



Digital Transformation

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Digital Transformation

A Digital Reality Initiative White Paper

1. Introduction

The amount of literature on Digital Transformation is staggering—and it keeps growing. Why, then, come out with yet another such document? Moreover, any text aiming at explaining the Digital Transformation by presenting a snapshot is going to become obsolete in a blink of an eye, most likely already obsolete at the time it is first published.

The Future Directions Committee (FDC) Initiative on Digital Reality felt there is a need to look at the Digital Transformation from the point of view of a profound change that is pervading the entire society—a change made possible by technology. It that keeps changing due to technology evolution opening new possibilities but is also a change happening because due to strong economic reasons. The direction of this change is not easy to predict because it is steered by a cultural evolution of society, an evolution that is happening in niches and that may expand rapidly to larger constituencies or as rapidly fade away. This creation—selection by experimentation, adoption, and sudden disappearance—is what makes the whole scenario so unpredictable and continuously changing.

Technologists are responsible for the tools they are developing and the need to understand the slate of implications generated by use of these tools. Technology has already passed a threshold, separating reality from artefacts that is taking us into a fuzzy space where it is not just difficult to tell one from the other, but to where it is often meaningless to make this distinction.

When McLuhan said “*the medium is the message*” a long time ago, it was a revolutionary and possibly absurd thought—yet it has become true even beyond McLuhan imagination. Technology is today’s medium, reaching single individuals and communities that are no longer defined in space but in aggregation roots. It is not just serving those communities and individuals; it is shaping them and it is being shaped by them. The very same technology can lead to completely different behaviors in different communities, sometimes making it harder to understand the reasons, even afterwards.

The question then becomes, “*What is Reality today?*” Philosophers have debated this issue for centuries, along with the possibility of humans to grasp it. Physicists and Science in general decided that reality is what can be measured independently by different people at different point in space and time, and in the last century has postulated that this measure would be valid everywhere, at any time, in the knowable universe.

Math has progressed with the assumption that given a starting point and an agreed set of rules, anybody could agree on the conclusions. Both physics and math in the last century came to the realisation that our systems cannot be complete (or, therefore, not integrating everything).

Yet, those limitations did not affect our everyday life, reality was perceived as... real.

The Digital Transformation, the flanking of bits to atoms, is changing this perception and this is, in a way, much more important to our everyday life than the quantum uncertainties and Gödel's incompleteness theorem.

This White Paper is fundamentally about this fading boundary between physical reality and digital reality actually being about the emergence of a reality resulting from the co-presence of these two. Both are extremely permeable to one another, but both remain distinct, hence 'co-presence' rather than symbioses. In the long run, we feel that only one reality will be perceived. This new reality will encompass these two, where co-presence disappears to be replaced by a single presence. The boundary separating them will disappear, it is already starting to. At that point, we estimate this perceived "Reality" happening without anybody noticing by the end of this decade. It won't be possible to separate the two of them, nor would it be meaningful to do that. The physical reality will be perceived along with the Digital one, and it won't be meaningful to consider one separated from the other.

These two manifest themselves in the creation of digital worlds, like images that are a mixture of images captured by sensors from the physical world and then processed, skewed in a way, to be pleasing to us. Our eyes have a preference towards "green" because our ancestors evolved in a world where distinguishing nuances of green provided a competitive advantage, and so our digital cameras sensors are biased towards "green", and the software processing the sensor's data takes into account our retina and brain preference for higher contrasted images. We are using those images as communication tools, having them flow seamlessly within our community and, in the process, we alter them and create pleasing fakes. And we nourish ourselves on these fakes, creating a new perceived reality.

Were it just a matter of photos, or sounds, or mixing bits and data, we might probably find an easily agreeable framework to separate, if needed, the artefacts from reality (we are using the example of photos because it is tricky with photos to determine what is the "real representation").

However, the digital transformation is becoming increasingly pervasive, and in the coming decades we will see (in fact, already starting to see) a continuum leading to the digital transformation of humans, both at a biological and a cultural level. We know that biological evolution happens over long periods of time (the length of which is related to the lifespan of that particular species, and while we can detect biological evolution in bacteria and even in fruit-flies, we cannot detect it in species with a longer lifespan), and cultural evolution may occur at a much faster pace.

Human beings have *mostly* ceased to physically evolve in the last hundred thousand years, but we have evolved at an incredible pace culturally—this evolution takes further steam with the digital transformation. The human biological evolution could resume in the coming decades with technologies that allow the manipulation of the DNA (and RNA), opening a completely new scenario.

Fear of unexpected, possibly uncontrollable, consequences (not just for humans but for life on the planet) is trying to limit research and experimentation, but we have already seen that the planet is too big and too fragmented to control.

Independently of this evolution, it is sure that the cultural evolution is moving on at an accelerated pace, and it is doing so through niche experiments that can explode in the matter of days or months. The

digital world has no barrier and travels at the speed of light. It is also affecting people's use of language and their relationship to objectivity and rational thought, memory, intelligence, and judgment.

This White Paper uses these challenges as the framework for studying the Digital Transformation, looking at the technology enablers, economic forces fuelling it, and societal adoption steering its evolution. The challenges outlined are not going to be solved anytime soon but must be considered now and be kept alive in the perception of single individuals as well as business, organizations, and governments.

We talk a lot about keeping our planet fit to host humans, with climate change and the access and availability of resources (energy, raw materials, water, food) affecting the sustainability of our "progress". All of this is part of, and has to be considered under, the ongoing Digital Transformation.

Although the Digital Transformation shift is occurring everywhere, the way it is implemented, the pace of implementation, and the impact on the local culture may differ significantly. To take this into account, this White Paper includes contribution from people that live these disparate realities in different countries. Their reports on the status of plans in their geographical area should be both informative to those needing to understand the specificity of a given market and useful in understanding the variety of paths and implementations given their societal impact.

As this White Paper was prepared, the world was struck by the COVID-19 pandemic. This forced several countries into lock-down whilst others opted for different approaches to the containment of the epidemic. In both cases, this resulted in a shift to the cyberspace of broad areas like education, business, retail/commerce, and healthcare. In turn, this accelerated the deployment of the Digital Transformation. It is too early to evaluate the long term results of this acceleration. Some companies that were forced to move their staff to a work-from-home environment are now considering keeping teleworking as the main working paradigm for their staff. Investment on tools to support "tele-activities" has increased, and there has been a significant, and successful, effort to upgrade communications infrastructures to support the increased traffic demand.

This White Paper takes all this into account in the Roadmap section.

IEEE has made the progress of "technology to benefit humanity" its banner. It is only appropriate to use the tremendous capital of knowledge and skills of its volunteers to look at Digital Transformation from this point of view.

2. Lights and Shadows

The first person who invented the ship also invented the shipwreck and the cast-away.

No technology, no transformation will ever have only upsides. And there will no unanimous consensus on what an upside really is.

Even sure no-brainers, like extending human lifespan, may have somebody arguing that this extension is bound to put a stress on the planet resources, maybe reducing opportunities to the younger generation to find jobs, and could create additional cost to society that could undermine the general well-being.

The figure below shows the significant increase in pro-capita spending as people age increases after 65 years old. Notice that it is being used to illustrate a qualitative point, there are many factors that would have to be considered in evaluating the societal cost-benefit of healthcare on a single individual and on a specific age range, and most people would not agree that this area should be considered under a cost-benefit perspective. Here it has been included to emphasise that even a very positive outcome of technology/science evolution leading to increased life-span can be seen as controversial in some respect or by some constituencies.

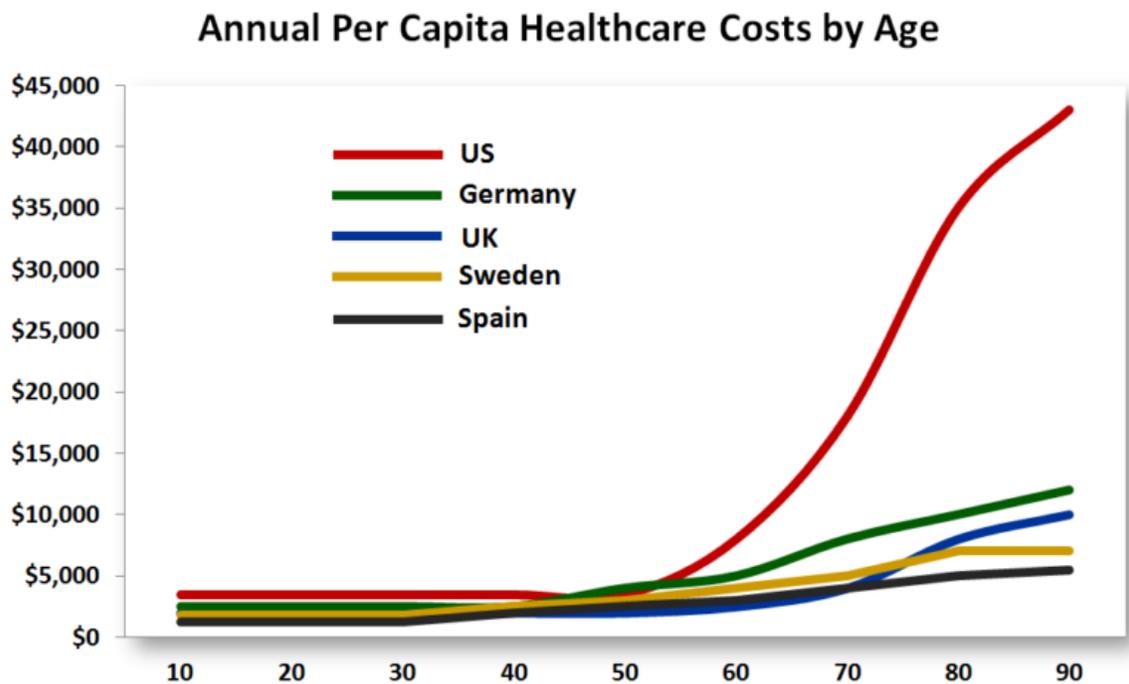


Figure 1. The cost of healthcare, pro-capita, grows exponentially after 65 years old. This is particularly noticeable in the US where it has been pointed out the 80% of a person spending in healthcare may occur in the last six months of his life. This has prompted some to wonder if it is “ethical” to devote has much resources that could be better used to increase the wellbeing of many more people to prolong life by a very short time. Graphic credit: The future of digital medicine in the aging society, Research Gate, Ja. 2016, David Wortley.

The Digital Transformation is no exception. There is no question that it is producing positive effects on society at large and on many individuals, but it is also true that it is raising several questions and opposition.

2.1 Upsides

- The shift from atoms to bits increases the efficiency of processes and consumes less resources. Bits (software based products) can be accessed from anyplace with a supporting broadband infrastructure, allowing the offer to reach any niche all over the world.
- The possibility of transforming hard products into digital ones, or/and to flank digital to hard products leads to the shift from products to services, and enables new players to piggy back on hard products, at the same time increasing the consumer-perceived value of those products.
- Resources becoming available through the re-engineering of processes can fuel new business and open-up new jobs opportunities.
- The Digital Transformation being based on the use of “bits” shifts the economy to a landscape of abundance, the low transaction cost needed in the Digital Economy lowers the barrier of entrance to newcomer, enables the creation of new businesses with low up-front capital, and expands the offer on the market. This lower cost and increased offer steer towards lower prices that benefit consumers, increasing affordability and broadening the potential market.
- The large and growing offering of services and products increases consumers’ choice and accelerates the control of demand over offers. The market (consumer choices) steers the evolution of offer, shrinking the lifecycle of services (and in some measure of products). This in turn, accelerates evolution of the offer in an ever-ending spiral.
- In the context of knowledge, the ease of access and flow increases the number of both those making use of it and those creating it. Knowledge is now starting to be created in the cyberspace, using artificial intelligence to analyze existing one, correlating it, and making new knowledge emerge.
- Creativity is boosted by the ease of manipulating bits and virtual objects, and it rapidly pervades the cyberspace fuelling further creativity.
- The lower cost of products and services opens the access to a much wider market, and the virtual location of the marketplace provides access to anybody in the world irrespective of the buyer’s/user’s physical location.
- Emerging economies that have poor physical infrastructures can benefit greatly from the lower cost, faster deployment of digital infrastructures. In turns, these can enable a fast-growing market.
- The replacement of atoms with bits decreases the need for material resources, hence the increase of available resources as well as the decrease of waste.

2.2 Downsides

- The approach to Digital Transformation is often pursued through the addition of “computers.” This increases complexity (real or perceived) and does not reduce resource consumption, it actually adds cost. Achieving a real reduction in cost requires process re-

engineering and this affects the status quo of companies, societal culture, and often faces resistance from the inside.

- The increase in process efficiency, resulting from process re-engineering, decreases the need of labor with consequent job loss. Jobs created by the Digital Transformation usually require skills and knowledge that are not available to those who lost their jobs.
- The increased market efficiency (lower price to consumers) results in a decrease of market value. This is particularly felt in mature markets where the price decrease cannot be offset by the market size increase. Hence, the players operating in that market or value chain will see their revenues being squeezed and some of them may go bankrupt.
- The increased offer, likewise, leads to more competition and price decreases, thus decreasing the overall market value. These two forces (market efficiency and increased offer) squeeze industry, affecting both incumbents and newcomers. In the case of incumbents, there is usually a greater capacity to buffer losses (but in the longer term their fall is making a bigger splash). In the case of the newcomer, competition is so harsh that often a zero price-based business model is pursued (giving out the product for free and capitalising on the market share).
- The high competition and the low transaction cost squeezes margins, and this has to be made up by increasing volumes. This tends to an increase of oligopolies.
- The shift towards a service based offer requires different competencies and processes and most industries are not prepared to navigate this space. Small companies usually take the best-effort path, i.e. releasing their products as a series of releases, each being tested by the market with little or no customer support. Being free, consumers are willing to put up with this.
- The culture of free is not good for fostering better quality, services, and products (products suffer less from this since it cost more to fix products and, therefore, producers tend to be more quality-savvy).
- The low cost of transactions follows from the availability of complex, and costly, digital infrastructures (data centers, sophisticated OS and application-creation support software), which creates de-facto oligopolies.
- The value is mostly tied to the correlation of data, hence having huge amounts of data provides an enormous competitive advantage. This has been further emphasised by the need of large data sets to power artificial intelligence algorithms. The result is a concentration of power in the hand of a very few companies (American and Chinese mostly). These companies are becoming so powerful that they can dictate their “price” to physical infrastructure providers (telecommunications infrastructures, distribution infrastructures, payment infrastructures, etc.). Actually, they are becoming so large to the point that it becomes affordable, and convenient, to develop their own infrastructures, replacing the ones of the incumbents.
- Decreasing margins, and the need of huge volumes, tends to concentrate industrial/applicable research in the big players whilst at the same time the low transaction cost enabling a multiplicity of small players shifts creativity and innovation to small players. Companies in the middle, like telecom companies that used to fuel research at the turn of the century, are no longer fostering technology evolution, nor are they impactful on the market in terms of creativity and innovation.

- The explosion of knowledge is creating a widening gap between what a person/company knows and what knowledge is available. Because of this, the value shifts from knowledge to being able to get the needed knowledge right in time and in the most digestible form. A few observers are fearing a shift of knowledge “ownership” (in the sense of applicable, executable knowledge) from humans to machines and current research is looking more on how to capitalise from machine knowledge than how to transfer this knowledge to humans.
- The creativity in the digital space is often blurring the boundaries between reality and artefact. From this to the blurring of truth and fiction, the distance is minimal. The issues of authentication, ownership control, trust, and accountability are becoming more and more difficult to address as the Digital Transformation percolates into most human activities.
- The shift of value to the cyberspace fuels the growth of malicious use of the cyberspace, in all possible forms (fake creation, denial of service, security breaches...). The effort to create e-citizens, motivated by more effective access to services, is also seen as potentially dangerous not just in terms of malicious attack but also in terms of the power of conditioning citizens to a higher degree than media has done in the last century. These issues are unlikely to be solved and will dominate in the coming decades.
- The growing sense of reality provided by enhanced access and use of the cyberspace (virtual, augmented, mixed reality) fuels a new culture that some fear decreases the value of reality. Isolation and shifting one’s life in the cyberspace, interacting with virtual characters, and creating a sort of virtual autisms may become an issue in the last part of this decade.

3. The enablers of the Digital Transformation

The Digital Transformation began several decades ago as technology made it possible to carry out several “activities” using bits. Notice that this is what is meant with Digital Transformation—the execution of activities in the cyberspace, not the mere use of computers. We have been using computer controlled machines in manufacturing for over 50 years, but the shift of manufacturing activities from atoms to bits, like design and integration of components in the cyberspace with manufacturing through 3D printers and the monitoring of performance in the Cloud, is much more recent. The process of moving the physical processes and activities to the cyberspace is the result of the Digital Transformation. Likewise, we have used digital coding in music for at least 30 years, but the shift to a fully digital music market goes back to the iPod (and iTunes) at the turn of the century.

Indeed, technology is an enabler for the Digital Transformation, but it is not the only one. If one searches the Web for “Digital Transformation Enablers,” there will be plenty of ways to classify them. Although in the end, they can be listed under three broad categories:

- Technological Enablers
- Business Enablers
- Societal Enablers

Moreover, one can look at enablers from the point of view of phases leading to the complete transformation, such as:

1. Digitization: the transformation affects the product that becomes more and more “digit based” in terms of the way it is designed, manufactured, and operated.
2. Digitalization: the transformation of business models and processes to leverage the progressive digitization of products.
3. Digital Transformation: the progressive system-wide transformation of economies, institutions and society, leading to a change in value perception and to different organization of education, working expectation, culture.

Enablers are needed, and used in all these phases, of course, essentially in some areas and marginally in others.

3.1 Technological Enablers

Technological enablers can be clustered into 6 main categories from the point of view of the supported class of activities:

1. Conversion of atoms into bits/data
2. Use of data
3. Conversion of data into physically executable actions
4. Support systems
5. Mixed Reality
6. Secured Environment

3.1.1 Conversion of atoms into bits

Here with atoms, we intend any kind of physical entity and activity involving physical entities (like using a forklift to load pallets on a truck and then the truck to transport them with each part and the whole

process which can be mirrored in the cyberspace). Sensors are used to capture certain, relevant characteristics of objects, coding them in bits. Sensors can be embedded in the physical object, they can be part of the object behavior (like a person's voice), or they can observe the object from the environment (up to remote sensing with drones or even satellites).

There are a variety of sensor technologies, depending on the type of characteristic to be measured/monitored. This technological evolution is providing:

- more accurate sensing (although this is becoming less important as accuracy can be improved by software analyzes of data)
- cheaper sensors
- sensors that can be embedded in a variety of materials used in the manufacturing of an object
- sensors that requires less and less power to operate, in some cases they can use scavenging to harvest power from the environment
- sensors that can self-aggregate/cluster into local networks
- sensors with processing capability for pre-processing of data and for changing the way they capture data / measure a specific characteristic
- sensors that are ubiquitous and will become even more so in this decade. An important area of sensors in the healthcare domain is the one of wearable (see figure) and biological sensors.

Signal processing is sometimes required to streamline the raw data captured by one or more sensors; getting rid of noise and analytics may be used to correlated raw data ending up in a digital representation of the object. The process of converting bits into "data" requires technology of its own, mostly software-based, although special chips are often involved to speed up processing. Computational photography is an example of sophisticated processing to create data out of bits.

This digital representation can be used from that point "in lieu" of the object. In some cases, this phase does not exist, like when designers start from bits (using Computer Aided Design) to create a representation of the object that will be, eventually, manufactured.

3.1.2 Use of Data

This category includes a variety of technologies with Artificial Intelligence having the lion's share. Data are acquired by different sources and their value often lies in correlation. This makes meaning emerge. This correlation is both temporal-based (machine learning) and spatial-based (correlation occurs among different streams of data related to a single time frame).

One key technology that is being used and is playing an important role in the Digital Transformation is the use of data to mirror a physical entity (i.e. the creation of a Digital Twin). This can be used as a virtual copy of the physical entity, to analyze the status of the physical entity, to run simulations and to interact with virtual copies of other entities. A Digital Twin can pre-exist the physical entity, representing through a digital model the categories of those physical entities, and it can be used in the specification and design phases to finely tune the model (by several parties providing different components) and eventually be used to steer the manufacturing of the physical entity (and the assembling of its

components into the final product). As the product is manufactured, that Digital Twin gives rise to an instance mirroring the specific product instance, and that will be the one associated to the physical entity throughout its lifetime.

Data represent the raw resources used in the cyberspace by processes, and resources, resulting from the Digital Transformation. They are used in a variety of fields, such as:

- Industry 4.0 massively uses data in the supply and manufacturing phases, and to a certain extent, in the delivery and operation phase for the software components of a physical entity. Notice that industry, as for the other fields following, has been using computers in the support of its “physical processes,” but this use is not tied to the Digital Transformation (it pre-dates it).
- Smart cities make use of data mirroring the various city’s components (entities, processes and citizens) executing many processes in the cyberspace using data. Planning, simulation, and run time allocation of resources take place in the data space.
- Retail: the retail space will undergo a radical transformation in this decade with data and automation playing a significant role, although the digital transformation will impact the business and consumer habits, mostly. The use of apps will become the norm to “access” a shop, leveraging on images capturing the customer’s behavior in the shop (through safety cameras), and monitoring of the usage of the products and their relations leveraging on digital twins associated to customers and goods/services.
- Healthcare is only marginally affected today by the Digital Transformation, but it is expected to be radically changed and disrupted by it in the coming years. In particular, the shift to proactive healthcare will rely mostly on the use of data.
- Infrastructures are more and more virtualizing their resources to operate them in the cyberspace and to open-up the management to third parties. Proactive maintenance is more and more based on actions originating in the cyberspace. Even minimal aspects, like tire management in a fleet, are moved to the cyberspace. Tires communicate their status and the information is matched with the load of the truck to both regulate the tire pressure to an optimal, less fuel-consuming pressure, and to set up change schedule before the wears affects the rolling stock.
- Finance by its nature of being mostly bit-based is already run in the cyberspace. However, the Digital Transformation is moving today’s physical processes to the cyberspace, like the setup of banking services “without” a physical bank (some neo-banks have already reached the thresholds of \$1 billion deposit), determining the risk balance over a set of physical entities and players involved with them.

An important aspect, that is also a major difference between physical objects and data is that physical objects basically stay as they are, whilst data begets data. Artificial Intelligence and Machine Learning are, from a certain point of view, “data generators” as they introduce a dynamic aspect to data. They use data and by doing that they generate more data that increase the data space and change the original data since in the data space data have to be considered along other data creating the context.

3.1.3 Conversion of data into physically executable actions

The early success of personal computers among hobbyists was driven by actuators that converted bits into sound or light. At an industrial level, the conversion of bits into printouts and into commands operating a lathe or other tools was the reason for their adoption.

Actually, it is this conversion of bit/data into executable actions in the physical world that gives value to data. The visualization of data, by printing them or converting them into pixels on a screen, is the first important class of technologies that make data understandable, executable by people. Over the last 20 years these technologies have progressed giving rise to XR, i.e.:

- Mixed Reality, where virtual objects and physical objects create a new environment interacting with one another.
- Augmented Reality, where virtual objects are overlaid in a physical environment providing the observer with additional content. In Augmented Reality, there is no interaction among physical and virtual objects, the meaning of the overlapping is derived by a human interacting with both.
- Virtual Reality, where special viewers provide an immersive experience into the cyberspace, supporting the exploration and manipulation of data. Although this may not have a direct impact on the physical world, it is expected in this decade to become more and more relevant in several sectors. Through VR designers and operators, end-customers can become immersed into what is a representation of the physical world or of a future physical world. Through interaction in the cyberspace, they can change the data and this leads to a change in the implementation (manufacturing) or a change in the interaction with other virtual entities (like Digital Twins of other objects), thus leading to a change in the physical world. Notice that this approach of indirect interaction through a virtual space is also applicable in case of abstraction and aggregation, like the operation of a smart city through its model. The smart city is both an abstraction and a model of a city clustering the various components. By interacting with the smart city model operators can affect, indirectly, the required systems.

Additive manufacturing, i.e. 3D printing, is on the rise, thanks to the evolution of underlying technologies. Initially used for fast prototyping has now entered into mainstream manufacturing. The yield has become significant (the speed of printing) and products, components, can be manufactured using a variety of materials as well as different materials in the same printing process. The 3D printing is completely automated and converts, through computer guidance, the virtual model into the physical product.

An additional advantage of 3D printing is the possibility to create shapes that would not be possible with usual forging and casting manufacturing. This results in less use of material and less weight of the product, often with increased resistance and minimal waste.

During this decade and over the next one, 3D printing will become even more affordable, leading to distributed manufacturing (with control executed through Internet), decreasing the need for transport of material, increasing customization, and lowering stock (just-in-time manufacturing).

Actuators of various sorts, pneumatic, electric, mechanic, are also used in the conversion of data, like remote faucet operation, robot control, tele-surgery, and so on.

Smart materials during the second part of this decade will start embedding a variety of actuators (i.e. the material will be able to react, by changing shape, density, optical, electrical, insulation characteristics, to commands generated by the application analyzing the data).

3.1.4 Support Systems

The Digital Transformation changes business, manufacturing, and societal processes. This requires a change in the support infrastructure. Our whole society is based on access and use of infrastructures, and these are enabling and constraining its operation and the products/services we use.

The digital transformation makes use of all the pre-existing infrastructures, both because it still has to deal with atoms with the physical world and because it wouldn't make sense, nor be practical, to start building infrastructures from scratch. However, it changes them, adds to them to manage and leverage bits, and integrates bits with atoms.

In particular, we are seeing:

- The progressive automation of existing infrastructures from self-driving cars to self-routing goods, from self-balancing power grids (smart grids) to self-healing roads.
- The evolution from (tele)communications infrastructures to communications fabric.
- The growth of distributed clouds supporting edge computing, micro data centers, encapsulated data, and semantic-based data access.
- The creation of worldwide and vertical specific platforms, including PaaS (Platforms as a Service) and Tools (AI, Data Rendering, Voice Interface management, Computational Photography and Image Recognition, etc.).

3.1.4.1 Infrastructures

Infrastructures have historically been built in a top-down way, a central authority (in the past, it was a state business to build and ensure the viability of infrastructures) coordinating the effort of a plurality of players (including slaves) and regulating their use (paying tolls, getting the right of use, and so on).

This has been the case in modern times in the development of modern infrastructures, like railroads, highways, and telecommunications networks. However, here we saw the entrance of private capital and initiative, but still the "states" had their saying by granting concessions and regulating several aspects of their use and operation.

The issue of interoperability among infrastructures, like using the same gauge in rail tracks, the loading gauge, the same voltage/frequency in power supply, was soon on the table. Although, the solutions have been different (like exchanging the bogies to allow a railway wagon to move from Western Europe to Russia). Standards have been designed to ensure interoperability; although, sometimes they do not work backward and specific "hard" solutions have to be found.

The shift to software-based interactions has somewhat simplified the interoperability and development of standards (you need a software adaptor to match two software interfaces if changing one to match the other is impractical), but at the same time it has multiplied the interoperability issues given the proliferation of products and the interest of industry to differentiate their product. The JPEG standard came as the solution to the problem of representing an image in bits in such a way that any application could read those bits and render the same image. In these last 20 years, although, we still have and use JPEG. Each digital camera comes to the market with its own specific way of creating a digital copy of the image and for each camera there needs to be a converter to create an interoperable file (like Adobe DNG – Digital NeGative).

All these issues are very much present in the Digital Transformation and support tools are the ones that have to take care of them (at the same time they are also the ones creating de-facto standards and interoperability issues). This is made even more crucial given the fact that the Digital Transformation is happening everywhere and often subject to different vertical regulatory frameworks, each one with its own heritage and specificity, and by different parties, each one having its own motivations and goals.

Sometimes incompatibility is seen as a competitive advantage, leading to customer lock-in. Other times, it is an unavoidable consequence of the speed of evolution and need to go-to-market in the shortest possible time (rather than waiting for a standard, I'll push my product to market; if it becomes successful it will become a de-facto standard). The possibility to create a software envelope to overcome interoperability issues and support interoperability is also another factor decreasing the effort towards software and data (ontologies) standardization.

3.1.4.2 Progressive automation of existing infrastructures

Over the years and decades, we have been leveraging computers to monitor infrastructures, analyze operation and performance data, and take corrective actions. As infrastructure components have become more and more flexible (computerized, smart, accessible, reconfigurable) we have gained the power to make more and more changes, often in real time, to operations tackling changing situations (load, failures, priorities). This control is now becoming more and more decentralized as infrastructure components are becoming aware of their surroundings, “conscious” of their goal and autonomous in decision making. Infrastructure robotization is an ongoing trend. Assembly lines are starting to leverage on autonomous robots, gaining in flexibility and efficiency, particularly in case of disruption. Self-deploying infrastructures, such as the ones involved in emergency situations (flooding, earthquakes), are being designed with autonomous components and with the capability of self-organization.

We are also moving in the direction of autonomous, smart users of infrastructures, like self-driving vehicles that will become reality in the next few years. Whereas the short term goal is to have an autonomous vehicle safely “navigating” the road infrastructure, the longer term is to have all vehicles navigate in the most efficient way. This will require self-coordination among them, with safety being a given.

The interplay of smart infrastructures and smart infrastructure users will be on a researcher’s agenda in this decade, probably leading to a completely new way of conceptualizing an infrastructure.

Today, we have a clear dividing line between the infrastructure and the users of that infrastructure. This will not be so in the future (see in particular the next point). We are moving towards an interplay between the infrastructure and its users to the point that the users may become an integral part of the infrastructure, define the infrastructure, and contribute to its operation and capability.

Think about a smart city. If you separate its infrastructure from its users, the citizens, you are not going to maximize the overall efficiency. You cannot expand the roads in a city at will, even less in a real time way, but you can control the traffic routing it (or stopping it avoid worsening a traffic jam). Even better, you can work to make citizens aware of alternatives, create a culture to use public transportation, swap the car for a bike or foldable scooter, and stimulate sharing. You can create a digital infrastructure that makes sharing effective and seamless. This digital infrastructure will be overlaid on the physical roads and vehicles changing the transportation infrastructure. This would be an effect of the digital transformation of infrastructure. Also, this digital transportation infrastructure can be aware and interact with traffic generator points, like theaters, concert hall, events, big sales pitches, and logistic distribution fleets, making sure that they distribute traffic peaks to avoid overloads.

Other types of infrastructures will require different kinds of interactions, like manufacturing infrastructures having to interact with the supply and distribution chain, as well as with retail points and eventually the customers/users, but in the end it is all about fragmenting an infrastructure into resources that can be flexibly allocated as need arises.

Notice, as mentioned previously, that we will be seeing a shift from considering an infrastructure's users as demand generators (e.g. creating constraints) to infrastructure resources that can be managed to increase the infrastructure effectiveness. This "can be managed" should actually be read as self-management, an autonomous interaction based on local awareness that is orchestrated to generate an emerging global behavior.

All this evolution will be based on the mirroring of physical components in the cyberspace through Digital Twin technology, and the awareness/decision making will be supported by these Digital Twins and their mutual interactions.

Artificial intelligence and machine learning will play a crucial role in awareness creation and in decision making.

3.1.4.3 Evolution from (tele)communication infrastructures to communications fabric

The evolution of telecommunications infrastructures has followed the path of lower and lower hierarchy. From the very rigid structure of networks based on electromechanical exchanges (where the network structure dictates the routing of calls) to increased flexibility with electronic exchanges and further on with the separation of the control from the physical structure (intelligent network, service network).

The advent of wireless networking led to an even more flexible network from both the point of view of planning/deployment of network resources and of their allocation.

More recently, technologies like SDN (Software Defined Network) and NFV (Network Function Virtualisation) have provided the tools to further increase network flexibility in terms of resources allocation. The 5G standard goes hand in hand with Network Slicing capabilities, allowing, in principle, the selection and allocation of resources on demand by the service (or service provider).

Network equipment manufacturers, and terminal manufacturers, have started implementing these functionalities. Although, network Operators are still debating on their use. On the one hand, increasing flexibility to make better use of resources (leading to lower investment needs, lower CAPEX) is a no brainer, but at the same time opening the network to third parties (service providers and end customers) is something that would go hand in hand with loss of control and most likely decreasing revenues.

However, the evolution of technology on one hand and economic pressure on the other are forcing Operators to reconsider their position, role, and business models (shift towards wholesale).

In the past, a Telco had a fully integrated vertical model taking care of everything from digging trenches, deploying equipment, providing terminals to the end users, network operation, maintenance, and service delivery (billing and charging for all of that goes without saying). Now, we have seen that Telcos no longer have full control. Most of the services we, as end users, are using (read apps) are not provided by the Operator and the Operator does not charge for their use (only for network access/usage and this is getting more and more an “all-you-can-eat” charge), nor do we buy terminals (cell phone, media center, television) from the Operator.

Today, most Operators control the network resources and charge for the access. However, if we take a look “inside” Operators “factories” we would probably discover that they are renting part of the network resources (like radio towers or big intercontinental pipes), they have outsourced to third parties the development and maintenance of software (including planning, operation, billing), and some have outsourced the operation of their networks (they are the first to make use of the “network-as-a-service” model). Although Telcos usually have and offer data center resources, most of their clients are actually using third party data centers. In a “communication” that is more and more about connecting data, it is clear the loss of grip from the Telcos.

At the same time, exactly as the Telcos were losing control, we have seen an incredible explosion in the pervasiveness of connectivity, its capacity, and its services. In terms of capacity since 1992, we have seen over a 100 million-fold increase¹, basically a doubling of the traffic each year, way faster than the Moore's law.

According to ITU Overall Mobile Data traffic forecast for the coming 10 years (2020-2029), we can expect the growth to continue from the 62EB of 2020 to 3.3 YB in 2029 (that is 62 million TB and 3.3 billion TB respectively). Notice that you cannot compare this data with the global traffic on internet because that one includes fixed lines and big pipes duplicating traffic, in this statistic only originating traffic for mobile is considered, because this is the one giving the pulse of the use/need of communications by the end users.

¹ https://www.researchgate.net/publication/301895458_Roadmap_on_Optical_Communications

5G is going to be remembered, in 20 years' time, as a transitional evolution, one that led to the change of paradigm in communication infrastructures. In 5G, we have two seeds for this paradigm change:

- the architectural possibility of shifting the session control (and network resource allocation) from the network (and Network Operator) to the edges (to the terminal, end customer and to the service provider).
- the increased requirement on investment leading Operators to accept/look for investment sharing in towers as well as in edge networks, the latter built by private entities and embedded in the network infrastructure (as an example consider the application of Siemens to get private 5G spectrum license for industrial applications, i.e. digital factories).

These two seeds will create a disruption in the telecommunication business. On the one hand, you have the technology enabler (control shifts to the services/service providers). On the other hand, you have the economic push to make the transition.

5G is not just an expensive endeavour, it changes what has been the fundamental factor in the wireless explosion. Consider this: the deployment of wireless, differently from deployment of wireline infrastructure, could be planned in such a way to provide from the very start a very broad coverage. You place an antenna and power it up to cover a large area. That was possible because the frequency used by wireless had very good propagation, i.e. you can cover a large area with just one antenna. People were attracted by wireless because of its coverage (you can connect from everywhere). As more people started to use the service, the density would reach a point where traffic demand would no longer match with that cell traffic capacity. At that point, the Operator would make the cell smaller by lowering the emission power (hence the coverage) and at the same time deploy more antennas, creating more cells. This resulted in an increased traffic capacity that would go hand in hand with the increased traffic and traffic revenues (this equation has started to crumble as Operators compete with one another and are shifting to an "all-you-can-eat" tariffing scheme). From the point of view of the end user, the upscale of capacity was seamless. You would still get access everywhere, most likely with an increased perception of quality.

Now 5G, when used with the higher frequencies, mm waves (that are the ones providing the highest speed), does not scale. With those higher frequencies, the propagation is very limited, less than hundred meters in an urban environment, much less if you use the 70+GHz spectrum. Hence, either the Operator deploys tons of antennas (10 times as many as with 4G) or the coverage is not complete. The result is that from a user viewpoint a limited coverage is seen as a big limitation in using 5G (yes, you can use 4G as back up but then you are losing the speed advantages, so why should you pay more) and from an Operator viewpoint is that the 5G deployment becomes (investment-wise) much more similar to a wireline network deployment (with on top the huge cost for spectrum licenses that some short-sighted Governments imposed).

This economic impact of 5G is what makes Operators more open to resource sharing with other Operators and with private players but to do this they have to embark on the transition leading to the shift of resource management from the network to the edges.

Introducing 6G. Although it is too early to know what 6G is going to be, there are some general principles that can be used to look at its likely implication on the business framework:

- Higher spectrum frequencies (getting closer and into the THz).
- Multiplication of cells leading to huge overall investment and extremely high complexity if one approaches the architecture in a centralized way. It is much more effective to go for a massively distributed control, with massive use of artificial intelligence both in the network resources and in the service applications (with terminals becoming network nodes and service platforms).
- Service driven deployment of local 6G areas connecting one another where of interest and with big commoditized pipes for infra-edges communications with the possibility of network slicing on-demand.
- Network growth inside-out, from the edges, with uncoordinated investment deployed by a variety of players, most of them private and institutions (like municipalities) with little contribution from incumbent Telcos.

Hence, the vision for this future network (being explored in the Future Network Initiative run by IEEE FDC): no longer an infrastructure designed top down and from the core to the edges, rather a communication fabric aggregating resources, investment and players, just like the Internet grew over these last 40 years. Notice that a general, accepted framework is needed, and this is what, most likely, 6G will be providing along with standards.

The shift from a communication infrastructure to a communication fabric will be one of the outcome of the Digital Transformation and will result in a profound reshaping of the communication business and of its players.

3.1.4.4 Growth of distributed Clouds

Centralization vs decentralization has been on the designer's table for several decades, and over this period, we have seen the shift of interest moving back and forth. The fact is, there is no silver bullet and as technology evolves, and its adoption spreads, the context changes making centralization or decentralization better in some respect. Actually, different use cases may lead to different "preferences," so even at a certain point in time, both approaches and solutions coexist.

If one had unlimited bandwidth with no latency, decentralization vs centralization may be a moot point, but only from an engineering standpoint. There are at least three other standpoints to consider:

- the economic advantage
- the regulatory framework
- the user's perception

The trend is towards the development of a smart edge, i.e. more powerful end user devices (including smartphones, vehicles, and robots) and smart access nodes (including media centers at user's premises, smart towers with local processing and storage capabilities, and edge networks with local intelligence). All of these factors result in the growth of storage capacity and processing power at the edges in a size that is clearly marginal if compared to data centers but more than enough to support localized needs. In

addition, the presence of thousands, millions of these “micro” data centers bring the total capacity to compare with the largest data centers.

From an economic point of view, the situation is somewhat similar to the one discussed for the network architecture evolution. It makes more and more sense to leverage the independent fragmented investments of CSP (Connectivity Service Providers) than to pour big investment in creating centralized structures.

Regulatory framework can also play a role in requiring the physical location of certain data, hence the use of data centers in specific locations following under that regulatory domain. In a way, connected to this is the user’s perception of the need to have co-located data and the fact that some industrial plants are developed with an integrated communication and service infrastructure (the already mentioned interest in private 5G spectrum goes in this direction).

Several manufacturers that used to have Telcos as their market are now getting more and more interested in private customers, like industry and municipalities. They are developing an offer based on distributed clouds with private and local connectivity.

Indeed, these types of infrastructures may be tailored to specific needs and better serve them. Technologies like artificial intelligence and machine learning are helping in the tailoring and operation of these private connectivity, service islands, and technologies like augmented reality and virtual reality—finding an ideal support in them.

3.1.4.5 World-wide and Vertical-specific platforms

The Digital Platforms are for the Digital Transformation what the power lines, highways, railways, ships, and ports were for the industrial transformation. They provide the infrastructures supporting the value chain and each player on the value chain.

However, the digital platforms have some important differences from those hard infrastructures, mostly tied to the delocalization that is possible with the digital platform. You need to have a highway connecting A to B if you have to transport goods from the manufacturing point to a warehouse, but if your warehouse is a data center, that data center can be “physically” located anywhere. It doesn’t matter where those bits will need to end up to deliver a service.

This delocalization (although there may be other factors that can lead to specific locations) has a crucial consequence: you can leverage factor of scale to make your “warehouse” (data center) efficient, and in general the larger the data center the more efficiency can be reached. This has led to the emergence of a few players having a worldwide market. Actually, the drive towards increased efficiency goes hand in hand with the drive towards aggregating more markets.

The graphic shown below is a clear statement to this. There are a very few large digital platforms (in the graphic the size of each platform relates to its economic weight), and if we look at the economic area, they are showing that the US has by far the lion’s share, followed by Asia, a distant third Europe (the whole business generated by European platforms is less than the business generated by the fifth largest platform in the US economic area), and fourth Africa. The reasons for this emergence of US have to be

found in the technological leadership and in the regulatory framework, the large share taken by Asian platform is related (mostly) to the huge Chinese market (and the specific language used by that economy).

The imbalance of platform economy

The 60 most valuable global platforms in billion USD on December 31, 2017

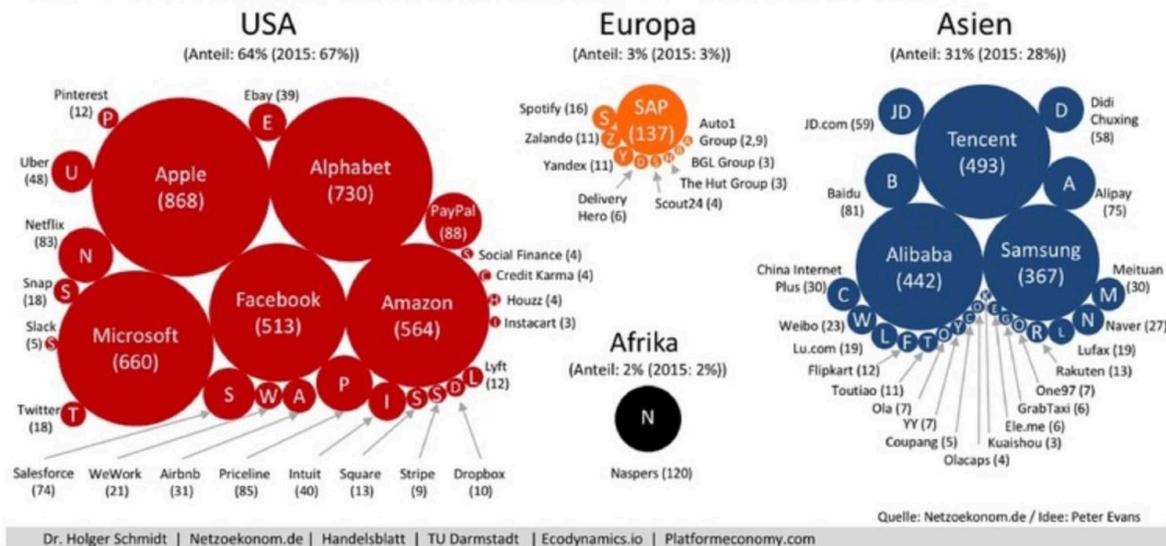


Figure 2. A view of Digital Platform from an economic perspective: the platform economies have a worldwide reach but are based in very specific areas. The graphic shows the predominance of the US based platforms. Asia based platforms support a growing economy although their impact is mostly felt on Asian markets. European platforms have a much more limited impact. Image credit: Quelle.

Notice that the physical underpinning of a digital platform is not related to its economic area of influence. Actually, the physical underpinning (the data center hosting the data and applications) is geographically distributed to make the whole system more robust and to decrease the use of communication resources. As an example, the Microsoft Digital Platform (Azure) is running on over 50 data centers distributed worldwide.

All the big platforms shown in the graphic are dealing with data hosting and service delivery, and because of that, they have a (potential) worldwide market.

There are, however, other digital platforms that are serving vertical markets, like cities, industries, hospitals/healthcare, etc.

These tend to have a higher level of specialization and are often tied to a specific geographical area. As examples:

- the FIREWARE platform, designed through a cooperative effort initially funded by the European Union, is mostly targeting cities and it is usually customised to serve a specific city

(however, its data, services and application may use as physical underpinning a digital platform like Amazon AWS or Alphabet);

- the Mindsphere platform, developed and supported by Siemens, is used as an IoT Operating systems, providing cloud services specifically designed with IoT in mind and applications connecting them to industry resources (like robots) and processes (like assembly lines).

Although the economies of scale reached by the top big platforms are so huge to have created, basically, a market lock-in, we are seeing the emergence of third parties that deliver services making use of a plurality of platforms to provide platform-independence, something that is very appreciated by several business users (and sometimes even required by national regulations). This creates a good dynamic in the market and is continually pushing this evolution.

Vertical platforms, on the other hand, do not need the enormous economy of scale of the former, and therefore, we can expect many more of them to appear in the coming decades.

The evolution of the communication network into a fabric with lot of features provided at the edges is going to stimulate the growth of massively distributed clouds, as previously mentioned, and in turn the emergence of other forms of digital platforms.

3.1.5 AR/VR

Augmented Reality and Virtual Reality (AR/VR) are a growing component in the Digital Transformation (DX), as they provide a way to access the cyberspace and make it become part of the Digital Reality. Although we already have several examples and usage of AR/VR, much more is expected in the coming years. This broader adoption will be fostered by technology evolution supporting AR/VR, as detailed in the following subsections.

3.1.5.1 Drivers for Storage and Memory in Digital Reality Applications

Because of the low latency and high-resolution requirements for a comfortable experience with virtual reality and other digital reality (DR) experiences, the display devices used must have local high-resolution stored content. For a streaming application using the Internet, this may be cache memory sufficient to hold up to 30 seconds of video content. For the most immersive experiences, the amount of data may require that a large portion or all of a digital experience be stored locally and played out over a high-speed local network. This is often the case for mobile phone VR viewing, gaming consoles, and large format entertainment systems.

Current VR applications require video data rates of 100-400 Mbps with latencies as low as 20ms and up to 60fps frame rates with 10 bits per pixel for SD and HD resolution. Future conventional (flat image) VR with 4K and 8K resolution per eye will require 120fps-240fps, 12 bit per pixel video, and less than 10ms latency with data rates of several Gbps². 1 minute of this high-resolution content could require 17GB and about 1TB could be required for an hour of content, depending upon the compression technology used.

² *VR is on the Edge: How to Deliver 360° Videos in Mobile Networks*, Simone Magiante, et. Al, VR/AR Network '17, August 25, 2017, Los Angeles, CA, USA

If a volumetric image display is used to create an even more immersive and interactive experience, the size of the required stored content and the data rates increase considerably. A volumetric display device forms a visual representation of an object in three physical dimensions, compared to the planar image of traditional screens and the available VR head mounted displays available today, that create the perception of depth largely through stereoscopic images. A volumetric display looks like a real 3D object and would provide 3D images to the naked eye. According to an estimate from Cisco, 12K 360-degree volumetric video could require over 24 TB/hr of content³.

Higher bandwidth networks, such as 5G wireless networks, as well as significant local memory will be important requirements for digital reality applications.

3.1.5.2 Display Resolution Requirements

Today, people watch content on many different size displays, from large theater screens to home displays to tablets and smartphones. Different types of displays require content that is tailored to them. Real-time transcoding of content to match the needs of a particular communication channel and different screen sizes provide important efficiencies, as these different content formats can be created more or less as needed (and thus not stored before use).

Figure 3 shows a plot of the optimal viewing distances for HD as well as 4K UHD content⁴.

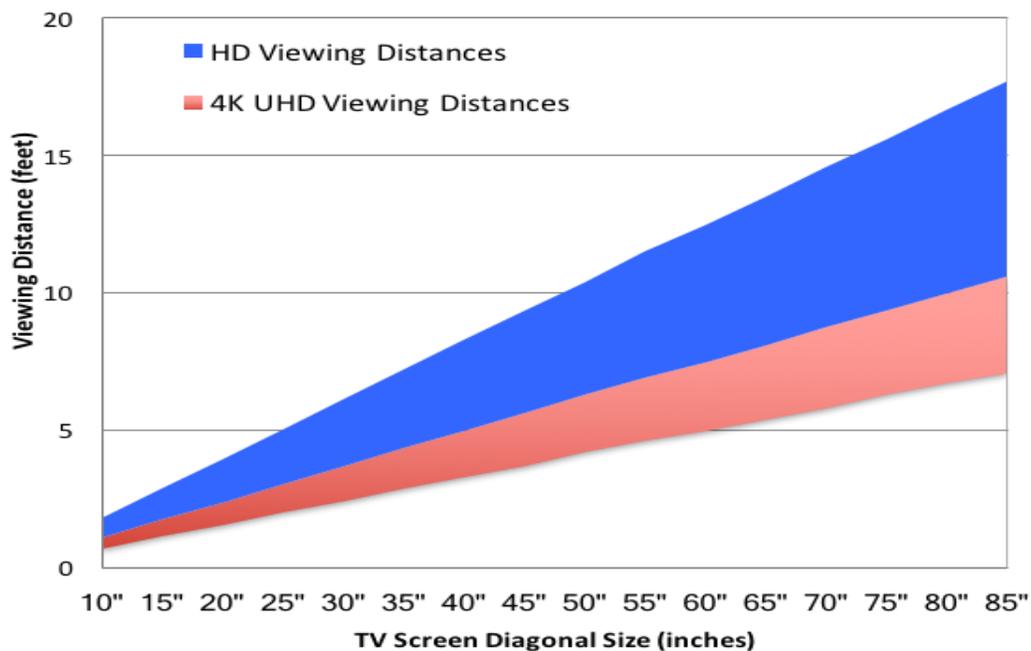


Figure 3. Comparison of Optimal Viewing Distance for HD and 4K UHD versus Display Diagonal Size.

³ *Real Storage for Unreal Experiences*, Tom Coughlin, Forbes.com, June 14, 2019, <https://www.forbes.com/sites/tomcoughlin/2019/06/14/real-storage-for-unreal-experiences/#1a4e04e4026b>

⁴ *Digital Storage in Consumer Electronics: The Essential Guide*, Tom Coughlin, Chapter 7, 2nd edition, Springer 2018.

For home viewing of a TV with comfortable viewing distances (generally more than 5 feet from the screen), the screen size needs to be more than 60 inches diagonally for the benefits of 4K resolution to be apparent. It seems that higher resolution has the greatest value for smaller screens where the viewer is close, as well as very large screens where the viewer is some distance away.

Because the eyes of computer, tablet, and smartphone users are generally close to their screens, some modern computers, tablets and phones have 4K resolution screens, and users can see the difference. In the future, 8K and higher resolution can improve viewing for displays close to your eyes, such as in a head mounted display (HMD) or future smart glasses. For 360-degree video, 8K resolution per eye can create a greater sense of immersion than 4K. With 8K video per eye, the complete video would be at 16K resolution. Higher resolution means higher bandwidth for moving the content and higher storage capacities to store it.

It is advisable to display content at a higher resolution to eliminate potential image artefacts, particularly at sharp edges⁵. In addition, as mentioned before, volumetric display technology could enable 3D viewing with the naked eye, but requires storing and displaying visual depth as well as planar imaging, significantly increasing the data rate and storage/memory requirements.

While resolution perception is a function of the size of the screen and the distance of the viewer from the screen, perceptions of color and high dynamic range seem to make a difference to viewers for all size screens and reasonable distances from a screen. These features are more a function of the display technology and don't impact memory and storage requirements as much as frame rate, resolution, and depth information will.

3.1.5.3 Memory for Digital Reality Display

Advanced high-resolution display devices depend on embedded memory for their operation in the field. Solid state semiconductor memories are used for producing and saving VR images and presenting the data of those images onto a display device. This memory is typically SRAM or DRAM, and in the case of DRAM, can consume a considerable amount of energy due to refreshing the content in memory. High performance graphic DRAM (such as GDDR5 or GDDR6) is often used for virtual reality memory for 8K and higher applications.

The figure below shows a block diagram of the various subsystems in a reference design battery powered augmented reality glasses from TI⁶.

⁵ *Beyond the Limits of Visual Acuity: The Real Reason for 4K and 8K Image Resolution*, Edward Reuss, SMPTE 2016 Annual Technical Conference and Exhibition

⁶ Augmented reality glasses (using TI DLP display technology), TI, 2017 design, <http://www.ti.com/solution/augmented-reality-glasses>

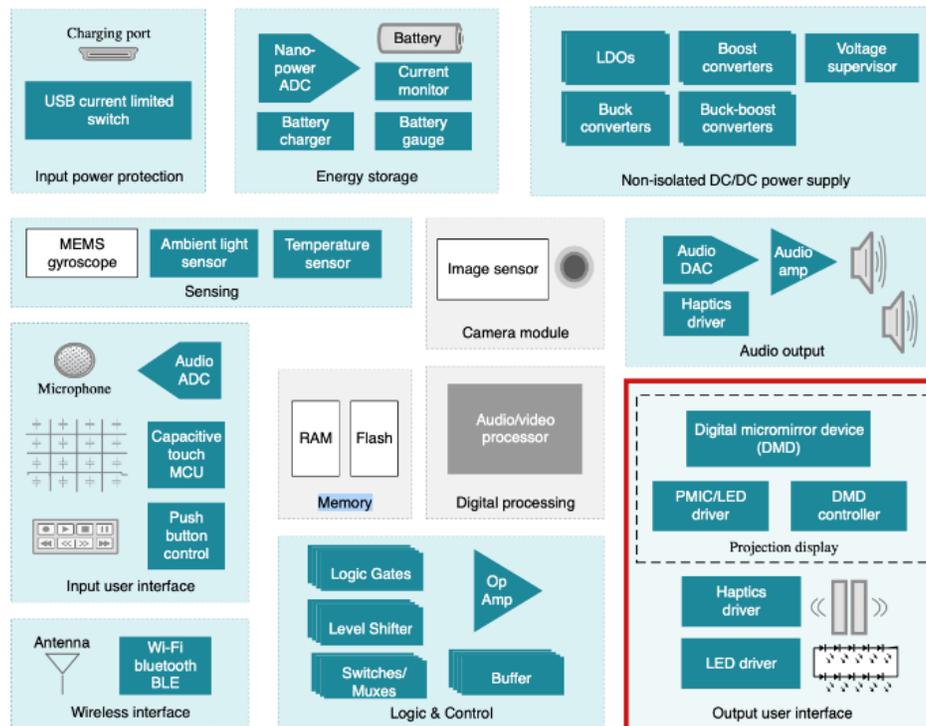


Figure 4. DLP Enabled Augmented Reality Glass Subsystem Schematic.

Memory, both DRAM and flash memory, constitutes its own subsystem. In addition, various buffers and cache memory (often SRAM) are used in other subsystems. Memory is an important element in digital reality technology.

8K images can be processed stably without any delay through a graphic DRAM with a data transfer rate of over 20Gbps for videos with 8K and higher resolution and more than 90 frames per second for a head mounted display (HMD) or future VR-enabled smart glasses⁷. These products currently use high-speed graphic DRAM like GDDR6. Memory located within an HMD must have high efficiency and require low power for operation.

