019 (doubling every 2 years). Interestingly, while only 9% of data produced in 2010 was structured (usable by AI), 13% of the data produced in 2019 was structured (that is 180 EB in 2010 vs 5,300 EB in 2019, a 30 times factor growth). This increase has gone hand-in-hand with the increased performance of AI and increased, widespread use.
- Generative Adversarial Networks (GAN) were "invented" in the 2010-2014 timeframe and are now starting to change the landscape of AI. GAN’s make it possible to develop AI from much smaller datasets. In other words, AI no longer has to be associated with the big guns of data (G-MAFIA and BAT).
- Data storage has started to shift to the Cloud. It was just 10% in 2010, but by 2019 it grew to 70%. In the last decade, the word "fog" has become increasing used to identify clouds at the edges. Interest is now focused on federated clouds and related aspects such as edge computing, Software as a Service, Platform as a Service, and Infrastructure as a Service.

List of Acronyms

AI:	Artificial Intelligence
AIaaS:	AI as a Service
ALS:	Amyotrophic Lateral Sclerosis
AR:	Augmented Reality
AWS:	Amazon Web Services
BCI:	Brain Computer Interface
CAD:	Computer Aided Design
CAGR:	Compound Annual Growth Rate
Cas9:	CRISPR associated protein 9
CAT:	Computerised Axial Tomography
CDT:	Cognitive Digital Twin
CEO:	Chief Executive Officer
CES:	Consumer Electronic Show
CO2:	Carbon Dioxide
CRISPR:	Clustered Regularly Interspaced Short Palindromic Repeats
DAI:	Distributed Artificial Intelligence
DFR:	Deposit Facility Rate
DNA:	Désoxyribose Nucleic Acid
DRI:	Digital Reality Initiative
DT/PDT	Digital Twin/Personal Digital Twin
DX:	Digital Transformation
ECB:	European Central Bank
ECG:	ElectroCardioGram
EHR:	Electronic Health Record
FAO:	Food and Agriculture Organization
FDA:	Food and Drug Administration
GAN:	Generative Adversarial Networks
GDP:	Gross Domestic Product
GPS:	Global Positioning System
KPI:	Key Performance Indicator
IFTF:	Institute For The Future
IMF:	International Monetary Fund
IoT:	Internet of Things
IPA:	Intelligent Process Automation
LIDAR:	Light Detection and Ranging
MaaS:	Mobility as a Service
MAS:	Multi Agent System
ML:	Machine Learning
MRO:	Main Refinancing Operations
OECD:	Organization for Economic Co-operation and Development
OS:	Operating System
PC:	Personal Computer
RAM:	Random Access Memory
RNA:	RiboNucleic Acid
RPA:	Robotic Process Automation
SAE:	Society of Automotive Engineers
VR:	Virtual Reality
WEF:	World Economic Forum
WHO:	World Health Organization