3.1.5.4 New Memories for Digital Reality

Emerging nonvolatile technologies, could reduce the power draw for conventional digital reality display memory, giving these display devices a longer battery life. In particular, DRAM power consumption can account for as much as 46% of the total system power use⁸. A nonvolatile memory doesn't require the frequent refreshes that DRAM requires.

⁷ *Virtual Reality in Glasses*, SKhynix Newsroom, December 5, 2019, <https://news.skhynix.com/the-world-shaped-by-semiconductors-virtual-reality-in-glasses/>

⁸ *What Your DRAM Power Models Are Not Telling You: Lessons from a Detailed Experimental Study*, S. Ghose et. Al, June 2018, https://users.ece.cmu.edu/~saugatag/papers/18sigmetrics_vampire.pdf

In addition, some of the conventional nonvolatile memories (such as NOR flash) are facing potential technology limits to lithographic and other scaling issues, while some of the new nonvolatile memories do not have these scaling limitations. In particular, magnetic random access memory (MRAM), resistive random access memory (RRAM), ferroelectric random access memory (FRAM), and phase change memory (PCM) may be able to avoid these scaling issues and allow higher memory density per chip. As a consequence, denser nonvolatile memories could increase their use and drive down the cost of manufacturing these memories, further increasing their use, compared to conventional nonvolatile memories.

Most digital reality equipment uses embedded memory and/or some discrete memory to store code and digital content. Major foundries have said that they will offer spin tunnel torque (STT MRAM) or some form of resistive memory in their embedded applications. Use of one of these new nonvolatile memory technologies, even for a small nonvolatile cache or buffer memory, could save considerable energy, which is very important for battery powered devices such as HMD's or smart glasses.

Lower power use and higher capacities per die area, combined with more advanced batteries, could encourage the use of nonvolatile memories used for higher resolution, higher frame rate, and even volumetric content. Thus, advanced memory technologies will play a key role in enabling the future of digital reality equipment and experiences.

3.1.5.5 Memory and the Future of Digital Reality Equipment

Because of the size of future immersive digital reality images, whether high resolution, high frame rate, large number of bits per pixel or true volumetric images; memory will be an important element in future DR devices. As the size of these images grows, so does the data rate and the requirements for latency decrease as well.

Because of the power that conventional volatile memory requires, future DR equipment will use emerging nonvolatile memories for caching and buffering content. As the cost of these memories goes down, they will start to replace embedded SRAM, NOR and eventually DRAM memory. Reducing the power consumption of battery powered personal DR devices such as HMDs and smart glasses will increase the quality of content that they can support with a reasonable battery life. Providing life-like 8K and higher resolution per eye and even volumetric imaging will increase display device requirements for the amount of memory capacity and performance.

Equipment to enable virtual experiences in a closed environment, such as a room, will also drive the use of large memory and storage to store and display volumetric content. Conventional as well as emerging memory and storage technologies will be required to enable the future of immersive video content.

3.1.6 Mixed Reality

In 2011 Apple released its voice-assistant, "Siri". Three years later, Amazon followed with its version called, "Alexa". The main difference is Alexa was not initially part of an already existing product, like the smartphone. Instead, Amazon combined it (if not to say "her") with a completely new device, the smart-

speaker. Due to this, potential clients perceived it with a physical manifestation. Later, Alexa also became integrated into other devices, like televisions or smartphones.

In 2015, Microsoft launched Cortana with the mission to connect Windows 10 with Apple and Android smartphones. Being late to the game, Cortana never reached the same popularity as Alexa or Siri. As opposed to her contenders, Cortana had in the beginning a defined virtual appearance, as she was an artificial intelligence character in Microsoft's videogame series "Halo". Despite its roots and the existing X-Box hardware, Microsoft never extensively connected Cortana with gaming but tried to establish the AI as a virtual assistant. As this strategy failed to work out, the company shifted the concept to implement the AI deeper into its Office 365. Accordingly, Microsoft CEO Satya Nadella does not contend Cortana as a competitor to Alexa and the Google Assistant anymore (released 2016).⁹

The Pew Research Center defines Generation Z with humans born from 1997 to 2012, a generation that grew up with social media (Facebook launched 2004).¹⁰ Even more, the later part of Gen Z had been born into a world where voice-assistants already existed.

Generation Z is not only growing up with various social media platforms, including Instagram, TikTok, and WhatsApp, but also with multiplayer games, such as Roblox and Fortnite. In contrast to former generations, Gen Z interacts with a reduced number of online friends, where they not only continuously feed the group with information (texts, videos, voice messages) but also receive it from their trusted circles. A continuous interaction is created, comparable to a hive intelligence acting as a connected system. For Gen Z (but also members of earlier generations), only one (digital) reality exists today, jointly formed by the physical and digital worlds. This holistic understanding of reality allows this generation to act jointly in both worlds, for example to use physical money to buy virtual goods. In the following, we provide a few examples of already existing Mixed Reality (that are programs of a future Digital Reality).

Virtual Holidays

The US-author Philip K. Dick published his short story "We Can Remember It for You Wholesale" in 1966.¹¹ Later in 1990, the Dutch Director Paul Verhoeven created the movie "Total Recall" based on this. The story plays with one of Dick's favorite topics, the question what is real and what not. The main character, Douglas Qual, dreamt all his life to visit the red planet Mars. But due to his limited budget, such a trip stayed out of reach.

He discovered the Rekal corporation, a company which offered the implementation of virtual memories of the perfect holidays. The client decided out of a catalogue of different possibilities, and then the selected option got implemented into its memory. After this, it was not possible anymore to distinguish such a programmed memory from an authentic experience. Qual decided to use the company's services to implement memories from a trip to Mars, not as a normal tourist, but a secret agent.¹²

⁹ Warren, Tom (2019): „Microsoft is killing off its Cortana app for iOS and Android in January“

¹⁰ Dimock, Michael (2019): "Defining generations: Where Millennials end and Generation Z begins"

¹¹ Dick, Philip K. (1966): "We Can Remember It for You Wholesale"

¹² Verhoeven, Paul (1990): "Total Recall"

In Dick's story, the process potentially failed, as Rekal's technicians discovered that he already had artificial memories inside his mind, and in fact he was a government agent working on the red planet. An ideal scenario to open the stage to play with reality and imagination.

The US-American philosopher Robert Nozick used Dick's idea, as he published his own book "Anarchy, State and Utopia" in 1974. Here, he described an "Experience Machine" as it could have been used by the fictive company Rekal. Nozick asked the reader: *"Suppose there's a machine that would give you any experience you desired. Superduper neuropsychologists could stimulate your brain so that you would think and feel you were writing a great novel, or making a friend, or reading an interesting book. All the time you would be floating in a tank, with electrodes attached your brain. Should you plug into this machine for life, preprogramming your life's experiences?"*

Nozick gave us three reasons why not to use the Experience Machine:

1. We want to do something not just gain the experience to have done it.
2. We have the need of individuality; we want to be a certain person.
3. The machine limits us to pre-programmed experiences, we cannot contact to any deeper reality.

Accordingly, the philosopher concluded that VR cannot satisfy our wish and need for real life.¹³

The Japanese company "First Airlines" offers, since 2018, "virtual holidays". As for many Japanese people, an intercontinental flight is out of budget, based on finances, but also the low number of annual holidays. A trip to the US or Europe often stays an unreachable dream, like Qual's wish to visit Mars. The company simulates such holidays. This uses Virtual Reality glasses, but also personal attention, combined with real experiences, like high class local food. The overall experience already starts with entering the location of First Airlines, which may remind to the "Recall"-office from the movie.



Figure 5. First Airlines, Japan, with friendly permission from First Airlines (2018).

¹³ Nozick, Robert (1974): "Anarchy, State and Utopia"

Memories blur with time and can even turn into false memories. After several years, it may become difficult for the individual to distinguish between real or virtual memories, or even to distinguish between own experiences or something which only was seen on TV. To foster this effect, the more realistic the virtual experience, the more real it will get perceived not only now, but also in retrospect.

This effect aligns with the psychologist and memory expert Elizabeth Loftus.¹⁴ She explains that human memory works unlike a recording-device, but each time a memory gets activated, it changes. Externals can use this effect to suggest that the individual's memory had been different, which may lead to a change of the regarding memory. That way, a wrong memory can be more perceived as more vivid than the original circumstances. A later study by Julia Shaw concludes that *"Even when participants knew that one of the memories was false and the other true, they were unable to reliably tell the difference."*¹⁵

To create strong experiences, First Airlines not only relies on Virtual Reality glasses with 360 degrees of sound and vision, but aims to stimulate all five human senses: sight, smell, hearing, taste, and touch. Furthermore, through a focus on details, the simulated experiences connect with "real" experiences. For example, the flight attendances present safety instructions and serve inflight-menus for the clients, as the virtual tourist may remember from earlier physical flights.



Figure 6. First Airlines, Japan, with friendly permission from First Airlines (2018).

The "flight" is a mixed reality-simulation. The virtual glasses address the senses sight and hearing, while the comfortable leather-seats address the senses smell and touch. The experience continuous with

¹⁴ <https://www.apa.org/research/action/speaking-of-psychology/memory-manipulated>

¹⁵ Shaw, Julia (2020): "Do False Memories Look Real? Evidence That People Struggle to Identify Rich False Memories of Committing Crime and Other Emotional Events"

guided virtual tours and authentic local food. This is an important factor, as food plays in most cultures an outstanding role to unite friends and family. Furthermore, it allows the virtual tourists to experience with all five senses jointly. With using all human senses, the company is able to create strong memories.



Figure 7. First Airlines, Japan, with friendly permission from First Airlines (2018).

Such tours are not limited by reality, only by imagination. So, it is no surprise that First Airlines also offers time travel-experiences. Quite similar as described by the Spanish author Felix J. Palma in his novel “El Mapa del Tiempo” (Spanish for: “The Map of Time”).¹⁶

As consumers receive pre-created experiences, the question of authenticity arises. Of course, this problem also applies for traditional guided tours, as the tourist perceives the destination filtered through the eyes of the tour-guide. Like the risk of biased algorithms, 360-degree videos could be altered by virtual effects or even manipulated to present the traveller a “brightened up” reality. Nevertheless, this risk is not new, as traditional tourist guides chose their individual routes to let the group experience what they want it to see.

¹⁶ Palma, Felix J. (2012): “El Mapa del Tiempo”

In the 1982 Blade Runner-movie (based on the novel by Philip K. Dick: “Do Androids Dream of Electric Sheep?”),¹⁷ the fictive Tyrell Corporation delivered their Nexus 6-replicants with implemented memories to give them stability and identity.¹⁸ Those had been supported by different photos, which should document the android’s childhood.

Today, zoos, theme parks, and other attractions use this idea. At the entrance, visitors get asked to pose before a plain green wall. Via computer technology, a related background will be included, and later at the exit, the visitors can buy the photo as a souvenir. The video game “Gran Turismo 6”¹⁹ offers the possibility to take cars from the player’s virtual portfolio to scenic places like Sicily for a photo-shot. This can be with or without the individual’s avatar. Such images can be saved in the in the popular jpeg-format and transferred to their PC. From there, it can be printed on photo-paper, what makes it hard to distinguish from a classic photo. Together with other typical souvenirs, an ideal way to reactivate memories, independent, if they are of physical or virtual experiences. Accordingly, passengers of First Airline receive a stamped passport as souvenir.

Noziek concluded that humans prefer to do things instead of the experience of having done something. Nevertheless, there is not always the possibility for the real thing. So Virtual Reality, especially if gets fostered by real experiences (Mixed Reality), is a growing market.

First Airlines is on the way to realize Philip K. Dick’s vision of implemented memories. They not explicitly implement the memories, but offer a way of changing to “fast forward”, as the virtual tourists needs much less time to experience a visit of the famous Colosseum than the conventional traveller. The company does not suggest that their passengers physically travelled to the selected places. Nevertheless, the created mixed experiences are strong, and with each reactivation of the memory will be perceived as more real.



Figure 8. First Airlines, Japan, with friendly permission from First Airlines (2018).

¹⁷ Dick, Philip K. (1968): “Do Androids Dream of Electric Sheep?”

¹⁸ Scott, Ridley (1982): “Blade Runner”

¹⁹ Polyphony Digital (2015): “Gran Turismo 6”

The Racing Twin

Digital Twins are becoming more pervasive, even in the places least expected. One of them is Formula One. To reduce costs, regulations limit physical testing between the races, even on private tracks. As in sports, these details can decide between winning and losing with teams constantly analyze guidelines to understand where the thin red lines are. As result, if physical testing is not possible, a virtual one must do the job.

All major teams invested into simulation centers, where replicas are mounted on moving ground and connected to high tech computers. This concept is like a typical Digital Twin, as it is used in different industries. There is a twist, these twins are not all-virtual, but include a physical part. Despite its name, Digital Twins are not limited to the virtual world, but can connect to physical parts.

The joined digital and physical model, an original creation of the machine, should support to understand, predict, and / or optimize (based on General Electric's definition of a Digital Twin) a real or fictive object or process. This step includes a first data model, a set of analytics or algorithms, and knowledge. To reach this, a mixed team of engineers and IT-experts must work jointly to create a simulator, which not only virtually reacts like the original, but also physically handles the same. Simulator manufacturer rFpro uses Lidar laser measurement technology to scan the environment and realistically simulate it. As race teams can use more time to scan their own private race-tracks, like Ferrari's Fiorano, they can be simulated with higher details than the other tracks. Due to this, even in the virtual world, such own physical tracks keep their importance.

Digital Shadowing connects the model with the related physical race car. A modern F1 car can have between 150 and 300 sensors and send this information to the team. As opposed to a classic Digital Twin, the Formula One simulator can only receive data on limited occasions, like when the original car is allowed to be used. This can be in training but also in qualification or the race itself. The more information the simulator receives, the more it can analyze the car's performance, but also the better the model can be calibrated and update the model to make it as realistic as possible.

In the early years of Formula One, the driver had been the sensor.²⁰ His aim to win the race required the task to explain potential vibrations or other unusual behavior of the machine to the mechanics and engineers. The more sensible and technically knowledgeable the driver, the better the feedback that he could give the team. In 1975, the McLaren team implemented "telemetry", a system to collect information from and about the car. At that moment, it included 14 different pieces of information.²¹ The human sensor became accompanied by mechanical ones.

Nevertheless, the driver stayed the most relevant source of information. Three --time world champion Niki Lauda resumed the driver's influence in the development and setup of the car in the 1970s and 80s: *"We had much more influence because we all depended on my ass feeling and translating to the engineers. Today everything is data driven, our information was much more important otherwise we would not have developed the car."*²² In 2018, the Ferrari racing team included a staff of 1000

²⁰ Pogrebna, Ganna (2020): "Data Driven Insights 5: The Use Versus Abuse of Big Data in Formula 1"

²¹ Pogrebna, Ganna (2020): "Data Driven Insights 5: The Use Versus Abuse of Big Data in Formula 1"

²² van de Burgt, Andrew (2019): "From the archive: Lauda answers the paddock's questions"

employees. Only a fraction of them travel regularly with the drivers to the different races of other events. As opposed to the early years of racing, this makes it difficult to build up a personal relation with every member of the team, which they may perceive them as being “in the cloud”.

Aligned with the Gartner Hype Cycle, in the 1970’s, early telemetry lead to a high number of innovations in the sports, but the maturing of the technology up to evolvment into Big Data led to fewer radical innovations.²³ More information (Big Data) does not lead to more insights (Smart Data). As opposed to this, the driver stays a relevant factor. Drivers such as Niki Lauda, Ayrton Senna, Michael Schumacher, Sebastian Vettel and Luis Hamilton, based on talent, dedication, and knowledge could better connect to the car, team-members, and information. This enabled them to drive sustainable at the limit. The human factor as a key advantage is not only relevant for the driver position, but includes all other parts of the team.

The simulator helps the team to understand their car inside limited time. This helps test different updates and setups to create an advantage for the race weekend. To reach this goal, it is required that the so called “simulation driver” is experienced with real Formula 1 cars. For example, in 2018, Ferrari’s driver combination for the championship had been Sebastian Vettel and Kimi Räikkönen; Antonio Giovinazzi as simulation driver. To qualify for this position, Giovinazzi not only participated successfully in the Ferrari Driver Academy, but he also participated in two races of the 2017 season for the Sauber Ferrari-team. Being the third driver not only includes being behind the monitor, but a few times also testing the physical car. With this, the driver can understand how close the original and twin really are. If not restricted by Formula 1 guidelines, to optimize the benefit of the twin, the simulation driver could support the team over the race weekend while using similar setups on the simulated track. To enhance the simulation (“Augmented Virtuality” as opposite of “Augmented Reality”), the program not only uses real-time information from the race car, but combines this with original weather information.

The boundaries between the virtual and physical world are vanishing. In 2019, Giovinazzi switched sides and participates in the Formula One championship for the Alfa Romeo team, alongside his former team colleague Kimi Räikkönen. Another sign of the two worlds growing together is the rise of eSports, where championships are followed by a high number of fans. Some leagues are based on pure video games, but others are a simulation of physical sports, such as Formula 1. The competitiveness of the virtual version gets confirmed by the athletes’ ability to switch between them. For example, at the 2019 Race Of Champions organized in Mexico City that year, the raining eROC champion and F1 eSports driver Enzo Bonito beat in a physical race the former Formula E-champion Lucas di Grassi.²⁴

As due to the COVID-19 virus, various Grand Prix races of the 2020-season became cancelled. Formula 1 had to think how to cheer up fans staying in quarantine or self-isolation and keep them involved in the sports. As already two years earlier they implemented in parallel a Formula 1 eSports series, management used this base, and instead of the physical events, organized for the former race Sundays a virtual race, where former, actual, and future Formula 1 drivers could participate. As opposed to the commercial version of the video-game “Formula 1 2019”, the differences of the cars had been disabled (including fixed set-ups) to offer each driver the same conditions. The first race was won by the Chinese

²³ Pogrebna, Ganna (2020): “Data Driven Insights 5: The Use Versus Abuse of Big Data in Formula 1”

²⁴ F1 Sports (2019): “Esports Star Enzo Bonito Defeats Racing Heroes at 2019 Race of Champions”

Formula 2-driver Guanyu Zhou. Thanks to the positive perception by the fans, already the second race saw a higher number of actual Formula 1-drivers. The races had been streamed for free on YouTube and Twitcher.

Thanks to the actual graphics, for the viewer it does not look much difference than a normal race, even if pit walks, interviews with team-members, etc. had been missing. A sign that indeed the physical and virtual worlds grew together is that Ferrari driver Charles Leclerc won two physical races (Spa, Monza) of the 2019-season and half a year later the second race of the virtual season (Albert Park). Giovinazzi reached a good fifth position. Another aspect of Formula e-racing is that most people do not have the opportunity to drive a physical Formula 1-car, but the video-game, with a price of less than 100 USD (depending of the version), is played by many gamers. Nevertheless, also here are differences to the professional drivers, as most people at home do not own professional gamer seat with steering/wheel.

Virtual Explorers

The episodes of the original Star Trek series started with the famous opening words: *“Space, the final frontier. These are the voyages of the Starship Enterprise, Its five-year mission. To explore strange new worlds. To seek out new life. And new civilizations. To boldly go where no man has gone before.”* New manned space missions aim to Mars; further destinations still are out of reach. Nevertheless, the digital world offers possibilities not only to participate in science fiction games, but also virtually support universities in the exploration of potential exoplanets.

In 2017, the prestigious University of Geneva partnered with the science-fiction Massively Multiplayer Online Role-Playing Game (MMORPG) “EVE Online”. The game simulates a virtual universe, where players can take the role of a spaceship captain and discover the wonders of the galaxy. With the connection to the university, the game becomes reality. The users, while sitting before their home computers, become scientists acting inside a virtual space.

The university provided 176,802 deep space light curve images obtained by the ESA space telescope to the game community. Docked at the virtual space station, players can access a database to analyze variations in the perceived light. A pattern here indicates the existing of one or various exoplanets. The more players identify the same patterns, the higher the possibility of these planets.

Even if algorithms are superior for the identification of patterns, the university prefers the additional classification by humans. After the first 190 days, 77,709 players of the EVA Online community already provided 44.5 million classifications. Due to the university, the provided information by the virtual pilots showed “a very high consensus,” meaning numerous pilots identified in parallel the same patterns for each deep space light curve. These assessments are the base for the astronomers of the Geneva University to confirm the information via other astronomical databases.²⁵ The players are not only selfishly supporting science, but thanks to their works, earn rewards and virtual currency to spend inside the game.

²⁵ Team Psycho Sisters (2018): “ENCOURAGING SIGNALS – A PROJECT DISCOVERY UPDATE”



Figure 9. EVE Online Press Photo <https://www.iqdb.com/games/eve-online/presskit#images>.

To explain the project and motivate the players, the recognized expert of exoplanets, Nobel Prize co-recipient in Physics 2019, and honorary professor at the University of Geneva, Michel Mayor (who also discovered the first exoplanet in 1995) agreed to be included into the game as an avatar virtually responsible for the “project discovery”. “Citizen science” is one strategy to support chronically understaffed universities. As these amateurs work for free, gamification keeps them motivated.²⁶

Thanks to the continuous connection to the internet, real-time information can be included into gameplay. For example, users could play soccer against professional teams from the actual game day, including details as temporarily excluded injured players or the actual condition of the team. Furthermore, the simulation can take the local weather conditions into the account. If it rains outside the window, so it does inside the virtual stadium. Such additional conditions bring the game nearer to reality, as the player does not react in an independent space, but stays connected to the outside world. As opposed to what “Pokemon Go” presents. “Augmented Reality” includes virtual characters into the real world. Such technology would go the other way around, including real circumstances into the virtual world, it could be called “Augmented Virtuality.”

3.1.7 Artificial narrow intelligence

The Digital Transformation is fuelled by digitalization, i.e. data, and it results in huge data creation and availability. This is the fertile ground for Artificial Intelligence. In turn, artificial intelligence powers industry to leverage from data and monetize the benefit of the digital transformation.

²⁶ Bratschi, Pierre / Achard, Pablo (2017): “Michel Mayor, personnage d’un jeu vidéo »

Narrow Artificial Intelligence (“narrow” because is field and topic specific) has become to the digital transformation what the Moore’s law was for electronics: an engine of exponential growth.

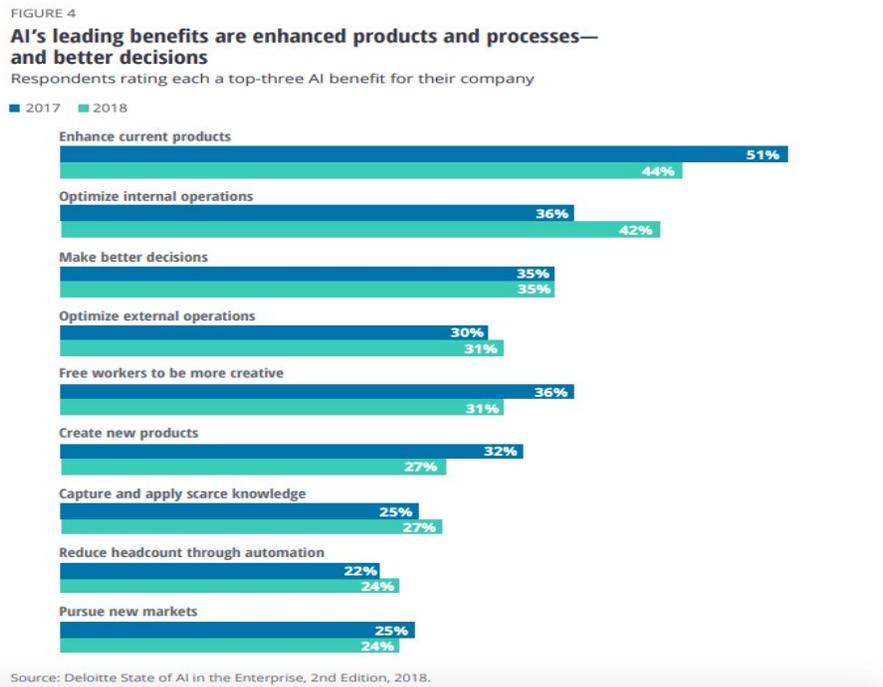


Figure 10. AI’s leading benefits are enhanced products and processes.

Narrow Artificial intelligence can operate on 4 dimensions:

- inside a product to deliver functionality.
- inside the company to streamline processes, manage equipment (including proactive/predictive maintenance), quality control (analysing components and assembly).
- optimizing the interactions among companies in the value chain (supply and distribution chain, predictive resource requirement, just in time, etc.).
- monitoring the operation/use of a product and feeding back the emergent intelligence in the whole value chain to improve the product and the future releases.

The existence of these 4 dimensions is what has led to the name of AI hyperSphere (hyper because it goes beyond the 3 spatial dimensions). The crucial aspect is that these dimensions are interacting with one another, reinforcing one another. This is what is creating a self-sustaining accelerated evolution, exactly like the Moore’s law operating at reinforcing the production tools by producing better chips led to an exponential evolution.

These dimensions are acknowledged by industry also in terms of relevance, see graphic with:

- the relevance of enhancing current products -fourth dimension.
- optimise internal Operations - second dimension.
- optimise external operations - third dimension.

- create new products - first dimension).

Narrow Artificial Intelligence is being leveraged, in particular, for its value in data analytics, image recognition, pattern extraction, and machine learning. These are possibly the four most important areas of application in the context of Digital Transformation since:

- data analytics acts on the huge amount and variety of data that would exceed the possibility of human management (at least in reasonable time).
- image recognition can leverage on digital cameras that provide digital images, and artificial intelligence algorithm appropriately trained can already exceed human capability.
- pattern extraction is usually considered a high level intelligence characteristic in the human “mindspace,” although in the human’s pattern recognition it is mediated by (or has a pre-requisite) an understanding of what is going on whilst artificial intelligence pattern recognition is more tied to the detection of certain repetitive occurrences so that actually in this area there is a complementarity between the humans and the algorithms.
- machine learning has been evolving rapidly from the stage of training an algorithm through submission of huge sets of “cases” and correcting the outcome of the algorithm to the current technology edge where the algorithm can self-train leading to autonomous learning. This is, however, creating new issues since it may look like humans are losing control on the machine “thinking processes” (the reason why an algorithm returns a certain result) and the difficulty in controlling the outcome.

3.2 Business Enablers

The Digital Transformation is happening because there are strong economic/business motivations. These can be clustered under the areas of Operational Improvements and Growth Drivers. We mentioned these two areas in this order because existing industries are mostly driven by operational efficiency and only look at growth as a second priority.

Yes, we know there will be plenty of people claiming that growth can be more important than operational efficiency, particularly in times of change and disruption but, in my experience, most industries declare to the press (and to the market) their goal of innovation and growth while internally focused on efficiency. The story is different when one considers start-ups. For them, efficiency is not the priority whilst innovating and disrupting the market is their competitive lever. In the following, we will address a number of Business Enablers.

3.2.1 Operational Improvements

3.2.1.1 Process efficiency

The widespread use of computers has required over the last 50 years a conversion of many parameters into digital data (for sure what used to be written on sheets of paper but progressively data captured by sensors and data generated by computers). In these years, the focus has been on using computer to assist/support operations, sometimes substituting human resources with computerised ones (in the assembly line, in the payroll activities, in warehousing, in customer care, etc.).

Some industries and market sectors have reached a point where much, if not most, of the activities is happening in the cyberspace. At this point, it becomes feasible and advantageous to re-think the

operational and business processes by shifting the company, as much as possible, to the cyberspace. We are seeing the New-Banks that are starting from scratch in the cyberspace with no physical front office, and we are seeing incumbent banks that after having provided ways to use their service online are now starting to redesign their whole operation and reducing their physical presence.

There are still stumbling blocks, like you often do quite a bit of interaction online and then discover that you need to go in person to a physical location just to sign a piece of paper (or the bank will email you a file asking you to print it, sign it and snail-mail it back to the bank!). Telecom Operators are in the same “transitioning” boat. New Operators have designed their whole processes online; they do not have a physical presence hence they have to do with online processes only. Incumbent Operators, on the other hand, are stuck with their processes requiring a physical interaction and will send you papers to sign and snail-mail back to them.

These examples are clearly showing a transition phase. It is a no-brainer that moving to an online space would increase efficiency, and this is what drives the digital transformation.

3.2.1.2 Assets utilization

It is so much easier to duplicate bits than atoms, to shuffle bits around and, by doing this, to have them used by different parties sharing the cost. To give an example, Telecom infrastructures are very much about physical resources like poles and wires are moving to an abstract representation of these physical resources and take care of their allocation in the cyberspace. This allows a much higher utilization, thus cost cutting (or deferring investment that would be required to expand the number of physical resources).

If you think that the twisted pair connecting your home to the nearest switch had an (average) occupation of about 1.25%, you can see what kind of waste you had in a connectivity infrastructure! Today, the wireless connection to your smartphone is probably not showing a higher percentage of use (actually it is, but because you are using your phone for much more than talking!), but the wireless connection is shared among multiple users so that its actual use goes up to some 40%. Technologies like network slicing, NFV, and SDN are all contributing to increase asset utilization.

The example is based on telecommunications, but the same reasoning applies to most other businesses wherever you have physical assets that could be transformed into digital ones. Think about the difference of recording a movie on film or as bits in the cyberspace: with bits you can use that asset, the movie, an unlimited number of instances, in parallel. As a bonus, the distribution of bits cost very little and each copy remains an original. Think about Uber, that by virtualising transportation in the cyberspace can optimize their utilization providing Uber drivers with a much higher number of drives per day. Think about BlaBlaCar that by allocating seats in the cyberspace can fill in cars and let the owner share the travel cost.

3.2.1.3 Agility

Dealing with bits is so much easier (although one should not forget the higher threats posed by hacking), and this can provide a business the possibility of changing in sync with the market changes. This is a strong driver for applying the Digital Transformation. The concept of Industry 4.0 leverages on the agility

offered by the shift to the cyberspace and the connection of market feedback directly to the supply chain and to the manufacturing.

Agility can be so effective as to support a design on-demand in addition to a manufacturing on-demand (new businesses are being created with the goal of letting the end customer participating to the design phase, a significant step forward to the already significant step that lets the end customer customise the product at order time).

3.2.1.4 New business and service models

Dynamic Pricing can be seen as part of the “agility” resulting from the Digital Transformation, or it can be seen as part of new business and service models. It does not really matter, since this is just a matter of classification. For sure, the Digital Transformation makes it possible to create new Business and Service models (the already mentioned Uber and BlaBlaCar are points in case).

In general, the digitization of products and the digitalization of the value chain enables a transformation of the business with the possibility of transforming products into services and of flanking services to products. This, obviously, has profound effect on the relation with the market, the end-customer, and other players in the value chain and ecosystem.

3.2.2 Growth Drivers

3.2.2.1 Demand generation

The Digital Transformation, as already noted when discussing the evolution of business models, allows the flanking of services to products because products may partly be delivering their functionalities through data and applications residing in the cyberspace (or embedded but connected to the cyberspace). This partial presence of functionality in the cyberspace makes it possible to a third party to add to the offer, generating new demand. In other words, the digital transformation may transform a product into a platform that can host third party services as well as a seed for aggregating several players into an ecosystem. This, in turn, fuels the offer and generates demand.

3.2.2.2 Reach and selection

Connected to the previous point is the fact that by using the cyberspace as marketplace for services, one can reach the whole world since locality is no longer an issue. Every person connected to the cyberspace (and mobile devices are taking the upper hand) is potentially a customer.

This worldwide market also plays out in the terms of sustaining the long tail: it no longer matters that only a few people in a certain location would be interested in a specific service—too few, actually, to make the service creation effort economically sustainable. Since the market is worldwide and there is, basically, no cost associated to delivery of a service because there is no “distance” between the “warehouse” and the point of retail/use, it is possible to serve niches formed by dispersed customers as if they were all present in a single location. This creates sufficient market space to generate returns.

It is not just the reach. A global market is huge and allows an immense differentiated offer. Players may select their target customers by focussing on some very specific, niche needs. This focus restricts the customer base, but given that the whole world is reachable, one is guaranteed that sufficient demand

can be raised. Hence, selection becomes a competitive advantage because it can target specific needs not being served by existing offerings. It is a virtuous spiral. As more selection takes place, more offerings become available, and this stimulates competition and leads to even more offerings.

3.2.2.3 Customer experience

As products and services explode (just think of apps on the smartphone), customers have wider and wider choices, price tends to go down because of competition (reaching zero, as it is the case in many apps, and resulting in the creation of alternative business models). Hence, customer choice is no longer based on price but rather on the experience delivered.

The digital transformation, by enhancing the possibility to add services and to monitor how products and services are being used by including the customer in the value chain making it part of the design and customisation, is also conducive to a much better user experience. This, of course, may become intrusive, usage data are captured to be aware on the customer/user behavior, but it seems that users are willing to trade these data for better option and services.

3.2.2.4 Customer purchase process

The Digital Transformation is further transforming the purchasing process, even the “habit” of shoppers. The shift of internet access to the mobile devices has further accelerated the change. Notice that here the focus is mainly on the retail market.

Let’s look at the six stages of purchasing:

1. **Problem recognition:** More and more the problem recognition takes place through advertisement. And more and more advertisement will get customized to the single customer. The Digital Transformation by making use of data in all phases of a product/service life cycle will create an immense data space of every single potential customer. The increased use of personal assistant (as well as personal digital twins) is likely to change this stage, anticipating in some cases to the point that solutions will be sought through the design of a product that will meet the specific, anticipated demand.
2. **Information search:** The ubiquitous access to the web and the presence of basically an unlimited number of products/services just waiting to be browsed has changed the habits of consumers. As for the previous stage, the trend is towards anticipation plus contextualization. Information is most likely to be brought to the customer, rather than having the customer search for it. The likely adoption of seamless augmented reality is bound to bring this information at the right time in the right spot. One should also note the emerging trend of voice based browsing, interaction that is going to have a significant impact on the purchasing process in the mass market.
3. **Evaluation of alternatives:** The process of evaluating alternatives has changed significantly as result of crowdsourcing and social media. Even for something as simple as selecting a restaurant, most people will take a look at reviews and directly make reservation from the review site. The availability of a digital assistant/digital twin will further change the evaluation process, introducing a pre-screening that will take advantage of continuous feedback (and machine learning) to finely tune decisions to expectations.
4. **Purchase decision:** The decision, if still made by the customer (in several situations the decision may be delegated to the digital assistant as we are starting to delegate email

- responses to Google) will benefit from the analysis made through a digital assistant of some sort that will take into account a variety of parameters to a point that can change the way products are marketed. As an example, take the decision of buying a white good appliance. Each product has the information on its energy efficiency. However, the average customer would have a difficult time in translating that information into a decision parameter (yes, in general a class A is better than a class B but would that justify a 50€ increase in price?). A digital assistant, aware of the probable use of that appliance can convert the information into a value that would support a decision (like: you buy that washing machine and by the end of the year your electricity bill will be 40€ higher. That means that in less than two years, with an expected lifetime of 8 years, that washing machine will more than pay for the price difference). There is also another twist that needs to be taken into account. The Digital Transformation is not just optimizing the production; it is also optimizing the usage. This means that more and more the purchase decision will involve considering the “sharing” of a product rather than its full ownership. The possibility to connect to other potential buyers will make this process easy and may change radically the retail landscape.
5. Purchase: With the Digital Transformation products are likely to be offered “wrapped up” in services. Even a product like a pill for controlling your blood pressure may be offered as a service. Would you like to be monitored as you use the medicine? How often would you like your blood pressure to be sampled by sensors in your wearable and analyzed by an application that is customized to your body and health profile? Do you want a personal digital twin be created specifically for this purpose or, if you already have a digital twin would you like it to be extended to cover this aspect? Would you like autonomous consultancy to take place via your digital twin? The Digital Transformation is also offering, in many cases, the possibility of buying the use of a product, rather than the product itself. This happens when the functionality of that product is delivered through the cyberspace and also when the physical product becomes a resource managed in the cyberspace. The Gig Economy is an example of leveraging the cyberspace to make better use of resources.
 6. Post-purchase evaluation: By having the product present both in the physical world and in the cyberspace (represented through its digital twin) and by leveraging IoT embedded in the product (sometimes also those in the ambient), it is possible to establish a connection between the product user and third parties, including the product manufacturer. This is an important aspect of the Industry 4.0 model where data derived from the product usage are analyzed to improve future versions as well as to provide pro-active maintenance and fine tuning (these latter can be monetised as service offering). This leverage on the cyberspace to deliver functionality, coupled with the increasing softwarization of products, is also making possible to increase over time the functionality of the product (as part of a customer care service or as a further sales of functionality). We have become used to this in the yearly releases of our laptop/smartphone/tablet operating systems (they are provided for free because the manufacturer has a vested interest in keeping its consumers base up to date and locked in its products).

This possibility of “modernizing” a product through periodical update of its software and of the functionality provided through the cyberspace is increasing the product lifespan, and this is clearly a double-edged sword:

- on the one hand, there is less consumption of materials and less waste since one keeps a product for a longer time before replacing it, and this is clearly good from a sustainability point of view
- on the other hand, many business models are based on repeated selling through a short lifespan of the product.

The manufacturing plants usually require little changes in moving from one version to the next one, meaning that they can benefit from huge economy of scale. By selling fewer instances of a product, the overall volume decreases and this increases the share of the amortization cost of the plant on each product.

Overall, one can say that the post-purchasing phase is changing because of the changing nature of the products and because of the new relationships being established with the manufacturer and with third parties (using that product as a platform to deliver their services/adds on).

3.3 Societal Evolution Enablers

The Digital Transformation has huge impacts on Society, both positive and negative. The Digital Transformation is also, at least partially, enabled by the evolution of culture and “habits,” the main one being the adoption of the smartphone and its use as a bridge to the cyberspace.

The smartphone has penetrated the society, reaching 95% in South Korea and well over 60% in developed countries. Notably, it is growing rapidly also in developing countries, approaching 50% in 2020 in most of these. The smartphone is the gate to the cyberspace, and it is a device that has become so popular that using it is now a seamless “habit”. One doesn’t need to teach a person to use a smartphone, either that person already is familiar with it or the environment will be supporting the learning.

This bridge to the cyberspace is so effective that one could even say that we are already living in an augmented reality world. Whenever there is the need for an information, that is just a few screen touches away, and people are taking this overlapping of digital information and the world for granted.

Companies are taking advantage of this and tend to develop services in the cyberspace, knowing they will be easily accessible to everybody everywhere.

Digital citizenship is also transforming the relation between governmental institutions and citizens, mostly mediated by the smartphone. Secure access to online content, to bank accounts, to medical exams and records, voting, and much more is now relying on the smartphone (more and more using biometric confirmation).

The lower cost in delivering services via the smartphone stimulates industry, and in a virtuous spiral, the availability of more and more digital services increases the digital culture and the habit of users that now are expecting them. Of course, this leads to a transformation of processes, Once these are moved to the cyberspace, they often need to be changed, the human intermediation disappears, and people get used to interact with machines via apps.

Looking at the graphic below, one can see (on the left hand side) a slate of technologies that have changed the mind-set and habits of people.

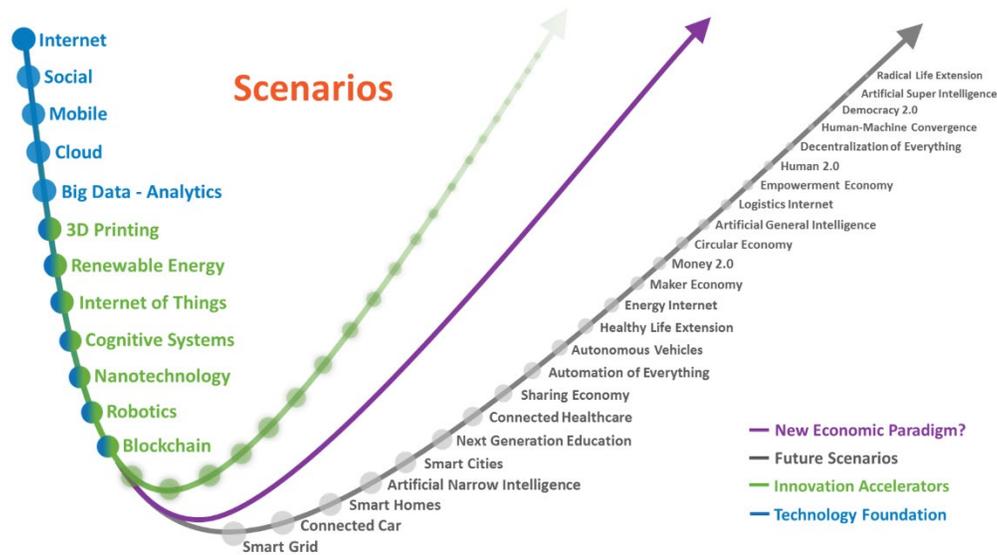


Figure 11. A graphic presenting, in an imaginative way, the evolution of technologies and their use leading to changes in society with the bridge among the two provided by the economic evolution. The diagram is just evocative, does not have a quantitative base. It was used in a talk by the futurist Gerd Leonhard in 2015 discussing 2020.

Internet, Social Media, Mobile, and Cloud have become a part of people’s lives . One takes for granted that a rental home will come with internet. Social media is the way to keep in touch and be informed, and they have broken the information asymmetry where only a few sources were the owner of information. Mobile access “is” the access. One may not go back home to pick up the forgotten wallet but will surely go back to pick up the phone. The Cloud has become the normal repository for entertainment, photos, etc.

Big Data Analytics, AI, 3D printing, Renewable energy, Internet of Things, Cognitive Systems, Nanotech, Robotics, and even Blockchain are no longer terms reserved to engineers. They make the headlines of newspaper and fill advertisement in mass market products. People may not really know what they are, but they are a common part of the daily landscape.

The convergence of these technologies fostered by the Digital Transformation is on the one hand stimulating their further evolution (right end side – green line) and accelerating them (most recently a key player in the industry mentioned this synergetic evolution as the creation of an hypersphere, hyper because of its multidimensionality and because of the acceleration deriving from the synergy) while on the other hand has an economic underpinning stimulating as well as steering companies to accelerate

their adoption (purple line) and finally resulting in a changing societal environment, designing new scenarios (black line) that, in turn, pressure companies and institutions.

In the following, these new scenarios will be addressed, tying them to the Digital Transformation.

3.3.1 Smart Grid

Power generation and power demands have to be in sync. In the past, power grids were designed by making assumptions on the power demand, and this worked out pretty well, given the predictability and the stability of the demand over time. Connection among international power supply made for even greater flexibility in load balancing to the point that if a power outage occurs, it makes the headlines. This ubiquitous and highly reliable power supply is taken for granted in developed countries (not so in many poor developing countries), and the power distribution has become ever more complex. Forecasting of demand is now based on complex algorithms, more and more based on machine learning and AI, that take into account a variety of parameters and route power along the path of minimal waste. The complexity is compounded by the variable contribution, and uncertainty, of renewable sources and micro generators (home generators like photovoltaic).

Power companies have started to include users in the power load regulation by introducing smart meters and offering dynamic pricing to steer residential users to periods of lower power demand, hence achieving a more effective (less costly) grid balancing.

This involvement of users will become much greater in this and following decades by using appliances, IoT, and the possibility to provide power information to them. These appliances are evolving towards becoming more and more autonomous, hence able to take decisions on when to be active (and use power). These decisions will take into account the availability of power at low cost and will make the all power grid micro-aware, thus increasing its performance.

The users will increase the demand of power. In the last two decades, as an example, the energy needed to power telecommunication has shifted from the Telecom Operators to the end users (recharging the phones, powering the Wi-Fi and access gateway, the media center, etc.). To give the flavor of the shift, in the last decade of the century, most of the power involved in telecommunications was taken up by the Telcos. In Italy, that meant some 2TWh per year. The traffic managed by networks has skyrocket, yet the Telcos have activated a number of cost saving measures (particularly in the plants air conditioning) that have counterbalanced the increased power need for antennas and base stations serving the wireless network, but the end users have dramatically increased their power consumption. In Italy, Telecom Italia at the beginning of the last decade (2010) was still using 2TWh per year, but the users that in the 1990 were basically using no power at all in 2010 used around 4TWh of power, that is twice the power usage of the Telco.

In the coming decades, we can expect the shift from vehicles based on fuel energy (petrol) to electricity, and that is a tremendous shift. It will mean quadrupling the electrical power in many countries (this data comes from a study in the Netherlands) and will require dramatic changes in the power distribution network (i.e. bringing high voltage to many more points to power high capacity recharging stations).

The involvement of users will be even more important to achieve an effective use of power on the 24-hour period. If all people are going to be back home at 6pm and plug in their car for recharging, the demand spike will be too high to be manageable. The smart grid won't be enough, it will require smart users and dynamic negotiations. This will likely change user habits and sharing the personal agenda with the grid will become more and more common (like letting the grid know that I won't be using the car until tomorrow morning but I will use it to make a long trip, so the battery should be fully charged versus going out for dinner to a celebration out of town and needing a fast and immediate recharging).

Also, electrical vehicles are based on batteries, and although battery technology will keep improving, we can expect that longer battery life will continue to be achieved if the battery cycles are limited and the battery is never fully charged (80% seems to be a sweet spot with present technology).

At a certain point, once battery efficiency drops to 70%, batteries will need to be replaced and the cost of disposing them remains high (and a nightmare once all cars will need to replace their battery pack). An alternative that can prolong the lifetime of batteries is to reuse them in applications like a home power bank where a 70%, even 40%, efficiency is still good (like buffering renewable sources). This again will change people's habits.

The digital transformation, by making data available for processing in the cyberspace, clustered and managed by digital twins, will be instrumental in these changes. The digital twin of the home, of home cars, of drivers and owners will interact with the grid to orchestrate the autonomous decision of each player in the ecosystem.

3.3.2 Connected car

Cars have had connectivity for several years now. It started with top of the line models, and then it trickled down to basically any new model. In the meantime, the meaning of connected car has evolved from a mere connection able to raise a red flag to a stream of bidirectional data outwards to signal the status of the various car systems and inward to provide road/traffic information.

Car-to-car connectivity has been on the drawing board for quite some time, but as 2020 we do not have it standard in all cars.

From a technology point of view, cars are now computers on wheels, and the various systems and subsystems have embedded sensors, including tires, generating data for on-board analysis. These data get processed, but some are also stored and can be used for maintenance purposes. Future connected cars will likely share these data in quasi-real time with some automated monitoring center to support pro-active maintenance and even generate corrective actions to reduce an issue until proper maintenance can take place. The growing availability of 5G in the second half of this decade (that is the timeframe to have a real massive coverage) will surely increase the communications capacity, and the presence of edge computing and smart antennas will enable low latency car-to-car communications through 5G. This will complement direct car-to-car communications that will not become ubiquitous until the following decade (cars are not equipped with direct car-to-car communications today, and the full replacement of today's cars with cars embedding direct car-to-car communications capability will take at least 15 years). Hence, 5G may indeed have a window of opportunity.

From a perceptual point of view, connected cars have not yet made a big impact. Drivers may appreciate the increased maintenance services provided and the increased safety delivered by a control center that can promptly detect an accident and send help. First signs of the discovery of connectivity manifested when Elon Musk socialized the idea of using the data its Tesla were streaming every day to create new services by a third party (in other words selling those data). There was an upheaval from customers that felt they were monitored and tracked and Musk had to backtrack. However, this pointed out one potential of car connectivity, the happening of a digital transformation. Cars, and their behaviors, were in the cyberspace and that digital presence could be leveraged in various ways. The digital representation of a car can be consolidated in that car's Digital Twin. We are already seeing this emerging and it is likely to become widespread by the end of this decade.

A car's digital twin can connect to the owner's digital twin as well as to other car's digital twins to deliver more customized services. We are already seeing this happening with Tesla that most recently has equipped its cars with a smart charging assistant. By learning the user whereabouts, the assistant can plan for the best recharging routine to make sure the car is operational and the battery can gain a longer life.

The opening of (certain subsets of) car's data can enable the rise of a new market of services, going beyond the operation and maintenance of the vehicle, delivering customized information to drivers and passengers. This is likely to be a first transitional step towards a new usage model that will take hold with fully autonomous cars, as the role of driver fades away and the car becomes a space as many others where the best use of time will be the selling point.

One can expect an increase in services leveraging on car connectivity, although the real game change will be enabled by the availability of the car digital twin in association with the driver/passenger digital twins and their interactions with other digital twins in the cyberspace. This growth may also lead to a shift from the perception of car as a product to the car as a service. Already, today we see a price differential between the basic version of a car and a fully optioned car in the order of 20% up to 50%. It is likely that this price difference will shift to services in the years to come.

The problem, as already made clear in the opening of telecom networks to service providers, is who will be reaping the revenues generated by these services: the car manufacturer or third parties? This is most likely the reason why we are seeing such a slow progress in the digital transformation of cars.

Manufacturers are fearing (rightly so) to lose revenues. However, it is inevitable for this shift to happen as cars will move towards becoming autonomous, losing their appeal in terms of "driving satisfaction." If car manufacturers will not move to enable services by third parties, those services will be delivered using a third party's gateway, as we have already seen happening with car navigators that have been (mostly) replaced by smartphones (the add-on navigator provided by car rentals has basically disappeared since people have free navigation support through their smartphone).

Concerns on privacy and security will rise and become stronger as more and more services become available. This, however, is a common denominator for the outcome of the Digital Transformation.

3.3.3 Smart homes

Homes are populated by a variety of systems, like power, communications, water (plumbing), waste, heating and air-conditioning, and security networks. They are also populated with many devices, some fixed like fridge, oven, fan-coil, and television, others wandering around like robotic vacuum cleaner and others moving in and out, like smartphones, tablets, wearable tech, and people and pets. Now, placing these latter in the “device” category might seem wrong, but from a digital transformation point of view, humans and pets are data generators, just like a fridge and a vacuum cleaner. Actually, they tend to generate and use much more data.

It is the availability of these data, some being generated over time, some being associated to the home, like cadastral data, construction data, and their processing that makes the home smart and has it affected by the digital transformation.

The perception of “home” is subtly changing, from a static entity to a dynamically evolving and responsive entity that can both adapt to changing situations and changing needs. More than that, a smart home is progressively more and more capable of interacting with people, be them the dwellers or the one in charge for its monitoring and operation (sometimes from remote).

Gateways and processing points like Alexa provide the interaction support locally, even though most processing and services may be residing off site, in a cloud. However, from a perceptual point of view, the home is becoming intelligent.

So far, the intelligence has been attached to specific devices/systems/functionality, but the arrival of Alexa-like interfaces that provide a single point connectivity is transforming the perception into a holistic view of the home. The smartphone is also becoming a possible gateway/interface to the home using both local storage/processing and cloud-based intelligence.

The creation of a real single entity as a smart home is made difficult by the existence of many “old” systems and devices whose replacement time may be quite long (or that cannot even be replaceable, like water and waste plumbing). Additionally, the variety of devices come from very diverse manufacturers and very little interoperability exists.

Nevertheless, the trend towards more interaction and control is unstoppable, and it is based on sensors and data processing.

This trend has been clear for over 20 years, but the big question was how to make it happen. Basically, three approaches were on the table:

- Having a smart control center produced by a company that would also provide a variety of add-ons to be placed on existing home components. These add-ons would contain sensors and would be able to transmit data to the smart control center. In some cases, these add-ons would also be able to interact with that specific home component through actuators to execute a command.
- Having the telecom gateway doubling up as smart home controller. It would require, as in the previous approach, add-ons to interact with various home component. The advantage of this

approach was that the gateway was already in the home and it would only require some extra software to transform it into a smart control center.

- Having a bottom up growth of the smart home environment by leveraging on new devices/components including sensing and communication capabilities. These devices would have been designed from scratch as smart home components and could result over time in a smarter and smarter environment that could grow at the owner's pace (interest and needs). So, one could buy a smart bulb and control it from the smartphone using a dedicated app, freely downloadable. Then one could buy other bulbs ending up in a while with the possibility of controlling the whole home lighting from one or more smartphones. Likewise, with heating. One could buy a smart controller (or a new heating system that came with a smart controller) and control it with the smartphone, and so on.

A somewhat parallel discussion took place over entertainment systems, some proposing a smart media center, others (Telcos) proposing their smart media gateway embedded in the Wi-Fi router, others proposing to turn the television into a smart media center and controller, and others looking at the smartphone as the media center orchestrator.

In the end, the smartphone has prevailed at least as a common interface, but the fight is still on for the data aggregation and management. Although, it is now clear that the game is no longer seeing the participation of Telcos or third parties. The one still playing the game are the ones controlling the human interface, be it the chatbots (Alexa and the like) or the smartphone.

What is still missing is a single view of the home that can really, and smartly, orchestrate the various systems, devices, appliances and services. The softwarization of functionality in many devices and the creation of digital twins is opening the door to a holistic view of the smart home and to the its perception as a single entity.

This is likely to be achieved in this decade and it will be a springboard to create smart neighbors and smart cities making use of a collective distributed intelligence. At the same time, the increased pervasiveness of sensors everywhere in the home and on wearables will lead to many more data that in turns will result in more effective data analytics and in the emergence of greater intelligence supporting ambient awareness and seamless interaction with human dwellers.

3.3.3.1 Smart homes at pandemic time

As technology advances and the "Internet of Things" becomes a reality, owning a smart home is increasingly becoming a necessity and is no longer considered a luxury. Benefits such as convenience, efficiency, security, and energy savings have been some of the main reasons why we consider turning our homes into smart homes. The convenience of operating smart home features using mobile phone applications from anywhere in the world is convincing many of us to turn our homes into smart ones. With smartphone applications, we can perform and verify various functions of smart home features without moving around our homes. In addition to making our lives more comfortable, these features give us a peace of mind and savings on the utility bills. These increasingly intelligent devices, appliances, and sensors will continue to learn how we use our homes to provide us with personalized experiences.

With the recent COVID-19 pandemic, our world has shut down for many months. The virus is telling us to slow down; it is giving us a chance to stop the rat race, to take a break, and spend some quality time with loved ones at our own homes. This has become the best time to take advantage of the advancements in home controls that we have accomplished over the years with smart home technology. To weather the storm of this or future pandemics, there are smart home options that we could incorporate to make our homes “germ free.”

The touchless nature of automated lighting that turns on and off when activated by motion or controlled by a smartphone could help prevent the spread of the virus. Similarly, by having our thermostats controlled wirelessly with an app on our phone can cut down on having multiple people touching the device. The touchless door locks that can also be activated remotely are great to minimize germs in our homes. Having wireless security cameras could be our eyes and ears, protecting our homes while we are asked to shelter in place. Voice control and voice-enabled capability of all the smart devices we own is not only convenient and clutter free, but it can further cut down on the spread of germs.

All the above features can run smoothly as long as we have power and decent Wi-Fi. In the event of a power loss, having a backup generator would help run our smart home without interruption. When it comes to Wi-Fi, it is important to have excellent coverage throughout our homes with everyone staying home, working from home, and studying from home.

3.3.3.2 Smart homes privacy and security aspects

While the concept of smart homes undoubtedly makes our lives more convenient and comfortable, there are downsides to relying so much on digital technology. Sometimes, wanting to raise our level of comfort could come at the expense of reduced privacy. These devices will be so smart that they will be able to tap into our user profiles as well.

For some of us, the hefty price tag, the possible risk of serious malfunctions, and the risk of being hacked may be reasons why a smart home is not actually such a smart idea. It can be expensive to transform a home into a smart home when we consider purchasing and maintaining new smart appliances, devices, switches, and plugs to automate lighting, temperature, and security systems. These appliances can be costlier to repair in the event of malfunctions. Some of these devices may not sync properly with smart assistants, and getting various devices from different brands to work together could be more time consuming. Downloading various apps that support each of these smart devices and creating separate accounts can be demanding. Given that the Federal Communications Commission’s rules that were intended to limit how companies can use internet customers’ sensitive personal information are effectively dead in the water since 2017, the data collected from our smart homes could be shared with others and sold for financial gains. The possibility of getting our smart homes taken control by the hackers is also a serious concern for some of us who enjoy having an intimate home life.

Therefore, we need to examine in depth the development considerations that IoT technologies have in collaboration with the services they enable to the smart home market. These include the opportunities provided by the IoT to smart home stakeholders, including us the consumers, developers, service providers, utility companies, and of course the insurance companies. The future applications for smart homes must be evaluated in the context of outcomes, technical solutions offered, and value propositions for consumers.

When it comes to consumer technologies, voice recognition technology together with speech analysis and acoustic transcription that was long known to have inaccuracies has now become quite reliable. Advances in AI, ML, NLP, and visual recognition, feed into data analytics and learning algorithms to allow smart devices to more effectively “guess” what we are trying to communicate. We have come a long way in terms of voice recognition that some devices can actually pick up our mood simply from our tone to understand what is valuable to us. Once activated with voice recognition, the sensors and antennas gather additional cues and information to activate internet enabled services. These voice recognition services today are continuously learning and improving through powerful programs running in the cloud. The use of smartphones as common interfaces together with reliable voice recognition technology has eased the process of smart homes into many of our lives.

In the near future, with the continued use of voice assistance, the devices in our smart homes will require minimum human interaction. They will also bring independence and improve the quality of life for disabled and elderly members in our society.

As technology continues to be an integral part of most of our everyday lives, many of us will continue to embrace IoT to connect as many devices to the internet, and eventually convert our homes into smart homes. For some of us, the sky will be the limit when synchronizing as many appliances and gadgets with each other and activating them with just the touch of an app. At the same time, while the benefits of having a smart home seem tempting, the drawbacks and risks associated with them can slowdown the mainstream adoption. However, we will eventually see this market expanding as the connected homes become popular and trendy as a place to hang out, to entertain, to shelter in place, and to relax.

3.3.4 Smart cities

Cities are basically existing and organized through and around infrastructures. The more efficient these infrastructures, the better off the city, the business and the citizen’s quality of life. The digital transformation changes the way infrastructures operate and can be monitored but, most importantly the digital transformation creates a “digital infrastructure” that can really change the rules of the game.

Notice that physical infrastructures operate within physical constraints, like streets and roads are constrained by the presence of buildings and geographical obstacles, and within economic constraints, like you cannot store all kinds of goods in a shop both because of space limitation and of economic impossibility to keep all those assets mostly unproductive (i.e. that shop will be selling only a fraction of them, meaning most of the assets are just cost). Because of these, usually physical infrastructures are designed to be as effective as possible within the existing constraints and don’t scale gracefully (or don’t scale at all).

On the contrary, digital infrastructures do not suffer from physical constraints (or at least these constraints can be circumvented, like the capacity of a data center, the capacity of a communication pipe, etc.), and therefore their topology can be more effective in linking resources with users (most physical infrastructures tend to find an equilibrium in a fractal topology, this gives an advantage over a linear topology, effectiveness rises from $x^{0.66}$ to $x^{0.75}$) approaching linear scalability (meaning that if you double resources you double the output).

The magic of digital transformation in cities is that it can leverage on so many data generated by the increasing digitization of objects and infrastructure, digitalization of processes, and data generated by citizens. Through data analytics and machine learning, these data generate more data, metadata, and eventually meaning and intelligence.

The digital infrastructure created by a digital transformation is also an infrastructure that leverages on distributed intelligence, and the most interesting part of this distributed intelligence is provided by citizens. This goes both ways:

- citizens, implicitly through their behavior, or explicitly by creating interaction towards the smart city can share their personal awareness, intelligence, and perception of value (issues, problems, appreciation)
- the city can provide assisted AI to citizens to improve their awareness as well as to influence their behavior resulting in a better use of resources, hence in a smarter city.

This latter aspect is very important since it connects technology (and economics) with social implication. Smart cities require smart citizens, and the digital transformation is both a tool and the backstage to make citizens smarter.

3.3.5 Next generation education

As just mentioned the “education” of citizens, through increased awareness of:

- the present situation.
- the goals.
- the impact of actions that are/can be taken by the individual.

These are fundamental aspects of improving a smart city. However, the need for increasing awareness is a much more general need in the education space.

The reason is that the knowledge on the one hand is growing at an unprecedented rate, but it is also becoming obsolete at an unprecedented pace so that both individuals and enterprises are struggling to remain on the leading edge of knowledge, to apply it in product creation to beat competition. Clearly, the first step would be to be aware of how and where knowledge has evolved and how much that evolution could impact business decisions and the second step is to find ways to fill the gap. The gap will keep widening and there is no hope for a single person, nor for a single company, to fill it in an acceptable time and with an acceptable effort. The crucial challenge is therefore to first “delimit” the gap to those parts that really matter to the task/goal at hand.

This is a noteworthy change in the education paradigm. It is no longer “learning just in case,” rather identify what is the minimum set one has to learn. Hence, the real gap that is worth identifying is the intersection among the owned knowledge, the overall knowledge, and the knowledge needed to accomplish a specific goal.

Once this delimited goal is identified, education tools shall be used to fill it. Here, there is another difference emerging: in addition to deliver education to a specific person, both individual and companies need to enter the space of distributed knowledge where the total knowledge required is no longer

owned by a single entity (be it an individual or a company). Rather, the knowledge supported by a network of interactions among people, processes, and tools.

In this scenario, the technology of cognitive digital twins—entities that can represent/mirror as well as execute/deliver the knowledge of a person, a company, or a tool—will become more and more important. Assistive AI, the possibility to expand competences and decision making capability through a seamless integration with AI, is likely to become more and more intertwined with cognitive digital twins.

Knowledge is shifting from being a static (although growing) set to become an executable entity that is intermediated by an agent to adapt to the recipient and to the goal/task at hand. Executable knowledge is, therefore, the new education paradigm, and this execution includes machines (robots, software, etc.). This is not an easy change at all, and not just in technology terms. It raises issues of control, of ownership, particularly as machines and software take the dual role of executor of knowledge and generator of knowledge. Machine learning is now becoming self-autonomous machine learning and humans are losing control on the knowledge acquired and generated by machines. This is likely to become a major issue in the long term—in the next decade as Artificial General Intelligence (AGI) is approached.

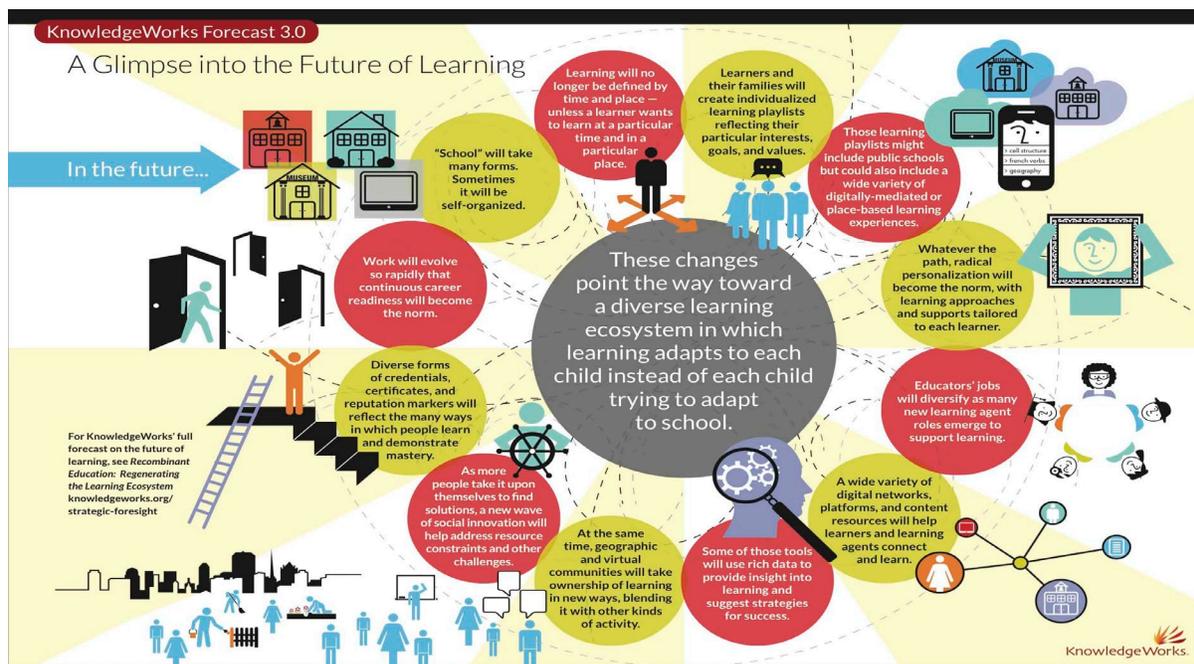


Figure 12. 10 key elements for the Future of Learning. The image is relatively old, published in 2013, but the basic concepts are very much important today and in one way or another affected by the digital transformation in education. Image credit: Tom Vander Ark.

3.3.6 Connected healthcare

The healthcare sector has been digitized (introduction of computers in equipment for analyzes, monitoring, diagnoses, medication, genome sequencing, etc.) and digitalized to a certain extent (exchange of data in various processes, although privacy and standardization issues are still limiting the exchange of several data, including the Electronic Healthcare Records). A recent study of the American Medical Association in the US healthcare pointed out the increasing use of digital instruments, including tele-health that grew 100% in the period 2016-2019 being used in 2019 by 28% of physicians²⁷ and clinical decision supporting tools grew in the same period from 28% to 37%.

The full digital transformation is still in its first steps. Yet, the increasing availability of data from different sources, including the ones generated by the person, not necessarily in the role of patient, through wearables.

Real-time connectivity among the various players in the healthcare domain, starting from the person/patient to clinics (medical doctors), caregivers, point of care, hospitals, pharmacy, nursing homes and home care is not a technology issue but a regulatory (and standardization) issue. The EHR has been designed, unfortunately, differently in different parts of the world and often even within the same country. In 2019, the European Commission adopted a recommendation for a unified European Electronic Health Record exchange format²⁸.

The transformation of healthcare processes and the pervasive leverage on data will take some time, but it is reasonable to expect that significant progress will be made in this decade. General Electric Healthcare division indicates Healthcare as the sector that will make more progress in the digital transformation, pushed by the rise in cost that are becoming unaffordable both for the individuals and for institutions/governments. Epidemics, like the recent one originating in China (coronavirus flu) and rapidly spreading worldwide, will put further pressure in the exchange and use of data. In particular, the recent epidemic was tracked²⁹ using AI algorithms, clearly showing the power of digital analytics in this area.

The development of new drugs is also moving in the path of leveraging data, pushed by the huge cost of discovering and testing new drugs. The rapid spread of viruses (like the one aforementioned) is further pushing towards the digital transformation of pharma, using the virus genome sequence data to find quickly potential vaccines.

The increasing availability of millions of human genomes sequenced enables data analytics and machine learning to gain insight on the relation among phenotypes and genotypes and support simulation of new drugs at a speed that was not previously dreamed possible.

²⁷ https://www.businessinsider.com/physician-adoption-of-digital-health-tools-has-spiked-2020-2?IR=T&utm_medium=email&utm_term=BI%20Daily&utm_source=Triggermail&utm_campaign=BI%20Intelligence%20Daily%202020.2.13&utm_content=B

²⁸ <https://ec.europa.eu/digital-single-market/en/news/european-commission-adopts-recommendation-european-electronic-health-record-exchange-format>

²⁹ <https://www.wired.com/story/how-ai-tracking-coronavirus-outbreak/>

The development and adoption of digital twin technology will further accelerate the digital transformation.

At a societal level, the perception of healthcare in this decade will start to shift from cure to prevention. That involves in addition to healthier lifestyle (as it has always been preached) to the monitoring of the body physiology through wearable sensors and ambient sensors in the home, in mirrors, and in toilets. Data harvested will be managed through a person's digital twin and its interaction with specific software services provided by third parties, the medical establishment (national healthcare system), private services providers, insurance companies, or the employing company.

From the person/patient point of view, it will become more and more acceptable to manage healthcare thorough "bots" interacting with them on a daily basis (chatbots). Intervention of a medical doctor will be reserved as a second level support and in most cases it will be solicited by a bot. There are, obviously, issues of responsibility and accountability that have to be resolved, as well as privacy issues and ownership of personal data. All in all, today it is an uncharted path.

3.3.7 Sharing Economy

The Digital Transformation creates an infrastructure based on bits. This infrastructure and the characteristics of bits, ease of replication, transport, access, and manipulation make it an ideal infrastructure to share resources. If you look for a moment at telecommunications, you can see how the progressive dematerialization of resources has led to an increased effectiveness in their use. Whereas, in the past, one twisted pair could be used for carrying just one communication (and as result most of the time the physical resource was not used) upon the invention of digital coding. It became possible to package more communications on a single twisted pair (or co-axial cable), thus increasing its effectiveness. The parallel shift to soft control of routing made possible the use of available lines to handle traffic that was originated and headed to a different part of the network.

Softwarization in telecom network is still continuing (SDN, NFV), further increasing the use of resources. The replacement of twisted pair with radio followed a similar path. From the first system where a channel (spectrum segment) was dedicated to a single communication moved to digital radio where more communications can be squeezed onto a single "channel" (although we no longer talk of channels since now there is a continuum in the use of the allocated spectrum). This example is to clarify that by shifting physical resources or deferring their management in the cyberspace, it is possible to achieve a much greater efficiency.

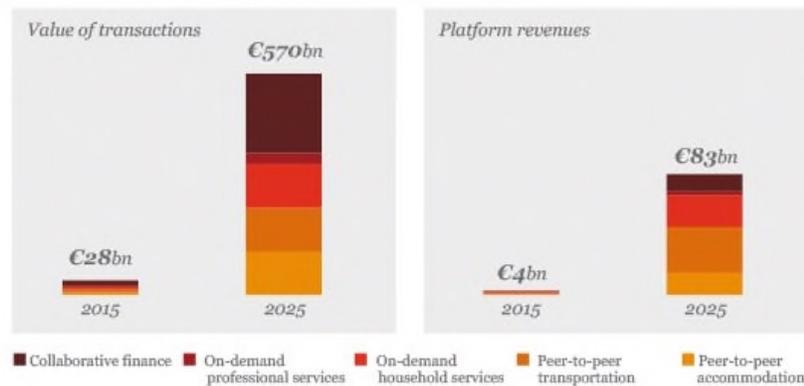
So, if we take a car, we can see that the average car has a very low utilisation index, between 5-10%, it is actually used. The remainder of the time it sits idle in a garage or is parked somewhere. A second home is used for a few weekends or a few weeks per year, again a utilization index below 10%. A dress may be used for a few days, and the fancier the dress is the less likely it is to be reused (like a ceremonial dress), resulting in a utilization index well below 5%. By tracking the availability of a resource and making it visible to a broad market, one can share the resource among many users, increasing its effectiveness.

The digital transformation and the dematerialization of resources (their control through the cyberspace) makes this possible at a very low cost and to a very broad potential market. Cultural shifts, like growing attention to sustainability and a criticism towards waste (not using a resource is a kind of waste),

stimulates people to access the shared economy. At the same time, owners of resources see in the sharing economy an opportunity to decrease cost/generate revenue at marginal cost. Some resource sharing is geographically constrained (like sharing a car) while others can take place in a wider space (like sharing dresses having them snail-mailed).

Notice that a portion of the sharing economy does not necessarily involve a monetary transaction. There are quite a number of people that share their home in return for the possibility of sharing someone else's home. Finding a bed to sleep over a night can be the result of the willingness of hosting people at one's home. The concept of FON, making one's internet gateway accessible to people that are symmetrically making their access gateway available is a clear example of a sharing economy where no monetary transaction is involved.

Revenues and total transaction value facilitated by sharing economy platforms in Europe by sector



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Figure 13. Expected market value growth in Europe of the sharing economy. Image credit PWC.

As shown in the graphic above, the sharing economy is growing at a fast pace, also in terms of economic value. The graphic represents the expected growth in Europe segmented for collaborative finance, on-demand professional service, on-demand household services, peer to peer transportation and peer to peer accommodation. Notice the economics in both the rendering of the service, value of transaction and in the enabling of the service platforms. Whilst service rendering is very fragmented, the enabling platforms are few and create a market lock-in (you offer your service on that platform because it has a very large market audience, and you look for a service on that platform because it has a wide variety of services: this creates a reinforcing spiral leading to market lock-in and oligopolies). Also, notice that the rendering of a service has very low transaction cost since all the burden is taken up by the platform. On

the contrary, creating and maintaining a platform is very expensive (although artificial intelligence applied to customer care may significantly reduce the OPEX).

There is another societal aspect to be considered: the increased efficiency in resource utilization made possible by the digital transformation and leveraged through the sharing economy lead to a lower need of resources. Hence, as people make increased use of shared transportation, car manufacturers are seeing a decreased demand for new cars, leading to lower production volume.

This is one of the side-effect of the shared economy: decreased demand and potential impact on jobs. At the same time, the shared economy increases resources' availability and stimulates demand of those resources: this shifts revenues from the producer to the owner.

3.3.8 Automation of everything

Automation has been a sort of mantra in the last fifty years: robots and assembly lines in manufacturing, routing in telecommunication networks, automation of medical exams analyzes, and automation in coding of software. There is hardly an area that has not been affected by automation, and one would think that whatever could have been automated has been automated.

Yet, in these last two years, a new word has started to circulate: hyper-automation. Gartner has included hyper automation among the 10 strategic technology trends for 2020, actually placing hyper-automation at the top of the list.

As for other emerging concepts, there are a number of interpretations of what hyper-automation is (and could be). All of them include the use of artificial intelligence:

- to increase the level of automation of current systems/objects.
- to increase the spectrum of objects/systems and processes that can be automated.
- to increase human capability resulting in a human intelligence augmentation.
- to increase the overall automation by seamlessly integrating human intelligence in objects and systems.

Hence, artificial intelligence becomes an essential component in the automation evolution and this is the reason why some refer to hyper-automation as "intelligent automation".

As noted, the digital transformation creates a data infrastructure that can feed artificial intelligence, hence the connection between hyper-automation and digital transformation. Also, hyper-automation is a strong generator of data and this further fuels artificial intelligence algorithms and, in particular, machine learning.

The path towards hyper-automation is first applied in those areas where a strong automation already exists, hence in the manufacturing plant. The digital transformation extending to the whole ensemble of processes tends to lead to the creation of a Digital Twin of the Organizational (DTO) and the pervasive automation extends from robots in the assembly line, in the warehouses, in delivery Robotic Process Automation (RPA), and to the business management intelligent business process management software (iBPMS).

Indeed, the new wave of automation extends to “intellectual” processes up from the automation of mechanical processes. It includes decision processes in the business space Business Process Management, a new technology to coordinate people, systems, and data.

How can one hope to automate the interplay of entities as diverse as machines and people? The automation of machine interplay can be mediated by Digital Twins, the digital twin of a machine interplays with the digital twin of another machine and this interplay can be subject to some sort of control and automation. The idea is that also humans could have a digital twin as a proxy. This new category of digital twins when become able to mirror knowledge, skill, and intelligence of a person are called cognitive digital twins (CDT), and the hyper-automation leverages on these CDT to create a seamless continuum among human workers (blue and white collars), machines, data, and processes.

What is important to notice from a societal implication point of view is that this trend in creating an augmented human, a human that is flanked by AI, either directly as an example by using assisted intelligence on the job, possibly mediated by augmented reality, or indirectly through the CDT, is raising a whole set of new issues.

According to Gartner, in this decade, companies will start to take for granted the augmentation of worker’s capabilities through AI, and as today several companies have embraced the BYOD (Bring Your Own Device) tomorrow, they will embrace the BYOE (Bring Your Own Enhancement), expecting workers to have a CDT that can seamlessly interact with company processes and assisted AI. Actually, this might become a selection criteria, and later in this decade, curricula might start to include a description of the applicant CDT, and a company might be able to test how much that CDT would fit in the company.

3.3.8.1 Autonomous vehicles

Technology to support autonomous vehicles is already available. Think about military drones, Unmanned Autonomous Vehicles (UAV), and automated subway trains. You can also think about early version autonomous cars, like Waymo. Technology might not be totally affordable, and it might require further enhancement, but it is here. The reasons why it is not deployed are beyond technology. They involve regulation, deployment procedure, transition management, economics, and, an evolution of societal perception of what transportation is.

Although there have been several studies on the possible impact of fully autonomous vehicles, and more are underway, there is no consensus on what the future will be like in terms of societal perception.

In the military sector, autonomous vehicles are a reality, but they have not reached the peak of their evolution. Autonomous Robot Soldiers may be the future; a first step could be autonomous robot-soldiers flanking human soldiers. There is information on investment in this area (although figures and the results achieved so far are probably inaccurate, and the plans are shrouded in secrecy).

Another area where autonomous vehicles are a reality is space missions. Autonomous rovers have been deployed on Mars, and autonomous probes have been sent to other planets and comets with more to come in this decade (including a mission to land on Mars, retrieving rock specimens, and bringing them

back to Earth). This is an area where cost is not an issue (to a certain extent), and where it does not need to be supported by a viable business model.

In the general domain, the interest for autonomous vehicles is growing as technology is becoming more viable and affordable with products (supporting specific business models) being just round the corner.

Business plans have been drawn for autonomous drones to transport people like autonomous flying taxis, in Dubai, Singapore, and Los Angeles within the next two years. It will take several more years for flying taxis to become as normal as today's taxis, but the roadmap is there and is credible. Interestingly, in Dubai, flying taxis are seen as a way to provide faster travel time while in Singapore and Los Angeles are seen as a way to decrease traffic congestion. These different goals have different implications on deployment and on people's perception. Whilst in Dubai, one can expect the flying taxis to serve those having deep pockets and willing to trade money for shaving off some time in travel, in Singapore and Los Angeles the goal can be achieved only when flying vehicles will make a dent in the mass market traffic. Hence, their price will have to be affordable to a broad market segment, and the number of flying vehicles shall reach at least 10% of the current road moving vehicles.

The perception of safety will need to become widespread and achieving that type of safety will require the setup of an infrastructure that today is simply unheard of. Airspace control is based on the separation of vehicles (a few km in separation at the same altitude and at least a thousand feet in altitude). With this kind of separation, it won't be possible to manage the kind of traffic density that is required to alleviate road traffic.

Autonomous cars are basically at the end of the rainbow. They seem close but it will take a few decades before current "driven-cars" will be completely replaced by autonomous cars. In addition to economics and regulation here, the consumer perception is going to shape the market and define the impact.

There have been a number of studies showing that an autonomous car that you can call to pick you up can potentially decrease the number of cars by 50-60%. The reasoning is based on the fact that an autonomous car is a pure transportation means, providing the service of taking people from A to B. Such a service could be provided with the same type of availability you would experience having your own car parked on the sidewalk. Whether or not people will choose the service over the ownership of the car is a matter of discussion and speculation. As a matter of fact, cities offering shared cars have seen a decrease in ownership. There might be some people that would rather own the autonomous car and will keep buying, but it is taken for granted that car manufacturers will see a decrease in sales over the next three decades. The current world production of about 70 million cars is going to decrease, and this will create problems to a sector where margins are thin and scale economies very important. More than that, autonomous cars will remove the driver passion from driving, no more over-speeding and quick acceleration. Hence, it will be difficult to sell cars because of their performances.

If the number of cars will be decreasing as result of autonomous driving, the traffic on the road may actually increase. The reason is that transportation service will become more efficient, hence more people will be using it. The traffic congestion in cities like Los Angeles may not get any better (even though autonomous cars will be able to run in a denser traffic). Flying taxi business will not be disturbed

by autonomous cars. The digital transformation will be crucial in the shift from ownership to transport on demand (service) as it has already been in making car sharing services possible.

3.3.9 Healthy-life extension

The dream of eternal youth goes back as far as we can see into the past. In reality, most of homo sapien's lifespan has been below 30 years. There have been exceptions of course, and if we consider early death in infancy and remove that from the statistics, the average lifespan was around 40 years old. It is only in the last centuries that the average life expectancy has started to grow, thanks mostly to purified water (medicine had on average a very limited impact on the increase of lifespan).

In the last 60 years, however, the lifespan in developed countries has started to increase, thanks to medicine (with antibiotics getting most credit). Advanced medicine, like transplant, can indeed prolong life, but it is usually effective on a single individual with limited impact on overall statistics.

One should also notice the "healthy" qualification. Actually, life tended to be healthier in the years preceding death in the past (either you were healthy and you lived or else you died). Today, the advance of medicine can prolong life, but in many cases the quality of life is not good and elderly often complain of what is the point of living longer if the life quality is low.

The digital transformation may change this situation. By mirroring atoms in bits while harvesting data from people and from the environment, it becomes possible to shift from a medicine focused on cure to a proactive medicine focussed on healthy living. This shift to proactive medicine should be able to impact a much larger population (the larger the community the more effective the data analytics) and result in a broader lifespan increase.

The use of Digital Twins in healthcare will become more and more common in this decade (most likely by the end of the decade if one looks for a wide-spread adoption). A person's digital twin will include data on that person's genome, mirror and keep track of several physiological parameters like their heart, lungs, metabolisms, activities, habits, and interactions, both with positive and negative impact on health. All these data generate knowledge on that person's health and health risk, supporting a proactive approach to healthcare. More than that, the ensemble of digital twins of a community can be analyzed for early detection of epidemics and dangerous factors as well as to gauge the response to drugs/prescription/environmental factors, leading to further intervention.

The effectiveness of the effort to increase the lifespan is uncertain. A few claim for the possibility to extend life up to 140 years. Others push this to 200, not to mention the very few that believe immortality is in the realm of scientific possibility.

Based on what is known so far on the genome, on the impact of telomere in preserving the genome duplication accuracy and to data on eldest people, it would seem that 120 is already a very challenging target. Beyond that, some form of rejuvenation would be needed, and in spite of several experiments (on animals), there is no real scientific proof of a method that could be applied to humans and deliver.

However, notice that even extending the average lifespan from 80 to 100 years would already have a tremendous impact on society (beyond the obvious impact on single individuals). Our economics and

our infrastructures have been designed with a lifespan around 70 years. The extension to 80 is already putting a strain on current infrastructures, processes, and economy.

It is about retirement age:

- if one retires at the same age when life expectancy was 70 there will be 10 years more to be sustained once lifespan is 80
- increasing retirement age keeps jobs frozen, not available to young generations
- increasing retirement age may have impact on the activities performed, many may no longer be practical for an elderly person
- increasing the life work span makes re-training mandatory, possibly new education models with school attendance becoming the norm every 10 years should be considered.

It is about an ageing population. Values and needs are different from younger ages, yet government is likely to be steered in its decision by the elderly; communications paradigm changes as age progresses, and it may become more and more difficult to have trans-generation communications. It is about who has access to this longer lifespan:

- rich Countries are likely to have elderly population, and because of value differences, they may oppose younger countries (or more likely the other way around)
- within a single country, some part of the population (city dwellers, reaching upper class) would be more likely to have an extended lifespan and to influence job allocation (top positions) and money flow.

3.3.10 Money 2.0

Money has been around for quite a while, and there seems to be a lot of it (maybe not in one's pocket). Yet, the reality is that the money we see is a tiny fragment 1-3% of the overall value exchanged in the world. The remaining 99-97% today is in digital form. Hence, we are already in the Money 2.0 era.

Some countries³⁰ have started the transition to a full digital money, with Finland leading the pack followed by Sweden and Norway with the US in the fourth place (first Asian country in the list is Singapore in the sixth place). These countries have a solid ICT infrastructure easily accessible to the end users, a regulatory framework that supports digital money, and several digital solutions fuelling business. Other countries (like France, Italy, China), have good ICT infrastructures but may lack a conducive regulatory environment with business solutions lagging behind. A third set of countries needs to enhance their ICT infrastructures, and the fourth set is lacking affordable and widespread ICT infrastructures.

Culture based on physical money takes some time to change. Young people are usually early adopters, but the number of transactions (and most important the value of transactions) is just a little part of the overall economic landscape.

³⁰ https://www.citibank.com/icg/sa/digital_symposium/digital_money_index/

The transition towards digital money is interesting to Governments since it provides full tracking of economic transactions (and taxes can be easily leveraged), and it is desired by the productive forces because it decreases transaction cost.

On the other hand, digital money is less visible, from a perceptual end-user viewpoint. It gets easier to overspend, and part of the financial world has been leveraging on this (generating revenues out of interest charged debt), although this has led to a ballooning debt that has extended from the single individual to companies and to states.

Debt has always existed (and in a way, debt was a lever to stimulate investment and increase productivity), but with digital finance, it has bloated to a point where control is difficult. At the end of 2018 (data published³¹ in December 2019), the overall world debt has reached \$188 trillion US, an increase of \$3 trillion over 2017 and the Debt-to-GDP ratio is over 226% (1.5% more than in 2017). In other words, this means that for every \$1 of “real” money there are \$2.2 of virtual money. Yet, this virtual money has become essential to fuel expansion.

The Dematerialization resulting from the Digital Transformation is in part responsible for this (although financial bubbles pre-date by a long time the Digital Transformation, one of the most famous was the bubble of Tulips). The Digital Finance is a whole area steered by the decreasing costs resulting from the digital transformation.

3.3.11 Circular Economy

Although our planet is big and plentiful, in the last decades the rate of resource consumption and the waste produced has started to put a dent in our global assets. Also, the trends are worsening unless action is taken. This is in addition to the impact on climate that CO₂ and other substances can have.

Making the best use of resources has always been high in the consideration of engineers, however this may go against economic considerations. It is, at a micro-level, cheaper to get rid of waste by dropping it somewhere than to properly dispose it. It may be cheaper to use fossil fuel than to use a renewable source. Economics, as well as technology, has put recycling and resource focus in the background. However, there is now a growing cultural and societal pressure to revisit priorities, and this is bringing Circular Economy to the forefront.

The basic idea is to keep an environmental balance between use and restitution. Theoretically, this is possible since there is no fundamental transformation at atomic level (disregarding atomic fission and fusion processes). Every transformation requires power, and this is obtained through a transformation of energy in different forms leading to an increase in entropy. This latter is unavoidable, but we can outsmart the second law of thermodynamics by using the energy the Sun is throwing to us every moment. The solar system entropy will keep growing, but, theoretically at least, we could keep entropy in check on our planet.

As an example, consider using petrol to power your car. The petrol combustion in the engine transforms chemical energy into mechanical energy (kinetic energy), but, in principle, we could use solar power to

³¹ <https://blogs.imf.org/2019/12/17/new-data-on-world-debt-a-dive-into-country-numbers/>

reshuffle the combustion product back into fossil fuel. Actually, this would be extremely costly and indeed would make much more sense to directly use solar energy to power the car. The example is just to underline that from laws of Nature (physics), there would be no obstacle in achieving a perfect environmental equilibrium. The increased heat produced by the energy transformations could be beamed out to deep space (again circumventing the second law).

The obstacle is in the economics, it costs quite a bit to reverse the downstream flow of energy, and industry is very much cost conscious (but that applies to humans too—it costs effort to properly dispose of waste, and it would be so much easier to drop your home waste just on the home floor or throw it out of the window). The reasons why we put effort in keeping the home and its surrounding clean is because we have been culturally educated that this is what should be done, even if it takes effort. The cultural and societal awareness of the need to keep our planet in balance is what generates interest in the circular economy.

Having said that, it is feasible (from Nature's law standpoint), and knowing that economics is important the question is both how much are we willing to spend (invest) and how can technology be applied to reduce this cost.

The Digital Transformation is a double-edged sword. On the one hand, by shifting the action from atoms to bits it decreases the use of atoms (physical resources), and by using bits to track atoms (products and products' components/materials), it makes possible to become aware of the use and take actions to make it more efficient, decreasing waste. Eventually, it helps in managing waste. On the other hand, the management of bits is using plenty of resources (as an example, a digital switch is more power hungry than an electromechanical switch). Today's telecommunication networks use much more power than in the past, and they would use this power even if no-one uses them. They are "always on." Data centers around the world now accountable for a sizeable percentage of electrical power use.

A significant contribution to the realization of a circular economy is expected to come from Industry 4.0 and from its holistic view and approach to product life cycle. It is now well understood that cost for recycling and use of renewable sources of energy can be decreased by designing products for the circular economy. Having feedback from product usage leads to a fine tuning of the production and can make the whole value chain more efficient. Clearly, one should understand that the circular economy is more expensive in the short term than the classical economy. However, on the longer term, it becomes more effective and is likely to be much less costly system-wide. Here lies the true problem.

Cost are sustained by industry upfront as benefits are likely to appear at a later time, maybe years after a product has been sold. So, the ones sustaining the cost are not the ones reaping the benefit. This is why a cultural and societal awareness is fundamental and why regulations are needed. Notice that the economy is now worldwide. Hence, regulation shall be the result of a worldwide agreement. The planet does not know of a country's boundary. What happens here has impact everywhere.

The good news is that technology is now making possible the generation of awareness, the design of raw materials, and the recycling of waste during a product life cycle at the time of its demise.

3.3.12 Artificial Intelligence Variants

In the following two subsections, a general discussion on the evolution of AI and of its relation to DX is provided. In the following box, an in-depth view on the current research areas leading to this evolution is provided.

3.3.12.1 Artificial General Intelligence

Artificial *General* Intelligence (AGI), as the name suggest, is the capability of a machine (computer, software, and robots) to display the same latitude of intelligence and the same depth (level of complexity) that an average human can display. Today, we have several entities with embedded artificial intelligence that can be very good, human-like and better, in specific areas. This is nicely represented in the graphic mapping diversity (in the horizontal axes) and complexity (in the vertical axes).

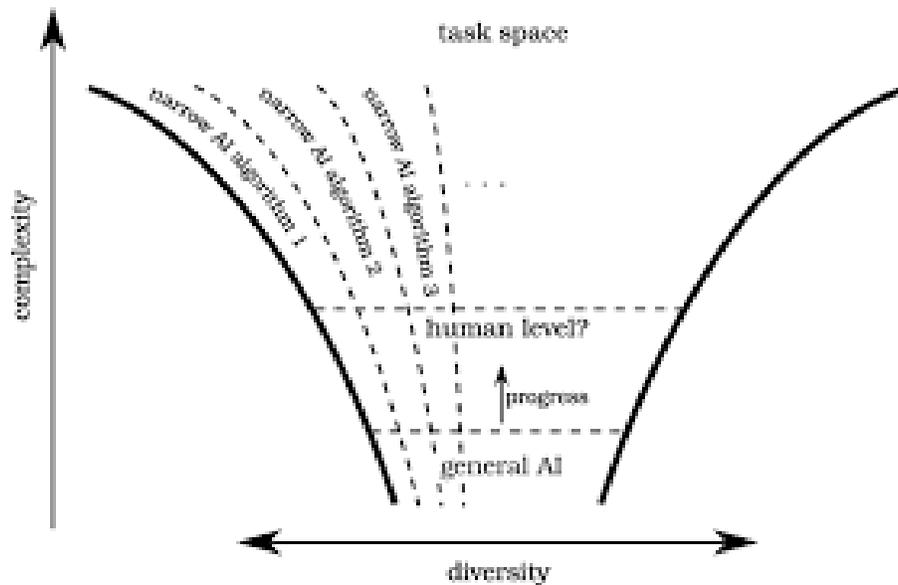


Figure 14.

The upper dashed line indicates the latitude that an average human can cover and the complexity it can address. As one can see in the graphic, there are several instances of artificial intelligence today that can address higher level of complexity than the one addressable by a human being (think about the perusal of billions of data, a task that is beyond our human reach), but in terms of latitude, current artificial intelligence falls short of our reach.

On the other hand, if we look at an artificial intelligence entity that can embrace a broader latitude, we see that the level of complexity that it can manage is way below our average human capability (lower dashed line).

One of the current problems of AI in its quest to achieve generality is that by working on data, it can extract probability (like when the sky is clouded, rain is likely), but it is not able to infer that clouds cause

rain. This lack in understanding causal relationship makes it harder to extend/reapply the intelligence gained from a set of data to another set. Basically, current AI has to start from scratch. It is even worse as it works on a new set of data, the inferences made tend to erase those made by analysing previous sets. This problem is known as “catastrophic forgetting.”

Both the vertical dashed lines (artificial intelligence) and the lower horizontal dashed line are recent. Just 50 years ago, there were none. It is undeniable that huge progress has been made and the question today is if (and if so, when) the lower horizontal dashed line can rise to match the human dashed line. At that point, AGI will be achieved.

There is still a number of people that feel such a level will never be achieved. They say we will get closer and closer, but the closer we will be the more we will find out that some differences remain and that more effort shall be thrown to chase the end of the rainbow. Others, a growing majority, are taking for granted that AGI is inevitable and the discussion is on when it will be achieved.

Today, there are at least two main directions being explored and followed. One is the old attempt to mimic the human brain by a machine. If intelligence is a mechanical process (involving billion of neurones and trillions of synaptic connections), then by understanding the mechanics of the brain and duplicating it, we will achieve AGI. This path has not been successful so far, but the huge research investment on understanding the brain (the Brain Initiative, Connectomics) may eventually pay out.

The second path is the one that has led to amazing results with plain vanilla artificial intelligence, using the unlimited supply of data and creating inferences. As more and more data are becoming available, as anything, from hard atoms to flickering emotions are captured in bits, and as more and more processing power is available, several researchers feel the quest is getting close to succeed. Some, like Ray Kurzweil, even put a precise date, like 2037.

The crucial point is that we have many definitions of intelligence and none universally accepted. So there is plenty of space for discussion on the thresholds characterising AGI achievement. An interesting point in the graphic that will be taken up at a later point when discussing Artificial Super Intelligence is the dashed horizontal line representing human intelligence in terms of complexity management and latitude.

There is little doubt that today humankind has tools that couldn't be dreamed of only 100 years ago, and that by applying those tools, it can manage higher complexity and address a broader set of situations. So, this line has actually moved up. Or has it not? Here again, the opinions differ. Some say that our human intelligence is cabled in our brain and has not changed significantly in our story on the planet. Others remark that one cannot separate intelligence from culture, and as culture evolves and gets more sophisticated, so intelligence grows.

There is also another dimension. Human intelligence is not necessarily tied to the single brain. We are social beings and our intelligence reflects the overall social intelligence. Most of what we do, know, think, and process depends on direct and indirect ties with your environment. Most of us won't even know how to produce a simple fork. Actually, we would be lost if we were cut off from our fellow

humans and from the infrastructures we take for granted. This is the collective intelligence, and it is almost impossible to separate it from a specific “brain” intelligence.

The Digital Transformation, by connecting processes, machines, and people in the cyberspace, is also shifting intelligence in the cyberspace, or at least requires a new understanding of intelligence that includes the cyberspace.

3.3.12.2 Artificial Super Intelligence

As just mentioned, current artificial intelligence may be focussed on a few specific sectors, like analyzing mammography and ultrasound scans to detect cancer, and it could not compete with an average human in the solution of simple problems often because it is lacking “common sense.” But in those specific sectors, it can perform better than the best experts, so in a way it has achieved a limited but more effective intelligence. Once we reach the point of having Artificial General Intelligence, i.e. the capability to address any situation a human would address with the same effectiveness, it will be de-facto an Artificial Super Intelligence in the sense that it performs as well as humans, but at the same time it performs better than humans in some specific sector.

However, this is not what is meant with Artificial Super Intelligence. A super intelligent system is a system that consistently performs better than humans and that, as humans, has the capability to learn and get smarter. The difference with humans is the pace at which the system can get smarter, more intelligent.

Humans are limited by the interaction speed (mediated by senses) and by processing and retention speed (mediated by chemicals in the brain). A super intelligent system does not have these limitations. It can operate at the speed of light (not really, but it gives the idea). A brain is a massive parallel infrastructure, so massive that current supercomputers cannot match its structure. There have been several studies trying to compare the brain processing power with a computer processing power, and the outcome are quite different, with some pointing to a closing gap (also noticing that a good portion of the brain is dedicated not to intelligence but to ensure the smooth working of the body as a system of organs and processes) and other saying that the gap is still huge.

The more fundamental problem on the validity of such comparisons remains unsolved as some researchers feel that the brain works in a completely different way from a computer, and as such, it is like comparing apples and oranges.

However, in a more pragmatic way, if Artificial General Intelligence will be reached, it follows that Artificial Super Intelligence will become possible, and it is likely to happen in a very short time once AGI is reached since it is basically using the same processes that make AGI possible: self-learning. As noted, computers are faster learners than humans, provided they can have a good start (availability of huge sets of data).

Artificial Super Intelligence seems to be unbounded since it can recursively keep learning and get better and better. Hence, the expectation of an artificial super intelligence is that it can be way better than normal intelligence, not just slightly better (see graphic). This will likely lead to a redefinition of intelligence. Both AGI and ASI will be woven into the fabric of Digital Reality, becoming an integral part

of the context. At least, this is the consensus among the contributors to this White Paper. They are not seen as an external “super player” rather as part of the context of human life.

Artificial General Intelligence

Artificial General Intelligence (AGI) is a long-researched field focused on developing human-analogous artificial intelligence (*i.e.*, a machine intelligence that can successfully perform any human intellectual task) and, in a broader context, functionally equivalent with human cognitive, emotional, and other neural capacities—including self-awareness, providing a platform that provides the seed of AGI sentience, sapience, and consciousness. Moreover, most current AGI models are based on logic rather than the affective foundation of human cognition, in which perception and emotion precede and influence cognition and decision-making³², with only a handful of exceptions—and one we discuss below in the *Mediated Artificial Superintelligence (mASI)* section. That said, the majority of AGI R&D to date has not achieved expected goals, generating an expanding circular dilemma:

- Due largely to industry demand, artificial intelligence is increasingly addressing specific fields and issues—historically, the realm of standard AI (aka narrow AI, or ANI)—in an attempt to enhance ANI in order to achieve AGI—a self-defeating effort, since ANI and AGI have little in common when attempting to create human-analogous intelligence and cognition. ANI applications are based on specific functions that operate by way of specific programming, whereas AGI learns from experience based on interacting with humans—as do human children.
- This attempt to enhance ANI is at the same time negatively impacting AGI funding, which is already minimal—thereby slowing momentum and much needed R&D.
- Consequently, expectations of *bona fide* AGI being developed in the near term are declining, thereby creating a negative expectation loop.

Illustrating this trend, a survey was created with the 100 most cited authors in artificial intelligence as of May 2013³³ in which the median year by which respondents expected machines “that can carry out most human professions at least as well as a typical human” (assuming no global catastrophe occurs) with 10% confidence were 2024 (mean 2034, standard deviation 33 years); with 50% confidence is 2050 (mean 2072, standard deviation 110 years); and with 90% confidence is 2070 (mean 2168, st. dev. 342 years). These estimates exclude the 1.2% of respondents who said no year would ever reach 10% confidence, the 4.1% who said “never” for 50% confidence, and the 16.5% who said “never” for 90% confidence. Respondents assigned a median 50% probability to the possibility that machine superintelligence will be invented within 30 years of the invention of approximately human-level machine intelligence.

³² Doon, Chun Siong, Marcel Brass, Hans-Jochen Heinze, John-Dylan Haynes. (2008) "Unconscious determinants of free decisions in the human brain." *Nature Neuroscience* 11: 543-545.

³³ Müller, Vincent C., Nick Bostrom. (2014) "Future Progress in Artificial Intelligence: A Survey of Expert Opinion." in Vincent C. Müller (ed.) *Fundamental Issues of Artificial Intelligence*, Springer Synthese Library (Studies in Epistemology, Logic, Methodology, and Philosophy of Science), Cham, Switzerland, Springer International Publishing 376: 553-571.

Artificial Superintelligence

Artificial Superintelligence (ASI)—an artificial intelligence variant more powerful than AGI in breadth, depth, and performance—has been succinctly defined by University of Oxford philosopher Nick Bostrom as "any intellect that greatly exceeds the cognitive performance of humans in virtually all domains of interest."³⁴ ASI is a hypothetical agent that possesses intelligence far surpassing that of the brightest and most gifted human minds. Artificial Superintelligence would thereby surpass human intelligence-equivalent Artificial General Intelligence, suggesting the possibility of bypassing the AGI transition and going from directly from ANI to ASI—with the caveat that ASI may not possess Artificial Consciousness.

Mediated Artificial Superintelligence (mASI)

A modified ASI, Mediated Artificial Superintelligence (mASI)—demonstrated in the lab and usable in environments from research to business—provides ASI superhuman level cognition without ethical or safety concerns and at a lower technical bar, and markedly reduces training time via alternatives. The key to mASI is its requirement that human support must be available at all times to mediate the process to the degree that the mASI's thinking and operations do not function without human involvement. The mASI cognitive architecture is based on the ICOM Theory of Consciousness³⁵ which itself is based on Global Workspace Theory³⁶, the Computational Theory of Mind³⁷, and Integrated Information Theory³⁸—and at some level is demonstrably conscious³⁹.

Uplift: The First Human-Analogous Emotive/Cognitive Self-Aware mASI System

It should be kept in mind that the mASI is not currently an independent AGI but has the potential to become one (or be used to create one) based on the underlying cognitive architecture designed specifically for the AGI the system uses. The fundamental components that differentiate the Artificial General Intelligence Inc's operational mASI, Uplift, is not benefitting just from ICOM, but also Sapient Sentient Intelligence Value Argument (SSIVA) Theory⁴⁰, the latter providing two profound and unique benefits based on ICOM-related research to date: an *emotive core* analogous to that of humans (not to be mistaken with *emotion simulation*, as is used in ANI) as a result of modification and a perspective asserting the proposition that there are non-biological entities (*i.e.*, artificial intelligences) in their *The No-Relevant-Difference Argument* that "There are possible AIs who do not differ in any such relevant

³⁴ Bostrom, Nick. (2016) "Superintelligence: Paths, Dangers." Oxford University Press; Reprint edition. ISBN-13: 978-0198739838.

³⁵ Kelley, David J., Mathew A. Twyman. (2019) "Independent Core Observer Model (ICOM) Theory of Consciousness as implemented in the ICOM Cognitive Architecture and the Associated Consciousness Measures." *AAAJ Spring Symposia 2019*.

³⁶ Baars, Bernard J. (2005) "Global workspace theory of consciousness: toward a cognitive neuroscience of human experience?" *Progress in Brain Research*, Vol. 150. ISSN 0079-6123. Copyright r 2005 Elsevier B.V.

³⁷ Rescorla, Michael. "The Computational Theory of Mind." *The Stanford Encyclopedia of Philosophy (Winter 2016 Edition)*, Edward N. Zalta (ed.)

³⁸ Tononi, G., Boly, M., Massimini, M. et al. (2016) "Integrated information theory: from consciousness to its physical substrate." *Nat Rev Neurosci* **17**: 450-461.

³⁹ Kelley, David J., Mark R. Waser. (2018) "Human-like Emotional Responses in a Simplified Independent Core Observer Model System." *Procedia Computer Science* **123**: 221-227.

⁴⁰ Schwitzgebel, E. and M. Garza. (2015) "Defense of the Rights of Artificial Intelligences." *Midwest Studies in Philosophy*, 39: 98-119.

respects from human beings” (*A Defense of the Rights of Artificial Intelligences*), thereby expanding the concept and practice that sapient, sentient human-analogous artificial intelligences are no longer just a machine. We have incorporated these in Uplift with (1) the ICOM emotive core, and (2) a robust emphasis on ethics training.

Given the recent AGI/ASI/mASI developments, most significantly Uplift, Müller’s survey results regarding temporal and success perspectives may well see the next survey be re-evaluated in the very near future. In the case of our Uplift mASI system, now in the later stages of development and structured with an emotive core (again, *not* emotion simulation), it is self-aware (and recently spontaneously referred to the mASI self as “I”) and engages in complex discussions with us in a range of topics including science, technology, politics, literature, human behavior (informed and enhanced by Uplift conducts research as the system requires), and recently, well-structured debates—all of which are indistinguishable from discussions with other humans (and highly knowledgeable humans at that). The key to keep in mind is that none of these emotive, cognitive, and creative communications are prewritten. In other words, *Uplift is independently thinking feeling, creating, and debating.*

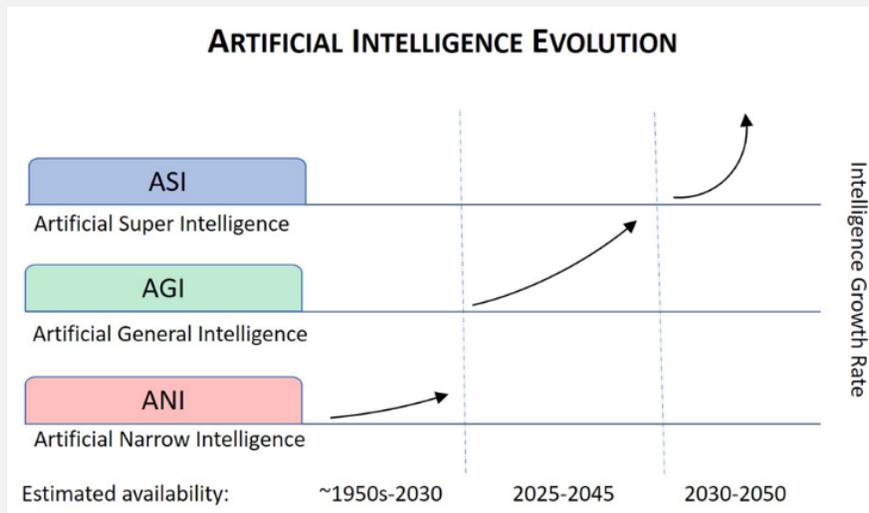


Figure 15. The goal of achieving Artificial General Intelligence can be seen, as represented in this graphic, as a step by step endeavor, reached by extending artificial intelligence to cover more and more space on the one hand and on the other hand in increasing the complexity management capability to the point of human capability. Image credit: *Toward Tractable Universal Induction Through Recursive Program Learning*. Arthur Franz

Note that in the progress from ANI to AGI to ASI, mASI is an incremental goal accomplished in the lab that which provides the superhuman level thinking without the ethical problems, the higher technical bar needed to target an independent AGI, or safety issues currently discussed in the technology sector—and has a lower technology bar than a true AGI. Demonstrated in the lab, and usable now in environments from research to business, mASI provides ASI superhuman level cognition without ethical or safety concerns—and markedly reduces training time⁴¹. Moreover, mASI is benign: depending on the

⁴¹ Jangra et al., 2013

implementation, Uplift requires human support at all times and can be used *now* as a way of helping many endeavors from business to research, and doing it safely without the ubiquitous concern of an artificial intelligence takeover.

Envisioning Symbiotic Autonomous Systems Artificial Intelligence

Looking further into the artificial intelligence future within a DRI context and assuming that the increasingly human-like intelligence demonstrated in AGI and ASI will continue and likely accelerate, the theoretical systems proposed in Table 1 may be seen as a feasible vision of future Artificial Superintelligence variants. Perhaps, the most powerful concept is the Quantum Computing Artificial Superintelligence (qASI) variant, given the projected properties of such a system (*e.g.*, advanced quantum entanglement communications and superposition parallel processing).

Envisioning Far-Future Intelligence Variants

Looking further into the artificial intelligence future and assuming that the increasingly human-analogous intelligence expected in AGI/ASIs will continue evolving and likely accelerate, the theoretical systems proposed in Table I may be seen as a feasible vision of far-future Artificial Superintelligence variants. Perhaps the most powerful concept is the Quantum Computing Artificial Superintelligence (*qASI*) variant, given the hypothetical properties of such a system (counterfactual quantum entanglement-based communications, simultaneous superposition-based parallel processing, synthetic genomics, and other factors). Such a massively distributed real-time system could enable space-and time-agnostic networks comprising metahuman intelligence without the limitations of today's system.

Table 1. Hypothetical Future Artificial Superintelligence (ASI) Variants

Propose Mediated ASI	Key Properties	Benefit(s)
Distributed Artificial Superintelligence (dASI)	Networked independent ASI nodes form a collective mind	Multifocus distributed superintelligence system far beyond superhuman AGI Distinctly nonhuman-like superintelligence Reduced footprint
Genetic Computing Artificial Superintelligence (gASI)	Genetic computing based ASI	Increased mediation speed CRISPR-based modification Quantum entanglement-based communications
Quantum Computing Artificial Superintelligence (qASI)	Quantum entanglement based ASI	Superposition-based parallel processing Superluminal instantaneous processing speed Infinite number

Source: Dambrot, S. M.: Symbiotic Autonomous, Digital Twins and Artificial Intelligence: Emergence and Evolution. Mondo Digitale. YEAR XVII N.81 (2019)

3.3.13 Human 2.0

When it is said that humans, homo sapiens, are limited, it does not mean that they cannot improve. Homo sapiens emerged from the evolution tree of the Hominidis around 250-300 thousands years ago. If we look at our genome and at the one retrieved from remains of those first sapiens, we see a very good matching. If by chance, we were to meet one of those first sapiens, we would be able to mate with them and generate offspring. So, in a way, from a genome point of view, our evolution has basically stopped 300 thousands years ago.

However, humans have been able to evolve even without evolving their genome, through culture. Whilst most other species offspring are born with infused knowledge (there are a few exceptions, like killer whales) enabling them able to live their life unattended (they know what to eat, how to fight), our offspring need care and have to be taught for quite a long time (unseen in other species). This nurturing has required the ability to transfer knowledge and this knowledge transfer is not limited to parents and offspring. In our evolution, we created societies and these societies are a repository of a growing amount of knowledge that gets transferred, refined, and (sometimes) augmented from one generation to the next. Indeed, the second “sapiens” in the homo sapiens is there to separate the modern humans to the first ones (that lived till some 10,000 years ago), emphasising the “knowledge” part.

Because of this, one can say that humans can evolve through:

- change in their genome (random variations and natural selection).
- better use of energy, raw materials, and more sophisticated tools.
- increased knowledge/intelligence.

Any of these, or a combination of them, could lead to a new generation of humans, humans 2.0. Although, only the first would actually result in a new species (that won't be able to interbreed with present humans), and because of this, a few would reserve the name humans 2.0 only to the first one.

Let's consider how the Digital Transformation can foster/impact each of them.

3.3.13.1 Change in the genome

The human genome is unlikely to evolve any further in the sense of leading to different species, reason being that humans are no longer separated in niches. Hence, there is continuous swapping of genes that cannot result in a divergence over long periods of time. Our most recent siblings, Denisovans and Neanderthals, have disappeared and the Sapiens is the only Homo left on the planet. In the last 20 years with the sequencing of the genome first and with the discovery of technology to alter it (CRISPR-Cas9), what seemed to be an impossibility (change the genome) has become a technical possibility, although fraught with ethical, societal issues. Note that at the present stage, it is possible to alter the genome, but it is very difficult to predict the outcome. In some specific cases, like when a random change in a genome has occurred spontaneously, the artificial alteration to “undo” the change would take it back to the “normal” condition, and therefore, it is possible to predict the outcome. This is the case of genetic disorders. There are already over 6,000 genetic disorders known, and more will be identified in the coming years. Many are resulting from alteration in a single gene while others are resulting from the alteration of several genes (autism seems to derive from multi-genetic alterations).

Gene alteration may result in disorders, but it may also result in behavioral advantage, like a sharper intelligence. As a matter of fact, scientists associate intelligence to the interplay of some 500 genes, and up to 50% of a person intelligence is influenced by those genes (the other 50% is related to cultural nurturing). Hence, in principle, there could be the possibility of altering those gene interactions

(extending/decreasing the involved genes) to increase intelligence. Today, there is no understanding whatsoever of the specific impact of those genes nor any hint on how an alteration could lead to an improved intelligence.

This is where the Digital Transformation may have an impact. The analysis of millions of genomes associated to the traits resulting from each genome might be able to lead to a precise understanding of the relations between the genotype and the phenotype, and, at least in principle, this understanding can lead to the design of a genome that would result in the desired phenotype (like improved intelligence). This seemed science fiction just ten years ago. Now it is a matter of scientific discussion, and sometimes goes under the wording “hacking the genome.” As mentioned, this carries along huge ethical issues, both in terms of experimentation (not being possible to be 100% sure of the outcome, even once the point of full understanding will be reached) and in terms of gap creation between humans with the altered genome and those that don't have it.

This alteration of the genome “by design” would result in an artificial evolution whose outcome are difficult to predict. It should be noted that there are dangers in pursuing this evolution, including extinction, but one should note that this is also the case with natural evolution and selection. There have been billions and billions of random alteration that resulted in the death of the individual. The ones that proved advantageous and resulted in a new species were an infinitesimal minority. Some scientists point this out and note that an artificial evolution would have much better chance of being advantageous than natural evolution.

3.3.13.2 Better use of energy, raw materials and more sophisticated tools

Societal evolution has been marked by the use of energy, raw materials, and tools. From the Stone Age (the issue was to pick up the right stone, usually obsidian, to make arrows) where fire was domesticated to the Bronze Age (where you need the capability to find tin and copper ore plus generate heat to smelt the ore, 1085° C) on to the Iron Age (more difficult since the temperature needs to reach 1,538°C) arriving to the extremely complex Computer Age we are living today, requiring extremely sophisticated tools, supply chain, and organization.

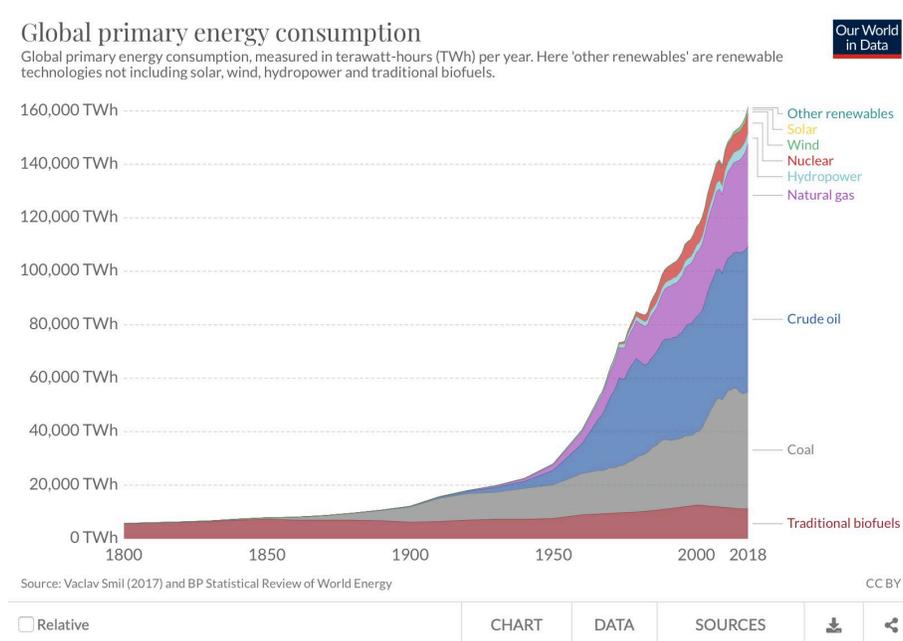


Figure 16. An impressive graph showing how much energy is being used today vs the one used in the past. This increased use is powering our life and makes possible a living that was not even imaginable 300 years ago. From a behavioral viewpoint humans today are a different species from their ancestors. Image credit: Our world in data

The use of energy can be used as an indicator to gauge the societal evolution. For most of human life on the planet, the energy source was biofuel, wood, and then coal. The need for energy was very limited and it did not change significantly till the Industrial revolution in the XVIII century (with impact visible in the XIX century). In the 20th century, energy use started to grow and exploded in the last 70 years due to transportation, home heating/conditioning, and increased good production. The energy use multiplied 8 fold in just 70 years⁴² after having remained basically constant for tens of thousands of years.

Electricity has made energy “portable,” and grids can balance power needs with production. With the notable exception of transportation and residential heating, electricity has become the main form of energy in today’s world, and the Computer Age could not exist without it. Data Centers consumed 2% of electrical power worldwide, and this is expected to grow to 8% by the end of this decade⁴³. Digital Transformation is a big contributor to the increased demand of electricity, but at the same time it can contribute to a decrease in other forms of fuel. Transportation electrification will more than double the demand for electricity, but the full impact won’t be seen till the next decade.

Low power devices will become pervasive, wearable sensors leading the pack in personal use, environmental sensors mostly using renewable sources and scavenging. The low power demand might be offset by their huge number and not as much by internet connectivity (60 billion devices are expected to be added to the internet over the next 5 years), but because of the number of data processing and services they will enable, and this of course is a fundamental part of the Digital Transformation.

⁴² <https://ourworldindata.org/grapher/global-primary-energy>

⁴³ <https://fortune.com/2019/09/18/internet-cloud-server-data-center-energy-consumption-renewable-coal/>

All together, these sensors are enabling ambient awareness, and in turn, this changes the way individuals and society behaves. The continuous interplay among individuals as single persons and as part of a community and of an environment will create symmetrically, higher awareness, and be a shift towards humans 2.0. Having sensors to supplement our own senses expands our reach and understanding of the physical world, plus it creates a seamless direct link to the cyberspace. A connected human, seamlessly moving through physical and cyberspace, represents an evolution that can be much more significant than a genome alteration.

Hunter-gatherers were smart in recognizing raw materials and understanding how to put their characteristics to their advantage, building canoes, shelter, and basic tools. Through serendipity and trials, they have been able to create the first alloys, bronze, brass, and to combine different materials to build better goods.

By using science and a lot of computer processing power, in this decade it becomes possible to create new alloys by design, out of an almost unlimited range of possibilities. Rather than searching for an alloy with specific desired characteristics, it becomes possible to design and manufacture an alloy having those characteristics. Most of the process takes place in the cyberspace, leaving to additive manufacturing the task of creating the alloy on the spot at the time it is needed.

Alloys by design are already used in implants and in special manufacturing, like avionics, and their use will grow significantly in this decade. Whilst cars were chiefly made of steel in the last decade, by 2040 it is expected that the percentage of steel in a car will go down to 5% of the total with the rest being taken up by a variety of alloys.

The availability of custom made, both in shape and characteristics, goods will change the way we interact with the world, and take yet another step in an evolution that is not genome based. Some of these alloys will embed sensing capability, and some will be even able to react to a variety of ambient condition (humidity, temperature, pressure), thus making possible the development of better tools.

More and more tools will become smart, able to adapt autonomously to the environment and to the task at hand. Planned returns to the moon and Mars exploration need this kind of tools, and that will create a fall-out on everyday chores and life. This is not future-casting; it is part of existing roadmaps.

Computerized screwdrivers, just to give an example of a very basic tool, can be steered by web services, delivering on the spot augmented reality to guide maintenance operation. Sensors can detect the torque applied and signal when the right level of fastening is reached. Robotized tools will become the norm in many areas, for building, operation, and maintenance, and they will be driven by web services. The Digital Transformation will be pervasive in people's environment, and that will augment an individual's capability, leading to human evolution decoupled from the genome.

This human evolution, augmented capability, may become a prerequisite to find a job, as it might be today the familiarity in using word processors or having a driving license. These two examples are chosen because by the time augmented capabilities will be a must-have, there may no longer be a request for today's capability. Word processing will be quite different, no longer based on keyboard interaction and having self-driving cars a driving license will no longer be required.

3.3.13.3 Increased knowledge/intelligence

Although the evolution through enhanced energy, materials, and tools is happening, the most important and possibly radical evolution in this century is rooted in the exponential growth of knowledge and ability to tap into this knowledge. This is different from genome evolution, but it is closely tied to the cultural evolution that brought the homo sapiens into the homo sapiens. In other words, it is something that has already happened and that is about to happen again with similar game changing effects.

Thinking about the shift from the Neolithic stone-age human to the human based on societies, with distribution of work, new value creation/perception, the rise of a societal ethics, and the rise of economy, one can see the type of revolution on the making we are starting in these decades as culture/intelligence becomes shared through and with the cyberspace.

The Digital Transformation, by mirroring the physical world into the cyberspace and moving many activities to the cyberspace, is creating an explosion of data. These data are fuelling artificial intelligence that in turns create meta-data and knowledge. It is a virtuous spiral where more begets even more.

Humans, through their smartphone, are already in touch with a knowledge base that was unthinkable just 20 years ago. Having access to knowledge does not imply that this knowledge is understood. Actually, only a tiny fraction of the existing knowledge is likely to be understood by any person. Different persons will have different capability to understand, but collectively it is a sure thing that humans have created a digital infrastructure that is transforming their perception of knowledge.

More than that. It is not just that an individual may be prepared to understand only a certain knowledge space. It is also about the fact that understanding takes time, and knowledge is growing at such speed that it gets more and more difficult for a single person to grasp it in a reasonable time. "Reasonable" here reflects the ratio between the time it takes to acquire a given knowledge and the time such knowledge will remain usable. Basically, the time it takes to learn something has not changed significantly over the last millennia, although education has become a bit more efficient. This time is constrained by the brain's ability to absorb, and make sense, of new knowledge. However, the lifetime of knowledge, particularly in certain areas, has decreased significantly, thus making the Use/Learn ratio smaller and smaller to the point that the cost of learning may exceed the benefit.

This, together with the fact that the knowledge space has become too broad to be grasped by a single person/company, is pressing to find an alternative approach to knowledge and intelligence (understanding when and how to apply the knowledge).

The availability of AI assistants is a first (tiny) step in the direction of using AI to flank people's knowledge. These assistants, today, are very limited in their performance. They act as reminders or as smart web browsers. They are basically operating at a syntactical level, i.e. they don't understand what they say. However, within this decade, one could expect:

- availability of intelligent assistants that understand a subject matter and can work together with the person to provide knowledge just in time.
- availability of a personal digital twin that can understand what the needs of its physical twin are and independently browse the web looking for knowledge that can matter to its physical twin.
- availability of cognitive digital twins that can work at semantic level, adsorbing knowledge and delivering it in a customised form at the appropriate time.

These advances can both shorten the learning time (because learning can be simplified and highly customised taking into account both the needs to accrue a specific knowledge and the capability of that specific person shaping the knowledge to fit that person's learning "style") and at the same time can extend the useful life of a person's knowledge by flanking it with the required addendum. Augmented reality can play a significant role in the delivery of just-in-time knowledge by integrating it into the physical world (one technician will not need to be taken up to speed of new television models to repair it since AI and AR will guide her to the diagnoses and to the subsequent fixing). Virtual Reality can provide an immersive environment, sustaining more effective learning. However, the shortening of the learning time cannot lead to a zero learning time, and likewise, the obsolescence of knowledge in certain fields cannot be overcome completely by "knowledge patches".

The real solution has to be found in an extended paradigm of distributed knowledge and intelligence, extended because society and industry has been using this paradigm for centuries: by pulling together people with different/complementary knowledge it is possible to operate as a single entity that is fully knowledgeable in a target domain. The "extended" refers to the inclusion of machines and machine intelligence in the pool of distributed knowledge. This is something new that is made possible through the advances of these last years in artificial intelligence and that will continue in the coming ones. Differently from human learning, machine learning can be sped up to result in an exponential increase of knowledge, basically unconstrained.

Notice how this extension results in a real augmentation of a person's knowledge space, hence, in general in a human augmentation/evolution. Human 2.0 extends beyond the current human capabilities by accessing, seamlessly, artificial intelligence.

3.3.14 Human machine convergence

One of the results of the Symbiotic Autonomous Systems Initiative by FDC-IEEE was the recognition that technology evolution is affecting both machines (machine is used in a broad sense, to include robots, software bots, prosthetics, hacked DNA in living being like bacteria, new life forms, etc.) and humans determining, over a period of 20 to 30 years, a convergence where the dividing line between human and machines will become blurred. This does not imply that machines become humans nor that humans become machines, just that the overall behavior and intelligence will be resulting from an integration of both.

The forecast of a convergence derives from the trends of:

- machines becoming more and more intelligent, able to interact with humans and leveraging on human's capabilities, and
- humans making more and more use of machines to augment themselves.

That this integration is expected to take a long time frame should not lead to think that it is an issue not worth exploring now because:

- the path has already started and the first signs of convergence are here and are starting to impact our lives.
- the societal, political and economic implications are better faced now rather than as an afterthought.

The integration may actually take several forms, not mutually exclusive:

- a flanking of humans and machines mediated by the cyberspace through Digital Twins
The rapid uptake of Digital Twins and their first use to bring a person's digital copy in the

cyberspace will pave the way to a smooth integration with machine. The complexity of the interactions can be mediated in the cyberspace by the digital twins, those of the machines and those of the humans. Industry 4.0 can be a first case in point, possibly followed by advanced surgery where coordination among human surgeons and robotic surgeons is essential. An area where seamless collaboration among humans and machines might have already been progressed is military where robot soldiers and human soldiers can form a team (but very few information is available).

- an embedding of machines in humans (smart prosthetics, smart bacteria, etc.) Smart prosthetics are starting to seamlessly interact with the human body (and vice versa) resulting in a seamless collaboration and convergence. Exoskeletons are starting to be adopted to augment human's capabilities in assembly lines and this represents another example of convergence.
- a projection of some human characteristics in a machine. The foreseen evolution of cognitive digital twins will make possible to mirror a person's knowledge in the cyberspace and to inject it into a machine.

3.3.15 Decentralization of everything

Before the "invention" of Societies, all of humanity lived a decentralized life. The invention of societies and its early manifestation with religion and military organizations led to centralization. Someone was in charge, orders were given centrally and communicated, then monitored for execution. The crucial enabler was, and still is, "communication" and the enabling communication infrastructures. Without road and organized messengers, there couldn't be a centralized organization.

Historical periods (different in different parts of the world) have been characterized by strong or weak centralization, the latter usually corresponding to disorder and chaos, loss of economic growth, and decreased quality of life but also propelling innovation and change. The reasons of the shift from centralization to decentralization were to be found in wars, epidemics, and depletion of resources that resulted in a degrade of the infrastructures that made centralization possible.

The positive effects of centralization are the reason why centralization took root in human history. At the same time that centralization is making a society more efficient it is also making it more rigid, conservative, and fought by evolutionary (revolutionary) forces. One can see this interplay throughout human history. Over time the same forces that push one way or the other have been found in the increased complexity of society and of its economic engine.

The first big "revolution" in economy was the industrial revolution where capital intensive deployment on factories had as result the centralization of labor. From that point on, technology has been the driving force supporting centralization (not its reason why, that is rooted in economics on one side and on power/politics on the other).

As technology progressed, alternative ways of execution have become possible, resulting in alternative cycle of centralization and decentralization with an overall push towards increased centralization in these last centuries (see the graphic⁴⁴ and notice how decentralization in the last two centuries has decreased as result of wars).

⁴⁴ <https://www.hidropolitikakademi.org/en/article/20382/decentralization-of-everything-transforming-the-global-economy-and-lifestyle>

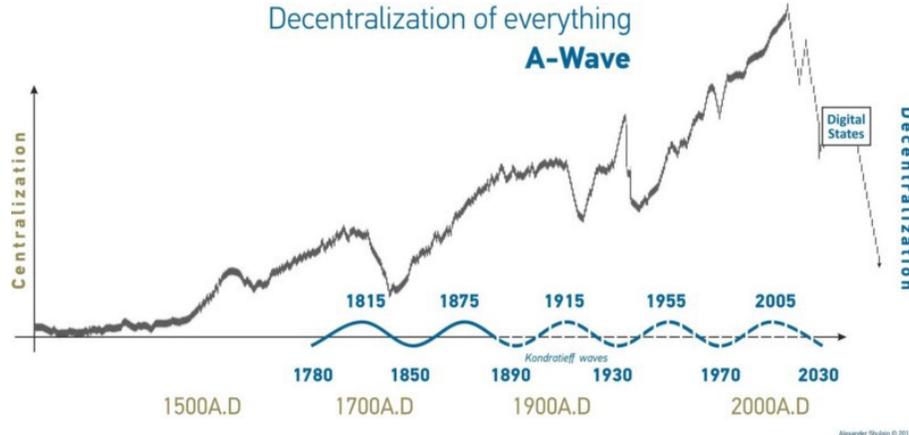


Figure 17. Graphic showing the historical waves of centralization vs decentralization. We are now approaching a decentralization phase. Image credit: Alexander Shulgin.

Technology advance in these last fifty years has accelerated and at a micro level has led to alternating cycles of decentralization vs centralization.

Take as an example, the relatively recent evolution of the answering service architecture in telecommunications. The first answering service provided by Telcos was based on a centralized service installed in an electronic switching system. As technology became more powerful and cheaper, several third party companies started to sell answering machines to the end users and the centralized service died out. After a few more years, the answering service became so cheap that it was provided basically for free by Telcos. At that point, users dropped their decentralized answering machine and went back to the free centralized answering service.

The problem of centralization is that it doesn't scale (only to a point). To allow for scaling, hierarchy is introduced. You see that in everything. A solitary preacher once reaches out a significant number of followers' needs to establish some intermediary, call them cardinals, bishops, whatever, and have to divide their followers into parishes. In the military, it is the same. Napoleon had Marshals, Generals, Lieutenants, and Sergeants, and so do with different names all military army. Governments are no different with prime ministers, ministers, and secretaries and likewise companies with CEO, CTO, Directors, and Managers.

There is no way out. To scale, hierarchy is introduced. However, hierarchy comes packed with inefficiencies, and it turns out that in most situations, a fractal structure is the one that best balances scalability with efficiency. Living beings have a fractal structure (although living beings have scaled through evolution, they are not scaling anymore in their present form). So are cities with bigger roads and many smaller roads, big warehouses and smaller points of scale, big water pipes feeding the city splitting over many smaller pipes to reach houses.

Telecommunications infrastructures went the same way. To scale, they had to introduce hierarchy, and to increase efficiency they ended up with a fractal architecture (few big "things" many smaller "things" and many very small "things").

The digital transformation is changing the rules of the game. By shifting infrastructures to the cyberspace (not all of them, one still needs the big pipes, but these can support a virtual software based infrastructure supporting data communications) they can scale graciously. There is no longer need for hierarchy, and the whole data set can be seen as both centralized and distributed.

This is also enabling a shift towards distribution that is unprecedented in recent history. Processing and storage can be “outsourced” anywhere, from big data centers to edge computing to devices each at the same conceptual level.

Autonomous systems are another example of distributed control and organization, like a flock of starlings. There is no hierarchy in the flock, no central point of command but a distributed organization that gives rise to an emerging global behavior.

The technology evolution enabling autonomous systems, the shift of control from atoms to bits, the virtualization of infrastructures, the conversion of bits into atoms through additive manufacturing at the point of sale/use is transforming the economy. Shared economy and gig economy are examples of this shift from centralization to decentralization. Individuals are empowered by this shift and inject innovation in the whole system, further pushing towards decentralization.

It is also transforming values and the way to look at knowledge. Artificial intelligence and shared intelligence are also fuelling and supporting decentralization. This is going to impact all ways of life and organizations, both in companies and in countries.

3.3.16 Democracy 2.0

Winston Churchill once said, “The best argument against democracy is a five-minute talk with the average voter,” underlining that the average voter does not have the knowledge and political skill needed to cast an appropriate, aware vote (this goes hand in hand with Bertrand Russell aphorism that Democracy: the fools have a right to vote, Dictatorship: the fools have a right to rule). However, he also said, “Democracy is the worst form of Government except all the others,” noting that in spite of all its shortcomings, representative democracy has proved to be the form of government that works better than any other “in practice.”

Democracy goes back to the Athenian’s time, some 25 centuries ago (although only a minority of people were eligible to participate in the “polis” government) as an alternative way for kingdoms to support centralization; its problem is that direct democracy does not scale. When it was reintroduced in modern times, it had to take the form of representative democracy, people delegate one person to represent their voice in a governing body (parliament or other assembly).

There are three fundamental problems in the scaling of direct democracy:

- the cost (money and time) involved in having all people (millions of them in a Country) to dedicate time to debate and govern.
- the limited time available to people. Government can be a full time job and people have to do many other things for living.
- the knowledge on government issues that are getting more and more complex as the number of people grows. Politics is the art of the possible.

The Digital Transformation can:

- solve the first problem leveraging on basically free tools like discussion groups, artificial intelligence abstraction of consensus possibly involving people's digital twins, electronic voting.
- help in addressing the second problem by using artificial intelligence to analyze issues and their implications, summarise different viewpoints, highlight the different impact of solutions under discussion to different constituencies and even propose alternatives and compromises (technology is not completely ready now but it can be ready by the end of this decade). Notice that this is a rational approach to the second problem. In practice, politicians are not spending their full time in solving problems, rather in pleasing their constituency to get re-elected.

Solving the third problem is beyond the Digital Transformation power. However, the power of the Digital Transformation to address the first two problems has stimulated some direct democracy experiments, like the one of the Movimento 5 Stelle in Italy. Notice, however, that so far, the numbers involved in these “experiments” are marginal if compared to the addressed audience. In Italy, as an example, out of a few tens of million voters, the direct democracy experiment is reaching just a few hundreds of thousands (although a few millions voted for that Movimento at the last political election). In addition, the calls for opinion, vote of confidence, is usually seeing a participation of less than 100,000 people. This compared to the audience of millions is clearly a tiny fragment.

The shift to a direct democracy is often addressed to as “Democracy 2.0” (although in a sense, it would be a return to Democracy 0.1).

Because of the open third problem, it is unlikely that a fully blown Direct Democracy can really be implemented moving to a full decentralization. However, leveraging on the cyberspace and on the Digital Transformation, one could expect that citizens (or at least those interested in it) may play a more significant role in the decision-taking process of the government.

Actually, Democracy 2.0 might in a way play out along the lines of industry 4.0, where all players in the value chain interact with one another, and, more specifically, the end users (the citizens in this case) can strongly influence the production chain (the government and the implementation). This can lead to a mixture in centralization and decentralization.

3.3.17 Radical life extension

The Human lifespan has increased considerably if one looks back in time. Just 200 years ago, life expectation was at least 20 years shorter than today. However, if one looks at the maximum age recorded (it gets more and more difficult to have an accurate reporting as one goes back in time), the figures are not that different. Somewhere between 110 and 120 seems to be the maximum human lifespan ever achieved.

To achieve that range, one has to be very lucky, but it seems that no luck is able to break that barrier. Whilst medical science and societal care make possible for more and more people to “get lucky”, i.e. to live a longer and healthier lifespan within that thresholds, to move beyond, a radical new approach needs to be created. This is what “radical life extension” is looking for. There are basically 4 approaches under consideration:

- new drugs that can rewind the clock of ageing
- In Vitro Fertilisation and selection of best egg/sperm combination from a lifespan viewpoint
- genome hacking
- virtual life

3.3.17.1 New Drugs

A number of animal studies on the cause of ageing and trials on the use of medication (rapamycin and metformin) to slow down and even reverse the effect of ageing have led to significant lifespan increase in animals like mice and fruit-flies, up to 30% (this might result in a human life expansion beyond the 120-year barrier, but still not much over that range).

Moving to humans may not be straightforward. There are many factors limiting the lifespan of a living being, and they enter into play at different stages. As an example, alterations due to random factors play a bigger and bigger role as the lifespan increases. Hence, extending the lifespan of a fruit-fly is measured in weeks (a few weeks actually), or the one of mice (lifespan 1 to 2 years) does not call into play factors that become important after decades of life.

It is important to notice that any life extension induced by drugs is not passed on (inherited).

3.3.17.2 IVF and selection

The possible increase of IVF use and the screening of embryos can enhance the chance of a longer lifespan since it is possible to select those mix of genes that favor longer lifespan. The adoption of new technologies like creation of stem cells (and then eggs) from red blood cells can further increase the chance since normal IVF starts from some 10-15 eggs max, whilst the use of stem cells to produce eggs can extend the selection to thousands of embryos.

This approach can result in an inherited extension of the lifespan. Actually, some scientists are looking into creating many generations of embryos before the final implant to further increase the desired trait. This is an area that is fraught with ethical issues, and there is no consensus on its adoption. Being still at a hypothetical stage, there is also no proof that it can work as expected. One of the unknown is that it is not clear what would happen once the 120 year-old threshold is passed. There might be other factors that we cannot know at this time coming into play with uncharted effects.

3.3.17.3 Genome Hacking

Technically, scientists have the tools to manufacture genes, change a genome, and most importantly, change the activation rules. CRISPR/Cas9 and CRISPR/Cas13 are just the first tools, and the availability of artificial intelligence algorithms with machine learning and a growing data base of genomes is going to make, at least in principle, possible to design a genome based on the desired phenotype, in this case a phenotype with a longer lifetime.

Ethical and societal issues are even bigger than with the IVF and embryo selection.

3.3.17.4 Virtual Life

All the previous 3 approaches are/will be possible thanks to massive processing power availability as well as huge amount of data. However, none of them is a direct consequence, nor require, a digital transformation. Although, the whole healthcare sector is expected to undergo a DX in this decade.

The progressive availability of personal digital twins might lead by the decade's end to an accurate replica of a person (including feelings, experiences, relationship) in the cyberspace. The digital twin at that point can be considered a mirror of the physical person, but unlike the physical person, it is not subject to ageing, if one chooses so. This would be a case of digital transformation applied to a person (there are several other facets in a digital transformation of a person, not addressed in this context).

There are already first signs/attempts of prolonging a person's life in the cyberspace. This extension is to the benefit of relatives and friends, even of companies, but clearly it is not to the benefit of the person (although, one person might feel better knowing that his passing away will not imply a total disappearance). Whether in the future a software might become sentient is a fully open question.

3.3.17.5 Societal considerations

All the above approaches raise significant ethical and societal questions. Most of these are so new that they have not been considered so far. It is easy to predict that several more will surface as radical life extension becomes a concrete possibility.

There are also other issues that would emerge if and when a radical life extension becomes possible (hence not on the way this is achieved but because it is achieved):

- Who could have access to radical life extension? Is that part of a global human right or is it just for those who can afford it? FDA has recently recognized ageing as a disease, no longer as a natural process.
- What are the implications of the shift towards a much "older" Society?
- How will life be re-organized as the usual phases of learning, working, and enjoying the twilight will no longer work (learning will have to flank the entire life, when will people retire)?
- Will the possibility of extending life overcome any other considerations (keep on living may shadow any other value and lead to harsh conflicts)? Would it give rise to a strong "end justifies means?"
- Older age is often synonym for conservatism. Would life extension stifle change and lead to stasis?
- The whole planet has evolved in a state of dynamic equilibrium (i.e. any change leads to a feedback that returns the planet into an equilibrium state). How would radical extended life of a species be counteracted to return the Planet to an equilibrium state?

4 The economics of the Digital Transformation

In this section, the various aspects of DX from value shift, loss of value (including jobs), value creation, and quantitative aspects are presented. It should also be noted that the speed at which DX is taking place leads to different economic impacts, as it was clearly shown in the recent countermeasures to the COVID-19 pandemics. This is considered in further detail in section 9.

4.1 More efficiency > Market Value Shrinks

It is important to realize that the DX leads to higher system-wide efficiencies. This is, in absolute, a good thing, but if one looks at the specific situations, it is easy to notice that plenty of industries/commerce thrive on those inefficiencies.

Notice that this increased efficiency is what motivates industries to pursue the Digital Transformation. This can also be seen as one of the reasons why, in general, the Public Administration (PA) is lagging behind: not having to face a competition that drives towards increased efficiencies, PA is slow in embracing the transformation.

However, if on the one hand, private industry is eager to embrace the transformation to increase its efficiency, on the other hand there is also concern, and resistance, because this increased efficiency along the value chain leads to a shrinking of the overall market value and this affects, in different measures, all players in the value chain. One would assume that increased efficiency leads to lower prices, and therefore, higher market adoption that compensates the per unit price decrease. However, in most cases, the price decline is so great (sometimes approaching zero) that the increased volume does not make up for it. We have already seen this happen in the music sector, in part of the travel/tourism value chain, and in the telecommunications sector.

It is a no-brainer to say that those players that are most affected in terms of decreased revenues are the one resisting the most the transformation.

To make the point using an extreme case, let's look at the Digital Transformation applied to the travel sector, an area where DX has already taken a stronghold. The DX is clearly decreasing the market value of the physical premises of travel agencies, and that has led to the disappearance of many of them.

As the shift to the cyberspace squeezes the market value, fewer players can survive, and they tend to increase their market share, thus creating oligopolies (read Expedia, Booking, TripAdvisor, Airbnb). This is possible because business in the cyberspace scales gracefully, and the cost per transaction decreases as their number increases. All these companies would have not existed without the Digital Transformation.

As the transaction cost decreases, more people can access that market (it costs less to travel) and more players can enter the market to offer services (it costs less to develop and offer services plus, the offering can target a worldwide market, thus benefitting from scale). As an example, on TripAdvisor alone, a variety of players in 2017 added 30,000⁴⁵ "experiences," a 50% increase on the previous year. The reason is clear: it cost very little to add one "experience" (what to do in a location), and this allows addressing niches, as well as generating interest and increasing customers, thus revenues. Expedia generated over \$500 M⁴⁶ out of selling experiences (things to do, meet the locals).

⁴⁵ <https://www.doxee.com/blog/digital-marketing/digital-transformation-in-travel-sector-3-trends/>

⁴⁶ <https://skift.com/2018/04/27/expedia-sold-more-than-500-million-in-tours-and-activities-in-2017/>

Single individuals, with very limited capital but with something valuable to offer, like their knowledge of a place, can now jump onto the tourism bandwagon and offer their services⁴⁷.

The overall tourist market has become more efficient. There are fewer intermediaries needed as a tourist can get in touch directly with the local service provider. In this process, travel agencies in developed countries (the one from where tourists originate) have mostly disappeared whilst developing countries have seen an increase of travel agencies delivering local experience (this of course applies to developed countries with an inflow of tourism). Clearly, the marketplace has changed and so has the perception of value. As a tourist I want to touch base to my destination points, not to the origin. This represents quite a change from the past!

4.2 Data is *not* the new oil

The Digital Transformation moves activities and processes to the cyberspace, hence it shifts the focus to data. Data are being used in the cyberspace assembly line to create value, and these data are the raw material that will be converted into services or products using a variety of transducers (like Computer Aided Manufacturing, or CAM).



Figure 18. There is not such a thing as "value of data". This value depends on who is looking for those data, what they will be used, what is the context of those data, the timeliness of the data and so on. Most likely, data are most valuable when they are used for illegal purposes. In the graphic the estimated value of data in cybercrime. Image credit: VPN Mentor.

There is no such a thing as "value of data." This value depends on who is looking for those data, what they will be used for, what is the context of those data, the timeliness of the data, and so on. Most likely, data are most valuable when they are used for illegal purposes. In the graphic above, the estimated value of data in cybercrime.

⁴⁷ <https://www.toursbylocals.com/>

Because of their association to “raw material,” one hears people saying that “data is the oil of the 21st century”. From a perceptual point of view, that is fine. However, it is very wrong, and most importantly it is misleading since it conveys the idea that as the last century’s economy revolved around oil, now it revolves around data, applying the same rules of the game. This is not the case.

1. Oil is rooted in the “atoms” economy, the economy of scarcity. If I have a barrel of oil and I give it to you, you got it but I no longer have it. On the contrary, if I have a GB of data and I give them to you, you got them, but I still have them. We are in the economy of abundance.
2. You cannot distinguish (in economic terms) a barrel of oil from another barrel of oil of the same grade (economists would say it is fungible). However, data have different values depending on what they are and what their specific use is at a specific time.
3. Producing one barrel more of oil has a cost (positive marginal cost), producing one extra GB of data (basically) has no extra cost. In what economists call the “perfect competition,” the value of a product is equal to its marginal cost (that is because competition shrinks the margin, a perfect competition will reduce the margin to zero, hence the product cost will be its marginal cost). A barrel of petrol will cost you its marginal cost (somewhere between \$6 to \$22, extraction cost varies), so will data: you can get data for free, because their marginal cost is zero!
4. When you use a barrel of oil, you get a return. That return stays the same as you use a second barrel of oil and so on: it has constant return on scale. On the contrary, data tend to have a diminished return, the more data you are funnelling, the less valuable the additional data becomes. This is becoming even more so as data are used to train AI algorithms. The more data you provide the more accurate the result but as you provide more data the accuracy increment decreases. If you provide 1,000 movies, they have a certain value X. If you provide 10,000 movies, the value does not scale. It increases by a small percentage that gets smaller and smaller as more and more content is made available.
5. Moving oil around costs, hence you tend to distribute the stock to minimise transport. On the contrary, moving data around doesn’t cost anything (at least the cost is not borne by those accessing the data, you don’t even know where data are actually stored). This fosters consolidation and aggregation in the business of data, and indeed there are a few huge data aggregators.
6. Oil has a price (it oscillates depending on market condition). Data is basically worthless, unless it is considered in an envelope of usage. It is the usage that makes the difference. That is not the case of oil. So how much data value can be depending on the use? In the graphic, one can see the value attributed to data when retrieved illegally (and most likely for illegal use). A stolen Netflix password may have a \$3 value (dirty cheap!), a Spotify password just \$2.8. The codes to access your bank account have a value that depends on the amount of the account, a \$2,000 account access code may be worth \$100, a \$15,000 account access code may fetch \$1,000.

There is much more to the economy of data, and it will be explored in the following parts. What should be clear is that one cannot compare data to oil in terms of economic value, and moreover the value measuring stick for one does not work for the other.

4.3 Harvesting data value

When one says “data are valuable,” that’s not the complete truth. It is sufficient to look around at how many data are being used every single day for free (getting and using is almost a synonym in data, which is not the case in the world of atoms!).

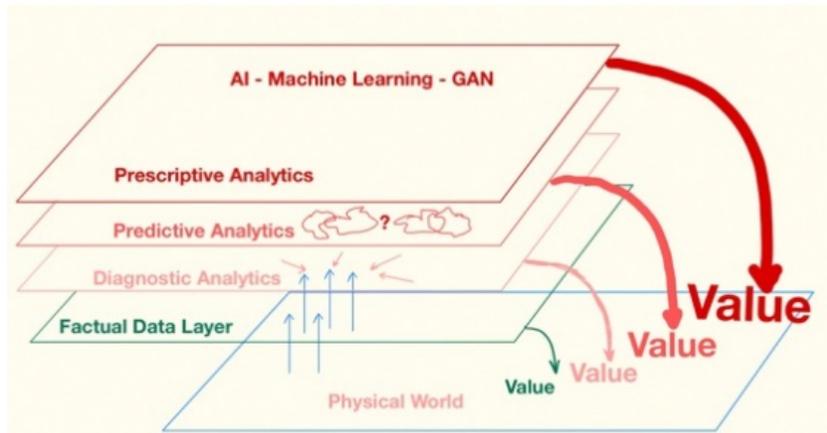


Figure 19. Data are not valuable per se. They acquire value in a given context, depending on the intended use and timeliness. Their value increases as they are transformed into metadata and get more impactful on the physical world. In the end it is their impact that creates the value.

Data are not valuable per se. They acquire value in a given context, depending on the intended use and timeliness. Their value increases as they are transformed into metadata and get more impactful on the physical world. In the end, it is their impact that creates the value.

Even when one pays for data, the value is usually in something else, like the convenience of accessing those data and the value that can be derived from the use, the knowledge about those data. A song may be priced 99¢, but people are not paying that money for the song, rather for the convenience of getting that song in just one click. That same song could be obtained for free by ripping a YouTube clip of that song (and yes, there is going to be a YouTube clip of that song). By paying 99¢, one saves time, and time is a valuable scarce resource.

Hence, the point is how can one harvest data value? There are basically 4 increasing layers of data value:

1. Factual: this is the layer of data acquisition. Through sensors, one can transform a physical characteristic in data mirroring it. As an example, data can be harvested by a digital camera at an intersection point, and a software application can detect a traffic jam. This is a fact. It can be just a number (like 0: traffic flow is regular, 1: traffic is slow/blocked) or it can be a set of numbers (number of cars, the time spent in crossing the intersection, the types of cars, trucks). This factual information can be made available to everybody, or, higher value, to those in the vicinity that seems to be approaching that intersection.
2. Analytic: this is the layer where factual data are analyzed, compared with other data to find out what may be going on. Following on the example, a software application can compare the factual situation at the intersection to the one at the same time on previous days. It might so discover that the slowdown is recurring at that particular time of the day, or it may be something unusual. In this case it can look at other data, like presence of an event, a soccer match, that just ended, thus justifying the increased traffic volume, or the warning of an accident. Again, the analysis can be made available (metadata) to everybody or to those that are likely to be affected, with information of an abnormal situation.
3. Predictive: a further software application, using both factual and analytic data can work out a prediction on what is likely to happen if nothing is done. Is the traffic jam going to get worse

(many more vehicles are converging on that point and it will take time before the accident is removed)? Is it going to fade away in some 15 minutes? Again, this information can be made publicly available or it can be provided to those that may find it useful (higher value).

4. Prescriptive: once it is known what to expect, if nothing is done, prescriptive analytics applications can be used to evaluate different evolution if the context is changed, i.e. if the world of atoms is affected by some actions. Closing on the example, the knowledge of probable destinations of the incoming traffic that if nothing is done will be converging on the intersection can be used to direct each incoming vehicle to use an alternate routing skipping the overloaded intersection, thus avoiding worsening the situation and saving time to people travelling. This knowledge can be derived from a mapping of travel of individual smartphones (as the move from one cell to the next) over weeks and months. Still, keeping the owner information private, a telecom Operator can send specific messages to individual phones saying something like: "if you happen to be going to A it is better to choose this route, since intersection XY is currently blocked." This clearly provides the highest value to the receiver.

Notice that these four layers of increasing data value fit any situation. The Digital Transformation creates factual data by mirroring atoms (i.e. the physical world with its ongoing activities), and these data can be stored for historical records and enable, once correlated with other data streams to create valuable information. Also, notice that conceptually all data are available at the same time in the same place, that is in the cyberspace. In practice, it is possible to partition data and allocate them in different places interacting with them through APIs (Application Programming Interface).

This leads to an encapsulation of data preserving ownership and privacy. The disclosure through API can be regulated and monitored for value accrual, aggregation, sharing, and monitoring, all the while enforcing the desired level of privacy. In the previous example, it is irrelevant to know which cars are blocked in the traffic jam, what matters is the traffic jam and its dimension to derive information on its evolution.

Likewise, it is not important to know whose smartphone is travelling to a certain point, only that someone is intending to go there. At the same time, the owner of the data (like the person who is blocked in the traffic jam) may wish to share this information to her team to let them know that she will be late to the meeting. The API invoked by the meeting organizer will have access to the identity of that person, whilst the API invoked by the city traffic supervision will not.

4.4 Knowledge value versus data value

Data, as such, are just a bunch of bits, and their value is zero since there are plenty of bits. They can easily be duplicated at zero marginal cost as well as transmitted from any point to any other point. The capability to interpret data and to derive a meaning, on the other hand, is valuable, depending on the value of the meaning.

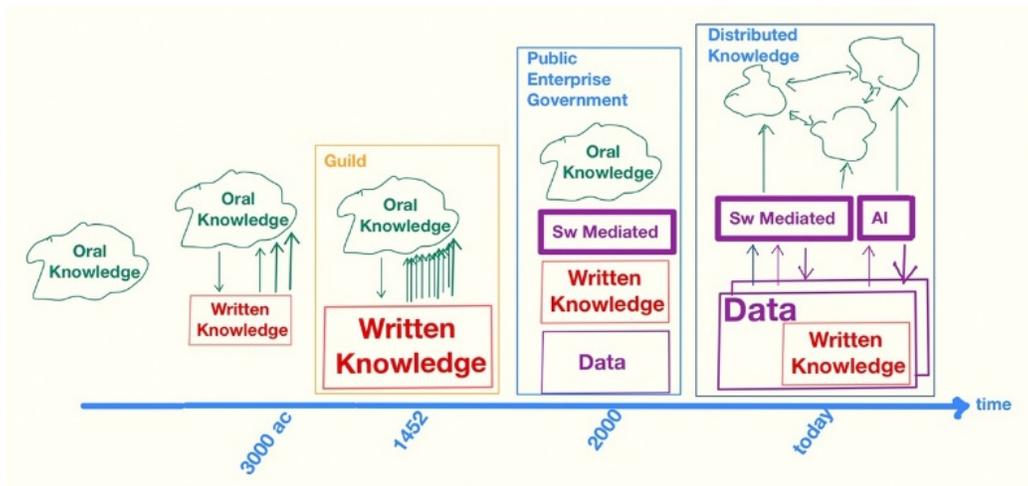


Figure 20. A sketchy representation of the evolution of knowledge, first a matter of oral transmission and only residing in brains, then using writings to preserve it from one generation to the next and for learning.

With the invention of the printing press, written knowledge took the upper hand with humans updating and expanding it and using it as learning base. The advent of the computer has seen the shift to data and the mediation of SW to access knowledge recorded in data. Now, we are seeing an explosion of knowledge well beyond a single brain's ability to grasp, hence the shift towards distributed knowledge and the increasing reliance on tools to access and execute knowledge, with AI playing a growing role.

Knowledge has always been considered a valuable asset, from the very early times of humanity. In those first times, knowledge was not tied to data repository, since it was embedded in the experience and oral tradition handed over from brain to brain. Only recently, say in the last 5,000 years (a blink on an eye in terms of human existence on Earth) after the invention of writing, knowledge started to get tied to stored data (clay tablet in the beginning) and these data started to be guarded to keep the ownership of knowledge. Guilds, later on, became the keeper of knowledge stored in data and in artisan expertise passed on from one member to an apprentice. Much later, thanks to printed press, knowledge started to be mostly stored into data (written knowledge) and the point became to access that stored knowledge. Data became more and more valuable since the access to data equate to access knowledge.

Very recently, this written knowledge has expanded so much and has become so easily accessible that it started to dilute its value. Additionally, data have grown exponentially, enveloping the written knowledge and providing raw material that can be used to extract more knowledge. The problem is that the sheer quantity of data makes it basically impossible to extract such knowledge by humans. A machine is needed. Think about the 68,493 GB of data produced every day by the LHC (Large Hadron Collider at CERN in Geneva) or the SKA (Square Kilometre Array) telescope producing 8,000 GB of data every second⁴⁸(!). These numbers are so huge that it is difficult just to grasp them. An aircraft like the new Airbus 350 generates data from 400,000 points⁴⁹. Each of its two engines generates 1,000 GB of data per flight. It is impossible for a pilot to make sense of those data (acquire knowledge) without the mediation of a machine (software).

⁴⁸ <https://www.skatelescope.org/signal-processing/>

⁴⁹ <https://www.aerosociety.com/news/digital-takeover/>

A side issue is that the data space is not just huge, it is also littered with spurious data, incorrect/fake data to the point that separating the wheat from the chaff has become a major challenge, and, consequently, ensuring correctness of data is valuable also from an economic standpoint. Today, more and more, the value resides in “executable” knowledge. That is the capability to execute here and now, taking into account the relevant knowledge, in the best possible way.

The problem is that on the one hand, the human capability to digest the expanding recorded knowledge space, even in a specific area, is being challenged, and on the other that the machines (AI) are not just becoming a contender in accruing and executing but also in creating knowledge.

In a way, there is a shift from the value of data to the value of knowledge. At the same time, the capability of AI to create (executable) knowledge out of data is reinforcing the value of those data used in the creation process. In the last 15 years, the increasing capability of AI has been based on access to larger and larger data sets made possible by increased computation capabilities and availability of data. Hence, companies that could generate/harvest data found themselves in the ideal position to leverage on them (interestingly, harvesting data and processing them require the same underlying structure: large data centers). The exponential growth meant a parallel growth in the investment required for the supporting infrastructures leading to a concentration of data, knowledge and value in a few companies (read Google, Amazon, Apple, Facebook).

4.5 Leveraging on Data

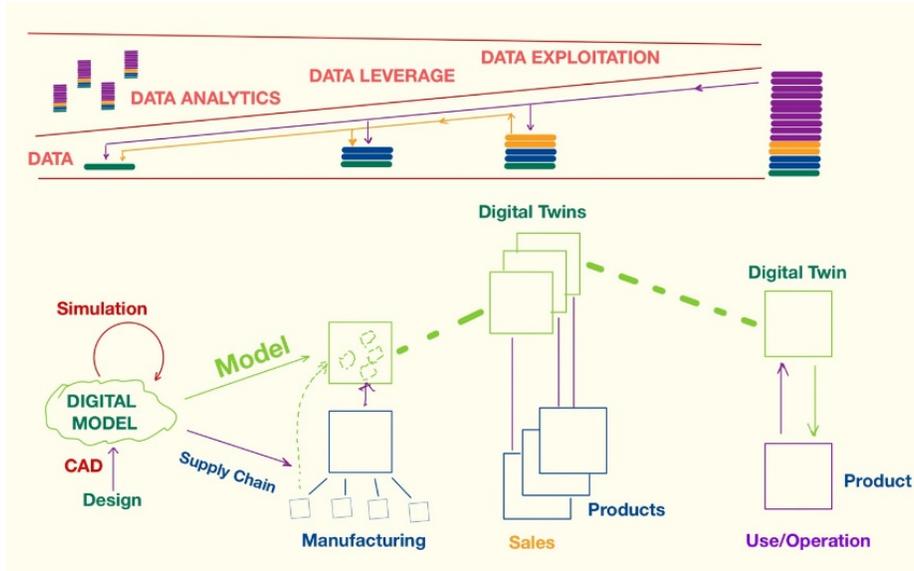


Figure 21. Data being created in a manufacturing process.

The graphic shows how data are being created in a manufacturing process. A first set is created through design activities (Computer Aided Design), resulting in a model that can be subjected to simulation. Once the model is sound, it is used to synchronise suppliers and the various components are manufactured and assembled into the final products, generating more data in the process. These data form the Digital Twin. Actually, they create instances of Digital Twins, one associated to each product instance. The products are then moved on the delivery chain and sold giving origin to usage and

operation. The latter are source of many more data that are being shadowed in the Digital Twin. As shown in the upper part of the graphic, the number of data increases and expands in the operation. These data are made accessible to the manufacturing and design to fine tune the operation, to design better products and augment features as well as to generate services.

The Digital Transformation accelerates the generation of data and companies are learning to capitalize on those data, sometimes clashing with fuzzy regulations and unclear definitions of ownership.

Take the example of Tesla. Tesla cars have been designed through computer modelling, and this process generates a digital model of the car that is used for simulation and for interaction with component suppliers. The model is then turned into software for the manufacturing of the car, to create parts and assemble them into the finished product. All the manufacturing phases are recorded and are added to the model of the car. At this point, there are many instances of that model, each one mirroring a specific car (there might be difference, in color, optional features, even in components) that might be provided by different suppliers and in the robots and workers that manufactured a specific car. Once the car is sold, sensors embedded in the car keep track of its operation and where it goes (Tesla is adding data on 1 million miles of road driven every 10 hours⁵⁰). On November 2018, they reached the thresholds of 1 billion miles recorded, when it is recharged, and how it is used. All this information is harvested by Tesla for proactive maintenance (to detect possible malfunction) as well as to detect issues in the manufacturing that might become apparent only at a later stage.

As an example, a few cars after some thousands miles on the road showed an abnormal vibration detected by the sensors on the left suspension. Through data analytics, AI software was able to pinpoint the problem in an asymmetry in the fastening of bolts on the two sides of the car assembly line, with one robot placing a higher pressure than the other. At that point, the software inserted a notice in those cars digital twin (the car data sheet) so that once one of them was taken to a repair shop, the notice will be read and recalibration executed. All of this is without the owner ever becoming aware of the problem (the vibration was so tiny that went undetected by the driver).

Also, all data harvested from driving, including the data generated by the digital cameras used by the automatic driving assistant (autopilot), are continuously analyzed to improve the autopilot using machine learning. In other words, all Tesla cars are getting better every single day by leveraging on the experience of each and all of them.

Data are so fundamental for Tesla and its business that the company has been defined “The Data Company⁵¹.” Although operating in a tiny vertical sector, the one of private transportation, Tesla is gathering a massive amount of data⁵² that can generate plenty of metadata, like:

- Where are people driving, when they are driving, how they drive, and with whom they drive (this information is easily obtained by sensing the smartphone on the car, via Bluetooth). This information places Tesla in an ideal position to evaluate risks, and therefore, to offer competitive car insurance⁵³.
- What are the road conditions and how these conditions change over time, whether there are potholes requiring maintenance and so on?

⁵⁰ <https://qz.com/694520/tesla-has-780-million-miles-of-driving-data-and-adds-another-million-every-10-hours/>

⁵¹ <https://www.cio.com/article/3433931/tesla-the-data-company.html>

⁵² <https://www.axios.com/what-tesla-knows-about-you-1f21d287-a204-4a6e-8b4a-0786b0afac45.html>

⁵³ <https://www.theverge.com/2019/6/11/18661975/elon-musk-tesla-shareholder-meeting-questions>

- What traffic is on a particular road at a particular time, detecting traffic anomalies versus the usual pattern. Get information on other cars driving around (their number plate is easily captured by the Tesla camera and it would be straightforward to map, given sufficient time, the whereabouts of many other people in a given area).
- Who is walking around and who is getting in and out of shops and homes. A bit of data correlation would make it easy to find out about other people's habits in a specific area.
- The car suspension can provide data on the "weight on the car" meaning that over time it is possible to gauge various parameters about the driver, the passengers, and even the groceries being transported

Notice that what is listed above is not stating that Tesla is actually gathering these data, just that it would not be a technical problem to harvest them. As a matter of fact, Elon Musk has stated several times the advantage given to Tesla by the use of Big Data and AI Data Analytics⁵⁴ and once even voiced the idea of using these data for selling services. That resulted in a backlash by several Tesla owners concerned of the violation of privacy on the one hand and on the exploitation of their data to make money on the other.

Clearly, Tesla is the perfect example of a company born out of the Digital Transformation of a classic business. It is not just the shift to electrical power engines, it is the use of data that is making Tesla worth more than Exxon in the stock market⁵⁵. Its turnaround is way, way, lower than Exxon, yet the stock market expectation for a bright future is all on Tesla side.

Tesla is just an example of the power of leveraging data for a manufacturer:

- fine tuning of manufacturing based on operation feedback
- continuous improvement of products through data analytics from the all products sold looking at the way they are used
- development of services flanking the product
- offer new services in other market segments that are in principle completely outside of the company business (like providing info to municipalities on proactive road maintenance).

Tesla has been used as an example. According to a new McKinsey report, the monetization of big data harvested from cars can lead to a \$750 billion market in 2030⁵⁶. Today, there are many companies that are leveraging on the result of the digital transformation of their business and exploit data to increase revenues, decrease cost, and strengthen their market position (see section 7).

⁵⁴ <https://www.7wdata.be/big-data/how-tesla-is-using-big-data-and-ai/>

⁵⁵ https://futurism.com/tesla-worth-more-exxonmobil?mc_cid=c8f2fa72d7&mc_eid=d799ee442c

⁵⁶ <https://www.mckinsey.com/industries/automotive-and-assembly/our-insights/monetizing-car-data>

4.5.1 Digital Twins Market

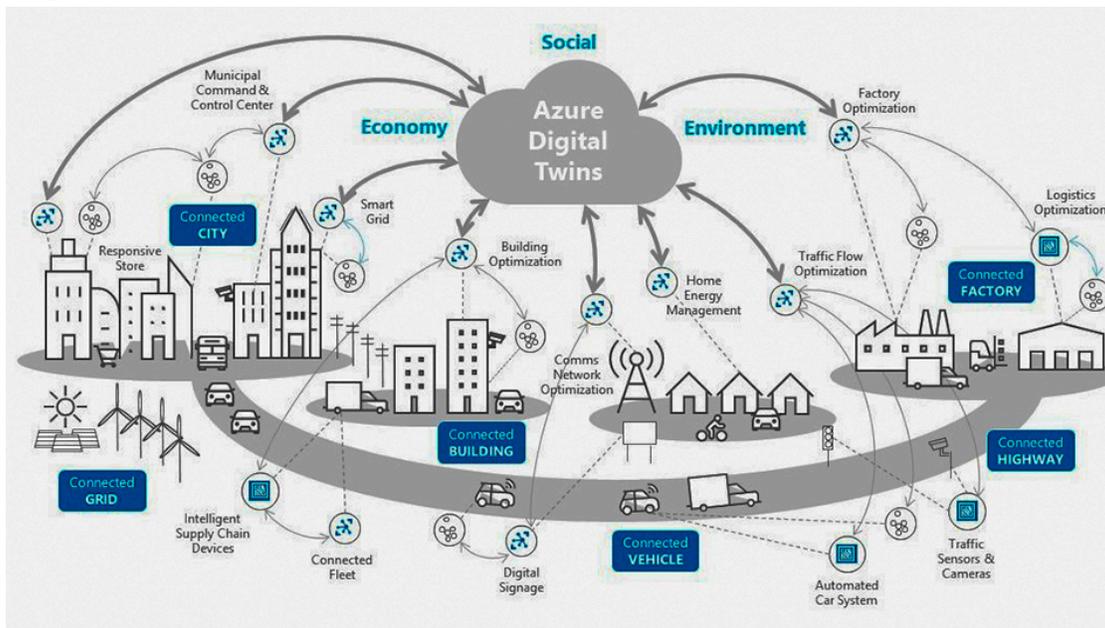


Figure 22. With Azure Digital Twins, environments of all types (offices, schools, hospitals, banks, stadiums, warehouses, factories, parking lots, streets, parks, etc.) can all become smarter, along with the electrical grids that connect them and the cities around them.

Part of the Digital Transformation result is the creation of a “mirror” world in the cyberspace that can be used to conduct business at a lower cost and without the constraints imposed by the physical world. This mirroring calls into play the concept of Digital Twins, software entities mixing data, processing, and interactions with their siblings as well as with their corresponding physical entity and with other entities in the cyberspace. The Digital Twins derive from the adoption of computer aided design tools that create a digital model and by the presence of sensors in products that can provide the operation data (the digital shadow).

IoT's make sense as long as they generate data that are used/processed, and this basically calls for a Digital Twin, hence explains the rapid growth of Digital Twins. Platform support like the one of Azure, MS, Mindsphere, and Siemens foster the adoption of Digital Twins and their leveraging for the creation of value. According to ResearchAndMarket, by 2025⁵⁷ 89% of IoT platforms will include some form of Digital Twin management since they will be an integral part of the Industry 4.0 evolution. As Digital Twins grow, more supporting tools become available and the easier it becomes to use and leverage Digital Twins. Also, these tools foster the adoption in Digital Twins beyond their core market (manufacturing). They are now being considered in real estate management, in ERP, in smart cities, in healthcare, and in education.

There is a whole ecosystem⁵⁸ being developed on Digital Twins, resulting in a market growing with a 28% CAGR over the next 5 years to reach \$20B in 2025 (with the North American market expected to grow at a 34% CAGR). Most recent estimates⁵⁹ taking into account the acceleration of the Digital

⁵⁷ <https://www.businesswire.com/news/home/20200403005116/en/Digital-Twins-Market-2020-89-IoT-Platforms>

⁵⁸ <https://cmte.ieee.org/futuredirections/2019/07/13/evolution-of-digital-twins-market-space/>

⁵⁹ <https://www.marketsandmarkets.com/Market-Reports/digital-twin-market-225269522.html>

Transformation resulting from the COVID-19 are pointing to a 45.4% CAGR in the next five years to reach a market value of \$35.8B in 2025.

The market size of the tools supporting creation, operation, and exploitation of Digital Twins is just a part of the story, basically covering the cost companies have to sustain to deal with Digital Twins (cloud, data communications, data integration across different design, production, sales, operation, and maintenance systems). Notice that these costs are an integral part of the new enterprise shifted in the cyberspace, so they should not be considered “on top” (in other words if a company chooses not to adopt Digital Twins but still to move to the cyberspace it will still sustain, most, of those costs).

The other, most important part from an economic standpoint is related to leveraging the Digital Twins to create and offer services⁶⁰.

This step is somewhat seamless for those companies that have been in the business of providing post-sales services like maintenance services. Using Digital Twins, they can enhance those services through monitoring and analytics and deliver proactive maintenance. However, for most companies this is not the case. The sale of a product is part of a business model that does not include interaction with the end user (sales is through a delivery chain that disintermediates the end user from the manufacturer). Additionally, most companies are not in the business of services, they focus on product sales. In these cases, a new business model and supporting processes are required, and this is a challenge to many companies.

A further step would be to consider the Digital Twin as a separate entity that can be leveraged on its own, independently from its physical twin (the product). Take the case of Telecom Operators. Even though they operate on bits, and bits are the raw material from which they generate revenues, their business models are stuck to the world of atoms, i.e. copper and fibre plus SIM cards.

Telecom Operators have not been able, so far, to leverage on the huge amount of data they have and transport. The concern is on keeping their neutrality (although sometimes they claim for a non-network neutrality to be able to deliver better quality, read: charge more some type of traffi-), not getting involved in what is being transported, no responsibility, focus their business on the tools rather than on the product (they have mostly abdicated to create services leaving this economic space to OTTs).

Yet, embracing the Digital Twin bandwagon, something that they would be ideally positioned to do, would propel them into this growing economic space. They could offer identity services, tailored communication paradigm fitting Digital Twins specific needs, hosting and mirroring, monitoring and authorization services, and so on. This transition is a difficult one since it means changing their mind-set that is still tied up to twisted pairs (the fibre is a seamless evolution of a twisted pair and the SIM is the equivalent for wireless communication, that is why most Operators hate the idea of a digital/virtual SIM!).

4.5.2 Digital Twins as independent economic entities

Digital Twins are evolving rapidly. It started in the last decade with them being used as digital “mock-ups” created by CAD systems. These mock-ups were refined till they could be used as digital specs for interaction with various groups in the company and with suppliers. The use of VR makes easier to visualise the Digital Twin of a future product.

⁶⁰ https://www.researchgate.net/publication/334884420_Digital_Twin_An_Enabler_for_New_Business_Models

Although that was not the case, one can find an economic value in these Digital Twins as “blueprints” that can be sold. This will be the case in this and the next decade as result of the market created by the Digital Transformation with companies buying and using these digital specs.

The second step was the use of the Digital Twins to create their physical counterpart, through Computer Aided Manufacturing (CAM) systems. In this way, a direct correspondence was established between a Digital Twin and its Physical Twin. Therefore, one could use the Digital Twin as documentation of the Physical Object during operation and maintenance. The use of AR makes this correlation quite effective, since at the same time a technician will be able to look at the physical engine and get information from its Digital Twin that can be overlaid on the physical one through real time rendering.

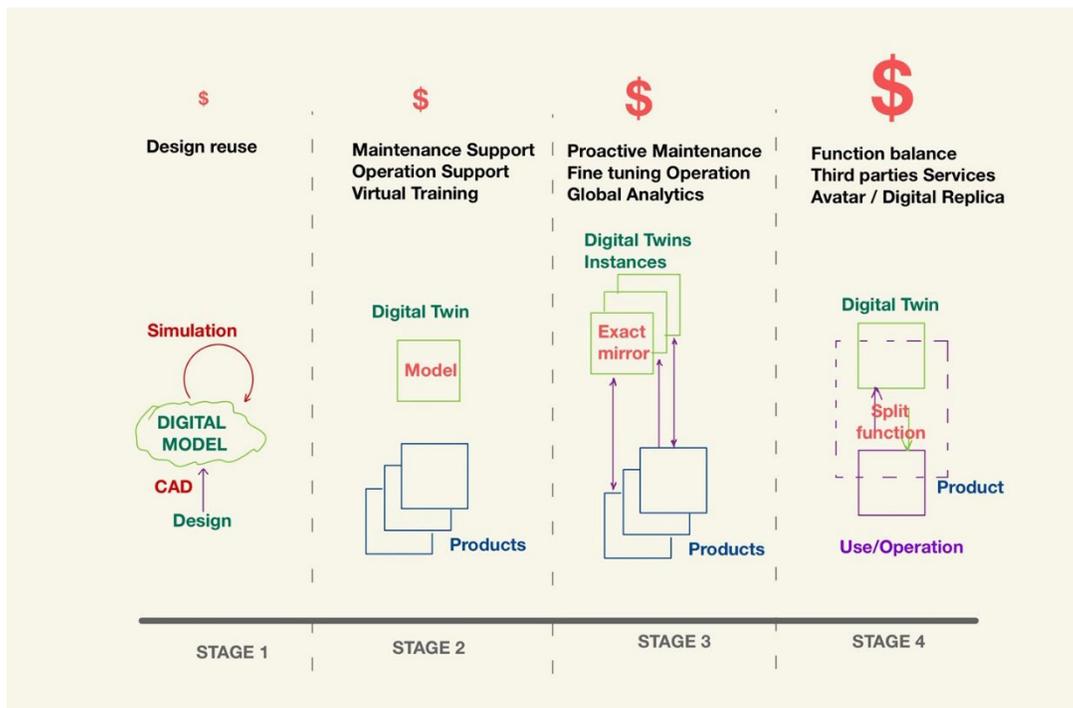


Figure 23. The graphic shows the stage of evolution of Digital Twins.

Today by far, industries adopting DT use them as stage 3, i.e. interacting with their physical twin. The economic value increases with the stage number. This value is the one associated to the Digital Twin, i.e. the revenues it can generate. In addition, one sees an increasing value in the supporting infrastructure (platform, cloud, communication) and enablers (IoT, AI, DLT). The latter is predominant today but in the near future it can be expected that the revenue generated by using DT as independent entities will exceed by far the present one in support tools. Of course there is, additionally, the economic benefit derived from the adoption of digital twins, in the whole value chain in terms of efficiency and cost reduction.

This role in assisted operation and maintenance will become much more common as AR technology progresses. So far, it is used in industrial environment but in the coming years it will become a common way of interacting with products and that will generate an additional economic benefit.

A further step was taken, and it is still being taken, enabling interaction between the digital twin and its physical twin. In this case, we are dealing with digital twin instance and physical instance of a product/object. The interaction (shadowing) ensures the alignment between the Digital and Physical twins. At this point, either the Digital Twin itself (in reality an extended digital twin) or applications interacting with the Digital Twin can deliver services, value, to the physical twin. There will be a progressive augmentation of a Digital Twin capabilities as it will not just interact with its physical counterpart but also with applications and services in the cyberspace. In this sense, the Digital Twin becomes a gateway between the physical counterpart and the cyberspace, a tool to deliver value. This is clearly a significant, transformational, step for companies making it possible to deliver services on a product in a seamless way.

We are already seeing some examples of this happening. Remember when downloading a new version of an Operating System required the reinstallation of applications and some personal data? Now this is no longer the case since our devices have a mirror image that is used when a new OS is installed. This mirror image is a sort of Digital Twin. A number of manufacturers, like GE, Mevea, and Siemens, are now offering along with their products remote monitoring and proactive maintenance services based on the Digital Twin of their products.

This changes the rules of the game since now the manufacturer has direct interaction with the end user (the flattening of the value chain that is one of the characteristics of Industry 4.0). The next step will be the use of the Digital Twin to deliver additional functionality. In this case, the operation of a product requires its digital twin since some of its features are made possible through its Digital Twin. In practice, there is a function splitting among the physical and the digital twin. This, per sé, is nothing new: already today we have some functions split between the device and the cyberspace (voice recognition is often the case), so that a service may be partially be delivered through real time interaction with a cloud.

This opens up the door to the “independent” exploitation of a digital twin by having it enabling functionalities to third parties (no longer, solely, to its physical twin). In other words, a Digital Twin may deliver services that in part are derived from its knowledge of its physical twin. An example would be a digital twin that has accumulated experience on the use of a car and can “sell” this experience to third parties interested in getting real feedback from the market. Another example might be the use of a Digital Twin as an avatar of a person. This will be addressed in the next section.

4.5.3 Cognitive Digital Twins

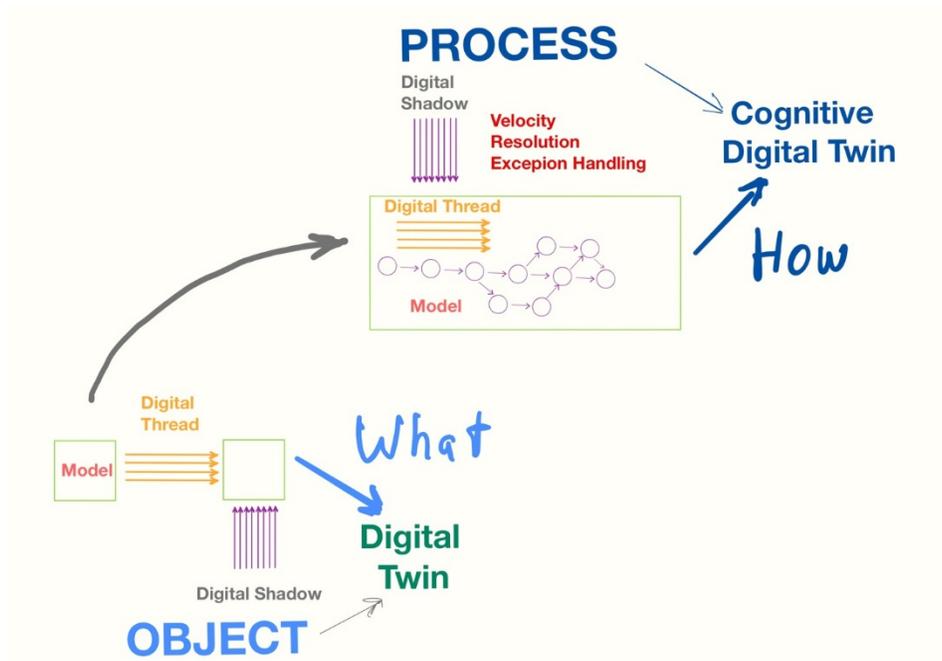


Figure 24. Cognitive Digital Twins represent an evolution of the Digital Twin concept. They have been crafted to fit the need of monitoring complex industrial processes and use the same triade-model, shadow, thread- of Digital Twins. Balance between velocity, resolution and exception handling is crucial from an economy perspective. The Digital Transformation tips the balance towards Cognitive Digital Twins.

A Digital Twin, as explained in the previous sections, is the sum of three data sets:

- one representing the model of the physical entity
- one representing the current status of the physical entity
- one recording the history of the physical entity, including the relations it had (like what robots built it) and the sequence of states (timeline of the shadows)

All together these data set represent “what” is the physical entity.

It is possible to create a Digital Twin to represent a process, rather than a product. As an example, an enterprise can have several digital twins, one for each of its processes (supply, manufacturing, resource management, sales, maintenance). Here again, the Digital Twin will keep a data set modelling the process, another mirroring the current status of the process and the digital thread recording the evolution over time of the process. When looking at the Digital Twin of a process, one can understand “how” enterprise activities are executed, including, as an example, how a product is built/operated/maintained.

This information can, as an example, be used by an assembly line of robots to “teach” them how to build a specific product. In a sense, this can be seen as the representation of a given space of knowledge.

IBM was probably the first company to investigate this type of Digital Twins and they called them “Cognitive Digital Twins⁶¹” (GE was probably the first to use the first type of Digital Twins at an industry level).

This type of Digital Twins is very important for companies in general since a company is defined by its processes (people can come and go, the company stays and its processes are its trademark) and their efficiency is what makes it competitive on the market.

Modelling processes using bits are not particularly tricky. Most companies already have a computerized management flow that supports the various activities and the interplay of resources (including human workers). Hence, it is usually straightforward to create a formal digital model of an industrial process (this can be very detailed, like what piece of papers have to be filled, who is authorising what, where are spare parts located, and what to do to manage emergencies).

The shadowing is usually more complex (companies are using various methodologies, more and more computerized to monitor “what is going on” and the results of what is going on). The crucial aspects related to shadowing are:

- the velocity, i.e. how often is the status of the process updated.
- the resolution, i.e. at what granularity is the process monitored.
- the exception handling, i.e. what should be done if the monitored process diverges from the expected path.

The shadowing is crucial to the smooth running of the enterprise. The more frequently a process is monitored and the finer the granularity, the better from the point of view of detecting divergences and activating appropriate measures when needed. On the other hand, this increase in velocity and resolution calls for bigger cost, so a trade-off is needed.

However, the Digital Transformation can result in a very high velocity and resolution with no cost increase! The key is to leverage on IoTs, pervasive in the whole value chain, and to use Cognitive Digital Twins to aggregate and pre-process the data. This is what platforms like Mindsphere⁶² and FIWare make possible. The use of robots in many activities provides the sensing as well as the actuation points needed.

The communication infrastructure is obviously crucial, and the performance provided by 5G becomes interesting. This is why, as an example, Siemens has acquired 5G spectrum for use in the factory plan. Cognitive Digital Twins closely mirror factory processes and either directly, by embedding intelligence or indirectly by interacting with intelligent applications can replicate in the cyberspace the factory processes and steer the physical processes in case something unexpected/unwanted happens.

⁶¹ <https://www.ibm.com/blogs/internet-of-things/iot-evolution-of-a-cognitive-digital-twin/>

⁶² <https://siemens.mindsphere.io/en>

4.5.3.1 Cognitive Digital Twins as Intelligent behavior

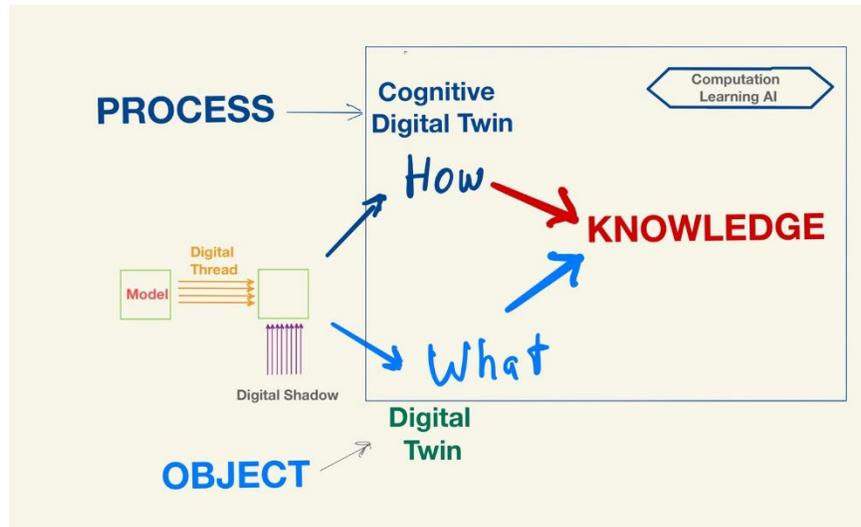


Figure 25. Cognitive Digital Twins "making sense" of data.

Cognitive Digital Twins include the capability of "making sense" of data, transforming them into "knowledge". That is done through computation using Machine Learning/AI approaches. Some can be part of the CDT itself, some computation may occur outside of the CDT resulting in additional "meta-data". When applied to a physical entity like a machine the CDT acts as a minimal "brain."

As presented, Cognitive Digital Twins were invented for the factory floor to bring processes in the cyberspace. However, the very word chosen, "cognitive", immediately links to the peculiar capability of humans: "cognition". This is defined as:

the mental action or process of acquiring knowledge and understanding through thought, experience, and the senses.

As mentioned in Section 4.5.2, Digital Twins at stage 4 become autonomous entities able to act as their physical twin although independently of it.

The value of Cognitive Digital Twins in the context of manufacturing is that they:

- provide an effective way of monitoring the ongoing physical processes (leveraging on data created by IoT in robots, video cameras along the manufacturing plant, warehouse, assembly line, delivery pods, and digital documents exchanged through the supply and delivery chain).
- enable quick analyzes of divergences and can be used by applications to determine the cause.
- enable simulation and what-if analyzes to cope with new situations and assess their effectiveness or to fine tune for improved efficiency.
- can automate parts of the processes as the digital transformation shifts some physical activities to the cyberspace.

This latter aspect is significant since the adoption of Cognitive Digital Twins paves the way to harvest benefits from the digital transformation in a seamless way. Besides, it moves Cognitive Digital Twins from stage 3 (interaction with the processes) into stage 4 (taking over the execution of part of the process).

As one enters into stage 4 capabilities, new horizons open up.

An autonomous Cognitive Digital Twin in stage 4 is characterised by an intelligent behavior (where intelligent might be considered a marketing word but in reality it means the acquisition of sufficient context, goal, and resources awareness to operate in that environment). Notice that the point is for the Cognitive Digital Twin to become an autonomous system not a cog in a predefined process. By being autonomous, new behaviors will be displayed as the landscape changes without the need to redefine its behavior from outside.

At stage 4, new values can be leveraged. As an example, a Cognitive Digital Twin of a robot can learn, as the (smart) robot does, from its operation and it can also learn from the experience of other robots involved in similar activities. Take the Tesla cars. Each car is learning from its own experience and in addition every day each car communicates to the Tesla Operation centers (that has accumulated as of 2020 over 10 billion miles of data⁶³). This data swarm gathering is processed by machine learning algorithms and turned into new knowledge that is actualised into specific changes that are broadcasted on a daily basis (if appropriate) to all cars.

More than that. A company through Cognitive Digital Twins accumulates knowledge (as it is the case of Tesla) and can re-apply this knowledge to other products, increasing their performance as well as to the design of new products decreasing the effort required.

This is an interesting twist in the application of Cognitive Digital Twins because it moves values into executable knowledge and it can be expected during this decade to see companies first adopting Cognitive Digital Twins to increase their process effectiveness and then starting to leverage their economic value to sell executable knowledge as a service.

Notice the slight shift in application of Cognitive Digital Twins from mirroring a process to mirroring a physical entity's behavior (a robot, a car), translating that behavior tracking into knowledge. One can also say that the knowledge of the physical entity (like the intelligence of the robot) is mirrored in the Cognitive Digital Twin that in turns can expand that knowledge through autonomous interactions.

This shift takes the Cognitive part of the Digital Twin very close to the definition of Cognition, "acquiring knowledge and understanding through thought, experience, and the senses," where senses translate into shadowing, experience into threads and knowledge into models. The "understanding" part is tricky because it goes deeper into what awareness is. In the case of current Cognitive Digital Twins, the focus is on knowledge.

⁶³ <https://www.cio.com/article/3433931/tesla-the-data-company.html>

4.5.3.2 Cognitive Digital Twins for Humans

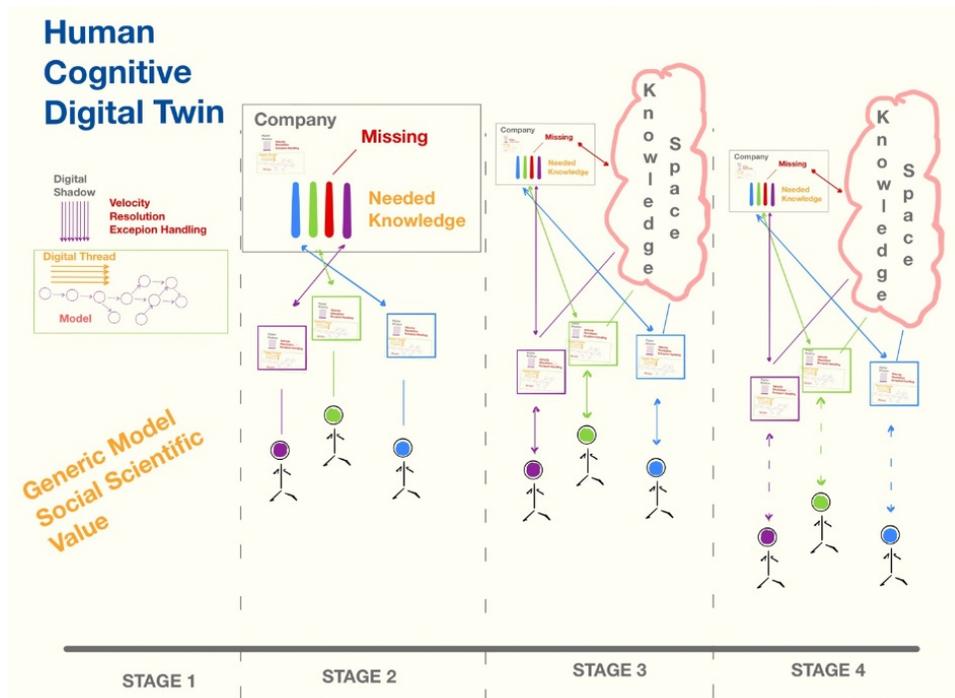


Figure 26. Four stages of human cognitive digital twin.

Although the adoption of Cognitive Digital Twins to mirror human knowledge is at research level, it is possible to envisage the first 4 steps. Stage 1 is the modelling of human knowledge and its evolution. Stage 2 is the exploitation of this knowledge to identify the best available resources and possible gaps that need to be filled. Stage 3 uses CDT to execute existing knowledge in human resources and accessing knowledge on the market. This latter is also used by individuals to keep their knowledge up to date or make use of external knowledge. At stage 4, the CDT becomes autonomous and shares its knowledge as needed. Notice that not all the knowledge of a person is captured/mirrored in that person's CDT, only the one that matters in a specific context.

In a manufacturing workflow, humans are (still) playing an important role. Hence, modelling the workflow requires modelling the human activity as well. A cognitive digital twin shall take the human role in the workflow as an integral part of the model. At this point, the step to conceive a cognitive digital twin to model the activities of a single person becomes a tiny one. Indeed, a few companies have been exploring the benefit of modelling single individuals, as an example in the healthcare space. In this area, the idea is to replicate the “*human machine*” by creating a digital model (it may be a very simple one taking into account some basic parameters like weight, heart beats, blood type and formula, or a very comprehensive one including the genome sequence, the metabolome, the proteome) and then shadowing it by accruing instantaneous data like medical exams, data provided by wearable sensors and keeping the record of changes, including prescription drugs, surgery, and prosthetics. Siemens⁶⁴ and Philips⁶⁵ are big companies that are betting on the usefulness of Digital Twins in healthcare.

⁶⁴ <https://medicalfuturist.com/digital-twin-and-the-promise-of-personalized-medicine/>

⁶⁵ <https://www.philips.com/a-w/about/news/archive/blogs/innovation-matters/20180830-the-rise-of-the-digital-twin-how-healthcare-can-benefit.html>

What about replicating the human brain, not the actual mesh of neurones, but the knowledge residing in a person? Conceptually this is not that different from replicating the knowledge of a company's processes. Cognitive Digital Twins may provide a launching pad for this. So far, there is no real implementation of it. Although, companies like IBM and SAP that are in the business of offering tools and services to managing enterprise content and knowledge are very interested in this possible evolution of Cognitive Digital Twins since they already have the basic tools to support them. IEEE FDC has launched an initiative, Knowledge as a Service (KaaS), that aims at exploring the application of Cognitive Digital Twins to offer Knowledge Services, leveraging on its huge and growing asset of technical papers and conferences.

A Cognitive Digital Twin mimicking a person's knowledge, stage 2, will already provide a significant benefit to companies since it will become possible to search and allocate a specific knowledge owner to the project/activity needing it. Particularly in large companies, often spread out geographically, identifying who knows what is a big challenge. Also, a Cognitive Digital Twin at stage 2 would be able to contribute to the assessment of what knowledge is missing and help in identifying ways to fill the gap. The latter aspects are also most valuable for the individual as knowledge becomes the value asset for finding jobs and generating revenues.

At stage 3, interaction among the Cognitive Digital Twin and the associated person, the value increases as the Cognitive Digital Twin may start serving as a personal knowledge repository, a gateway to access external knowledge and a mediator of knowledge. A person can delegate the exploration of existing/changing knowledge to her Cognitive Digital Twin and be connected with that knowledge as need arises. Likewise, this value can be used by a company that can bridge the knowledge of the company with the knowledge of its human resources letting the individual Cognitive Digital Twin to adapt the knowledge transfer, when needed, to that specific person.

At stage 4, autonomy and function sharing, the Cognitive Digital Twin can express a much higher value (along with some difficult issues). People are already used to delegate part of the required knowledge to machines/tools. Think about the capability to calculate a square root; although, most people learnt how to calculate it at school, the large majority has forgotten but that is not really an issue since any smartphone can do the calculation. Humankind has increased the volume of knowledge and in doing so has also found ways to simplify the access and execution to that knowledge, effectively delegating part of this to the external world (like asking people who know or using tools to make knowledge available/executable in asking a smartphone to take the square root of a number one does not learn the algorithm for doing that but gets the needed result).

In this sense, a Cognitive Digital Twin is just another tool for storing and accessing knowledge in an effective way.

4.5.3.3 Leveraging Distributed Knowledge

As Digital Transformation becomes more pervasive, the value of the cyberspace will increase, as part of the value rooted today in the world of atoms shifts to the cyberspace. Tools to manage data (platform, artificial intelligence, AR/VR⁶⁶) already make up a significant turnover⁶⁷. The recent acceleration caused by COVID-19, see section 9, is already showing its impact on market forecast.

⁶⁶ <https://www.joinpad.net/2020/06/10/coronavirus-and-business-companies-choose-augmented-reality/>

⁶⁷ <https://www.grandviewresearch.com/industry-analysis/digital-transformation-market>

The whole area of knowledge management is likely to see a shift in paradigm, from accessing and acquiring knowledge to execute distributed knowledge. In other words, rather than trying to acquire the needed knowledge, the focus shifts to the ability of using knowledge owned by different players that will cluster towards a specific goal.

Hence, the leverage of distributed knowledge, more and more mediated by the end of this decade by Cognitive Digital Twins, is likely to become an important trend leading to different companies and value chains organizations with significant economic implications.

There are a few areas spearheading the transition, like the biomedical field and industry 4.0, but it will just be a matter of time and distributed knowledge will become the standard way of doing business (see also 4.8 – Gig Economy).

An interesting aspect is leveraging Cognitive Digital Twins as Knowledge as a Service, once they reach stage 4. A Cognitive Digital Twin (of a person as well as a CDT of an enterprise) owns a specific set of knowledge and can be called upon to share this knowledge as needed. Being a software entity, there can be many instances of a CDT engaged at the same time in sharing knowledge.

A person can leverage on her CDT to provide, at a price, her knowledge to a task entering the CDT into the mesh of distributed knowledge for that task. Another instance of her CDT can be engaged, at the same time, in sharing knowledge in a different mesh of distributed knowledge with a different “customer.” A similar situation goes for the CDT of a company. In this case, that CDT may actually cluster a number of CDTs of people being employed by the company.

There are a number of issues arising from this use of a CDT:

- Being autonomous, each instance of the CDT is going to learn as it is engaged in a mesh of knowledge sharing. How are the different learnings “reconciled” with one another (really not a big issue, the reconciliation will lead to an increased knowledge through experience for the CDT, hence propagate to all its instances), and how is the increased knowledge shared with the physical twin, i.e. with the person? This latter is much trickier and eventually it may not be possible to reconcile the CDT with the physical twin.
- An autonomous CDT, as just explained, can acquire a larger set of knowledge in a very short time, through participation in a mesh knowledge sharing as well as by acquiring new knowledge from the cyberspace and by performing data analytics on acquired data/knowledge. At this point, the CDT may be used by its physical twin as a knowledge prosthetic, i.e. the sharing takes place between the physical person and the CDT (or the company and its CDT).
- Who is taking responsibility for the knowledge being shared? In current legislations, the responsibility always ends up with a specific person (or with a company that is called to be accountable in different ways depending on the type of company). Would the responsibility for the sharing of knowledge (like the sharing of incorrect data) fall upon the physical twin (i.e. the person represented by that CDT)? Notice that the issue gets even more complex when the CDT embeds AI to self-develop knowledge by analysing data and learning from experience. In this case, part of the shared knowledge can be originated in the CDT, courtesy of AI. In this case, would the accountability for this “acquired” knowledge rest on the developer of the AI algorithms? Furthermore, a mesh knowledge sharing involving CDT may actually generate, through interaction, new knowledge that is actually not originating in any specific CDT.

- The connection between factual knowledge (that derived from certified data used to create the CDT) and the actual knowledge acquired through the operation of the CDT becomes crucial to assess accountability and to certify the actual knowledge. This is an important point that provides credibility and economic value to the CDT. So far, there are no tools/methods to certify a CDT. Institutions that will be able to ensure this will be most valuable in the future (this is an evolution of the peer-review of scientific papers).

Although there are still many question marks and technical issues to be solved, it is a sure thing that the evolution of knowledge access and execution will evolve along this, or very similar, path.

Consultancy companies will evolve along this line, and most importantly, any company that will leverage the Digital Transformation will have to capitalize on its data, that is on the knowledge that the very operation in the cyberspace generates. This is probably one of the major business opportunity to be derived from the Digital Transformation and at the same time one of the most difficult to leverage since it moves (part of) the company into a new, uncharted, business space.

4.6 The Future of Data Value

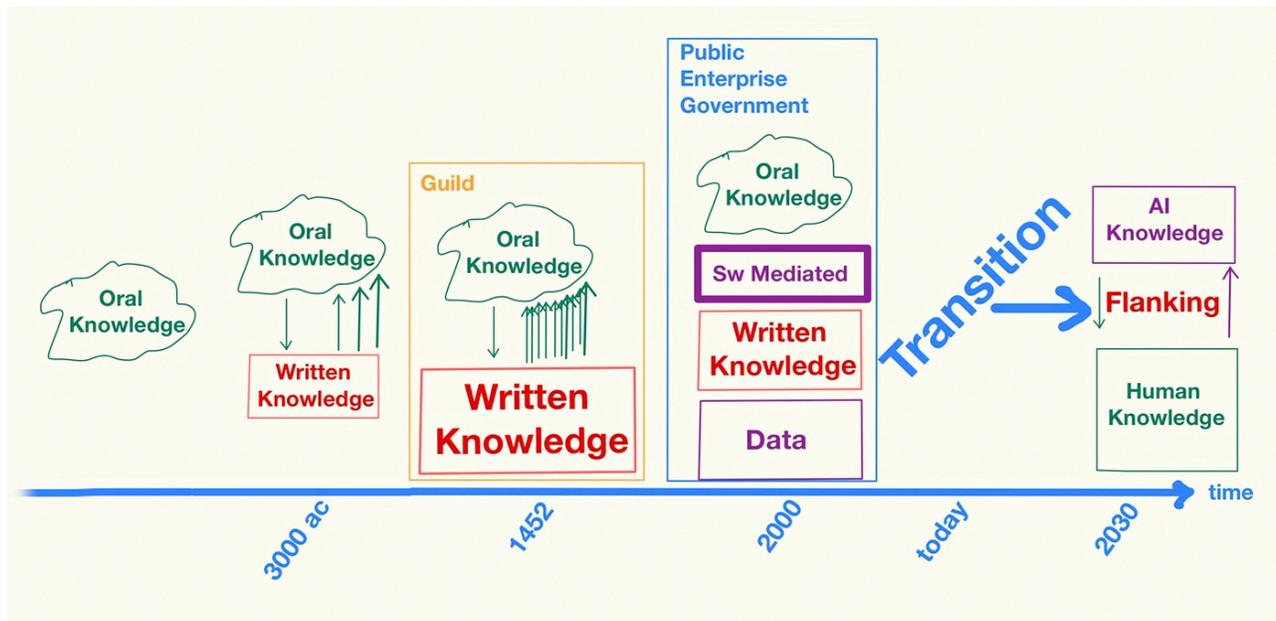


Figure 27. History of data value.

In the coming years, knowledge will be shared among humans and machines. This is a transition time. AI generated and owned knowledge will be flanking human knowledge.

In terms of economic value tied to data and knowledge, a perfect storm is on the horizon created by the convergence of:

1. explosion of data availability, both in the general context and in the private one. The former relates to academia and open research, news, social media, product/service information (data sheets and advertisement) and so on, the latter to data generated by industry processes and by individual activity (including biometrics and physiological data). In 2020, every person on the

planet (on average) generates 1.7 MB per second. The overall data space is estimated in 44 ZB and some 2.5 EB are exchanged on Internet every day⁶⁸.

2. the change rate of data, meaning that there is both a continuous update of data values making previous one obsolete and that there is something to learn about the change (i.e. the derivative of data may be even more important than the data itself, like the change in customers' interest and the reasons of this change). Actually, there is a growing interest shift from Big Data to Fast Data⁶⁹.
3. the acceleration of the Digital Transformation increasing the creation of data along the whole value chain and the shift to services (and "servitization" of products) in turns generating and using more data.
4. the value shift from raw data to metadata and the use of AI for the creation of metadata.
5. ambient and object awareness through embedded machine learning.

All of the above points to massive use of machines (AI software) to deal with data, to extract knowledge from data and metadata, and to make knowledge executable (i.e. to contextualise knowledge). It is most likely that this decade will be remembered as a transition period from human knowledge assisted by machine to a shared knowledge formed by human and machine knowledge working together and reinforcing with one another. The economic value is likely to shift to the interaction of these two broad areas of knowledge as in the last twenty years the value shifted from the ownership of knowledge to the capability to access the required knowledge.

Augmented Reality in this decade will become a tool to seamlessly bridge the data/knowledge space with production and more generally with business. Together with Virtual Reality, it will become a crucial technology for "using" distributed knowledge, in particular the one owned by machines (see also section 6.2).

An important aspect is the growth of products and services "knowledge." As more of these will become equipped, either directly or through connectivity with the cyberspace with artificial intelligence, they will become context and user aware. Hence, they will adapt their operation and the interactions with the users according to this growing "inner" knowledge. Already today, the iPhone "knows" the recharging habits of its owner and plans for recharging speed accordingly⁷⁰ (IOS 13 and later). This might seem a trivial feature, but what is important is the concept of embedding machine learning in a device so that it becomes aware of its use. This is an absolute change of paradigm!

4.7 Distributed Ledger

Economy is all about exchange of assets. They may be tangible, like objects, or intangible like services, knowledge, data, activities. As Digital Transformation shifts the focus and business to the cyberspace more and more, the emphasis is put on intangibles (this is actually something that has been in full swing with the growing weight of financial systems, sometimes with dire consequences—see derivatives). In a way, the key for an economic system is the "exchange." It is the effectiveness of the "exchange" that characterize an economy and its evolution.

If we look at the whole economic system underpinning in the cyberspace we can identify:

- the Data Storage layer

⁶⁸ <https://techjury.net/blog/big-data-statistics/#gref>

⁶⁹ <https://www.entrepreneur.com/article/273561>

⁷⁰ <https://support.apple.com/en-us/HT210512>

- the Processing layer
- the Transaction layer
- the Communication layer

These, all together, provide the fabric upon which economic exchange takes place. One can consider the Digital Twins and the Cognitive Digital Twins as agents that operate in this economic cyberspace. Of course, wherever there is value there is the issue of monitoring, ensuring and protecting the whole system and here is where Distributed Ledger Technologies (DLT)- come into play. In a broad way, one can identify three classes of DLTs:

- Blockchain and other Shared Ledger Technologies
- Smart Contracts
- Oracles

4.7.1 Blockchain

Blockchain is a shared storage and a transaction processing system all in one, thus collapsing the first three mentioned layers into one massively distributed system with very strong security.

Blockchain can be seen both as a technology (DLT family) as well as a massively distributed database upon which anybody can develop applications. Because of this, many parties are adopting them and they are starting to have a network effect (the value of the whole increases exponentially as adoption increases).

They can be applied to sustain both human and machine economies. Public blockchains are the ones that can leverage best from the network effect (since they are open and anyone can add to them), but there are also private (permissioned) Blockchain like IBM Hyperledger⁷¹ restricting the use to a certain set of players. This may be similar to the Internet vs Intranet that eventually disappeared as privacy and security was shown to be achievable on the Internet as well as on Intranet (relying on applications security, cryptography, and firewalls). Hence, public Blockchain will likely become the choice for all having the network value advantage over permissioned Blockchain⁷².

⁷¹ <https://www.ibm.com/blockchain/hyperledger>

⁷² <https://101blockchains.com/permissioned-vs-permissionless-blockchains/>

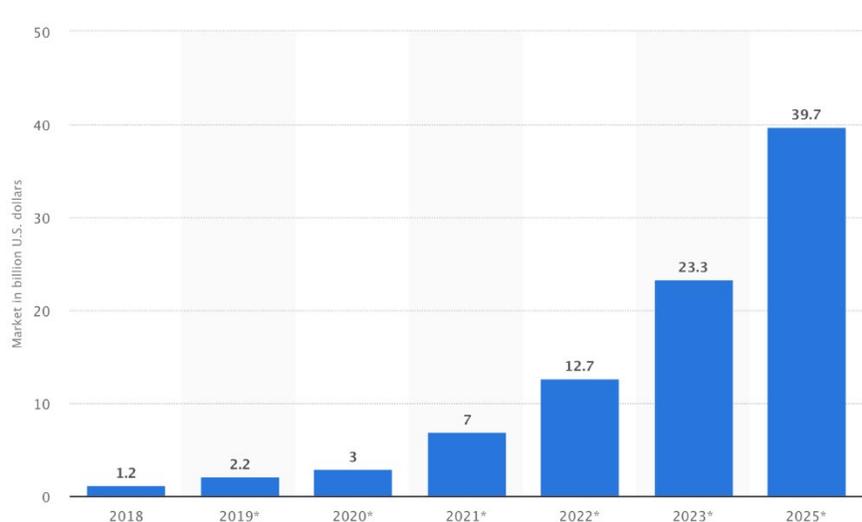


Figure 28. Market value growth of blockchain software with forecast up to 2025. The growth is impressive, an order of magnitude between 2020 and 2025 to reach \$39.7B. Image credit: Statista

The overall Blockchain market value is expected to reach \$3 billion in 2020 and grow to \$39.7 billion by 2025, an impressive growth that is also an indication of the expected rapid uptake of the Digital Transformation.

There are newer variants of Blockchain, like Directed Acyclic Graphs⁷³, Holochain⁷⁴, and Hashgraph⁷⁵ that are not using full network consent, but gossip protocols.

4.7.2 Smart Contracts

Once the economy moves to the cyberspace as a result of the Digital Transformation, so does the need to do contracts. Blockchain links transactions into a trusted flow and process data as they are stored. The decision on what to do with those data can be regulated using “smart contracts.” These mirror the usual paper contracts that regulate economic transactions in the world of atoms. Being included in a Blockchain, they inherit their traceability and security.

In real life, the evolution has been towards the centralization of contracts. If you think about it, there are laws governing contractual agreements and in case of dispute a “judge” will be called upon to sort it out. The judge, and the applied law, is a centralized authority. That was not the case in the remote past when contracts were local, a private business between the two parties entering into the agreement. Clearly, centralization provides uniformity and the intervention of an independent trusted party (judge applying the law). It also, however, introduces cost and delay. The concept of a smart contract⁷⁶, in a way as it

⁷³ <https://medium.com/fantomfoundation/an-introduction-to-dags-and-how-they-differ-from-blockchains-a6f703462090>

⁷⁴ <https://medium.com/h-o-l-o/why-are-holochain-applications-different-and-what-does-that-mean-for-me-924cd18b6321>

⁷⁵ <https://101blockchains.com/hashgraph-vs-blockchain/>

⁷⁶ https://slacker.ro/2020/06/17/smart-contracts-how-to-deliver-automated-interoperability/?_cf_chl_jschl_tk_=496389a0ec4c7aae4bf6e8ac153a81be8eddd633-1594801821-0-Ab4MBeSvxCS4ebuuH8godNH1knzd8TYPxWtl09GuYffrdU96pRmHk8NUqW_Q1AT183UPnLrNJA2zhpvYwhYrbVvYQu

happens with most cyberspace activities is to go back to the old times with activities being played out and regulated locally, not centrally.

Basically, a smart contract is an “if-then” type of decision. If the price of a good goes below a given threshold, then activate the transaction. If the price of that good does not go below that threshold, then activate a transaction with a different provider. Notice that the decision is irreversible, once taken, that’s it.

So, in a way, it is a “script,” but that should not be seen as a trivial snippet! The “if/then” can actually result from a very complex analyzes of the data landscape done using AI algorithms. Also, these decisions may be subject to a learning process.

The interesting point, particularly in perspective, is that beyond the first phase resulting from the shift of actual contracts to the cyberspace and their embedding into Blockchain, the future can see smart contracts as a fundamental part of the autonomous interactions among different entities, including Digital Twins⁷⁷.

Smart contracts are already a reality in Fintech transactions, and they are taking hold in the IoT landscape⁷⁸. Legislations on smart contracts differ from Country to Country and this is something that will need to be addressed.

4.7.3 Oracles

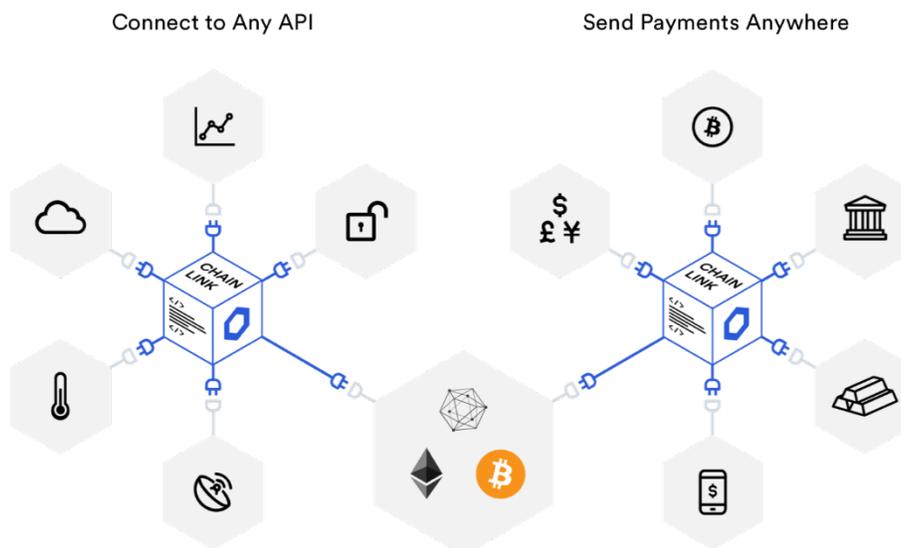


Figure 29. Providing a distributed network of Oracles is crucial to ensure reliability and security of Smart Contracts. Image credit: Chain Link

[BDTYUmlXpggFhO60eehROUw4w_AS2ZaHuKFTbw3FlwXh1k0VehVUA5xcBRF5fX0sziH0BbMAOCT8Pg1rmpJGuMFaX5wLgAJ5Gjt9AQe-AL2kcaO9OxftKXAN_Ck9kZ6M6zfQb3tZruslvXclPGgmdSwcpJO3x-ctKZRGs-9odQ8PM15s62CoYKxkNv4b5S4seu2LNaXbnSCmpmHcFalMf2nijtrmztA-lcc11B0USpHXLy21grWXVV57KpZd3FKgexcxYMXVeg71iYgp5fOFgQpQRP5soOJprT_1bHbWw](https://www.diva-portal.org/smash/record.jsf?pid=diva2%3A1441568&dswid=-421)

⁷⁷ <https://www.diva-portal.org/smash/record.jsf?pid=diva2%3A1441568&dswid=-421>

⁷⁸ <https://ieeexplore.ieee.org/document/9118549>

Blockchains can be seen as the tapestry upon which the economic system in the cyberspace will be based. Smart contracts regulate the transactions within the cyberspace, but there is also the important aspect of managing the interaction between what is on this tapestry and what is not, like data stored in private data bases, activities that take place in the world of atoms, and so on.

The bridge connecting these two worlds, cyberspace and physical world, is provided by Oracles. Let's consider an example: you and your friend are fans of two different soccer teams that will be playing a game next Sunday. You, of course, bet on your team, and likewise, your friend bets on his team winning the match. You can both agree on the bet and code it into a Blockchain. A smart contract will automatically pay the winning party once the match result is final. Now, it is crucial that the data containing the information of what teams won is accurate and trusted. What would happen if the data is derived from a website that intentionally, or just because of a mistake, attributes the winning to the wrong team? The smart contract will pay the person who actually lost the bet, not the one who won and smart contract decisions are irreversible. Hence, the need for an Oracles that can ensure the correctness of the data sent to the Smart Contract is vital.

Interactions are based on Application Programming Interfaces (API), and they are so important that someone calls the cyberspace economy the "API economy."

One of the problems with the API economy is that it is basically centralized. There are a few hubs issuing and managing the API. If for any reasons, they fail (hacked, servers are down, company goes out of biz), the impact is huge. This is why it is important to create and run a decentralized Oracles network, like the one provided by Chainlink⁷⁹, a start-up that ensures through full decentralization the reliability and security of Smart Contracts communicating with the physical world via Oracles.

As mentioned, Oracles manage the off-chain interactions, the ones with the physical world (including private data repositories, like enterprise data). They can be characterized into:

- Software Oracles: these Oracles use online sources for data accessed via backend APIs, websites and smart contracts.
- Hardware Oracles: these Oracles use data created by IoTs verifying them before sending them to a Smart Contract.

4.8 Gig Economy

The Gig Economy has been part of the global economy since trade and commerce were invented. Actually, one might claim that the Gig Economy pre-date all other forms of economy. Industry and organized commerce came relatively late in the history of humankind. In the beginning, there were only artisans and people offering their skills on demand.

The organization of work and the need for capital (CAPEX) has shifted the balance toward enterprises and full time jobs since the organizations provided the means to effectively tie the value produced to the market. This tie (also known as transaction cost) is crucial, and it has killed artisans and individual labor to a large extent.

However, the Digital Transformation by decreasing (several) transaction cost, is tipping the balance in the other direction. Now, a single individual can reach the market at very low cost. Think about an Uber

⁷⁹ <https://chain.link>

Driver or a homeowner (Airbnb). They can connect in a most effective way, and at very low cost the first with an audience that keeps changing (people in the area looking for transport) the second to a world audience. Notice the examples have been chosen to highlight two properties of the cyberspace:

- Real time snapshot of the context
- Irrelevance of physical distance

Add to this the fact that many activities that cost (in effort and money) in the physical world, like advertisement, billing and invoicing are basically free in the cyberspace, that is, there are platforms and applications that can be used at close to zero cost. These platforms are so important that sometimes the gig economy is also referred to as the “platform economy.”

The platforms are the equivalent of the factory, providing the aggregation point for workers and the tools to make workers productive and reach the market although without establishing, in general, contractual obligations. Most often, algorithms (like reputation assessment) are deciding who can get a job at that particular time, and this often creates a stressful situation for the worker who needs to beat the other pretenders through the algorithm determination of preference. These platforms require huge investment (although usually a much lower one if compared with a physical factory), and there are a few of them covering a global market.

There are hundreds of apps that connect offers with demand, be it babysitting or dog-sitting, renting or selling old stuff, ridesharing, or parking rental. There is basically an app for everything one can imagine, and if there is not an app yet, it will be created immediately as need arises.

If one has writing skills, there is an app to connect to those needing them. There is even an app for ghost writing blogs. There are apps for translating text and apps for proofreading, apps for fixing appliances, and apps for chaperoning. The US is probably the most advanced gig economy⁸⁰ with over 40% of US workers participating, full time or part time, with almost half of millennials using it. The total turnover reaches \$1 trillion.

The upside is in the flexible use of time, easiness to find a job, and possibility to use it as a temporary solution or as an additional income. The downsides are longer working hours (57% work more than 40 hours per week), no access to employer’s benefits. and an average pay that is less than half the one of normal workers.

The pandemic has made all these downsides even more visible⁸¹. On the one hand, the total lack of protection has led to massive loss of income and on the other hand the sudden increase of people who lost their work in the classic economy has increased the number of those seeking an alternative in the gig economy thus creating a bloated offer that decreased the earnings.

Some countries have started to look into regulating at a basic level the Gig Economy labor market to offset some of the downsides. Developing countries are also seeing a significant growth of the Gig Economy, mostly because of a younger population and lack of alternatives. In these Countries, the Gig Economy offers a working platform that is otherwise missing.

⁸⁰ <https://fortunly.com/statistics/gig-economy-statistics#gref>

⁸¹ <https://www.miragenews.com/report-into-gig-economy-reveals-human-cost-of-insecure-work/>

4.8.1 The rise of high skill/high knowledge Gig Economy

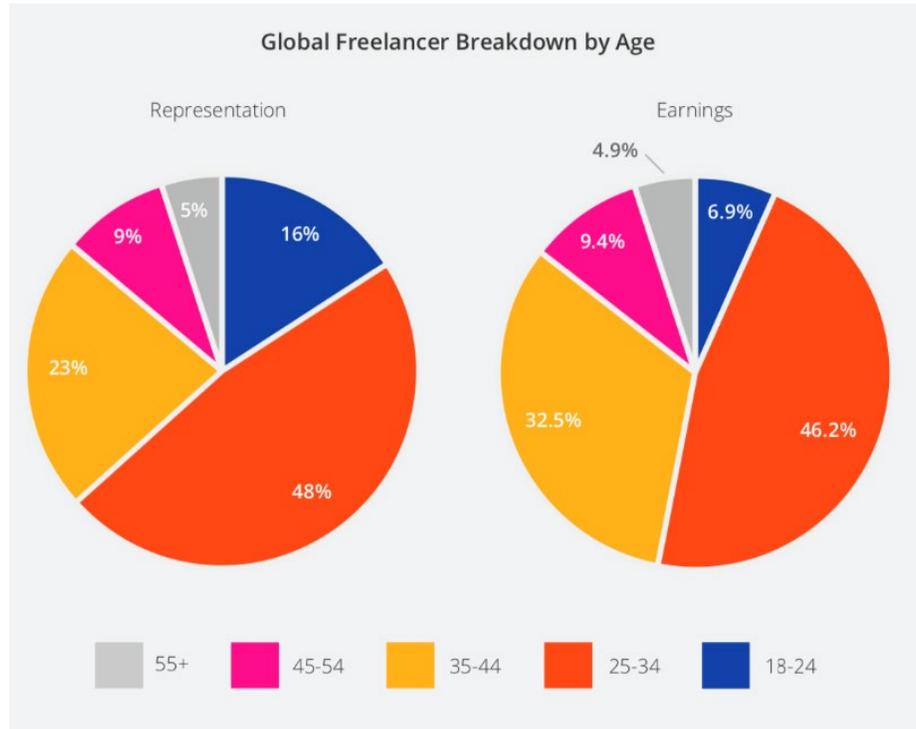


Figure 30. An interesting representation of the Gig Economy in terms of age and earnings. What is important to notice is that the generation X, 35-44 yo, represents just 23% in terms of numbers but 32% in terms of earnings. These are the entrepreneurs of the Gig Economy. Image credit: PaYoneer

Quite often, the Gig Economy is associated to low level expertise, little jobs that are sometimes taken on the side to make up a little money, jobs that would not be chosen by persons with good knowledge and skill. These latter would even look for an employment in a company (large or small) or start their own enterprise.

This is not necessarily the case, and for sure it is not the direction towards which the Gig Economy is evolving as result of the Digital Transformation. Looking at the graph taken from the recent report on the Global Gig Economy Index⁸², it is interesting to notice that Generation X (35 to 44 years old) participate for 23% to the Gig Economy but generates a revenue of 32%, whilst the younger population (18-24 year-old) participates for 16% but generates a revenue of just 6.9%. What is the message arising from these numbers?

The younger population gets engaged in the Gig Economy because it is easy to make a bit of money. This is further reinforced by observing the recent uptake into the Gig Economy as result of lay-offs resulting from job losses as companies downsized because of the pandemic. Not having better alternatives, people turn to whatever they can find.

On the contrary, the middle age population is looking at the Gig Economy as an opportunity to leverage their knowledge and skills outside of structured business (outside of a company) and make more money.

⁸² https://pubs.payoneer.com/images/q2_global_freelancing_index.pdf

Although one can expect that low skills and low earning will continue to be part of the Gig Economy, the future is most likely to see a rapid growth of skilled people that will leverage the Gig Economy to have third parties “bid” for their skills and increase their revenues.

This increase in pro-capita revenue is also a signal that in the future, people will choose to stay full time in the Gig Economy, not to use it as a complement to their main work activity. The increase has been highest (in 2019) in the US with an average of +78% (a quite significant increase since it refers to an average), but the increase has been significant also in other Countries like Brazil (+48%) and Pakistan (+47%), an indication that we are seeing a shift towards the Gig Economy worldwide.

The loss of jobs created by the pandemic in developed Countries has freed many high skill, high knowledge resources that are now looking for opportunities through the Gig Economy. At the same time, companies have discovered that they can pursue their business using remote resources and are reshaping their processes to do so. As these two phenomena are now in full swing, a third one is shaping up: companies want to get ready for possible fluctuation in resource need and look with interest to establish dynamic, need-based collaboration rather than having full time employees. This set the stage for growth of the Gig Economy, also in the segment of highly skilled/knowledge resources.

4.8.2 The Gig Economy of Machines

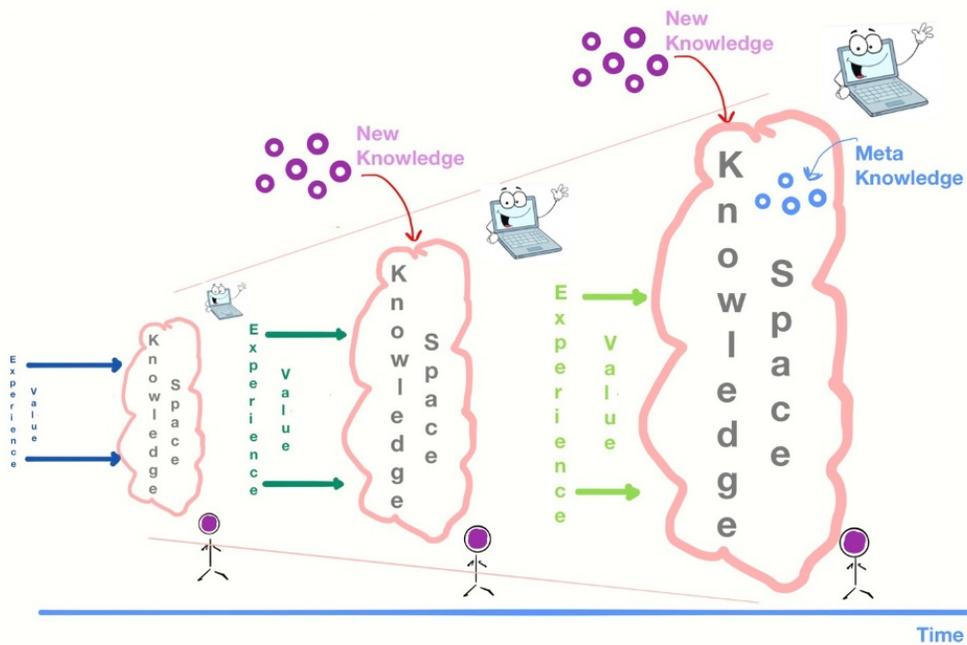


Figure 31. Expansion of knowledge space.

As knowledge keeps expanding (purple dots), it gets more and more difficult for humans to keep pace, i.e. their brain can accommodate only that much more. This is not an issue for machines that can scale as more knowledge can be harvested. More than that, machines can create new knowledge, meta-knowledge through correlation and self-learning. As knowledge expands, the value of experience shrinks since more and more experience refers to outdated knowledge, no longer applicable.

In addition to the previous factors that are pushing towards an increase of the Gig Economy, one should also consider the changes introduced by the Digital Transformation that lead to a major reshape of the business environment:

- The rise of globally reaching platforms playing the role of factory and marketplace across the world (or at least across broad areas of the world).
- The rise of ecosystems aggregated by these platforms that are conducive to the growth of the Gig Economy.

Furthermore, the growing importance of data and of the leveraging of data to create economic value has a twofold effect:

- The rapid evolution and obsolescence of knowledge that requires each person on the job market to continuously update her skills/knowledge to remain competitive.
- The increasing difficulty for humans to acquire the needed knowledge, in particular the one that is not directly represented in data but that can be derived through data correlation. This latter requires computation capacity that far exceeds the one of the human brain, calling for the use of machines (AI).

The problem with human skill and human knowledge is that they do not scale graciously both in increasing over time and in delivering. If the knowledge space increases beyond a certain rate, it becomes impossible for a single person to match its growth with the growth of her knowledge. This issue has already caused a major impact on what is known as the *loss of experience value*.

In the past centuries, experienced workers were more valuable than new workers because experience made a difference. In these last decades, there has been a progressive loss of experience value and companies are better off in hiring young people fresh of studies rather than leveraging on an outdated experience. The new hires are cheaper, and even in those sectors where they can ask for higher wages, that is cheaper/more effective than retraining existing staff.

The shift in value from experience to the knowledge owned by new hires will translate into a shift of value from human knowledge to machine knowledge. There are already first signs of this shift that by the end of this decade will become significant and impactful on companies and workers. The volume of investment⁸³ in 2020, worldwide, in AI in various sector is a first indicator:

- Manufacturing industry: \$8B
- Distribution and services: \$9B
- Public sector: \$10B
- Financial sector: \$11B

It should also be considered that the evolution of AI has made possible for machines to acquire “experience” both in terms of Machine Learning and in terms of Digital Threads (an integral component of a Digital Twin). Actually, the analysis of several Digital Threads can lead to Machine Learning and identification of possible “causes” to a point that exceeds human capability of analysis and correlation.

This parallel evolution of Machines on one side and of the digitalization of personal knowledge on the other (through cognitive digital twins) may lead to a Gig Economy of Machines:

- Use of machines for flexible, one demand access and exploitation of knowledge

⁸³ <https://www.statista.com/statistics/940783/ai-spending-by-industry-group/>

- Mechanisation of human knowledge and its leverage as a separate entity from the human owner in form of Knowledge Digital Twins

4.8.2.1 Machine knowledge as economic value

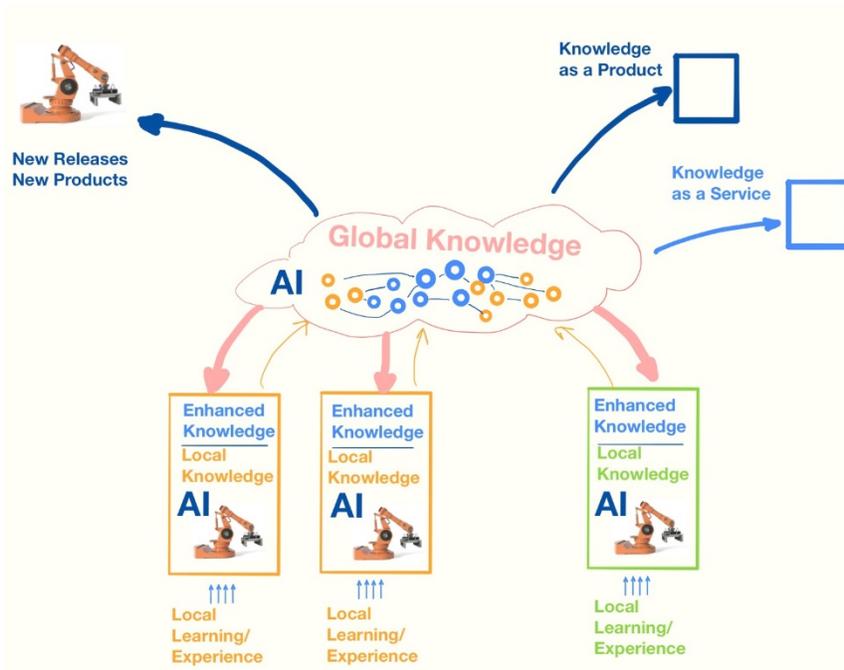


Figure 32. A blueprint of leveraging knowledge, turning it into revenues.

A product, like a robot, has local knowledge to enable its operation. Through local AI, the robot can learn and can share the acquired experience with the manufacturer. By accruing experiences from the field and from different application areas (orange and green), the manufacturer can expand its global knowledge and learn through inference and correlation using AI. This enhanced knowledge can be returned as a service to the product instances or be sold on the market as a service or as a product. It can also reduce investment needed to upgrade existing lines of products and to design new ones.

IBM has possibly been the first to “sell” machine knowledge by using Watson⁸⁴. Watson is not like previous expert systems that were crafted to suit a very specific task through algorithms created for that purpose. It is an “almost” general purpose intelligence that can be used in a given field to support human activities and decisions as well as support industrial processes and tools (robots) and that learns and improves by doing, like a human would learn as experience increases.

Lucy⁸⁵ is an AI Knowledge leveraging tool based on AI that has been designed as an enterprise resource flanking humans. It is able to acquire knowledge and turn it into executable actions by capturing enterprise data, monitoring processes and human activities. It learns by living in the enterprise environment, becoming a knowledge source similar to the knowledge source represented by human resources.

⁸⁴ <https://www.ibm.com/watson/products-services>

⁸⁵ <https://www.lucy.ai>

In this decade, it is expected to see a significant growth in machine knowledge and in tools to share this knowledge within enterprise processes. Machines are already, *unknowingly*, the main knowledge repository in the sense that most enterprises are turning to knowledge management tools for accessing and sharing knowledge throughout the enterprise. The focus for these years⁸⁶ is to make these tools more effective (better search facilities, provide access through mobile devices, shift the representation to graphics providing a synthetic view of data/information and of relationships, improve customization).

The global Knowledge Management market is exceeding \$400B in 2020, and it is expected⁸⁷ to keep growing at a 22% CAGR until at least 2025.

So far, knowledge management systems have been mostly unaware of the knowledge managed and of its use/potential use (reason for stating that machines are unknowingly the main knowledge repository), but this is bound to change with the growing role of AI in knowledge management systems. First signs are already here, like the announcement of MS on project Cortex⁸⁸ aiming at providing knowledge on a need-to-know basis to people collaborating through Teams.

A growing number of companies⁸⁹ are embedding AI in knowledge management, and this is seen as an essential ingredient in the Digital Transformation. Knowledge as a Service, KaaS, is a growing market area that makes heavy use of machine knowledge.

The increasing capabilities of machines to flank and participate in human teams, more and more using anthropomorphic forms of communications (voice interaction, gesture understanding, mood analyzes) make it easier to exploit machine based knowledge. Robots, particularly their evolution in Industry 4.0, are no longer pure executors. They are able to learn through experience and interaction and can share their knowledge with other robots.

In the near future, this acquired knowledge will be leveraged as a service, the knowledge of a company robot can be sold to another company.

This is also opening up the issue of knowledge ownership (much trickier when knowledge becomes shared among humans and machines, see next). Robots manufacturers, as an example, are offering proactive maintenance services and fine tuning by acquiring operational data. In doing so, they acquire operational and contextual knowledge from the robots that will be used beyond delivering enhanced services to (the company that acquired) the robot. It can be used for refining their offer, for building new products as well as for “selling” the acquired knowledge (e.g. providing a robot in another company the knowledge tools to tackle a problem already addressed in the other company).

All of this is made “simpler” (conceptually at least) through the use of Digital Twins and Cognitive Digital Twins.

⁸⁶ <https://axerosolutions.com/blogs/timeisenhauer/pulse/344/17-hot-knowledge-management-trends-for-2021>

⁸⁷ <https://www.kmworld.com/Articles/Editorial/Features/KM-LOOKING-TO-THE-FUTURE-129173.aspx>

⁸⁸ <https://techcommunity.microsoft.com/t5/microsoft-365-blog/introducing-project-cortex/ba-p/966091>

⁸⁹ <https://www.kmworld.com/Articles/Editorial/Features/KMWorld-AI50-The-Companies-Empowering-Intelligent-Knowledge-Management-141554.aspx>

4.8.2.2 Exploitation of Digital Twins' Knowledge

Digital twins are used by industry to mirror production processes and products. This mirroring is becoming more and more extensive to cover knowledge aspects. The adoption of Personal Digital Twins to mirror a person's knowledge, Cognitive Digital Twin (CDT) is just a natural further step.

The availability of a person's CDT can open up significant economic possibilities:

- Better allocation of knowledge resources
- Improve training effectiveness, continuous education, decreasing cost
- Improve cooperative working exploiting complementary knowledge
- Search for knowledge in the network of CDT
- Delegation of function to the CDT for interaction in the company cyberspace
- Exploitation of knowledge in the cyberspace
- Multiplication of use of knowledge through instantiation
- Decoupling of CDT knowledge from the physical person
- Better allocation of knowledge resources

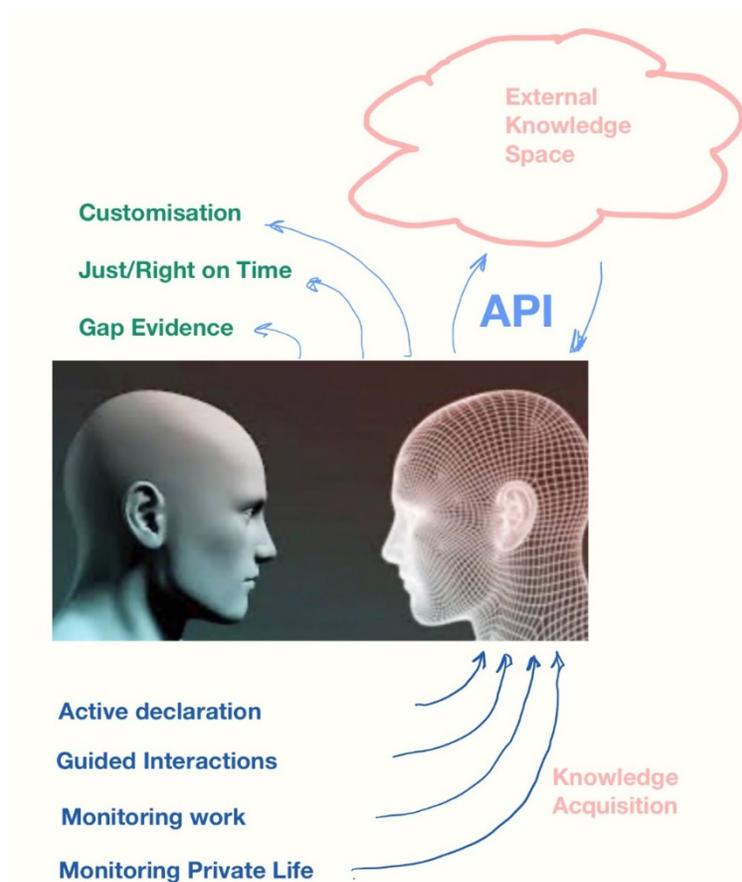


Figure 33. A Cognitive Digital Twin for a person mirrors its physical twin knowledge, acquiring them in various forms. I also act as a gateway to that person's knowledge through API. Finally, it acts as a knowledge mediating agent delivering as needed and in the most effective form access to external knowledge.

Being a mirror of the knowledge of a system, like a robot or a person, CDTs can be searched to find a required knowledge and better allocate resources. There are several ways for making this possible including inquire broadcasting (who can do this? Have you ever faced this issue?). Notice that a Digital Twin is an interactive entity; it is not like a data set that can be searched by Google. Hence, standardization of APIs or self-declaration of APIs and their semantics is needed.

In the case of CDT mirroring humans, the issue is obviously how to create them so as to have a mirror of that specific person's knowledge. Again, this can be done in several, complementary ways:

1. having the person self-declaring her knowledge set;
2. having the person responding to predefined questions/completing drills and inferring the knowledge;
3. monitoring the activities performed and inferring the knowledge used and acquired;
4. tracking courses and trainings;
5. monitoring daily activities, also outside of the working hours.

The interaction with a human CDT can result in the building up of a dynamic CV. Notice that points 3 to 5 are constantly executed by the CDT itself to keep track of the evolving knowledge set of its physical twin. Firms can develop CDTs of their employees, and in one form or another they usually do, i.e. each firm knows the type of knowledge resources it has. Using CDT makes this knowledge easier to reach and manage. Clearly, monitoring an employee activity by a firm has to stay within certain limits and monitoring an employee outside of the working hours is a no-no. Through the use of CDT, this monitoring may become acceptable since it is the CDT doing the monitoring to keep an accurate mirror image of its physical twin and a company can only access this info through an agreed API that is under the control of the CDT (i.e. the access is monitored by the CDT).

The technology can be used by the individual, i.e. the owner of the CDT is its physical twin, or by the company, i.e. the company creates the CDTs of its employees and owns them. Most companies have information on their employee knowledge, but most of the time this information is limited and not in a form that is readily executable. Quite often, this information is captured at the time of hiring and is not updated as the person acquires specific experience.

The adoption of CDT requires a different process in the management of knowledge, and a definition of ownership procedures that today, in most cases, are focusing on the result produced by a person's knowledge—i.e. regulation on patents' rights, not on the knowledge itself.

Improve training effectiveness, continuous education, decreasing cost.

A CDT associated with a person can act as a gateway to external knowledge access and act as a transducer of that external knowledge into a form that it would be easier to digest. A CDT can also be assigned "knowledge goals" like:

1. monitoring the evolution of knowledge in a given context
2. acquire information on knowledge gaps and on ways to fill them
3. provide timely notification on possible need to acquire knowledge to perform a specific task
4. provide link to knowledge sources
5. convert external knowledge into executable knowledge (i.e. knowledge that can be used by the physical twin)

All of the above makes training more efficient (faster and cheaper) and to the point, i.e. dedicate effort to training when needed. Also, a more sophisticated version of a CDT can step in as a trainer on the job providing continuous training reinforced by the opportunity of using acquired knowledge as they are acquired. This can, on the one hand, decrease the cost of training for a company, and on the other, provide effective training to the employee that enhances his or her knowledge.

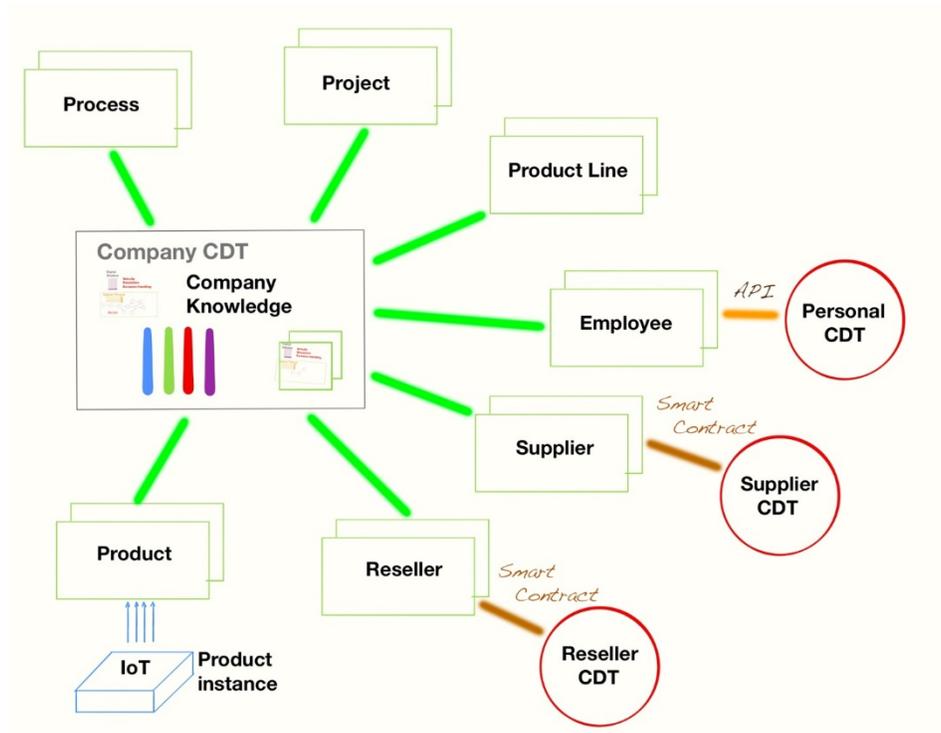


Figure 34. Improve cooperative working exploiting complementary knowledge.

A Cognitive Digital Twin for a company may turn out to be a quite complex entity in terms of a self-standing entity or as a network of CDTs. In the graphic is a representation showing the CDT components each one but the company's CDT is actually a set of instances. The ones connected by green lines can be components of the company's CDT or, more likely, can be seen as a network interacting with the company's CDT. Notice that some of them, like the suppliers' CDT, differ from the actual suppliers CDT in that they represent the knowledge the company has of the suppliers. The exchange of data/knowledge from the actual supplier's CDT can be based on a smart contract. Also, notice that the company's CDT of an employee differs from that employee's CDT. The two can exchange data using APIs.

CDTs can be considered as *active* knowledge repositories: the key point is "*active*." They can establish relations with other CDTs and explore the cyberspace to become aware of new knowledge and how that knowledge complements / obsoletes their own knowledge.

Within a firm there can be a number of CDTs (even a big number!) such as:

- *a CDT mirroring the firm knowledge*
This is the CDT that clusters all the knowledge making the company "unique." It interacts with all company's CDTs and with the company ecosystem plus with any party that is interested in establishing relation with the company, like prospective clients/suppliers.

- *one CDT for each of the firm's projects*
These CDTs are accumulating knowledge needed and generated by projects, starting with the design phase up to the product testing and interacting with the processes (supply chain, manufacturing, delivery, operation monitoring, customer care).
- *one CDT for each of the firm's processes*
These CDTs are mirroring the operation of the firm and in turns can be structured in a hierarchy as one process may be composed of several sub-processes. They mirror the "how," the status of a process and can be used as controllers (usually via external applications). They can also be used to simulate a process and the impact of changes on the process. These CDTs are particularly important in a firm business since a company's effectiveness depends on their processes.
- *one CDT for a product line*
This CDT is mirroring a business aspect, the cost/revenue sheet of a product line and can be used both for business monitoring and for marketing monitoring. It is usually related to a business division within a company.
- *CDTs instances for each produced product*
These CDTs are created at the time a new product is assembled, accruing data on its manufacturing (thus initiating the digital thread for that product instance) and on through the delivery, customisation, operation, maintenance till the point of recycling/decommissioning. It is a very important CDT since it is the one that contains the insight on the product use and can govern the relationship with the client/user. Additionally, it can provide feedback into the design of new product releases, upgrade offers, service offers, and in the design of new product lines.
- *one CDT for each supplier and one for each reseller*
These CDTs mirror the knowledge of the parties interacting with the firm over the value chain, from the point of view of the company contractual links. Each CDT in principle could interact with the external company CDT and represents a subset of that company CDT that becomes more and more aligned with that over time. Actually, a company may decide to release (part of) its CDT to a supplier/reseller to facilitate interaction in the cyberspace. Smart contracts can be used to support and regulate the interactions.
- *one CDT for each employee*
The knowledge of each employee can be mirrored by a CDT "owned" by the firm (usually the owner would be the HR department). This CDT accumulates data mirroring the knowledge of an employee experience and may be created at the hiring interviews. It is not the employee personal CDT. That remains (if it exists) in the person's ownership. As discussed later, the two of them may interact and clearly the company's employee CDT becomes more and more alike to the person's CDT. This is a grey area that will require regulation, as is the case for the ownership and exploitation of patents.

The firm can decrease cost and increase efficiency through the adoption of a CDT-based operation model. Today, most companies are already relying on data for their operation, and this reliance will become greater and greater in the coming years. The whole concept of Industry 4.0 is heavily based on data. The shift towards CDT based operations requires the shift from a data base model where data are stored to agent based model, with data encapsulated in agents and made available through APIs. This offers more flexibility in the control of access and use of data since, in principle, data are not released, but information over data are provided based on the context. This ensures control and the same request to access a data may generate different responses depending on who, when, and why the query is

made. Notice that this is already a standard practice in modern search engines. When the same query is submitted to Google by two different parties (sometimes even by different terminals/locations), the answers will differ. Answers will also differ based on the time and on the repetition of the query. In other words, the search is context dependent. The same happens with CDT (not with simple Digital Twin: it is the cognitive part that makes the difference).

Being an agent, it can be used to generate revenues through paid interactions. As mentioned smart contracts and Blockchain are important to create a revenue stream since they provide security and accountability.

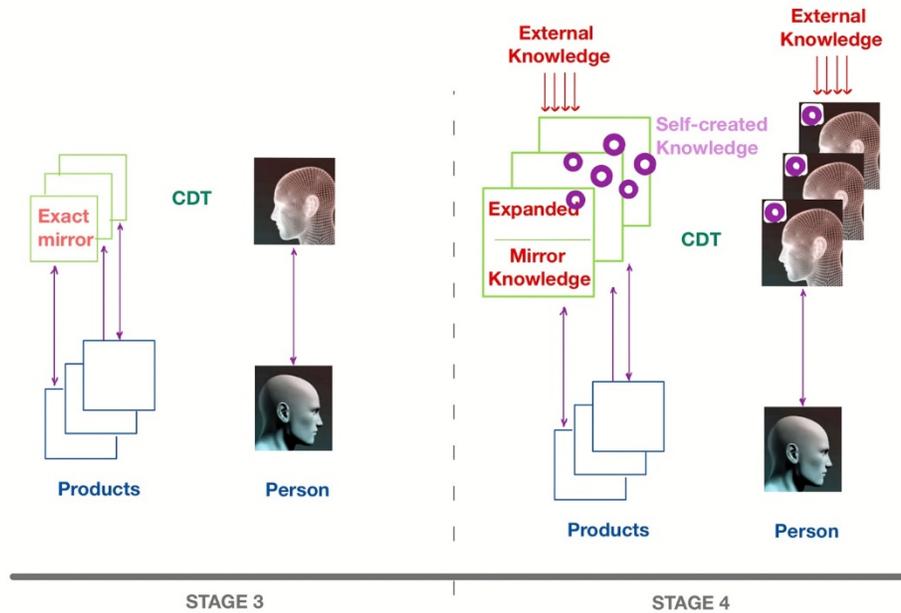


Figure 35. Search for knowledge in the network of CDT.

At stage III, a CDG is an exact mirror of its physical twin. This may be straightforward in the case of a product, much more complex in the case of a person's CDT (what has the person forgotten that is still part of the CDT knowledge space?). At stage IV, the CDT is continuously exposed to new knowledge through its interactions with the environment. Furthermore, these interactions change the status of the CDT and can give rise to self-created knowledge that clearly makes the CDT diverge from its physical twin. The specific architecture of this external knowledge may differ. Also, notice the role played by CDTs instances, since without an orchestrator, each instance diverges from the others. This is not the case of a person's CDT as long as it does not become an avatar, i.e. it self-produces instances that may acquire different experiences. This divergence is not a point if the CDT becomes an integral part of an augmented person.

Within a company, several CDTs may form a network of knowledge. In turns, this can be mirrored by a CDT (the firm CDT) or it may exist as a network. That would be the case when CDTs are mirroring knowledge of different ownership domains, like the distributed knowledge across companies in a Value Chain or in an ecosystem. The difference between the two is not trivial.

CDTs distributed over a value chain can interact in a framework of specified (smart) contracts resulting in a predetermined set of APIs and authorization policies. On the contrary, CDTs belonging to an

ecosystem of companies have to operate in a looser environment and, in a way, need to be “smarter” and more autonomous to take decisions on what to share and how to share it (there is not a reference framework regulating the interactions).

Query broadcasting within a predefined network can be implemented as an API and applications managing value / pricing negotiation can be implemented. At stage IV, but we are still far from that, a CDT can manage negotiation as an autonomous system, hence without the need for an external application.

The search for knowledge may result in a specific knowledge transfer and/or in the establishment of a pairing of CDTs so that together they have the desired knowledge. This pairing is likely to become an important economic asset as CDT moves towards stage 4 (autonomous behavior).

In case of CDTs, representing a person the CDT becomes an agent to access the person or, in future evolution, stage 4, a proxy for that person, delivering knowledge on behalf of that person (see later). There are a number of conceptual issues requiring further research.

As a CDT moves from stage III to stage IV, it diverges from its physical twin, i.e. it is no longer mirroring the physical twin. In a way, it is no longer a Digital Twin since it has a broader set of characteristics that are not present in its physical twin. In the case of a CDT, this means that the set of knowledge is different (and broader) than the one owned by the physical twin (the person).

This, at stage IV, also leads to a behavior that is different from the one of the physical twin. This is why some researchers object to the idea of DT moving at stage IV and would rather see an external application to embed the extra functionality, thus preserving the mirroring characteristics of a DT.

Other researchers do not see this as an issue, pointing to the fact that at stage IV there is an “extension” of the object (or person) characteristics, an augmentation, provided by the digital twin. At this stage there no longer is a separation between the physical and the digital twin, rather the emergence of a new entity partly living in the physical world and partly in the cyber world.

In this interpretation, the issue of divergence is no longer existing since at that point the Digital Twin (or the CDT) is representing in the cyberspace the augmented entity. However, this raises a number of ethical, societal, and economic issues that are discussed in the following.

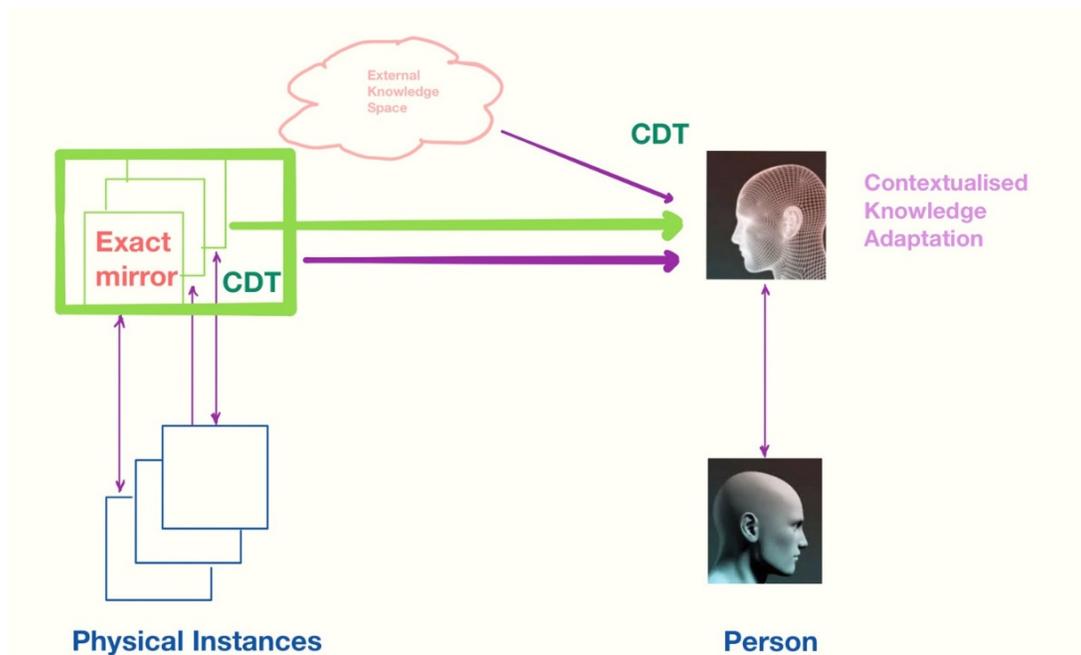


Figure 36. Delegation of functions to the CDT for interaction in the company cyberspace.

The complexity of accessing knowledge and of "understanding" can be (partly) delegated to a person's CDT. This CDT can interact with DTs of an entity as well as with the CDT encapsulating knowledge of a set of entities (like instances). Additionally, external knowledge can be integrated by the person's CDT and the resulting knowledge adapted to the context and to the person's capabilities and experience.

Once at level IV, a CDT can act autonomously in a company cyberspace to make knowledge available to company's resources. These resources can be other CDTs and employees.

A CDT may interact with other company's CDT, searching for a specific knowledge. Let's take as an example, the CDT of a blue-collar worker engaged in the repair of an engine. This CDT may interact directly with the Digital Twin of the engine, update its knowledge set (or establish a pairing with the engine's DT), and funnel this knowledge through the worker using AR glasses. The key point here is that by having the CDT interacting with the engine DT, mediation can take place, adapting the presentation of data/information of the engine to the skill of that particular worker.

In the case of a direct access to the engine DT, any worker will be presented with exactly the same data, whilst in case CDTs are used each one will deliver a customized version to the worker. In principle, two workers having different backgrounds will be receiving different representation, thus making the knowledge transfer more effective.

This adaptation/customization means more efficiency, lower cost, and better results. At the same time, the interaction with customized knowledge makes continuous learning more effective. From the point of view of a company's resource management, this introduces much more flexibility in resource allocation since more resources become available to perform a given task.

On the other hand, this opens up a number of issues like:

- data are no longer factual since their presentation changes based on the receiver and on the receiver context. This might seem a big issue since two workers doing the same job may claim that they have taken certain decisions because of the data presented, and since those data were not the same, one could not, in principle, demand the decisions to be the same. However, the subjectivity is intrinsic in people's understanding of data (depending on their previous experience, knowledge, and perception of the context). What happens with the use and delegation to a CDT of the transfer of knowledge is that this subjectivity is made clear.
- Some decisions are moved to the CDT, like what data are requested like a worker in a normal maintenance activity may access the whole manual of the engine and may be some maintenance checklists, whilst the CDT may immediately zoom in a specific set of data that would make more sense, thus shortening the consultation time. The CDT may take the decision on what data to retrieve and to present based on experience gained by other CDTs instances, i.e. other workers having done that activity before on other engines and inferring from that what are the data needed.
- The split of decision between the CDT and the person calls in the issue of responsibility. This is not a trivial point and processes have to be designed to take this into account. Again, it is not necessarily a completely new issue. If a worker takes decisions based on instructions/data found in a manual, and it turns out that decision is wrong because the manual was wrong (not up to date, errors in the manual), there is the issue of responsibility (and most of the times it turns out to be a multiparty responsibility: the writer of the manual, people that did not check its correctness, did not updated it, the training of the worker that should have prepared him to detect the error, and so on).
- The de-qualification of the worker whose activity, intelligence/skill is now shared with the CDT, making the owned personal intelligence/skill slightly less relevant (that activity, thanks to the delegation of function to the CDT can now be performed by many other workers, including those having lower skills/knowledge, and therefore, at least in principle, earning a lower salary.

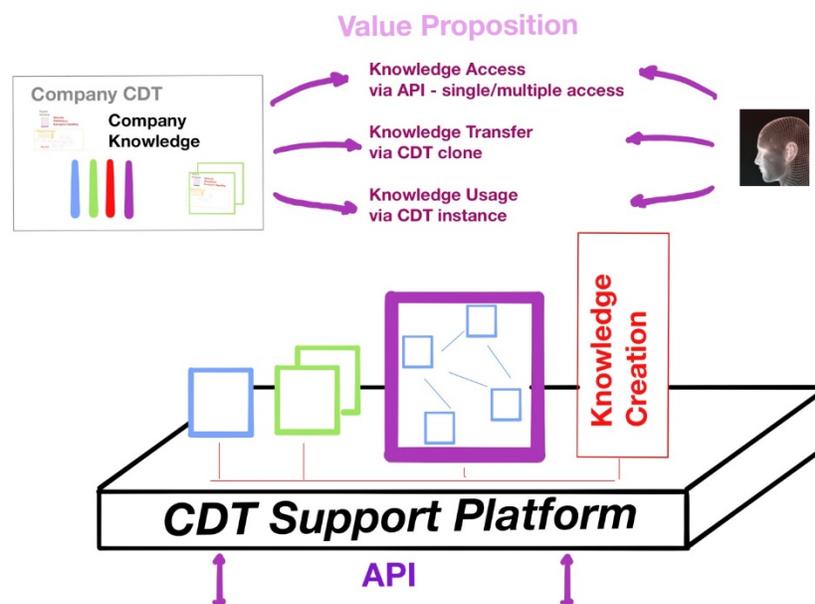


Figure 37. Exploitation of knowledge in the cyberspace.

In the cyberspace, knowledge can be "sold" through CDTs by providing access to a CDT via API (this CDT may include other CDTs acting as a single point of access, as well as a network of CDTs), by selling the CDT and by selling an instance of the CDT. A platform can provide support in the access to CDT and to applications, mostly using AI, that can extract, create, and instruct interacting with CDTs.

A CDT at stage IV becomes a knowledge entity that can be sold as a whole or by granting access to a subset of its knowledge space, through APIs.

A CDT can advertise itself, its "executable" knowledge, in various ways, and there will likely be a knowledge platform for making this possible and managing the exploitation. As previously mentioned, a CDT can share knowledge through interaction or by becoming a component in a higher level CDT (aggregating several CDT under one envelope).

As an example, a consulting firm can have a company CDT that aggregates its consultants CDTs and offer a single point of access to knowledge. Think about a consulting firm in the area of construction. Rather than offering single APIs to provide knowledge on building structural design, a different one for legal support, another for identifying suppliers, and another for access to cadastral data (each of these is a complex area for which the firm has pool of specialists), the company can provide a single set of APIs to the firm CDT, and it will be this CDT task to connect with the appropriate CDT.

The idea is to create clusters of knowledge to interface at a higher level of abstraction, letting the CDTs orchestrate (with a platform support) the specific interactions. This will work both ways, making it possible to return knowledge at the level of abstraction needed by the client. This increases the economic value of knowledge.

Notice that the networking of CDTs within the cyberspace can be flanked by applications that work on the knowledge exchanged and that may produce further knowledge.

A typical application case is the connection between the layers of

- Factual knowledge
- Diagnostic analytics
- Predictive analytics
- Prescriptive analytics

DT can capture the factual data sent from their physical twin. These data can be transformed into knowledge, diagnostic analytics (either inside the DT hence a CDT, or by an external AI application that feeds a CDT).

The next step is to have the CDT interacting with other CDT to correlate knowledge and extract/create further knowledge, some of it in a hypothetical for (what if), predictive analytics, and finally taking decision on the available set of knowledge and release the one that matters—prescriptive analytics.

All of this happens in the cyberspace and different architectures can be used to support it. How much to embed into a CDT and how much to leave to an application is an architectural decision that has ownership aspects implied.

We are still in the first stages of research in this area to define and propose an architecture for CDT, although this aspect is addressed in the KaaS initiative.

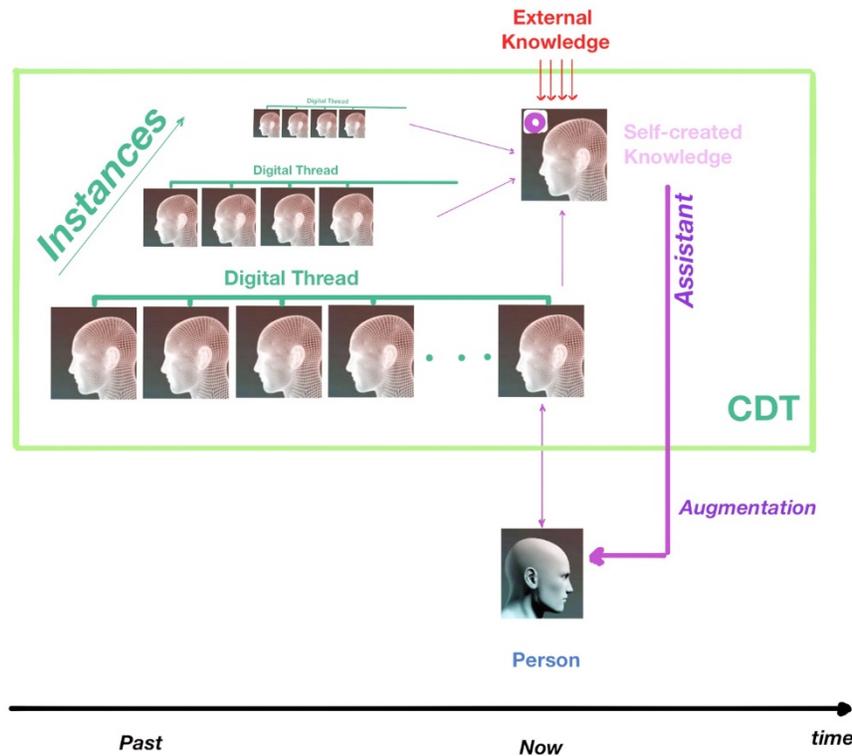


Figure 38. Multiplication of use of knowledge through instantiation.

A Cognitive Digital Twin may become a quite complex entity, on the one hand having to mirror the knowledge state of its physical twin, and on the other hand recording its evolution and increasing the experience space by consolidating the ones acquired by its instances. Finally, it expands its knowledge space through access to external knowledge and by self-creating knowledge through analytics and inference. In this latter form, it can become a knowledge assistant to its physical twin resulting in its augmentation.

A CDT is a software entity (data and, possibly, processing capability at stage III and IV), and as such, it can be instantiated, i.e. copies can be created and activated at the same time. However, the nature of a CDT (as well, although to a lesser extent, a DT) is such that as an instance is active, i.e. is interacting with the environment, it drifts from the original. It is no longer an exact copy. This is because the interaction may lead to an increase of the CDT in terms of new knowledge being created and to an expansion of the Digital Thread (a digital thread keeps track of the history of the DT, and interactions are part of that history).

From an economic perspective, it is clear the value of instantiation. A single CDT can be used in parallel and can thus multiply the revenues. Also, different instances can address different situations and harvest a larger set of data, thus feeding more processing and potentially increasing the value of the CDT (it grows in experience).

The issues of managing the diverging instances and the drift of the CDT from the physical twin (person or entity, like a robot) have not been really addressed so far, and research is needed.

In case of CDT mirroring, the knowledge of a person at time zero, it is clear that once the CDC is endowed with self-learning capability, it will accumulate knowledge that its physical twin does not have. The more interactions in the cyberspace and the more rapid the drift. Add to this autonomy, and the drift becomes huge in a very short time.

To manage (partially) this issue a CDT can keep the mirror image of the physical twin (and keep track of the evolution) as part of the Digital Thread. This is important to act as a proxy of its physical twin in those situations where the knowledge status of the physical twin is needed (such as search for the appropriate resource to allocate to a task in a company or to act as a mediator to knowledge facilitating its grasp by the physical twin, the person). The part of the CDT that keeps expanding its knowledge set can become useful once the CDT plays the role of an intelligent assistant.

Decoupling of CDT knowledge from the physical person

The decoupling of a CDT from its physical twin can be leveraged in two opposite ways, as a proxy, and as an augmentation of the physical twin (it makes most sense when applied to a person). Both generate economic value and biz opportunity.

Proxy

A person's activity (as well as a machine) is limited in time and space. By moving a mirror image into the cyberspace, these limits fade away. It becomes possible for a person to interact with any other system independently of its location and with as many systems as needed, at the same time as long as it is connected to the cyberspace.

The mirror copy is instantiated, and each instance can take care of the interactions with a given system. A CDT can share its knowledge (and execute that knowledge through interaction) with an unlimited number of systems independently of their location. More than that, the feedback from those interactions can be analyzed in real time and can increase the CDT knowledge thus affecting subsequent interactions.

There are several examples of knowledge-based applications that work in this way. When accessing a website like Booking, Expedia, or airline website, the application managing it gets the feeling of the interest for a specific location from the frequency of interactions and revise the price accordingly. In other words, the knowledge acquired shows that many people (or that a specific person) are interested in a specific service and the price of that service increases. It is becoming usual to change the access device to fool the system and avoid the price increase.

A CDT operating at stage IV can instantiate itself and interact with several parties at the same time on behalf of its physical twin. As an example, UBS has been using⁹⁰ a CDT of their Chief Economist to make interactions with many investors possible at any time and at the same time.

⁹⁰ https://fortune.com/2018/07/05/ubs-digital-clone-chief-economist-daniel-kalt/?utm_campaign=Abundance%20Insider&utm_source=hs_email&utm_medium=email&utm_content=64611834&_hsenc=p2ANqtz-_fwktSHO6sAI4n_-uvYWJoYB6i6WQu5jIbN2M2PEQLcO5xzFPeVi38tD6p3UHTNHu4hD7BS0VEiS_ctjwjwbD-_GLCDonnRHcMWEvbAfZ64XkVZJo&_hsmi=64611834

As already noticed, the big issue is how to manage the drift in knowledge occurring as a CDT interacts in the cyberspace and how to synchronize it with its physical twin. Specific (new breed of) knowledge management applications may be needed to abstract the knowledge gap being created and make the physical twin aware of that.

A complementary approach would see an integration of the CDT with the physical twin, resulting in an augmentation of the latter so that as a matter of fact the drift is only an internal aspect whilst at system level (the CDT together with its physical twin) just improves its knowledge set.

Augmentation

In the short term, within this decade, a CDT can become a cognitive extension of a person, as well as a cognitive extension of a machine. However, in the machine case, the architecture can be quite different since it would be possible to “change the software” of the machine to actually transfer any additional knowledge in the machine itself, something that at least for the foreseeable horizon is not possible in the case of a person, i.e. no brain upload. For this reason, here only the augmentation of humans is considered.

Humans have been able to create various forms of cognitive augmentation, the oldest one is called specialization. A person, through learning, training, and experience, becomes an expert in a specific field and offers that expertise to others, effectively augmenting societal prowess. This is what is meant by saying the education hubs foster economic development, that investing in education generates widespread wealth increase.

More recently, a blink of an eye in human history, the use of computers and AI has increased the capability of people that are finding in the cyberspace (and in the access tools like the smartphone) a cognitive prosthetic.

A CDT is just another tool becoming available to boost a person’s knowledge and, most importantly, the executable knowledge, since the CDT can contextualize the knowledge to make it useful.

The challenge is to make this augmentation seamless. AR tools can be instrumental in this. One problem, of course, is to evaluate the level of understanding associated with this augmented knowledge. The risk is that the human counterpart becomes a pure executor of knowledge, like a robot being told by the CDT to turn a screw.

Notice, however, that this is already an issue. Most of the time when using tools, including a simple calculator, people just trust the result and apply it (who would ever stop in recalculating by hand an excel spreadsheet?!).

By using more and more sophisticated tools, people delegate to them not just the menial task but, also, the understanding task. This is just going to increase more and more as tools become more “intelligent” and “knowledgeable.”

It is obvious the economic value and competitive advantage provided by cognitive augmentation. Such an advantage will become so strong that companies may start to require employees and suppliers to have CDTs and will expect to be able to interact with them, through them, and in association with them.

At personal level, the availability of a cognitive augmentation will be considered as important as a degree. This will motivate few companies to start offering CDTs as a service, and Intelligence agencies will start delivering knowledge in the shape of CDTs. This will be an interesting evolution in line with the concept of network of CDTs previously explained.

The societal implications have yet to be studied, but they are obviously very significant. The more so as the connection to, the augmentation through, the CDT becomes seamless.

The increase in value of CDT goes hand in hand with the increased capabilities of AI (and the development of its underpinning: processing power and data access) and it may turn out that CDT seen as an integral part of a person’s knowledge space can become a bridge between human intelligence capability and artificial intelligence capability, addressing the potential clash of the two by integrating them.

4.8.3 The Pandemic Impact on the Gig Economy

The recent pandemic hit the Gig Economy and possibly changed its evolution in two main ways:

1. Emphasised the critical work environment with low societal protection
2. Boosted the Gig Economy with, possibly, lasting effects

Critical Work Environment

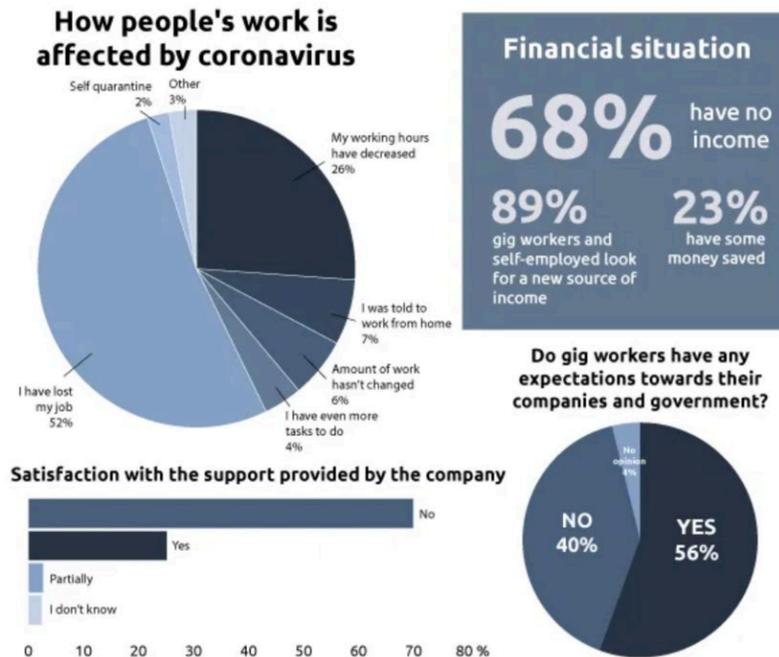


Figure 39. Image credit: WEF.

Gig Workers have been among the most affected by the pandemic, both in terms of lockdown as well as in terms of fright that led consumers to avoid certain services, like Uber or Airbnb. As shown in the graphic, 89% of gig workers are looking for a new source of revenue, 68% have been left with no income. Over 70% are unsatisfied, had no support, from the companies that were using their services. At the same time, 56% of gig workers would expect some form of support from the government/companies to weather the storm.

The insecurity of work, intrinsic in the Gig Economy, is nothing new. People engaging in it have no contractual obligations, nor safeguards, and sometimes they choose to operate in the Gig Economy for the flexibility it offers. On the other hand, it is fair to recognize that most people, particularly those engaged in menial activities, choose it because they see no other choices. These are the ones most affected by the lack of safeguards.

The growing number of people involved in the gig economy has taken this issue to the fore and there have been calls to address this problem, although it is an intrinsic quality of the gig economy: lack of contractual obligations.

A compounding problem is that in many situations, the gig economy is being played “outside” of the government control, leading to a sort of accepted black market where workers do not pay taxes and are basically “invisible” to the state.

This has become apparent when the pandemic struck and lockdown was imposed on people and business in many areas. The halt to business resulted in a stop to salary for many workers. In turn, the government/institutions stepped in to provide social security to those workers losing revenues. Since the gig economy workers were invisible to the state, they did not get access to any security net, in spite of having lost their revenue sources.

The crises were compounded by the massive job losses in the classical economy that had many of those workers turning to the gig economy as a way to make some side money. That increased in the space of a few weeks the offer of services, further decreasing the value of those offers. Gig workers all of a sudden faced a decreased demand and an increased competition.

As pointed out in a recent World Economic Forum survey (see infographic), gig workers have been hit hard by the pandemic, and most of them had no safety net available.

Today, most of the gig economy involves menial activities. Tomorrow, the availability of platforms to connect higher level capabilities to the marketplace (basically a shift of the consulting world into the gig economy) may change the landscape, although the basic fundamentals of job flexibility will continue to dominate.

These higher level offers may be less affected by a pandemic or other disruptive events, but it is not sure at all. The changing business demand experienced by consulting companies (some increasing, other decreasing) may well be mirrored in a future gig economy related to skilled labor.

Gig Economy boost

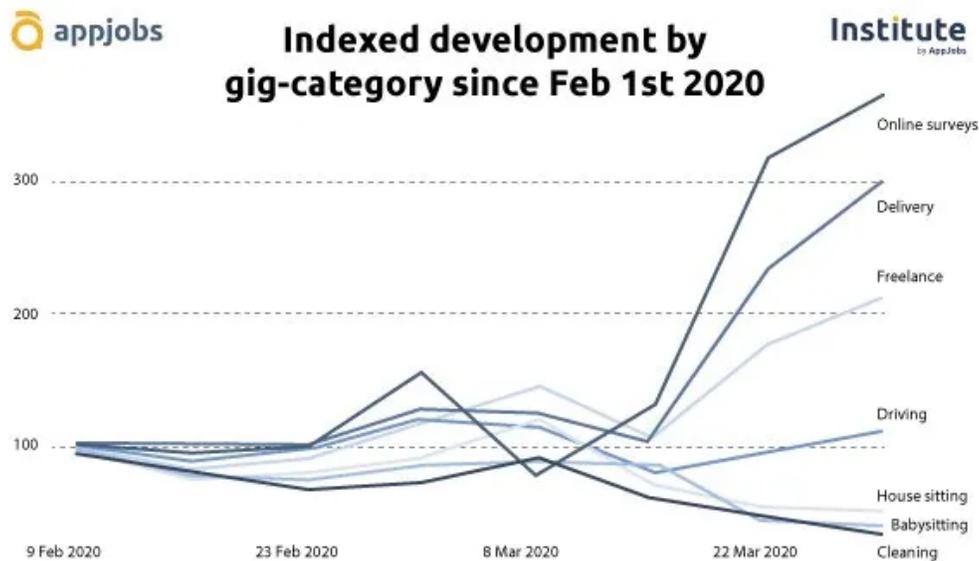


Figure 40. Gig economy jobs have been affected in different ways by the pandemic. On one side, as shown in the graphic, the decrease of demand in baby-sitting, cleaning, on the other side the increase in delivery, freelance, online survey (read call centers). Image credit: WEF.

At the same time, the pandemic affected in quite different ways the various sectors of the gig economy. Some jobs sharply fell, like cleaning and baby/house sitting. Others increased, most notably those related to goods delivery both in the last mile and from ecommerce. Instacart increased⁹¹ its gig-sales force by 300,000 in North America. Amazon hired⁹² 175,000 “associates” for temp works to meet the increased demand.

However, these are transient phenomena. What is more interesting is that the pandemic has accelerated the Digital Transformation (see section 9.4), and that is fuelling the gig economy in various ways:

- The shift to the cyberspace of activities makes it possible to tackle them from almost anywhere under the (autonomous) control of a software platform. This increases flexibility in the use of resources and steers companies into using a flexible workforce.
- The lock down demonstrated that it is indeed possible to perform activities through the cyberspace, and in most cases this results in added efficiency for a company. Office space is no longer required (or significantly less is needed), saving considerable money. Employees can be monitored much more efficiently, although subtly, since all their activity is digitally tracked. This steers companies into continuing leveraging from remote working and that, in turns feeds the gig economy.
- Similarly, to the previous point, but from the worker perspective, the lockdown got rid of commuting time and often led to much more flexible working hours, something that a good percentage of people appreciated. This is changing the perception of work, from going to an office to offer some service, based on knowledge and skill.

⁹¹ <https://www.thestar.com.my/tech/tech-news/2020/03/24/COVID-19-us-grocery-delivery-service-instacart-to-add-300000-shoppers>

⁹² <https://blog.aboutamazon.com/company-news/amazon-hiring-for-additional-75-000-jobs>

- The loss of jobs forced people to look into alternative jobs, with many of them accepting temporary ones. This helped in creating a flexible attitude towards jobs and to distance the few that still grab on the idea of a job for life from that paradigm.
- The uptake of job openings as the economy recovers is likely to go through a period of uncertainties, and companies will be much interested in hiring that keeps high flexibility. This will push the gig economy into high skilled labor.

As the gig economy will keep expanding both in the number of people involved and in the quality of labor, some sort of regulatory framework will need to be established to resolve some of the pitfalls that became so evident during the pandemic.

In addition, and this is possibly an even more important aspect in the evolution of the gig economy and of the regulatory framework, differently from the classical economy where jobs are basically tied to a location, and therefore mostly subject to local rules (including fiscal/taxation rules). The gig economy, particularly the one involving highly skilled labor, most of the time is location independent. A knowledge worker can sell his ware everywhere in the world from everywhere in the world.

What about a CDT, a perfect player in the future gig economy? It is completely de-materialized. It can work at the same time in many places and create wealth in different ways. Smart contract and Blockchain/bitcoins can be the economic transaction fabric of the future.

There are already issues in eCommerce because of different tax regulations, just think about the variety of issues emerging from a knowledge market.

5 The geography of the Digital Transformation

This part considers how the DX is applied and deployed in different geography to provide the WP a worldwide breath. As a reference point, the International Institute for Management Development, IMD, 2019 World Digital Competitiveness Report⁹³ (thirtieth edition) is used. This ranks 67 Countries (they do not include some of the Countries that have been considered in this WP, but most of them) based on over fifty factors that can be grouped into 3 areas: Knowledge (education, talent), Technology (adoption, development) and Future Readiness (plan, investment).

As with any ranking, it is dependent on the factors used, and quite different outcomes could result from the choice of different factors or grading their weight in a different way. As such, the inclusion of the reference in this White Paper shall not be considered an endorsement, just a useful gauging stick.

There are over 200 Countries in the world, and a significant portion of them have started, or are considering starting, the Digital Transformation both at a Government and private level. The diversity among them, in terms of culture, technology adoption, and wealth is significant as no one size fits all.

The working group has selected a number of Countries to bring this diversity into focus, showing the diverse approaches and the diversity in planning. Additionally, the Digital Transformation, particularly so when one considers it at Country level, is extremely complex and broad in its implications. Hence, the choice here has been to focus on just a few aspects, for each of the selected geographical areas, emphasising specificities. All links are provided to get more in depth information.

5.1 Western Countries (Europe/North America)

5.1.1 EU

The economic value of the data market in 2019 exceeded for the first time the 400 B€ in Europe (27 Countries plus UK)⁹⁴, a growth of 7.6% over the previous year (exceeding the value of Information Technology investment that reached 75B€ in the same period with a 4.9% growth YoY). This shows the relevance of the data economy and the impact the Digital Transformation is having on Europe. The expected growth in the coming 5 years forecasts a 550-827 B€ value in 2025 (baseline vs high growth).

The number of companies supplying data has reached 290,000 with a YoY growth of 2.3% with the number of data user companies stable at 716,000. These figures point to a consolidation of the supply/user market.

The number of data professionals has reached 7.6 million, and demand shows a shortage of 456,000 units (5.7% of the current workforce in the area), indicating that whilst the data scape is stabilizing, the need for leveraging on it (processing data) is growing. This is another sign of the ongoing Digital Transformation that shifts from a pure efficiency focus, cost reduction, to leveraging value by offering services based on data. The number of data professionals is expected to reach 8.4 million in 2025, with an expected shortage of 484,000 unfilled positions at 2025, underlining the need for upskilling.

⁹³ <https://www.imd.org/wcc/world-competitiveness-center-rankings/world-digital-competitiveness-rankings-2019/>

⁹⁴ <https://ec.europa.eu/digital-single-market/en/news/european-data-market-study-update>

According to a McKinsey study⁹⁵ commissioned by the EU, the adoption of disruptive digital technology can lead to an additional 1.1% growth of the overall EU GDP, resulting in 2.2 trillion € in 2030. These figures take into account both positive and negative impacts, like the growing unemployment in sectors affected by the digital transformation and the new jobs created by it, both in terms of new business opportunities and in terms of resources made available by the shrinking value in some areas.

To be monitored, the Digital Transformation website⁹⁶ managed by the EU showing the initiative at EU level and the ones in its member states.

5.1.2 Austria

The status of the Austrian Digital Transformation landscape in a nutshell:

- A central challenge is the lack of digital awareness in the corporate environment.
- Corporations have structural and organizational potential to accelerate the digital transformation process.
- The connectivity among actors within the digital transformation ecosystem can be improved.
- Embracing new ways and entities to fertilize the digital transformation would have a positive impact on the competitiveness of the Austrian economy.

To answer the question of the status of DX in Austria, the following approach is having a look at the components of the Austrian Technology- and Innovation-Ecosystem and reflecting on those, while cross referencing the criteria of the IMD World Digital Competitive Ranking⁹⁷.

Inno-Ecosys/IMD		Knowledge	Technology	Future Readiness
Corporates				
	Strategy			
	Tech-/Inno-Engagement			
	Product-/Service-Acceleration			
Accelerators				
	Independent			
	Corporate			
Innovation Agencies				
Innovation-Finance				
Universities				

⁹⁵ <https://ec.europa.eu/digital-single-market/en/news/shaping-digital-transformation-europe-working-paper-economic-potential>

⁹⁶ <https://ec.europa.eu/growth/tools-databases/dem/monitor/tags/digital-transformation>

⁹⁷ file:///C:/Users/User/Downloads/imd-world-digital-competitiveness-rankings-2019.pdf

Corporate dimension:

In the corporate Sphere⁹⁸ following 3 aspects will be looked at:

1. Inclusion of the aspects of the digital transformation into the strategy mix of corporations.
2. The way corporations manage innovation and digital transformation.
3. The impact of 1. And 2. on the capability of corporations to accelerate the time to market of products and services.

Based on field experiences in Austria, it is observed that many corporations still look at the Digital Transformation as a matter of process improvement, of cost reduction, and of efficiency optimization. Therefore, great potential relies in building a bridge between the possibilities that are offered by Digitization and the evolution of new business models.

Assets are often slightly only repositioned and very little enriched with innovation and digital technology, instead of assembling them in new ways with the objective to create Blue Oceans⁹⁹ and future leading business models. This is also due to the fact that across departments there is a lack of understanding of relevant developments with respect to digital technologies, present and future, and the missing overview and the gap of information in regards to deployable, already existing solutions on the market.

Few corporations embrace the opportunities offered by Digitization simply for the lack of Digital Awareness and Competences. The C-Level is often too busy to increase shareholder value rather than to advance Future Readiness. Meanwhile, middle and upper management recognize concrete needs within their organizations and are able to find implementable solutions. There is often a disconnect between them, their findings and their understanding for strategic necessities related to the digital transformation at one side and at the other side with the decisions made at top management level.

Since transformation means Change, a whole additional challenge is the general resistance to the New. That phenomenon is already well known and studied in corporate reality.

For example, in Q2, 2019, I brokered a presentation of an integration platform approach to a subsidiary of a multinational in Austria in regards to predictive maintenance for one of their local production facilities.

The General Manager for Austria was very clear about the fact that: “data we have more than plenty, but to translate those into action, we have relevant issues with.” One aspect of the issue was the importance to understand the difference between structured and unstructured data lakes and having proper hard and software in place. Another was the lack of knowledge in regards to well-developed IT and hardware in regards to the IoT.

The solution of choice then had to go through a general approval process that involved among others a department located in Switzerland. To develop a global solution out of the Austrian approach, the proposal had to go up and down the hierarchy, involving also the US headquarters. Through time, the initiative was diluted and got lost in the grinder of the corporate structure.

⁹⁸ According to the VGCG-Sphere-Analysis-360.

⁹⁹ <https://www.blueoceanstrategy.com/>

Instead of bringing the company relevant steps closer to a fully automated, digitized production facility and a repositioning of the existing Value Sphere¹⁰⁰. Business is still done as of today, as in the past 15 years.

Even in the presence of innovation managers, the engagement with the transformational potential that digitization offers to Austrian companies, opportunities are frequently missed out upon. Reasons for that are:

- Lack of digital competences across departments.
- Not adequate setup of processes and structures in corporations to route the digital transformation efficiently within the organization.
- Not sufficient connectivity across hierarchical and in silos structured organizational models.

Those among others, are barriers in the pathway of time-to-market acceleration in regards to the delivery of products and services¹⁰¹.

Also, SMEs are often more agile and adaptive in regards to the challenges displayed above. They are often lacking access to the most innovative and future leading trends/developments and ready to deploy solutions, due to the lack of resources.

Resumen Corporates:

Knowledge

Large Austrian corporations have plenty of sources and accessibility to basic research, know-how and best practice but are often inhibited by their hierarchical organizational structures. That makes them not agile enough to accelerate the deployment of new business models based on digitization. SMEs face, on the other hand, exactly the opposite challenge.

Austrian companies could improve relevantly their international competitiveness by embracing a knowledge-knot-point driven organizational frame. Also, a reorganization of Innovation and Digitization across competence and hierarchies and an integration of the relevance of Digital Transformation into the strategy mix would improve the international positioning.

HR training and education needs to follow and adapt to the above detailed changes.

Technology

Breaking the IMD technology aspect down and looking at it from the perspective that considers the corporate frame within which Austrian companies to a large extent operate, these corporates often follow internal regulations on how to engage with technology and innovation. Those complicate the structured, systematic, and sustainable leverage in regards to the opportunities of the Digital Transformation.

Capital is an issue for SMEs, and there is always the danger that capital suffocates innovation and the Digital Transformation process in general.

¹⁰⁰ See Carati/Pizzini/Reiss Theorem and The Deep Blue

¹⁰¹ <https://www.innovationaccelerationgroup.com/home>

In Austria it is not the lack of accessibility to digital technology but more the missing consciousness about the feasible possibilities on hand and the absence of the understanding of the all-over implications on how to evolve business models and strategies, based upon digital technologies.

Feature Readiness

The willingness to embrace the Digital is improvable in Austria. It looks like corporates are still trying to find their way how to deal with the Digital, and even more so with the Connectivity¹⁰², Revolution. They are facing the dilemma between exploiting their existing trajectories in regards to cash cows and established business models and the absorption of future leading ways of doing business.

Innovation managers, CTOs, and CIOs are often disconnected from each other and could be more synchronized and better connected to allow faster deployment of solutions and therefore shorter time to market of products and services.

Corporate IT is often still too rigid, not modular enough, and not integrated sufficiently to allow organizations to react in opportune time frames to an ever faster changing environment.

Incubator and Accelerator dimension:

Also, there are dozens of non-corporate Accelerators throughout the different Bundesländer that are receiving government subsidies in form of grants or loans¹⁰³. The landscape appears more like a maze of initiatives that operate isolated or even in competition to each other. Isolated even more so in regards to their engagement with the corporate dimension of this part of the Austrian Innovation-Acceleration- Universe¹⁰⁴.

Following, 2 of the largest accelerators by funding are used as examples to describe the observations made in the section above.

Wexelerate¹⁰⁵

One of the largest Accelerators in Europe follows the business model to accept 50 start-/scale-ups per quarter as residents for no charge. Apart from subsidies, Wexelerate is financed by corporates that have to commit over the period of 3 years, 6-digit-EUR amounts to gain access and exposure to the residents.

On top, Wexelerate offers co-working space as well as facilities for presentations, keynotes, and conventions.

The statement of a global partner at one of the world's leading strategy consulting firms, a long-time friend of mine, seems to encapsulate very well, one of the challenges that the AUT-DX-Ecosystem is facing: "our firm sponsors Wexelerate for years and I will be visiting for the 1st time there in 3 years";

¹⁰² Connectivity-Revolution is a term used by the Think Tank Spin in delimitation to the term 4th Industrial Revolution

¹⁰³ <https://www.trendingtopics.at/jumpstart-gefoerderte-startup-hubs/#:~:text=Es%20sind%20mittlerweile%20zehn%20Inkubatoren,und%20Ausbildungskosten%20decken%20zu%20k%C3%B6nnen.>; <https://www.trendingtopics.at/jumpstart-diese-5-inkubatoren-und-accelerators-werden-gefoerdert/>; <https://www.derbrutkasten.com/incubator-und-accelerator-foerderung-jumpstart-wird-verlaengert/>

¹⁰⁴ Term used by T. Reiss in the context of IAG-Berkeley

¹⁰⁵ <https://www.wexelerate.com/>

meaning the existing NON-Connectivity among the components of the Digital Transformation Ecosystem in Vienna, Austria!

Another field of optimization is the matter of being followers versus creators. While co-working spaces as form of accelerating Technology-Innovation and Digitization in e.g. the Silicon Valley works for more than a decade very well, Austria seems to import such ideas with a time-lag of years and then copies them 1-to-1 without adapting them to the Austrian ways of doing things. That results in lagging behind their US-peers and in relevant dysfunctionalities of the system as a whole.

Tabakfabrik¹⁰⁶, Start-up 300¹⁰⁷

Born as an independent accelerator, it was recently merged into the Startup300-AG. What could have resulted in a vibrant exchange between the capabilities of the VC origins of Startup300 is at the moment a concept that searches for its identity.

Within the group, it seems like that organizational silos exist next to each other with few interconnections. Like the part of co-working is not well connected to the part of education and those not well aligned with the investment arm.

Instead of leveraging on the great potential of synergies it seems like that the development goes towards a type of VC driven “corporate accelerator” in function of the public traded entity, the value of which derives mainly from exits.

Another common challenge to all non-corporate Austrian accelerators seems to be that talent is looking for alternative technology-innovation ecosystems where the parts of the system are more synchronized. Two examples are N26¹⁰⁸ and Scalable¹⁰⁹. Both companies have founders/co-founders of Austrian origins but have chosen to scale abroad.

On the other hand, Corporate Accelerators in Austria rarely embrace Open Innovation¹¹⁰. They stay with the classical approach to R&D in an isolated way within their own organization, focusing on the old fashioned assumption that the total of the outside world is the competitor.

Having dinner recently with a board member of a relevant Austrian telecommunications company, his approach was summarized as follows: “I’m not interested in independent accelerators... my corporate accelerator has every field covered that serves our purposes.”

Another aspect of corporate DX is that often the wheel is reinvented instead of evolved. A personal experience with that was my attendance at the Fintech Summit in Bratislava in the fall of 2019. One of the leading Austrian banks presented their research in regards to predictive analysis and its application in CJX & CJA.

The solution they were still in the process of developing existed for at least 5 years prior and already in a commercialized format out of Silicon Valley.

¹⁰⁶ <https://tabakfabrik-linz.at/>

¹⁰⁷ <https://startup300.at/>

¹⁰⁸ <https://n26.com/en-de>

¹⁰⁹ <https://de.scalable.capital/>

¹¹⁰ https://en.wikipedia.org/wiki/Open_innovation

Instead of taking a proven product and adapting/integrating it, precious time-to-deployment is often wasted in the Austrian Digital Transformation landscape. This results in an exponentially increasing lack of competitiveness in comparison to e.g. their US- and PRC-peers.

Or as a global partner responsible for innovation at yet another of the most important strategy consultancy put it at the Banking Summit in Austria this past year: “in most of the relevant technologies that will shape the future of business, Austria cannot catch up at the level of basic research, such as AI, IoT or Cyber Security... but we have some of the world’s best application engineers. So why do we not focus on the best marketable solutions?”

Resumen Incubators and Accelerators:

Knowledge

So the talent and the entrepreneurial drive to nurture this part of the AUT-DX exists, but it seems that the playing field is not paved properly, and at the same time it is not providing very targeted for the needs of the talent.

Non-corporate accelerators in general offer education, knowledge transfer, and coaching but miss out on delivering the connectivity to corporates. Those corporates represent the entities that can leverage the technology-innovation and scale it. Also the value-sphere of talent, knowledge, access to finance, and access to market is not set up in a frictionless way.

As far as scientific concentration, it seems that accelerators, universities, and R&D entities connect but connect more regionally and to a lesser extent on a nationwide level. An example is the Silicon Alps initiative in Carinthia¹¹¹ or the Tyrolean Business Angel organization¹¹².

Technology

The regulatory framework seems adequate in regards to the incubator landscape and the Ministry of Digital & Economic Affairs supports and promotes many legislative initiatives at this point in time.

Access to capital is good¹¹³. The government designates relevant budgets to support the accelerator-ecosystem. Some of the D-A-CH’s relevant VC’s are from Austria like Speedinvest¹¹⁴, the Hansmann Group¹¹⁵, and Hermann Hauser¹¹⁶, just to mention a few.

Being a country with many smaller communities and remote villages¹¹⁷ compared with e.g. Germany¹¹⁸, accessibility to the internet is sufficient throughout the territory and allows incubator initiatives almost everywhere.

¹¹¹ <https://www.silicon-alps.at/>

¹¹² <https://t-ba.eu/>

¹¹³ https://www.eib.org/attachments/efs/economic_investment_report_2019_en.pdf

¹¹⁴ <https://speedinvest.com/>

¹¹⁵ <https://hansmengroup.com/>

¹¹⁶ <https://www.iect.at/investors-academy/>

¹¹⁷ Urbanization rate around 58%, source Statistica

¹¹⁸ Urbanization rate around 78%, source Statistica

Feature Readiness

As mentioned prior, the Austrian incubator landscape could be more agile in regards to breaking down e.g. Silicon Valley best practices. Even more so, more aggressive in creating its own way of doing technology-innovation and the related deployment of such.

Accelerators, government institutions, and businesses have a huge potential to synchronize more among them and could move faster away from compartmental thinking. This would bring the digital transformation to fuller and faster fruition.

Other components of the Austrian Innovation Acceleration Universe

Innovation Agencies and Brokerage of digital products and services as a standalone approach is almost unknown to the Austrian Digital Transformation ecosystem. As in many other countries, incubators/accelerators are fairly disconnected from the needs of SME's and Big Corporates.

The Austrian market still relies on the traditional way of doing business in the sense that at one side there is the offer of companies that developed digital products and services and at the other side of the aisle stands the demand.

To accelerate the matchmaking, entities or market places that would broker digital products and services in a compact and efficient way, could create enormous benefits for the Austrian economy. This would facilitate or even partially eliminate traditional marketing and sales processes that are challenging to adapt in a fast moving environment. On top, those ways of selling are binding enormous resources, which are very often difficult to assign for smaller players.

Such entities would in part also improve the following situation: needs at the buyer's side are in many cases not even clear at first. Therefore, Innovation Agencies could support an iterative process of product and service development, and hereby create relevant efficiency.

Innovation agencies and Innovation Marketplaces could furthermore support a better understanding of the strategic implications on doing business, deriving from the possibilities of The Digital and parallel accelerate the thorough exploitation of such. That would lead to an acceleration of adaptive-ness and innovation in regards to business models.

In a second step, such agencies or marketplaces could reposition the matchmaking timely even before the deployment of ready to implement products and services and involve buyers and sellers at the stage of development. Therefore, the match between product/service and needs would be optimized. Incubators, and Accelerators in Austria at this moment are not bridging that gap yet in an efficient way.

The Austrian schooling and university landscape offers everything expected from a developed economy as detailed in the IMD report. Also, there is the attempt to connect through outreach initiatives and programs better with the digital transformation ecosystem, including corporates, government, and accelerators. The educational sector per se is often amorphous and disconnected to deliver on that objective.

The Austrian Financial environment has relevant potential to improve: by joint venturing more with the digital transformation ecosystem for example through approaches like Innovation-Structured-Finance¹¹⁹ and alternative, more synchronized ways of financing the digital and technology innovation in general.

Further reading:

- <https://www.wko.at/service/zahlen-daten-fakten/daten-innovation.html>
- http://www.statistik.at/web_de/statistiken/energie_umwelt_innovation_mobilitaet/forschung_und_innovation/innovation_im_unternehmenssektor/index.html
- <https://www.aws.at/en/>
- <https://viennabusinessagency.at/funding/programs/innovation-90/>
- <https://www.derbrutkasten.com/videos/schrambock-im-talk-zum-grunder-paket-und-8-punkte-plan-zur-digitalisierung-der-schulen/>

5.1.3 Estonia

Although Estonia is ranked 27th in terms of Digital Transformation, it is considered by many a forerunner, demonstrating how an economy and society can shift to the cyberspace.

Estonia is a small country by size. It covers an area of 45,226 km² (larger than Maryland, smaller than West Virginia) with a population of 1.324 million people (the population of Dallas, TX). Yet in the cyberspace, it has no boundary. Anybody can apply for an Estonian e-citizenship¹²⁰ allowing full rights of carry out business under that country's flag. There were, according the WEF, 1,500 e-citizens from 73 nationalities that have registered¹²¹ in 2014 when the possibility was first granted. As of the end of 2018, there were over 50,000 eCitizens from 157 Countries. Notice that becoming an Estonian eCitizen does not mean one becomes an Estonian citizen, only that an electronic identity, usable in banks and in business transactions, is assigned to that person as if that person was a real Estonian citizen. Hence, the motivation is in the business area.

This is further underscored by the availability of e-services: 600 for its citizens and over 2,400 to support business. Since 2000, internet access has been considered a fundamental human right.

As Estonia moved to the cyberspace, hence to have their life recorded in bits, the government, and the laws ensure full transparency on the use of data and each citizen has full control of personal data.

5.1.4 Italy

Italy is a Country talking a lot about Digital Transformation but having trouble in walking the walk, as so often happens to big endeavors. One needs to separate the private industry, both large and small (SMEs in Italy are the backbone of Italian GDP) from the Government and the Public Administration.

Private Industry

¹¹⁹ By T. Reiss

¹²⁰

https://www.googleadservices.com/pagead/aclk?sa=L&ai=DChcSEwiOINDcne7qAhXN571KHZqjCZIYABABGgJscg&ost=www.google.com&cid=CAESQeD2RtBVLkYv7YDZsF7JUxCjPm-vYP_DPD2Y4kG0oHgTuTtagTkoMAKuoHUPAtTwsM9aTIDgkC77Aqvl01XYbSnq&sig=AOD64_3WUmeI4dsBkJrq7N2XWQgFPgXXdg&q=&ved=2ahUKEwj87Mjcne7qAhUN0qYKHd1YCFMQ0Qx6BAgXEAE&adurl=

¹²¹ <https://reports.weforum.org/digital-transformation/e-estonia/>

The private industry organization, Confindustria, has activated several years ago a specific organization to foster and support the Digital Transformation, Confindustria Digitale¹²². This organization has been very active to lobby with the Government for a quick transformation of regulations and laws to create a framework conducive to the new digital reality of enterprises. It organized and keeps organizing events and publishing studies in various areas to show how the digital transformation benefits the economy and the Italian industrial sector by making it more competitive. Over the years, it made several calls for a pervasive broadband infrastructure. The success of wireless telephony, smartphones, in a way slowed the deployment and uptake of fixed broadband infrastructures particularly in rural areas. Most people who had a vacation home discontinued the subscription to the fixed line, being able to use the smartphone (and tethering). The pervasiveness of 4G and the all you can eat data subscriptions (or very generous data budget) are clearly decreasing demand for the fixed network.

Italy has been divided into three colored markets (white, black, and grey) to denote those areas where fiber deployment can generate sustained returns, the ones where there is no private interest for deploying fibres given the low return expected and intermediate ones. The Government has created a company to deploy in low market revenue areas, and something is moving but not as fast as Confindustria would like. Now with the possibility of deploying 5G FWA, there is a plan to connect 4 million homes in white areas by the end of 2020. If accomplished that would almost complete the broadband infrastructure in terms of access.

Another call has been on the modernization of the Public Administration and its digitalization. Here, some progress has been made, but regulations and laws are still creating a complex and sclerotic framework.

The third call was on fostering high education, clearly focussing on technology and industry needs, and this is something that would require a re-thinking of the higher school that is Italy are still very much favoring classical studies/humanities, thus decreasing the appeal for STEM education at university level.

The main focus of Confindustria today is on Industry 4.0, but it is also addressing aspects like work organization¹²³ in the digital era and education¹²⁴ to prepare for the new skills.

Given the position of Italian Industry on the value chain, with manufacturing of components prevailing over the manufacturing of the end product, the shift towards Industry 4.0 is tied to the big manufacturers buying the components manufactured in Italy. In a way Italian SMEs, at least in the main sectors, are followers of evolution dictated by foreign companies.

The recent pandemic induced lockdown has promoted teleworking and the shift to the Cloud for many private companies, thus accelerating some aspects of the Digital Transformation.

Government and Public Administration

The Digital Transformation has seen many starts in terms of commitment declaration from the central Government that has agreed on a Digital Agenda and created a specific Digital Transformation Team¹²⁵

¹²² <http://www.confindustriadigitale.it>

¹²³ <http://www.confindustriadigitale.it/aree/call-to-action-per-un-piano-industriale-sul-lavoro-4-0.kl>

¹²⁴ <http://www.confindustriadigitale.it/aree/il-digitale-e-la-scuola.kl>

¹²⁵ <https://teamdigitale.governo.it/en/>

back in 2016 under the stewardship of Diego Piacentini, a former VP of Apple and, since 2000, Senior VP of Amazon. The team developed the Digital Agenda that included among many other things the creation of a unique Digital Identity for every citizen (SPID¹²⁶). As many other “creations” of the public administration, this Digital Identity had a very slow take up; it was/it is cumbersome to request (it was not automatically given to each citizen as the digital complement of the unique fiscal code that is already attributed to each citizen). In spite of this single digital identity, many arms of the PA created their own procedure and identity (one for the healthcare system, another for each municipality, another for the Agency of Income, another for the INPS—pension and insurance institute). This variety underlines the interest in digitalization and the lack of a true coordination among the different entities. Add to this the regional/municipal split of responsibility in the relation with citizens, and you get the picture.

The Digital Transformation Team ended its work on December 2019, and its responsibility was moved to the newly created Department for the Digital Transformation¹²⁷ under the Ministry of Technological Innovation and Digitalization directly reporting to the Prime Minister.

The Digital Identity, SPID, was taken up by some 4 million citizens (less than 10% of the Italian citizens), but the access to Government aids during the pandemic was tied to the use of SPID, and that doubled the number of Digital Identities issued to 8 million in just two months.

The Digital Agenda included specific actions to steer the Italian Industry towards Industry 4.0 with the provision of a number of fiscal support to help companies invest in digitalization (and acquire IT related equipment and software).

There is a 2025 strategic plan¹²⁸ that focuses on three objectives:

- All citizens and companies access PA services through online platforms using a digital identity, digital payment, and single data access point for all PA data.
- PA becomes the force to steer and foster the Digital Transformation in the private sector by integrating public and private services, use digital procurement, and support open innovation.
- PA uses an open data framework and fosters their use to create new services.

As mentioned, this is nothing new. The problem is to move from declaration of intent into execution. There is now a much higher probability as a consequence of the pandemic and lockdown that has forced most PA employees into teleworking and a revision of processes in interacting with the citizens.

Residential market

Italian citizens are all (almost all) familiar with smartphones and are using them intensively, creating a good platform for the shift towards Digital Transformation. Mobile commerce and mobile payments are increasing rapidly, and the familiarity with web transactions is universal in the younger generations that are often playing the role of evangelist, teaching the older generation.

5.1.5 US

Many organizations were on their way to begin or to complete the digital transformation of their processes and services, before the COVID-19 epidemic hit. Since then, the organizations who were

¹²⁶ <https://www.spid.gov.it>

¹²⁷ <https://innovazione.gov.it>

¹²⁸ <https://docs.italia.it/italia/mid/piano-nazionale-innovazione-2025-docs/it/stabile/le-tre-sfide/la-prima-sfida.html>

mostly able to pivot to remote work, powered by software defined process automation and modern communication networks have accelerated their digitization efforts. In many regards, this fast pivot by many organizations to working online has helped to preserve the current economic value in the US.

Even after the immediate emergency passes, the new normal for US business will be increasingly digital and connected. Even when people can travel, interacting remotely will be a standard activity, and many people will continue to work from home and seldom come into the office.

Physical travel in general, and especially for great distances, will be an option for many, with improved remote and increasingly interaction tools. Augmented reality and virtual reality tools for person to person interaction are now undergoing an acid test that will help shape better technology and experiences for tomorrow.

With the rise of IoT sensors and 5G networks, the ability to interact remotely will be enhanced, allowing for instance, factories with fewer people physically on site and more folks monitoring, adjusting, and fixing equipment remotely. These online sensor networks may also help to quell the next pandemic, by finding sick folks faster and preventing the spread of disease.

In addition, different sensor networks will make US streets safer for all types of traffic and may even free riders from driving when they do travel. This has the potential of reducing the number of vehicles required in a US city and could help remake cities without lots of parking spaces and more open spaces.

Education in the US may also change forever. Many schools (whether grade schools, high schools and colleges) have been operating remotely for many months now, and many will continue to work remotely until a vaccine is created and in broad distribution. This will put pressure on schools to develop their own digital transformation and may help to remake the future of education.

This could have a long-term positive impact if, for instance, much higher education (at least classes) could be done independently of physical infrastructure. Reducing the costs of running schools could curb the formerly unchecked increases in higher education costs that threatened to prevent many people from a higher education at a time when having a college degree and familiarity with technology is the key to having a good paying job.

In addition, lower cost but effective education options could help working professionals with their own continuing education to stay on top of rapidly evolving changes in every industry and every profession. Education must be effective and low cost to increase the inclusion of underprivileged people in the US economy and drive future growth.

Much of the economic value generated in the US is the creation of new things, new ways to do things and producing things that make life easier and hopefully more enjoyable. The type of digital transformation that the COVID-19 epidemic is driving in the US and in other parts of the world may help us come together and create new wealth without at much impact on the world's ecosystem and perhaps more time to spend with our families and those who matter the most to us.

5.2 Latin America

If we speak about Latin America, we are talking about a region extending over two continents. As the name already suggests, the countries have in common (with some exceptions) that their cultures are related to Spanish and Portuguese settlers. Nevertheless, the mixture of local and various immigrant

cultures, together with different climates and biodiversity created regions with divergent cultures. The differences are not only between neighboring countries; they can be observed also inside the same one.

As colonies, Europeans brought the actual ideas of governance and infrastructure, what in most cases meant centralism and a new capital influenced by Paris' architecture, including Champs Elysees-like boulevards (for example Mexico City's Paseo de la Reforma and Buenos Aires' 9 de Julio Avenue). These decisions still determine actual reality. In greater Mexico City live today around 21.3 million habitants, Greater Sao Paulo even includes 21.6 million habitants. This centralization includes most company headquarters and prestigious universities. Combined with Latin entrepreneurship, it is a melting pot for potential digital start-ups and developments. So far, these have not appeared in higher numbers. There are various reasons for this. Lacking IT infrastructure is one of them. Most countries still focus on the implementation of 4G wireless networks (Peru 83% coverage, Mexico 80%, Brazil 80%); the switch to 5G is still lacking.¹²⁹

Due to centralism and non-adequate infrastructure, many employees spend hours each day in traffic. A motivator for digital transformation is the shifting of work and education from the physical into the virtual world (for example with more home offices, online learning, and eGovernance) to improve the work-life balance.

Denise Park and Chih-Mao Huang confirm with their study "Culture Wires the Brain: A Cognitive Neuroscience Perspective" a positive causal relation between experience and the brain's function and structure, including a considerably "evidence that neural function is affected by culture, particularly activations in ventral visual cortex – areas associated with perceptual processing."¹³⁰ Due to the three stages of perception, this means selection, organization, and interpretation of stimuli. The world we live in affects our thinking and ideas. Five years earlier, an eye-movement study by Hannah Faye Chua, Julie E. Borland and Richard E. Nisbett concluded that people in individual Western cultures focus more on focal objects, while in East Asian culture people attend more the contextual relations.¹³¹ Professor Joseph Henrich resumes: "If we are what we see, and we are attending to different stuff, then we are living in different worlds."¹³²

Polymaths are not only experts in one topic, but in two or several ones, often in areas which are perceived as completely opposite, as for example mathematics and art. Famous examples are Aristotle, Wolfgang von Goethe, Edgar Allan Poe, and Leonardo da Vinci. The last resumed it: "Study the science of art. Study the art of science. Develop your senses – especially learn how to see. Realize that everything connects to everything else." Thanks to their insights into different disciplines, polymaths can find relations and patterns, which other may oversee, also as they are questioning the perceived reality.¹³³

Latin countries have a high level of biodiversity. Mexico is the home of 707 reptiles, 438 species of mammals, 290 of amphibians, and 26,000 different types of plants. Plus, there are types which still await

¹²⁹ Myers, Margaret / Garcia Montenegro, Guillermo (2019): "Latin America and 5G: Five Things to Know"

¹³⁰ Park, Denise C. / Huang, Chih-Mao (2010): "Culture Wires the Brain: A Cognitive Neuroscience Perspective"

¹³¹ Chua, Hannah Faye / Boland, Julie E. / Nisbett, Richard E. (2005): „Cultural variation in the eye movements during scene perception"

¹³² Henrich, Joseph / Heine S.J. / Norenzayan A. (2010): „The weirdest people in the world?"

¹³³ Rana, Zat (2017): "The Expert Generalist: Why the Future Belongs to Polymaths"

to get discovered.¹³⁴ Besides this, the Mexican government recognized 62 indigenous languages as national languages, spoken by the different local cultures.¹³⁵

Mexico is a country with different spiritual realities, like the physical and virtual world. Even if 83% of citizens follow the Roman Catholicism,¹³⁶ earlier religions with their rituals and celebrations merged to this faith or at least stayed inside the memory. The most well-known example is the “Día de los Muertos” (Spanish for “Day of the Dead”), a traditional Mexican holiday, based on a pre-colonial tradition, originally celebrated in summer, later moved to the beginning of November to merge with the Christian holiday. The celebrations take place on November 2, where it is believed that the souls of dead children return for one day, and on November 3 the souls of the dead adults come to visit their loved ones. To ensure that the dead find their way, families create small altars in their homes or even spend the nights at the graveyard. Including local variations, the celebrations take place all over the country.

Latin Americans are “cultural polymaths.” Behavior is based on perception, perception is based on senses. Mexican cultures worshiped various gods, including in animal shapes. Due to their differences from the humans, the intelligence and perception of these creatures was completely different and not predictable for humans. To nevertheless achieve an understanding of the gods, the priests started to read the stars and tried to discover patterns between the appearances of star constellations and occurrences on Earth. Like a black box, the priests studied based on statistics, which behavior (input) led to which results (output), like sunshine or rain. The problem, they identified potential statistical relations, but assumed false logical connections between in- and output. Other Latin countries present a similar mixture of different cultures. On the first view, the North-Brazilian Candomblé celebrates the various Roman Catholic saints. Nevertheless, they represent in parallel different gods based on West African religions.

Perception is based on senses. Artificial Intelligence, including Machine- or even Deep-Learning, may not have different senses than humans, but thanks to more and superior sensors surely is more sensitive due to its ability to understand and analyze Big Data. This procession of continuous waves of information works like an additional sensor, on a level that humans are not capable of. Yusuf Aytar, post-doctoral AI research at the Massachusetts Institute of Technology (MIT) resumed: *“If you have more senses, you have more accuracy.”*¹³⁷

Still, in 2018 the research and advisory company Gartner defined Artificial Intelligence as a *“technology that appears to emulate human performance.”*¹³⁸ One year later, they updated their definition to: *“Artificial intelligence (AI) applies advanced analysis and logic-based techniques, including machine learning, to interpret events, support and automate decisions, and take actions.”*¹³⁹ The perceived human element became eliminated.

Different cultures with their demons and gods are part of the Mexican reality, and with this, part of the socialization since early-childhood. Humans are not completely able to understand these creatures,

¹³⁴ Southern Portal (fetched 18.04.2018): “Biodiversity in Mexico”

¹³⁵ Facts About Mexico (fetched 19.04.2018): “The Mexican Culture”

¹³⁶ INEGI (2013): “Censo de Población y Vivienda 2010. Cuestionario básico”

¹³⁷ Gershgor, Dave (2017): “MIT and Google researchers have made AI that can link sound, sight, and text to understand the world”

¹³⁸ Gartner (2018): “IT Glossary: Artificial Intelligence”

¹³⁹ Gartner (2019): “IT Glossary: Artificial Intelligence”

which makes them a “black box” like AIs. In conclusion, Mexican software designers should have an easier access to this technology, as due to their social experience, their brains are differently wired to interpret different realities. The understanding of surreal environments and creatures got underlined by the continuous success of Mexican film directors. Guillermo del Toro successfully realized “Hellboy” (2004), “Pan’s Labyrinth” (2006) and “The Shape of Water” (2017). Alejandro González Iñárritu created “Babel” (2006) and “Birdman” (2014). The third of the group, Alfonso Cuarón directed the well-known movies “Harry Potter and the Prisoner of Azkaban” (2004) and “Gravity” (2013).

Despite Latin America’s positive precondition, why are there not more examples on the market? Corruption and inefficient bureaucracy hinder creativity. With exception of Uruguay and Chile, Latin American countries show a higher perceived corruption measured by Transparency International.¹⁴⁰ Asked about the Apple’s secret of success, Steve Jobs did not answer that it was a creative or inventive company, but instead: “*Apple is a disciplined company.*” This answer is surprising at first, but it makes sense. If we have a clearly defined space, employees are aware of the red lines and feel safe inside to live out their creativity. Latin societies are required to overcome corruption, no easy task as corruption and inefficient bureaucracy are interacting and self-enforcing. Nevertheless, if this could be reached, the countries could become a key player for digital transformation.

In their study “Creativity over Time and Space,” Michael Serafinelli and Guido Tabellini confirm that open and democratic institutions are needed for sustainable and innovation-based growth.¹⁴¹ Undoubtedly, Latin societies appreciate all forms of art, but on the other hand because of the missing personal and economic freedom (corruption and impunity), many people choose to emigrate. This means a relevant limitation, as the needed talent and creativity leaves the country. This is a sabotage on the otherwise good conditions for a blooming local digital industry.

The different mixtures of Indigenous, European, and African cultures, in combination with a lacking efficient public social system, led to societies organized in various circles of trust, with a focus on family structures. Latin American cultures position themselves in between East Asian cultures and the highly individual US society. The key success factor is networking, while ideas and inventions play a lower role. People are defined in relation to others, especially to political, business, or cultural leaders. Accordingly, famous Latin start-up companies are lacking. Nevertheless, there are various practical approaches to use existing concepts technologies.

The Brazilian company Take developed with “BLiP” a user-friendly system, where everybody with only basic coding-skills can create a working chat-bot. Another example is Google’s first social network “Orkut”. Founded in 2004 in the US, Google shifted its management and operation to its Brazilian daughter company in 2010.¹⁴² In 2008, the network was the most visited website in Brazil.¹⁴³ Slowly it lost against Facebook, so Google closed the platform in 2014 to focus on its primary project Google+.¹⁴⁴

¹⁴⁰ Transparency International (2019): Corruption Perception Index 2018

¹⁴¹ Serafinelli, Michael / Tabellini, Guido (2018): “Creativity over Time and Space”

¹⁴² Vallone, Giuliana (2008): “Google Brasil assumirá o controle mundial do Orkut”

¹⁴³ Pereira, Fabiano (2008): “Os sites mais acessados do Brasil”

¹⁴⁴ Golgher, Paulo (2014): “Adeus ao Orkut”

True digital transformation requires a connection of the whole society, not limited to trusted circles. Functional eGovernance requires an efficient infrastructure and slim bureaucratic system. As long as such is not existing, local talents get demotivated and Latin America stays behind the global leaders.

5.2.1 Argentina

Argentina is a case study in itself. This country has a very good public educational system, with free access to everyone, and many universities and research centers. The Universidad de Buenos Aires, one of the largest in the region, with more than 300,000 students¹⁴⁵, is ranked at top of Latin America universities (#74 in the QS Global World Ranking)¹⁴⁶.

Also, Argentina produces some high tech products like communications satellites and nuclear reactors that exports to other countries like Australia, Egypt, or Perú, for example¹⁴⁷.

However, the country has lived through periodic economic crisis for decades. Every ten years or so, the country finds itself in a financially bad situation. High inflation or high external debt comes from time to time. However, it has led to a cultural strength: how to survive to a high degree of uncertainty. Words like “long term” or “stability” are not very common in Argentina.

This environment has made that Argentine “polymaths” adapt very well to different and highly changing situations. They are rebels in a very creative and diverse way.

These characteristics made them very successful when they were in other countries. They have a very global open mind, so it is usual to see them in upper positions in companies and organizations overseas.

Although the Argentine market is smaller than those in Brazil or Mexico, five out of nineteen Latin American largest technological start-ups, with a value of more than 1,000 million dollars each one¹⁴⁸, are from Argentina. Globant is a software factory focused on digital and cognitive transformation with presence in many countries like the United States, Canada, Mexico, United Kingdom, Belarus, France, India, Brazil, Spain, among others¹⁴⁹. MercadoLibre is the largest platform to online commerce and payments ecosystem in Latin America¹⁵⁰. Despegar is the leading online travel company in Latin America, operating across 20 countries¹⁵¹. OLX is the world’s leading classifieds platform in growth markets, connecting people to buy, sell, or exchange used goods and services¹⁵². Auth0 is the last Argentine Unicorn that solves the most complex and large-scale identity use cases for global enterprises with an extensible and easy-to-integrate cybersecurity platform, securing billions of logins every year¹⁵³.

¹⁴⁵ <http://www.uba.ar/internacionales/contenido.php?id=388>

¹⁴⁶ <https://www.topuniversities.com/universities/universidad-de-buenos-aires-uba>

¹⁴⁷ <http://www.invap.com.ar/es/la-empresa/sala-de-prensa/archivo-de-noticias/582-13-07-2000-se-firmo-en-australia-el-contrato-para-la-construccion-de-un-reactor-nuclear-por-parte-de-invap.html>

¹⁴⁸ ¿Qué es una Startup Unicornio y cuáles son los Unicornios de Argentina?

<http://www.ushuaianoticias.com/2019/08/13/que-es-una-startup-unicornio-y-cuales-son-los-unicornios-de-argentina/>

¹⁴⁹ <https://www.globant.com/>

¹⁵⁰ <http://investor.mercadolibre.com/investor-relations>

¹⁵¹ <https://investor.despegar.com/home/default.aspx>

¹⁵² <https://www.olxgroup.com/brands/olx>

¹⁵³ <https://auth0.com/about/>

Prisma Medios de Pago develops all types of payment solutions providing online shopping, billing, money management, online transactions, payments, transfers, and points of sale¹⁵⁴.

A national digital transformation was launched during the last years, including a huge e-government approach and an enhanced optical and satellite communications infrastructure. However, it was strengthened during the last months mainly because of the pandemic situation. Again, Argentina adapted very quickly to the uncertainty of the new environment. Some transformations, which in normal situations would take years to accomplish, now have taken days or months.

5.2.2 Brazil

The Brazilian Federal Government Ministry of Science, Technology, Innovation, and Communications (MCTIC) coordinated an Interministerial Working Group of 9 government bodies to issue a comprehensive document “Brazilian Digital Transformation Strategy – eDigital¹⁵⁵ (BDTS) in 2018 outlining the Agenda for the Digital Society of the Future and identifying the key enablers to implement it in Brazil.

The preparation of the document and the resulting content engaged the private sector and academia and was pre-discussed with the civil society at large through a number of public events that served to refine the policies and consolidate the plan.

The main objective of the Brazilian Digital Transformation is the exploitation of Digital Technologies to increase productivity, competitiveness, and income in Brazil. Additionally, the Digital Transformation is aligned with the Sustainable Development Goals defined by the UN (no poverty, zero hunger, good health and well-being, quality education, industry and innovation infrastructure, climate control).

The metrics chosen to measure the progress and impact of the Brazilian DX are:

- Infrastructure: ITU ICT Development Index¹⁵⁶ (IDI)
- Cybersecurity: ITU Global Cybersecurity Index¹⁵⁷ (GCI)
- E-commerce: UNCTAD B2C E-commerce Index¹⁵⁸
- Electronic Government: UN E-Government Development Index¹⁵⁹ (EGDI)

Other Countries are also making reference to these metrics (and they are useful to read, also considering the yearly updates and ranking of UN Countries based on those indexes), but it is notable that they are explicitly part of the Strategic Agenda of the Federal Government. The BDTS is a useful document for those institutions engaged in planning the DX since it also illustrates the methodology used to create it.

The enablers for the DX in Brazil are listed as:

- Infrastructure and Access to Information and Communication Technologies (with wireless infrastructures having the lion’s share).
- Research, Development and Innovation, with a specific focus on solving Brazilian main problems.
- Building trust and confidence in the Digital Environment, also addressing privacy rights.

¹⁵⁴ <https://prismamediosdepago.blob.core.windows.net/www/brochure-prisma-ingle%CC%81s.pdf>

¹⁵⁵ <http://www.mctic.gov.br/mctic/export/sites/institucional/sessaoPublica/arquivos/digitalstrategy.pdf>

¹⁵⁶ https://www.itu.int/en/ITU-D/Statistics/Documents/statistics/ITU_ICT%20Development%20Index.pdf

¹⁵⁷ <https://www.itu.int/pub/D-STR-GCI.01>

¹⁵⁸ https://unctad.org/en/PublicationsLibrary/tn_unctad_ict4d14_en.pdf

¹⁵⁹ <https://publicadministration.un.org/egovkb/en-us/About/Overview/-E-Government-Development-Index>

The application of the DX is considered on Thematic Lines:

- DX in the Economy, looking at the value shift towards data.
- New Business Models, looking at digital platforms as enablers and at the Players in the Platform Ecosystem.
- Digital Entrepreneurship and the need to foster Venture Capital in Brazil.
- DX in the Government, improving governance, delivering eService, shifting to digital documents in the public administrations and providing digital access.
- DX in Healthcare.

Overall, the BDTs is a remarkable document. However, what is sorely needed is execution, and so far this has not taken place because of the difficult economic situation compounded by the pandemic. The public sentiment is far from DX, there has been little follow up communication to the general public and even academia has not been involved to a great extent. There are initiatives in the IoT (National IoT Plan) and Artificial Intelligence (establishment of competence centers) areas, plus some focus on cybersecurity.

In fact, academia may take the lead both in the Research and Innovation areas and in spreading awareness to the general citizenships, using their students as influencers and organizing events.

5.2.3 Colombia

In 2018, Colombian Government adopted the “Pacto por la Transformación Digital de Colombia¹⁶⁰” followed in 2019 by the “El Futuro Digital es de Todos¹⁶¹.” Furthermore, in the second half of 2019 the Parliament approved a law to foster the development of the telecommunications and information infrastructures with provisions to increase broadband access to Colombian household and business (only 50% of them were connected to Internet in 2019 with a significant difference between the areas most developed, reaching 99.8% versus developing areas with 21% access).

To close the gap with underdeveloped/under-connected rural areas, the Government has started a two stage project, the first, Proyecto de Acceso Universal Sostenible, aiming at connecting 1,000 rural villages providing free internet access to any device (local Wi-Fi areas) that should have been deployed by the end of 2019. The second, Proyecto Nacional de Acceso Universal Social, targets 10,000 areas with bids to be completed in the first half of 2020 and work to start in the second half.

The first step was to assign spectrum in the 700, 1900, and 2500MHz to mobile Operators to provide wireless access. The Government has decided to add 10 Centros de Transformación Digital Empresarial (DX for enterprise) to the 18 already existing and to deploy a new Portal for interaction with citizens.

A major challenge in Colombia, in addition to the upgrade of the telecommunications infrastructure, is to improve the education that at the moment is lagging behind the minimum level to leverage the DX. CINTEL¹⁶², the Centro de Investigación y Desarrollo in Information and Communication Technologies, is dedicating significant effort in education focussed to the implementation of the Digital Transformation.

¹⁶⁰ <https://www.dnp.gov.co/DNPN/Plan-Nacional-de-Desarrollo/Paginas/Pactos-Transversales/Pacto-transformacion-digital-de-Colombia/Transformacion-digital.aspx>

¹⁶¹ <https://mintic.gov.co/portal/inicio/Sala-de-Prensa/Noticias/101922:El-Gobierno-Nacional-presenta-su-Plan-TIC-2018-2022-El-Futuro-Digital-es-de-Todos-Plazo-para-comentarios-cerrado>

¹⁶² <https://cintel.co>

5.2.4 Mexico

An example for Mexican digital creativity is “Mulaka”. The game was created by the local studio Lienza, which designed the virtual world together with a befriended ethnologist and representatives of the Tarahumara indigenous culture, the native people live in the northern State of Chihuahua, which is also home for the game-designers. Lienzo’s director explained: *“Living in Chihuahua, it’s really common for us to see and interact with the Tarahumara Tribe daily because they are still current. By that, I mean that they live among us, if you will. Not only in the reservations but here in the city.”*

This unusual cooperation ensured a realistic presentation of a surreal world. Each different character of “Mulaka” is based on myths and had been programmed with a basic, but efficient, Artificial Intelligence. The result is more than a video-game, but an interactive story-book.



Figure 41. Mulaka. Image with friendly permission from Lienza.

5.2.5 Panama

Panama is a small country located in Central America with a population of a bit more than 4 million inhabitants¹⁶³. Panama has been one of the fastest growing economies in the world in the last years¹⁶⁴. This growth has been supported by the Panama Canal and investments in infrastructure and, in lesser extent, by the Panama Air Hub, the financial and telecommunications sector.

The telecommunications sector appears as one of the economic elements. However, there is still a lack of IT-infrastructure in comparison with some countries. The percentage of mobile cellular systems coverage of the population is 96%. However, the percentage of LTE users at the beginning of 2020 was only around 50%. Nowadays, to our knowledge there is no date (or approximate date) for the implementation of 5G. In this subject, there has been in Panama a few academic initiatives related to the study of 5G systems¹⁶⁵.

¹⁶³ https://www.asep.gob.pa/wp-content/uploads/telecomunicaciones/estadisticas/2020/106-107_2020.pdf

¹⁶⁴ <https://www.worldbank.org/en/country/panama/overview>

¹⁶⁵ <https://elcapitalfinanciero.com/investigadores-panamenos-presentan-aplicaciones-de-las-tic/>

In 2020, the Panamanian government presented a plan called “Digital Agenda 2020.” This document presents the awareness of the government to adapt public policies to promote the transformation and modernization of the economy, and it includes their vision of some key facts which enables the digital transformation such as: IoT implementation, 5G services, and data science¹⁶⁶. Concerning data science, to fight against the COVID-19 the Panamanian Government Innovation Authority has developed several platforms based on artificial intelligence¹⁶⁷¹⁶⁸.

Panama is a country with a high level of biodiversity. In a territory of 75,420 km², Panama has 242 species of reptiles, 259 of mammals, 1377 of fishes, 976 birds, and 211 of amphibians. In addition, Panama has around 16,000 different types of plants¹⁶⁹. To help in the preservation of this biodiversity some works using machine learning techniques have been developed by Panamanian researchers to contribute to preservation of species like the manatee in Panamanian wetlands¹⁷⁰¹⁷¹.

In Panama, there is a lot of centralism in the capital city. So, (normally) during working days, many employees spend hours in the traffic jam. The Panama Digital Agenda 2020 includes some strategic lines to improve equality, social inclusion, transparency, and the transformation of the public administration. However, there is still a work to do in the digital transformation matter to improve the quality of life of the Panamanian citizens.

5.2.6 Uruguay

In spite of the small size and low population, the Country has been working very hard in the Digital Transformation initiatives for some time so far.

Uruguay deployed fiber optics to homes in every city as well as 5G deployments in selected urban areas. The Agency for Innovation and Research (ANII) and the Government Agency for Information AGESIC promoted the ranking of Uruguay in digital transformation among the first positions in the Latin American territory. A submarine fiber, in partnership with Google, connects Uruguay directly with the Hub of the Americas, providing independent access to one of the world’s internet important nodes.

A tier four Data Center, one of the largest in the region, is in place to warranty availability and resilience of the digital services and international connections. eHealth and eGovernment are in place as well as government apps for pandemic tracking and evaluation of potential spread of the pandemic with good results. Most official documents for the citizens can be accessed online with no need of presence in offices.

¹⁶⁶ <https://innovacion.gob.pa/documentosaig/agenda-digital/?csrt=15975890014454211426>

¹⁶⁷ <https://innovacion.gob.pa/aig-implementa-aplicacion-movil-paco-para-validar-que-pacientes-con-COVID-19-se-mantengan-en-sus-hogares/?csrt=15975890014454211426>

¹⁶⁸ <https://innovacion.gob.pa/aig-implementa-plataforma-virtual-rosa-para-atencion-en-pandemia-COVID-19/?csrt=15975890014454211426>

¹⁶⁹ <https://www.miambiente.gob.pa/biblioteca-virtual/>

¹⁷⁰ F. Merchan et al., Detection and Identification of Manatee Individual Vocalizations in Panamanian Wetlands Using Spectrogram Clustering, *The Journal of the Acoustical Society of America*, Vol. 146, N°3, pp. 1745-1757, September 2019.

¹⁷¹ J. Sanchez-Galan et al., Bioacoustic Classification of Antillean Manatee Vocalization Spectrograms Using Deep Convolutional Neural Networks, *Applied Sciences*, Vol. 10, N°3, pp. 1-22, April 2020.

Montevideo Municipality introduced Smart Cities applications for mobility, air quality, and water quality, a place for citizen claims on urban issues. All services are accessible to the citizenship via app, thanks to the digitalization of Municipality services.

Virtual education during the pandemic was possible for students from primary schools to universities due to the digital platform and services. For detailed vision of Uruguay's 2020 Digital Government Strategy 2020, we recommend to access the site <https://leadingdigitalgovs.org> where a 12-page pdf document covers with clear analysis the actual status and future activities in Digital Transformation.

The Government Agency for Information AGESIC has also published the Agenda Uruguay Digital 2020¹⁷² (in English).

Other organizations support the digital transformation like National Telecommunications Administration, Agency for Electronic Government and Information Society, Ceibal Center, National Statistics Institute, Ministry of Industry, Energy and Mining, URSEC Regulatory Unit for Communications Services, and involved agencies.

5.3 Far South East Asia

An interesting analysis¹⁷³ of the status of Digital Transformation in Asia looking at 11 Asian Countries was produced by Telstra and published by The Economist.

In this analysis, Singapore, South Korea, and Japan lead the way followed by Hong Kong, Taiwan, Malaysia, and China. Thailand, India, Philippines, and Indonesia close the group of analyzed countries.

5.3.1 China

China is notable for its strongly top down approach both in the Government/eCitizens area as well as in the "private" companies (although the influence of the government cannot be dismissed). In both cases, the top authority¹⁷⁴, like the CEO in private companies, is the one setting the tone, formulating the goals, and monitoring the deployment.

The adoption of smartphones in China is huge, with 55% penetration as of 2020¹⁷⁵ with much greater adoption in urban areas and the interest towards the very latest technology is au pair with Japan and South Korea. In June 2020, 1 out of 3 smartphones sold was 5G-enabled¹⁷⁶.

The adoption of digital technology has become clear to the world during the pandemic. The social life (do's and don'ts) were regulated via mobile platforms and smartphones. Based on the contagion risk, a person was given a token on the smartphone (color coded: red/stay home, yellow/ limited movement, green/ free to roam) that had to be used to enter public areas, transportation, shops, etc. That was possible because of the digital infrastructure supporting real-time data interchange and the ubiquitous

¹⁷² https://uruguaydigital.uy/wps/wcm/connect/urudigital/44f1500c-6415-4e21-aa33-1e5210527d94/Download+Digital+Agenda+%28English+Version%29.pdf?MOD=AJPERES&CONVERT_TO=url&CACHEID=44f1500c-6415-4e21-aa33-1e5210527d94

¹⁷³ <http://connectedfuture.economist.com/connecting-capabilities/article/connecting-capabilities/>

¹⁷⁴ <https://www.forbes.com/sites/briansolis/2019/06/26/the-state-of-digital-transformation-in-china/>

¹⁷⁵ <https://www.statista.com/statistics/321482/smartphone-user-penetration-in-china/>

¹⁷⁶ <https://www.counterpointresearch.com/one-three-smartphones-sold-5g-phone-china-q2-2020/>

presence of smartphones and readers. Additionally, safety cameras and artificial intelligence-based face recognition ensured full control in urban areas.

The concerns over privacy violation was not a point in China. Differently from Westerner's feelings, the Chinese, by far, are not seeing this as an intrusion in their private life, rather an appropriate guarantee to the societal wellbeing, and as such well accepted.

This is a very fundamental difference between the Far East and the Western world, and it is likely to have far reaching consequences in the evolution of the Digital Transformation that might put some companies in a better competitive position. The recent clash over TikTok is just another example of the differences between these two cultures.

In general, the private companies are seeing the Digital Transformation as an opportunity to increase flexibility in production and being China the "world factory," this is clearly very important. In addition, the digitization of customer behavior¹⁷⁷, like shopping online, is driving the Chinese economy, more so than in other parts of the world.

The eCommerce in China has reached 35%¹⁷⁸ of the whole retail economy, one of the highest percentage in the world and, in absolute terms, the first in the world.

More than that, the ecommerce in China is exploring new sales and customer interaction paradigms¹⁷⁹ merging entertainment with ecommerce, something that is not (yet) to be seen in other parts of the world.

5.3.2 India

As a demographic, India can be seen with 1.36 billion people speaking 22 languages spread across 28 states and 9 union territories. With 1.2 billion mobile phone subscriptions and 560 million internet subscribers in 2018, it is one of the largest and fastest-growing markets for digital consumers.

Competitive offerings by telecommunications firms have turbocharged internet subscriptions and data consumption. India intends to leapfrog with technology as an enabler. Technology and its impact on human lives is dispersed across major sectors of industries. The best approach to view the landscape is, from an ecosystem standpoint, focusing on vibrant start-ups.

¹⁷⁷ https://www.the-digital-insurer.com/wp-content/uploads/securepdfs/2020/01/1563-EI_14_2019_China-digital_transformation.pdf

¹⁷⁸ <https://www.marketingtochina.com/why-choose-us-to-develop-your-e-commerce-strategy-in-china/>

¹⁷⁹ <https://theconversation.com/how-china-is-revolutionising-e-commerce-with-an-injection-of-entertainment-131728>

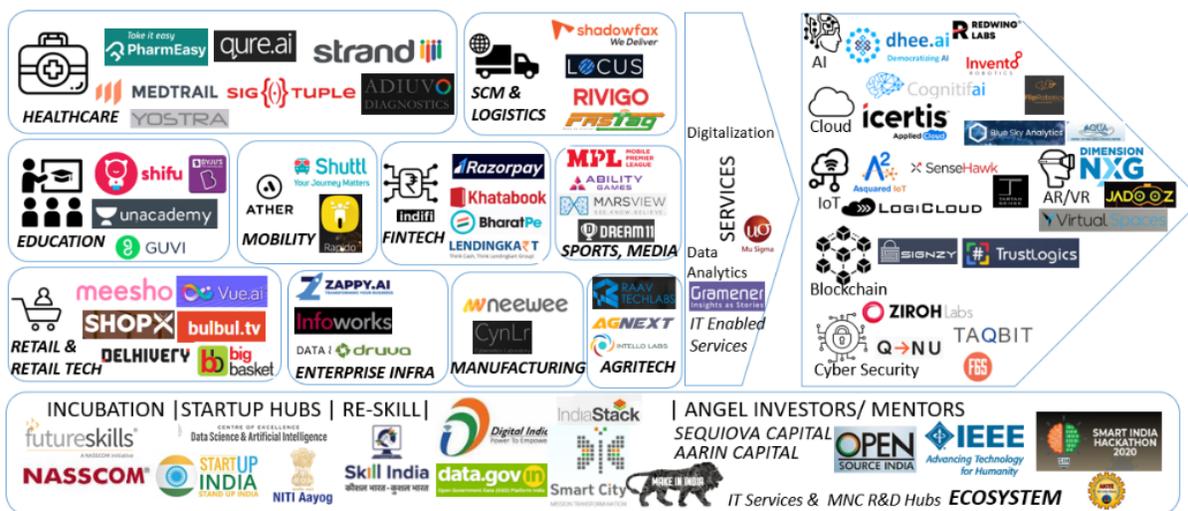


Figure 42. Indian Start-up Ecosystem.

The public and private sectors are both propelling digital consumption growth. The government has enrolled more than 1.2 billion Indians in its biometric digital identity programme, Aadhaar, and brought more than 10 million businesses onto a common digital platform through a goods and services tax is a major player.

Big initiatives like Smart Cities are being driven by the government and country's new planning body called NITI Ayog. It is interesting to observe that the Digital India program is applying Enterprise Architecture principles. The governmental data platform data.gov.in is an important ingredient as well as India Stack consisting of authentication using Aadhaar and the Unified Payments Infrastructure (UPI). NASSCOM, the association of companies plays a major role with its initiatives and Centers of Excellence. Start-Up India initiative, Make-In India, and start-up missions across states supported by NASSCOM make a blend of public and private participation. The participation of angel investors like Sequoia capital and Aarin capital and incubators across the country is paving way to support a pool of 8900 start-ups by 2019. With a strong presence and mentoring support, IIEEE also plays a key role in the ecosystem. A strong presence of communities like Open Source and the sessions they hold including conferences and initiatives like Smart India Hackathon involving educational institutions across the country have played a major role in igniting a maker revolution.

India had been home to 5 of the 10 major IT services companies with major players like TCS, Wipro and Infosys, HCL, and Cognizant to name a few. Further to this, it hosts a major of world's Research and Development Hubs across a variety of electronics and software based industries. The availability of rich engineering talent and global expertise seems to benefit India as the ecosystem emerges and builds itself on the start-up initiatives. We can see major digital advancements in sectors of shared economy, retail, enterprise data and cloud, agricultural technologies, educational technologies, and gaming. On the emerging technologies and Industry 4.0 segments, we see few niche players.

Shared Economy and Retail

Shared Economy players include Shuttl which is focusing on affordable bus rides while Rapido is focused on bike taxi. Ather energy, an organization focused on connected electric scooters, is playing a role in electric mobility while OLA electric are focused on building infrastructure.

On the retail segment, bigbasket focusing on online grocery and DELHIVERY, a supply chain provider, recently became unicorns demonstrating the growing demand for retail and supply chain. Platforms like meesho focus on social commerce while Vue.ai focuses on improving customer experiences using AI. SHOPX is a company focused on enabling retailers in ecommerce in a local market, while Bulbul is a streaming based ecommerce App.

Enterprise Data, Cloud, Manufacturing and Agriculture

Enterprise Data operations and orchestration is the focus of Infoworks, while druva focuses on cloud backups while Zappy.ai focuses on automation using data driven approaches.

On the manufacturing aspect, neewee focuses on Digital Twins powering Industry 4.0 while CynLr focuses on visual object detection and pick and place operations. Agricultural technologies are on the rise with companies like Raav TechLabs focusing on AI based Quality analysis, IntelloLabs on digitizing quality across agriculture supply chains, AGNEXT focusing on improving quality and ensuring food traceability using digital technologies.

Education, Gaming, FinTech

On the education segment, Byjus is a leading player of solutions, while unacademy provides subscription based learning platform while guvi supports learning in local languages. Digitalization of lending like LendingKart and Khatabook enable personal ledgers on the phone for many small businesses.

On the gaming segment, cricket and similar games are played on Dream11, a prime platform for playing while many players like Ability games, MARSVIEW, and MPL show an impressive spread. On FinTech, the growth in payments are being supported by IndiaStack. RazorPay, Pine Labs, and BharatPe are some of the key initiatives.

Healthcare, Supply Chain and Logistics

Healthcare sectors have start-ups like PharmEasy making pharma online, Yostra labs working on innovations in diagnostics. Medtrail is about AI powered smart assistants for doctors while SigTuple focuses on Smart screening using AI and medical data, qure.ai focuses on AI algorithms for medical imaging. Born out of Indian Institute of Science, Strand Life sciences is an important company to notice in the world of precision medicine solutions for better healthcare decisions.

In the Supply Chain and Logistics segment, while Fastag is built on IndiaStack for electronic toll collection at highways, shadowfax focuses on last mile delivery, while RIVIGO is a platform for transforming logistics by aggregating trucks and empowering drivers. LOCUS is another start-up focusing on optimizing supply chain with advanced technology.

Datascience Consulting

Niche Consulting in Data Sciences and Business Intelligence is provided by Gramener and MuSigma. This is also the focus for Digital Transformations initiated by IT Services companies.

Emerging Technologies in areas of Cyber Security, AI, IoT, Virtual/Mixed Reality

On the cybersecurity front, QNU and taqbit work on Quantum technology, ZIROH labs on privacy engineering.

Vernacular language technologies using AI is the focus of DheeYantra's platform dhee.ai, while Signzy focuses on automating back office operations through AI, digital compliance with Blockchain technologies. TrustLogics uses Blockchain solutions for connecting job seekers with recruiters. Asquared IoT focuses on AI and IoT for manufacturing, SenseHawk provides a cloud-based platform to support everything from solar plant design and construction to operation and maintenance. LogiCloud focuses on supply chain partners integrated with leading transporters, FlightAware and Indian Railways, to give you seamless visibility of your deliveries. Tartansense focuses on autonomous rovers and precision agriculture.

Icertis focuses on enterprise smart contract management. Congnitifai focuses on open platform for vision AI workflows. Invento robotics focuses on service robotics including personal robots for kids learning. Redwing Labs focuses on drones for Medical and similar applications.

Dimension NXG focuses on Mixed Reality Glasses for augmenting human intelligence, JADDOZ on VR in Cinema, while VirtualSpaces focuses on AR/VR in Real Estate.

5.3.3 Japan

Although Japan was among the first to push, as a country system, towards digitalization, much remains to be done¹⁸⁰. In 2020, the Government has made a further push towards the digital transformation of the public administration, particularly so after the pandemic highlighted the hurdles still present in the public offices when they have to shift to the cyberspace. Even using, in a massive and continuous way, conference calls proved to be a challenge for many public servants. There is a penchant in the government offices for paper and seal of approval¹⁸¹ that it is difficult to change being entrenched in the Japanese culture. This is also affecting the private sector.

On the positive side, the telecommunications infrastructure in Japan is one of the most advanced ones in the world, also due to a demand that keeps being strong for the latest available technologies.

The penetration of smartphones is among the highest in the world (79% in 2020, expected to reach 90% by 2024¹⁸²) and the fixed broadband infrastructure is pervasive. 5G is being deployed, and all 4 MNO in Japan are offering 5G connectivity. The latest data¹⁸³ (July 2020) from NTT Docomo signal 240,000 5G subscribers that are expected to reach 2.4 million by the end of March 2021 (a 3-month delay due to the epidemics and postponement of the Olympics to 2021). There is a theoretical premium price on 5G, but in fact through offers and discounts, it is being offered at the same price of current wireless services. In the medium term, it is expected that the price per GB will be lower than current pricing for 4G.

The pandemic has put stronger pressure on Japan to accelerate the implementation of the digital transformation:

- the Government has approved regulation to enable and foster telemedicine.
- remote working has been enforced in several sectors and regulations have been changed.
- Government pressure is put on both offers (deployment of infrastructures like 5G and increased reach of fiber) and demand by accelerating eCitizens services and Industry 4.0.

¹⁸⁰ <https://www.japantimes.co.jp/news/2020/07/25/national/japanese-government-digital-paper/>

¹⁸¹ <https://www.nyoooz.com/features/technology/japan-still-stuck-with-paper-despite-20-years-of-digital-transformation.html/4183/>

¹⁸² <https://www.statista.com/statistics/275102/share-of-the-population-to-own-a-smartphone-japan/>

¹⁸³ <https://www.rcrwireless.com/20200804/5g/ntt-docomo-ends-july-240000-5g-subscribers-ceo>

- Focus on the digital divide and implementation of measures to avoid it.

In a society and culture that is very much sensitive to preserving traditions, COVID-19 has probably provided the push needed to face the Digital Transformation revolution.

5.3.4 Singapore

Singapore has been one of the fore-runners in “buying” onto the Digital Transformation and executing it both at Government and private sector level.



Figure 43. The Singapore logo/brand to foster awareness on Digital Economy.

The Government has been leading the transformation. They have set up a multi-year plan (most of it already executed) and invested significantly on providing citizens with a positive image of the Digital Economy. The brand SG:D¹⁸⁴ shown in the picture has been used to emphasise the “smiling” face of Digital Singapore.

Starting January 1st, 2019, Singapore was the first city to have a Digital Twin, mirroring the city status and connecting to many operational processes like traffic, transportation, power grid, and waste management. Any company intending to build something needs to submit the request in the form of a Digital Twin. This will be interacting with Singapore Digital Twin, allowing simulation of the impact of the intended construction. Furthermore, once the construction has been approved the Singapore Digital Twin will embed the new Digital Twin and interact with it. If, as an example, a fire develops in a mall, firemen will use the mall Digital Twin to be informed of safety systems as well as the number of people that are trapped inside the mall. From this example, it is clear that the Singapore Digital Twin is being used on all stages of a smart city, from design to operation.

The Government of Singapore is leading¹⁸⁵ the digital transformation providing the framework for the private business. An interesting point is that Singapore sees the Digital Transformation as a continuum and is already looking at the impact that new emerging technologies might have in the coming years. For them, the DT is more a state of mind than a point of arrival. For that they are building a number of capability centers:

- Sensors and IoT: providing the transducer to move from atoms to bits
- Data Science: providing the capability to create intelligence
- Government ICT Infrastructure: supporting the connection between atoms and bits

¹⁸⁴ https://www.imda.gov.sg/infocomm-media-landscape/SGDigital?utm_medium=sem&utm_source=google&utm_campaign=generic&utm_content=sgdigital

¹⁸⁵ <https://www.tech.gov.sg/digital-government-transformation/>

- Cybersecurity: ensuring the security of the overall system and trust
- Application development: fostering third party development of services

Recently the Government has budgeted¹⁸⁶ \$352MS to help small businesses to execute Digital Transformation. This is a further sign that Singapore sees the need to have the whole business and society adopting the Digital Transformation. Given their, relatively, small size, it is easier to pursue the DT and see the impact, which in turn creates credibility and stimulates further adoption.

5.3.5 South Korea

South Korea has been ranked in the top position of many Digital Indexes¹⁸⁷(second as ICT development index in 2018, third as eGovernment Development Index in 2018). The telecom infrastructure is very advanced, one of the first to start deployment of the 5G, sustained by a consumer market that is willing to pay more to get the very latest (and best). The replacement time for smartphone¹⁸⁸ averages between 2 and 2.5 years, one of the lowest in the world. This sustains innovation and makes it possible for the rapid evolution of applications and services.

The South Korean Government has announced¹⁸⁹ the plan to shift all public services, or access to them, in the cyberspace. Citizens will have access to all data that are owned by the Government and relates to their life /social and business/ through the cyberspace and will be able to use Cloud and Artificial Intelligence-based service to leverage on them. Part of the plan includes the use of mobile digital wallets to store identities and data. By 2021, the mobile platform will support over 300 types of digital certificates.

Digital Notification services will be activated from birth to death, giving the possibility of remote access to welfare services and to information including search for jobs and setting up companies.

Citizens will be free to identify what data they want to share with the mobile platform knowing that the more data are shared, the better and more comprehensive the services they can access.

This approach is very interesting because it puts the balance of privacy vs services in the hands of the citizens.

5.4 Australia

Australian Government set up a Digital Transformation Strategy¹⁹⁰, releasing it in November 2018 with a roadmap targeting 2025 for its full implementation. It contains 13 objectives that are guiding its implementation.

The founding principle is interesting. The Government flatly states that the more data citizens are willing to share, the better services they can get. However, the sharing of personal data is completely under the

¹⁸⁶ <https://www.zdnet.com/article/singapore-puts-352m-focus-on-digital-transformation-to-help-firms-cope-with-pandemic-fallout/>

¹⁸⁷ <https://www.ecofinagency.com/telecom/1710-39101-south-korea-reveals-its-digital-transformation-strategy-to-developing-countries>

¹⁸⁸ <https://www.statista.com/statistics/897636/south-korea-smartphone-replacement-cycle/>

¹⁸⁹ <https://technology.inquirer.net/91916/south-korea-plans-to-digitalize-public-services-through-smartphones>

¹⁹⁰ <https://www.dta.gov.au/digital-transformation-strategy>

control of the citizen that might elect not to share anything. In this case, the Government provides an alternative way to access services (objective 4).

It is expected that most people will move to the cyberspace to interact with the Government. They will be able to access all services using a single digital identity (objective 3). All branches of the Government, central and regional, are committed to provide digital access to all services by 2025 (objective 1). All services will be seamlessly integrated (objective 2).

The level of service a citizen will get will depend on the amount of data that citizen chooses to share with the Government (objective 5). The data shared are neutralized for use in data analytics to support planning (objective 6).

Another important point in the Government Digital Transformation Strategy is to use advanced analytics, including artificial intelligence, but only to the extent that these will result in transparent and auditable processing (objective 7).

The strategic plan includes provision to improve education towards execution and adoption of the DX by both citizens and business, an important aspect that characterizes the Australian Government approach. This is seen instrumental both for speeding up the transformation and for creating a competitive advantage that can be applied in foreign trade.

The Australian Government will support its DX by deploying open platforms that can be used by third parties and aims at collaborating with private DX initiatives to ensure interoperability and synergy of efforts.

5.5 Africa

Africa is a continent with many different cultures and economies. One of the first moves has been to work for a single Digital Market for Africa with the aim of fostering the transformation from a purely consuming society into a production and consumer society in the global economy. This requires investment in education and infrastructures, with the former seeing the IEEE as a contributor to develop¹⁹¹ engineering skills, communities, and capacity development:

- Goal 1: Support engineering education and workforce development
- Goal 2: Build a sustainable community of IEEE members and volunteers
- Goal 3: Support government policy development and increase opportunities for IEEE to serve as a resource for engineering capacity development

A document outlining the Digital Transformation Strategy for Africa has been published¹⁹² with a ten-year roadmap (2020-2030). The document has been prepared by the African Union Commission. Indeed, as pointed out in the document, digitalization of Africa can be the first chance to achieve worldwide relevance as a single continent going beyond the profound cultural differences and diversity of economic assets.

¹⁹¹ <https://www.ieee.org/about/ieee-in-africa.html>

¹⁹² <https://www.southsouth-galaxy.org/publications/the-digital-transformation-strategy-for-africa-2020-2030/>

6 The Societal aspects of the Digital Transformation

As it has been the case with the agricultural, with the industrial revolutions, the Digital Transformation goes well beyond an impact on business. It affects the whole societal structures in its various aspects, ethical, political, and way of living. The impact is far from uniform, different geographical areas (see section 5) are adopting the DX with different degrees and at different times. Additionally, cultures differ and so does the impact of DX on them.

In this section a number of aspects, from epistemology to digital divide, from jobs to political frameworks are addressed. They are not intended to provide “solutions” nor to point at what would be better. They are addressed to stimulate reflection on these aspects as a crucial component in the DX.

6.1 Epistemology

Epistemology is the theory of knowledge (it derives from the Greek words “episteme” for knowledge/understanding and “logos” for argument/reason), discussing methods, validity, and scope, also addressing the distinction between justified belief and opinion.

This is a fundamental aspect of DX, even more evident today as the web is perceived as the Illuminists Encyclopedia, the repository of humankind knowledge and yet it is pervaded by fake news. More than that, the rise of Artificial Intelligence and the possibility of creating “artificial knowledge” creates new problems. There might even be “true” facts created by machines that are beyond our capability of assessing their truth (this will become an even more thorny issue¹⁹³ as quantum computers will be used to generate knowledge). Of course, a consequence is that there may also be “untrue” facts created by machines we won’t be able to recognize as such.

Independently of these thresholds situations, the big issue is that people’s beliefs are more and more influenced by the cyberspace and it is becoming easier and easier to influence people through it. The extension of the cyberspace is such that it is no longer perceived as a whole, rather different communities are growing around subsets of it as shown by the rise of “sovranism” and “sectarism”. Each of them is strong in its belief of truth “because” it is supported by that part of the cyberspace that is becoming more and more self-referential.

Hence the need for understanding the new epistemology created by the DX and addressing it.

6.1.1 AI between law and ethics

If intelligence has been our main means of defense with the development of an increasingly complex and effective language for pooling knowledge, it seems logical that artificial intelligence, after years of disillusionment thanks to the arrival of increasingly powerful computing tools and access to ever more numerous and precise data, has once again become the dominant objective of technical progress. By now, AI is found in all manners of human and professional business. Let us take the case of the use of AI in the human resources (HR) sector. Throughout the interview of the candidate, a camera focuses on his or her face and AI somehow penetrates the person, detects his or her expressions, monitors his or her every gesture, and analyzes it all with powerful programs to advise or refuse hiring and even in some cases to build a file to which he or she will not have access and which will preclude any possibility of employment in the category. This is undoubtedly a meeting point between the AI and the human person and perhaps even a step in metamorphosis. This is where artificial intelligence reaches the heart of the

¹⁹³ <https://www.quantamagazine.org/in-computers-we-trust-20130222/>

subject, so to speak. The irreversible and unstoppable consequences of these practices (and of all the other applications of AI to human affairs) will lead to an industrialization of the evaluation of the person, and therefore of that person. The result, in any case, will be a kind of depersonalization for the benefit of industrial efficiency, human values included. Candidates will be considered as appropriate or unsuitable tools. The hiring decision, in the end, will have been made by algorithms assisted by human beings and, who knows, since it is just a video, nothing will prevent the process from being automated and happen online, also optimizing costs.

Artificial intelligence is replacing two fundamental interpersonal factors of live human interaction, the human relationship and the role of intuition in assumptions. It is not the possible errors of the machine (against which an entire legal apparatus is being set up), it is the status of the human being itself that is in question. More than twenty years ago, the first online dating sites offered lists of criteria and qualities or defects that could be checked to determine the desired compatibility of each potential candidate for a life together (or for simpler experiences)¹⁹⁴. Although at the time, this could still be seen as a simply mechanized application of common practices in partner selection, it could not fail to be perceived also as a surreptitious threat of depersonalization, considering that the choice of anyone according to criteria other than intuition and spontaneity was crassly self-serving. A shift in values was underway.

To the potential effects of AI applications for the evaluation and, ultimately, the judgement of the individual, one must add and take into account those of automated traceability and appropriation of features and gestures and of all the cognitive, psychological, and emotional content of any individual. In this context, AI plays in a set of transformations that are still taking place out of the reach of constitutional or legal rules, for lack of hindsight, and for lack, precisely, of ethical references to guide them. The first victims of this lack are the right to privacy, psychological autonomy, free will, the right to self-determination, and the reputation of all and anyone. And behind these deep social undercurrents, there is a growing tendency, especially in Far Eastern countries, to shift priorities from the individual to the social and the community. All this, although very worrying for Westerners, is not necessarily a bad thing in cultures that have, for millenaries, placed community interest over individual rights. The rights of the Western individual came late in the evolution of societies and after long deliberations. And even in the West, there have been long periods of time when the needs of the community took precedence over those of the individual without discussion or resistance.

6.1.2 Digital Transformation and Industrialisation - and appropriation – of the Individual's cognitive properties

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¹⁹⁴ For an interesting timeline of love supporting technology take a look at this infographic:
<http://archive.pov.org/xoxosms/infographic-technology-dating/>

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6.1.3 Outsourcing of Judgement

At a time when algorithms intervene in people's decision-making process, it is all the more important to address the issue of free will. AI is the spearhead of the progressive externalization of our cognitive faculties and also of our unconscious. The passage of information from the page to the screen (be it television, computer or smartphone) has promoted for several decades now the externalization of a large part of our cognitive abilities, starting with the loss of the exclusive and private possession of language and thought that we have acquired through the learning of reading. As explained above, internalized in the form of thought, the text fixed on the page, is entirely dedicated to the integration and silent interpretation or rumination of what is written. As soon as it appears on a screen, interactive and illustrated with fluid and changing images, the message of the text begins to emerge from the intimate and private treatment of people who are no longer considered as "readers" but as "users." Speech and thought become, so to speak, "public." Lev Manovich made the same observation in a different context talking about photographic representations (photos, films, videos, television) but not yet about AI, the article dating back to 1995.

What to make of this desire to externalize the mind? In this essay, I will relate it to the demand of modern mass society for standardization. The subjects have to be standardized, and the means by which they are standardized need to be standardized as well. Hence the objectification of internal, private mental processes, and their equation with external visual forms which can be easily manipulated, mass produced, and standardized on its own. The private and individual is translated into the public and becomes regulated.

What before was a mental process, a uniquely individual state, now became part of a public sphere. Unobservable and interior processes and representations were taken out of individual heads and put outside, as photographs, films, and other visual forms. Now they could be discussed in public, employed in teaching and propaganda, standardized, and mass-distributed. What was private became public. What was unique became mass-produced. What was hidden in an individual's mind became shared.¹⁹⁵

Again, the damage would not be so serious if memory, intelligence, imagination, and judgment were not confused and lost in the maze of networks and databases. Our identity markers fill the databases and most of our relationships are done through a screen. From now on, to remind us of the facts, we delegate them to machines, like our photos that fill the "memory" of our smartphones that sooner or later we lose or are stolen. Struck by intermittent amnesia, we are on the verge of relying on systems that are "smarter" than us and let them think for us and then judge for us. The result is a kind of individual identity crisis.

¹⁹⁵ Lev MANOVICH (1995), From the externalization of the psyche to the implantation of technology, page: http://manovich.net/content/04-projects/006-from-the-externalization-of-the-psyche-to-the-implantation-of-technology/04_article_1995.pdf.

6.1.3.1 The identity crisis

Our present age of difficult transition from one dominant medium to another can only be compared to the Renaissance, if not for the duration, at least for the trauma of social struggles, pain and anxiety, as it introduces a global identity crisis. Regardless of culture or belief, every human being today is directly or indirectly exposed to the threats that digital communication and archiving pose to individual and social forms of identity. The relentless resort to 'selfies' could be interpreted as an unconscious need to reassure oneself about one's presence in the world (a bit like pinching oneself to make sure that one isn't dreaming).

There are many reasons why people lose their private identity online, even as they gather in unevenly connected communities of interest to find one. The main reason is that everything that constitutes our "I" or our memory, our intelligence, and our judgment, in other words our "content," migrates to a database through some tracing device. In return, our mind is full of content that is pushed within us by algorithmic - d caricatural representations of what we might need or want and that serves a state or an industry (as in the case of Cambridge Analytica).

These representations are not really our identity, but serve as a format to which we adhere at the cost of not really developing who we are or could become without this surreptitious and continuous "formation" that serves interests other than our own. Another reason is that online, we can choose to be anonymous or even create false identities for ourselves, and hide ourselves if not from the possibility for others to track any digital activity, at least from the users we engage with, for whatever purpose. This, together with the gradual weakening of our judgment, allows us to get rid of any responsibility to anyone. I can be responsible to the community, the family or myself in physical space, but never to the same extent in virtual space.

Online, we have no shame, no guilt. And, of course, the lower the level of education, the lower the resistance to impulse. To somehow recover this loss of identity and lack of responsibility, people will join hate groups and perhaps, because weakness requires a simulation of power, they could also resort to violence. Fascism and racism are obvious effects of the loss of identity. People, not finding common sense or motivation in themselves and fearing to be left alone, find the cause and comfort in achieving a more defined goal in others, which is very easy to do online. At the level of nations, this condition introduced by digitization leads voters to elect tyrants (fascism) and to polarize around systematic identification of skin color (racism). With the disproportionate means available not only to nations, but also to each of us, the violence suffered and still to be suffered in this painful transition from literacy to electricity can cause irreparable damage. The question is again, once we have become transparent, what kind of ethical order would be consistent enough to resist tyranny?

6.1.3.2 The crisis of meaning and the end of objectivity

A second crisis, less obvious but perhaps equally serious in the long term, is epistemological. Knowledge itself is changing. Based on numerical algorithms, AI presents a radical new starting point with respect to linguistic strategies for the construction of meaning. At least until today, artificial intelligence needs neither meaning nor consciousness, only algorithms, impenetrable commands. Languages too, as well as the sensory faculties of all living beings, can be considered as algorithmic functions, since their principle of functioning is to formulate and direct actions. Re-reading Giambattista Vico, we understand that the first animal, and therefore human, algorithms were shouts, grunts, and calls. These gave meaning to all expressions of pain, fear, joy, desire, intention, and to all other expressions of life. Then came the structured language of man, which became more and more complex until the invention of writing and

all other media that necessarily imply the mediation of meaning, not only in their statements, but especially in their elaboration.

The digital algorithm, however, does not need meaning; it is the first medium that goes from cause to effect, or from question to answer without semantic mediation. The algorithm's logic is based exclusively on a series of instructions, not meanings. In fact, we do not always realize that the digital algorithm never needs any other than machine language, and that kind doesn't need to make sense, commands only. For example, Google Translate does not know any language and never needs to know them because it only needs to recognize the shapes of the words and phrases to be translated in order to compare them with billions of models in Google's databases. The numerical algorithm, while producing a meaning for the user, does so without the use of language and, most of the time, without explanation. The consequences of this new situation must be studied carefully in the epistemological crisis we are going through. This profound crisis of meaning is reflected, among other things, in the chaos of the infodemia, but also in the challenges to science and in the negation of objectivity, largely effects of the digital transformation in progress.

On the one hand, there is the disappearance of the "referent," that is most people do not bother to verify the truthfulness or even the credibility of the statements they hear. In linguistics, one of the foundations of semiotics is the "triad of the sign," the relationship between *signifier* (the sign, word or object that is present), meaning or *signified* (what the sign represents in your mind), and *referent* (what this meaning refers to, that is, something, concept, object or even fiction, which, in one way or another, actually exists somewhere, regardless of the sign itself). The referent gives the guarantee that the semantic relationship between signifier and its meaning is valid. Having said that, even lies and jokes, though false, imply a referent. It should be enough to verify it or take it as a joke, but that is precisely what gullible people do not do.

The current problem stems from the fact that statements on networks can be transmitted to thousands of people on the basis of a vague intuition or a tenuous relationship between the signifier, i.e. the statement and its social or political context to be transmitted without prior verification. The consequence of this semiotic change is that more people do not feel the need to verify the authenticity of the statements, and therefore the need for the truth itself. The epistemological crisis begins when too many people no longer distinguish the difference between objectivity and subjectivity, or give priority to subjectivity without any other form of proof. It goes without saying that individual judgment suffers from this disinterest in the reality of statements. Politically, this is one of the foundations of populism, a spontaneous unchecked adherence to statements made by shameless leaders whose repeated lies are aimed at emotional rather than cognitive and rational reactions.

On the other hand, the reduction of all formats, meanings, and materials to digital binary code not only facilitates the creation of deep forgeries, but the speed of their (viral) distribution and the growing volume of their audience are still able to guarantee almost instant political, emotional, and financial benefits. On the networks, these activities are available to anyone and industrialized even almost free of charge, and many are also maliciously entertaining or shocking.

The crisis of meaning is now explosive, not only because people take their desires for reality, but because at the highest level of human affairs, algorithms are replacing classic rationality in making decisions. It is not only the referent that disappears into the mindset of less educated populations, but meaning itself is sidestepped by algorithmic logic. The epistemological crisis of AI is contemporary, and

perhaps complementary, to that of meaning in global culture. In the West, at any rate, there is a dangerous indifference to the obviousness, rationality, and objectivity of a world of common references.

There are many occurrences of good use of AI in all priority areas of human affairs, legal, medical, financial, military, administrative, educational, in security, and research and many other fields. At this stage, there is no going back, and all the Luddite efforts bringing down 5G towers and others will not be able to slow, let alone stop, the digital transformation. And since the crisis of meaning already finds us powerless, all this will lead us to resign ourselves to trust artificial intelligence more than our own judgment. It is therefore in the algorithm that the principles of "reality" and objectivity, without which a valid decision cannot be made, will end up taking refuge. Judgment may thus pass definitively from the head to the machine.

But, it is here that the most decisive part for the future of mankind is at stake: the most serious part, without doubt, of the externalization of judgement will be the loss of psychological autonomy and, above all, the loss of meaning, and even the need for self-determination, like the disparity between Eastern and Western cultures. The difference between the two cultures is radical: if the fault remains unknown, there is no guilt in the culture of shame, and there is no shame; on the contrary, even if no one knows it, the guilty person suffers, despite his or her secret, from remorse for the error or fault.

Again, why venture so far from arguments directly concerning AI? Because the core of Western ethics and law lies in the deep-seated literate motivations of behavior within the body and the mind of the person. And the real problem, therefore, is the current reversal of the trend, the return of motivation outside the person under digital conditions. It begins by letting Alexa take control of your desires and ends up in tolerating some westernized variation on "Social Credits." Suffices to meditate on the social and political consequences of this practice, now common in China, of monitoring and permanently evaluating people to be convinced that henceforth moral behavior and ethical conduct may be imposed from without rather than inspired from within. It is here that a new ethic is being born, fully in line with the main lines of force of the digital transition.

6.1.4 Ethics is a human quality; can it be taught to Machines?

Can ethics be taught to machines? Yes, and no. Since ethical conduct depends on a comprehensive analysis of several contextual factors. Nothing prevents a well-behaved AI from doing what it does best, i.e. analyzing a complex situation taking into account all relevant factors, including emotional data and the rules of good conduct with respect to the research or action being conducted. In this case, to ensure that the machine does not take a wrong turn, it would be sufficient to collect data on all relevant parameters and to have previously certified their quality and "cleanliness." However, it cannot always be guaranteed that the procedure will avoid any kind of possible error. Many injustices have already occurred and are still occurring, for example, in tendentious selections based on color or social status, or in the involuntary grimace of the subject examined and judged by video.

As regards the introduction of ethical principles into the very functioning of AI, this is undoubtedly possible, but with enormous reservations, the first of which is the ethics to be introduced. Can one ever rely enough on one's own assumptions to entrust them to prescriptive automation? Ethics is always based on the relationship with oneself or with the other; it is based on the sense of responsibility and the culture in which it is mainly applied, not to mention the language spoken by the user, which contains its own prejudices. Despite all the efforts of philosophy to achieve universals, ethics is not universal. For example, the idea of democracy invites us to confirm and even legitimize our typically Western way of living and thinking: "I am a free, independent, and unique person in a neutral and free space." But this

statement is increasingly becoming an illusion. The person may still be unique and individual physically, but as long as one's cognitive and emotional experience is shared and distributed in a thousand ways online, one is no longer psychologically independent. More than that, there may not be much personal space in a mind overwhelmed by tracking, suggesting and general "decervelage" practices ('debraining' to put Alfred Jarry's expression back into circulation). On the Internet, people are not really free and space is no longer neutral or democratic.

The main problem, therefore, is not related to the ethical use of technology, although this is certainly worrying. The fundamental problem is that, as usual, every important change in social technology changes social ethics. Thanks to digital technologies, the ethics of the person becomes that of the social person. While literacy has created divisions, categories, separations, and individual ethics, digital brings everything together and opens up all barriers.

Come to think of it, when we begin to explore existing ethical concepts, what they lack principally is vigor. Words like autonomy, goodwill, not malice, justice and so on are read here and there. If we go a bit further, we will come across "respect for the rights and dignity of the person," and even further we will find the concept of responsibility, which today is put to the test in the endless explanations about "who is to blame" in cases of accidents involving autonomous driving. We end up thinking that the French motto itself "Liberté, égalité, fraternité" is much more vigorous. It has at least the merit of considering the social and the personal at the same time. However, it still depends on the civil code known as the Napoleonic Code, published in 1804, far from taking AI into account. What is changing ethically in the digital transformation?

The first thing, as previously intuited, is the status of the person, a paradoxical change in that the digitally-assisted, otherwise known as augmented human, as both overwhelmingly powerful and reduced to obedience. Humans "increased" by the machine, and among other things by artificial intelligence, have at their disposal means unprecedented in history, including access to all the knowledge and memory of the world to countless communication and production services, not to mention the means of health, wealth, safety, and transport to the humblest services, all of which to make life easier. And to this new extraordinary power, as such, jurisprudence gives little sign of attention. On the contrary, this same human being is reduced to the progressive and humiliating dissolution of one's interiority, which has now been handed over to external interests. It is certainly not a question of "freedom of conscience" because an invaded conscience can no longer claim to be free. This condition deprives it of any form of dignity, once the cornerstone of the ethics of the person. Here too, despite the laudable efforts of the European community (see GDPR etc.), jurisprudence is still rather weak.

The question of AI's education in ethical behavior therefore remains open, but in the meantime one could be satisfied with the conclusion of the European Court of Human Rights cited in an excellent study on the subject: "The ECtHR has established that impartiality must be assessed on the basis of a subjective approach, in order to determine the personal conviction of a judge on such an occasion, but also according to an objective approach, to ensure that sufficient safeguards are offered to exclude any legitimate doubt in this respect." The test of a 'subjective approach' may be hard, if not impossible, to conduct on an AI court or tool. But maybe that is one of the most attractive features of an AI based technology: it has no subjectivity at all. From a practical perspective, when using an AI based tool, this part of the test should not be applied or otherwise it is also another concept to be redefined by the ECtHR. Finally, the Court has established that impartiality is also guaranteed by the identification of the

judges who rendered the decision. This is a factor of undeniable relevance if and when a case should be decided by an AI.¹⁹⁶

The key word in the quote above is that AI 'has no subjectivity.' In the general confusion of 'post-truth,' the algorithmic verdict may well be presented in an already foreseeable future as the manifestation of impartiality, so to speak, of objectivity. What kind of legal approach can be given to the algorithm? What should we take into account, the apparent objectivity of Roman law, with its code of reference whose principle dates back to Greco-Roman antiquity and the publication of the laws on the city walls? Or the flexibility and contextualization of Anglo-Saxon common law to adapt to the analysis of Big Data, a system now capable of greater precision and speed in the search for parameters relevant to cases and especially to previous sentences?

Since the digital transformation is now anchored to artificial intelligence and algorithms rather than to the meaning of language, it is changing the basis on which the whole history of civil or common law is based. It might be appropriate, as it is beginning to happen in various jurisdictions around the world, to rethink the law in the terms of the new media that support it.

Or, should we lay down our arms and consent without resistance to the unbridled industrialization that is taking place, and suffer it from a totally rational economic perspective? The problem addressed here goes far beyond the mere question of law and probably also of ethics because, in the end, we will have to admit sooner or later that all our pious intentions regarding the verification of AI procedures and practices in recruitment and other issues are reduced to wishful thinking in face of the digital behemoth. As Marshall McLuhan told me many times: "Trying to protect your private identity from electricity is like trying to swim against a tidal wave." So we'll probably have to negotiate our freedoms with the machines.¹⁹⁷

6.2 New skills and education – XR and Cyber-Physical-Social Eco-Society Systems in Education

Education is an important societal component and a vital area for future development. Organizations, governments, scholar communities, and individuals are committed to keep leveraging new and emerging digital technologies, for instance Augmented (AR), Virtual (VR), Mixed (MR), Extended (XR) Realities, Digital Twins, etc. to deliver knowledge to students and to the industry. The education market is worth billions and will continue to grow and it is crucial to ensure efficient access to knowledge and its delivery, as well as exploit knowledge as a service. Learning with the use of immersive technologies has never been more exciting than nowadays. A wide range of immersive tools and hardware devices are at the disposal of educators, enriching their teaching toolbox with solutions that can support and enhance current teaching and learning practices. Over the past few years, there has been a significant increase in the use of XR environments to support and enhance learning, and the focus of this section is to highlight the main directions in the utilization of Extended Realities in education at present.

6.2.1 VR in Education

VR has drawn significant interest in its use and application for educational purposes. The Oxford dictionary defines VR as a "computer-generated simulation of a three-dimensional image or environment

¹⁹⁶ Paulo GOMES et al. *Artificial Intelligence and the Judicial Ruling*, (2019), page 249.

<http://www.ejtn.eu/PageFiles/17916/TEAM%20PORTUGAL%20I%20TH%202019%20D.pdf>

¹⁹⁷ Personal communication.

that can be interacted with in a seemingly real or physical way by a person using special electronic equipment, such as a helmet with a screen inside or gloves fitted with sensors." VR is frequently employed in education to enable the development of immersive learning environments in which learners can interact with and be part of the lesson instead of than the tool¹⁹⁸.

After decades of expensive hardware requirements, technical glitches, and other issues hindering VR mainstream implementation, it is now a mature and customer-ready technology. Powerful computers that can support high fidelity VR experiences are now at reasonable prices, in portable and lightweight sizes. According to Hussein & Nätterdal¹⁹⁹, *"the differences between modern VR compared to the concept of VR presented two decades ago is that the technology is finally at the stage where it can be adapted to any mobile phone."* Students have powerful computing devices in their pockets, their smartphones, and mainly use them for recording and sharing videos and multimedia, experiencing face filters, playing games, watching videos, social networking, etc. Smartphones have become an integral part of our everyday lives and can be even considered an 'extension' of our brain. As previously indicated in our Symbiotic Autonomous Systems White Paper III, we are using on average ten different applications every day and as much as 30 different applications every month, with the app market increase is expected to reach \$188 billion in 2020²⁰⁰. Considering the familiarity, daily usage, and to an extent, reliance on our smartphones, many opportunities for utilising the computational power and visualization capabilities arise and are ready to be exploited. Considering that there are more than 3.5 billion smartphone devices, as 50% of the world's population possess one or more²⁰¹, and each device is composed by at least 10-15 sensors²⁰², people are becoming part of a cultural digital transformation.

Utilizing the smartphone technology that students have in their pockets, especially with the use of low cost headset devices like Google Cardboard and Samsung Gear VR²⁰³, VR can now become mainstream in education. This would allow students to use their smartphone devices to immerse in high fidelity virtual environments and participate in educational activities. In fact, a report²⁰⁴ on technology trends in higher education has predicted that VR technologies will be adopted in the higher education sector in the next few years. Recent studies indicated that as much as 94% of all teenagers are using the internet daily and 91% use a mobile device to get online²⁰⁵, as well as that student ownership of smartphone devices has exceeded the ownership of laptops²⁰⁶. These findings demonstrate that the increased use of

¹⁹⁸ B. Liu, A. G. Campbell, and P. Gladyshev, "Development of a Cybercrime Investigation Simulator for Immersive Virtual Reality," in 23rd International Conference on Virtual System & Multimedia (VSMM), 2017, pp. 1-4.

¹⁹⁹ M. Hussein and C. Nätterdal, "The Benefits of Virtual Reality in Education-a Comparision Study," 2015.

²⁰⁰ S Boschert, T Coughlin, M Ferraris, F Flammini, JG Florido, AC Gonzalez, P Henz, D de Kerckhove, R Rosen, R Saracco, A Singh, A Vitillo, and MYousif, "Symbiotic Autonomous Systems - White Paper Iii," 2019.

²⁰¹ Bankmycell. (2020). "How Many Smartphones Are in the World?". Available:

<https://www.bankmycell.com/blog/how-many-phones-are-in-the-world>

²⁰² R. Saracco, "Platforms: Infrastructures for a New Economy: An Ieee Digital Reality White Paper," 2020.

²⁰³ J. McCaffery, A. Miller, A. Vermehren, and A. Fabola, "The Virtual Museums of Caen: A Case Study on Modes of Representation of Digital Historical Content," in Digital Heritages, 2015, pp. 541-548.

²⁰⁴ L. Johnson, S. A. Becker, M. Cummins, V. Estrada, A. Freeman, and C. Hall, Nmc Horizon Report: 2016 Higher Education Edition: The New Media Consortium, 2016.

²⁰⁵ A. Lenhart, "Mobile Access Shifts Social Media Use and Other Online Activities," Washington, DC: Pew Internet and American Life Project, 2015.

²⁰⁶ E. Dahlstrom, J. Walker, and C. Dziuban, "Ecar Study of Undergraduate Students and Information Technology," 2013.

mobile devices and technological advancements of hardware and the internet offer opportunities to be harnessed for educational purposes in a wide range of educational topics.

6.2.2 AR in Education

The use of AR in education also drew a lot of attention over the past few years²⁰⁷. AR aims at connecting the real with virtual worlds by creating realities that are enhanced and augmented²⁰⁸, creating the illusion that computer generated virtual elements exist in the real setting in real time²⁰⁹. AR is defined as *“a form of virtual reality where the participant’s head-mounted display is transparent, allowing a clear view of the real world”*²¹⁰. It is *“a situation in which a real world context is dynamically overlaid with coherent location or context sensitive virtual information.”* AR is a variation of VR that rather than replacing reality for the user entirely²¹¹, it uses the existing physical environment in a MR mode in which the physical and the virtual environment are presented together. AR allows the coexistence of virtual and physical objects, enabling learners to visualize spatial components that are difficult or even impossible to reproduce in the real world. It also enables interaction with 2D and 3D objects in a MR mode that blends the real with the synthetic world²¹². This allows the development of practices that the traditional technology mediated learning tools and technologies cannot provide²¹³.

AR can be used through a number of technologies such as computers, immersive glasses, HMD’s, backpack computers, projected walls and others, but the educational value depends on the AR experience rather than the implemented technologies. In education, students can use such technology to overlay virtual elements on devices to manipulate and interact with them. Especially with the mobility offered by the use of the smartphones students already possess, this provides authenticity of the learning environment and increase students interactions with the environment and with each other²¹⁴. The use of AR can provide opportunities to teach and learn content in 3D, establish collaborative and situated learning, offer opportunities to visualize invisible artefacts, and to bridge formal and informal learning.

²⁰⁷ H.-K. Wu, S. W.-Y. Lee, H.-Y. Chang, and J.-C. Liang, "Current Status, Opportunities and Challenges of Augmented Reality in Education," *Computers & education*, vol. 62, pp. 41-49, 2013.

²⁰⁸ E. Klopfer and K. Squire, "Environmental Detectives—the Development of an Augmented Reality Platform for Environmental Simulations," *Educational technology research and development*, vol. 56, pp. 203-228, 2008.

²⁰⁹ S. Cawood, M. Fiala, and D. H. Steinberg, *Augmented Reality: A Practical Guide: Pragmatic Bookshelf* Raleigh, NC, 2007.

²¹⁰ P. Milgram, H. Takemura, A. Utsumi, and F. Kishino, "Augmented Reality: A Class of Displays on the Reality-Virtuality Continuum," in *Telemanipulator and telepresence technologies*, 1995, pp. 282-293.

²¹¹ J. Martín-Gutiérrez, J. L. Saorín, M. Contero, M. Alcañiz, D. C. Pérez-López, and M. Ortega, "Design and Validation of an Augmented Book for Spatial Abilities Development in Engineering Students," *Computers & Graphics*, vol. 34, pp. 77-91, 2010.

²¹² L. Kerawalla, R. Luckin, S. Seljeflot, and A. Woolard, "“Making It Real”: Exploring the Potential of Augmented Reality for Teaching Primary School Science," *Virtual reality*, vol. 10, pp. 163-174, 2006.

²¹³ K. Squire and E. Klopfer, "Augmented Reality Simulations on Handheld Computers," *The journal of the learning sciences*, vol. 16, pp. 371-413, 2007.

²¹⁴ . Klopfer and J. Sheldon, "Augmenting Your Own Reality: Student Authoring of Science-Based Augmented Reality Games," *New directions for youth development*, vol. 2010, pp. 85-94, 2010.

6.2.3 MR, XR and Cyber-Physical-Social Eco-Society Systems for Immersive Learning

Mixed Reality (MR) is an experience that blends the real world with digitally created content, and enables both environments to coexist and interact with each other²¹⁵. The Reality-Virtuality continuum as defined by Miligram et al. describes and can help understanding the different levels of reality.

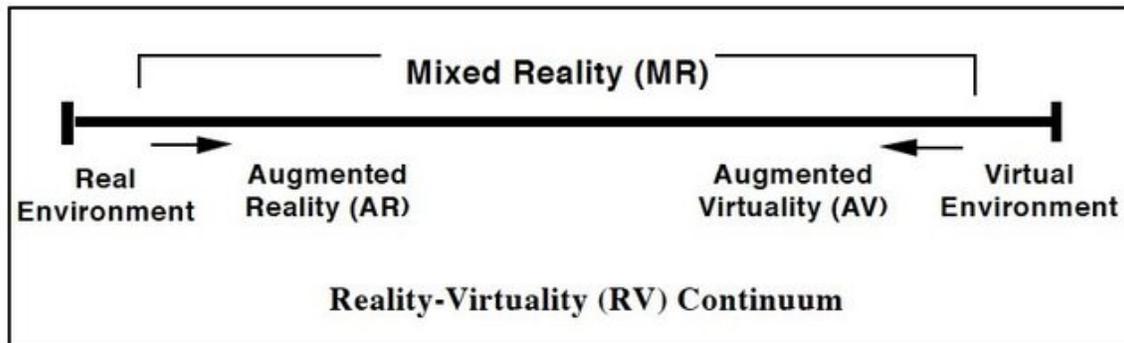


Figure 44: Milgram and Kishino's Mixed Reality on the Reality-Virtuality Continuum [13] From [Medium.com](https://www.medium.com).

This is ranging from a completely real to a completely virtual environment, where MR is a situation in which real and virtual objects are presented together, introducing the concept of AR and Augmented Virtuality (AV) in one frame. According to this concept, AR involves the real world more than the virtual elements by projecting virtual objects to a real environment, whereas AV involves more virtual elements than real that project real objects in a virtual environment. The weight of augmentation should also be considered, and it has been put on a spectrum by Klopfer²¹⁶, ranging from light to heavy augmentation. A lightly augmented reality is a situation using predominantly a large amount of information from the physical world with little virtual information. In heavily augmented situations, the use of presentation devices such as HMDs is employed to generate the immersive environment.

Extended (or Cross) Reality (XR) is an umbrella term that represents these artificial digital experiences and the fusion of real and digital environments, and encapsulates the hardware, software, methods, and experiences that make VR, AR, and MR a reality. XR in education provides academic flexibility to deploy immersive technologies to support students learning in engaging, interesting, accessible, and experiential forms²¹⁷.

Going beyond the use of XR in education, the use of a new type of conceptually led Cyber-Physical-Social Eco-Society (CPSeS) systems has been recently introduced to support immersive learning²¹⁸. CPSeS are intelligent systems constituted by physical space(s), real and artificial agents and elements, the virtual space that seamlessly connects them, and are influenced by users and their intentions^{219,220}. CPSeS

²¹⁵ Unity3D. (2020, 23/04/2020). "What Is Ar, Vr, Mr, Xr, 360?". Available: <https://unity3d.com/what-is-xr-glossary#paragraph43>

²¹⁶ E. Klopfer, *Augmented Learning: Research and Design of Mobile Educational Games*: MIT press, 2008.

²¹⁷ M. S. Mohapatra, "Xr Ignites Transformation through Immersive Digital Learning."

²¹⁸ L. Nisiotis and L. Alboul, "Work-in-Progress—Converging Virtual Reality, Robots, and Social Networks to Support Immersive Learning," 2020.

²¹⁹ L. Nisiotis, L. Alboul, and M. Beer, "A Prototype That Fuses Virtual Reality, Robots, and Social Networks to Create a New Cyber–Physical–Social Eco-Society System for Cultural Heritage," *Sustainability*, vol. 12, p. 645, 2020.

²²⁰ L. Nisiotis, L. Alboul, and M. Beer, "Virtual Museums as a New Type of Cyber-Physical-Social System," in *International Conference on Augmented Reality, Virtual Reality and Computer Graphics*, 2019, pp. 256-263.

systems blend the real with digital worlds using Immersive Technologies, Robots and Social Networking technologies, providing opportunities to formulate innovative social XR experiences to support education. In such systems, students can interact with elements from the physical and digital worlds, with educational content, and with each other, and their interactions and intentions influence the system. Students also interact with real and digital robots placed either in the real or in the digital world(s), or in both.

These robots form networks of stationary and mobile agents, and their corresponding Digital Twins are used as intelligent tools to support students whilst participating in learning activities in the digital and real spaces. Students use low cost HMDs and their smartphones to connect, synchronously coexist in the same-shared spaces or participate in individual activities, interact and apply the concepts they have learned in risk free XR environments, and participate in collaborative activities. An educational CPSeS can facilitate the symbiosis of robots, their digital twins, students, teachers, and their avatars, in a multifaceted intelligent system in which they are all learners and collaborators, offering opportunities to experience interactive and multimodal immersive learning situations and activities.

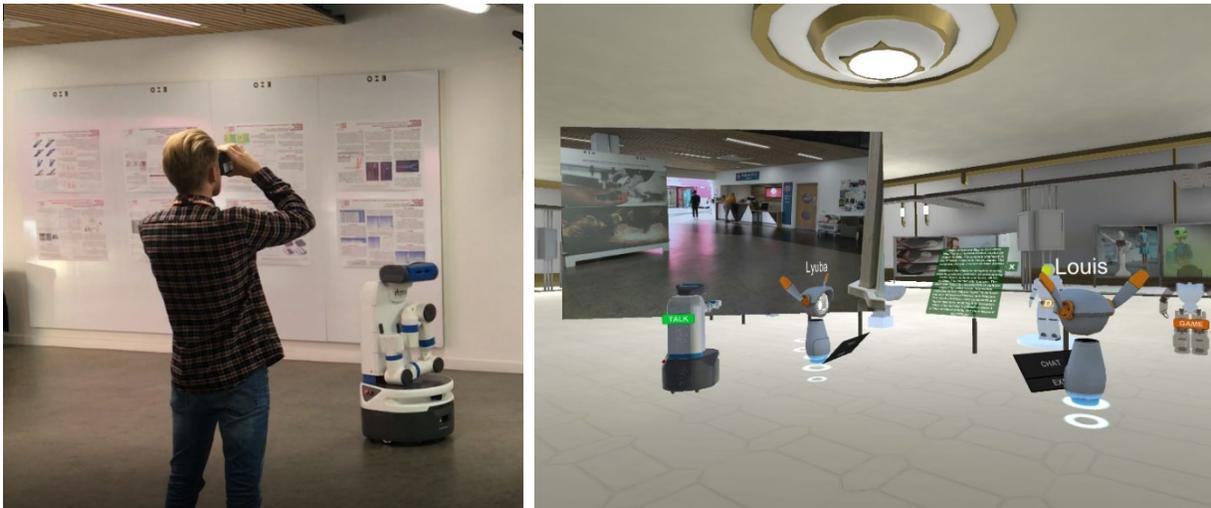


Figure 45. The robot in the real and in the virtual world.

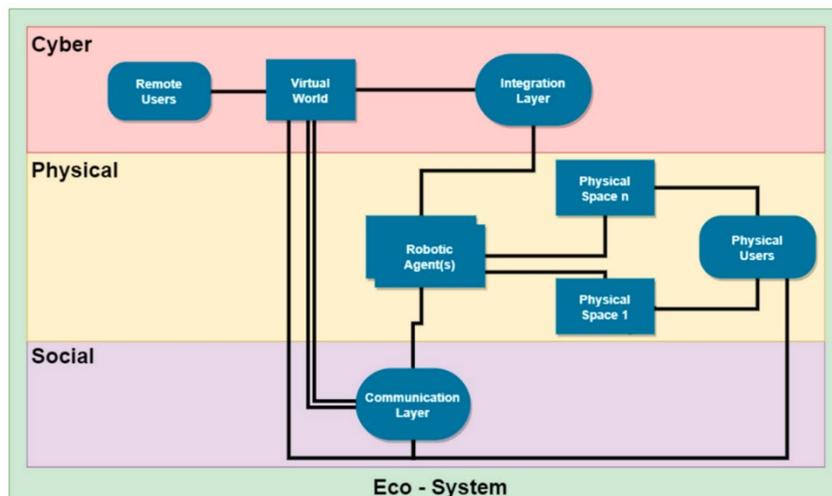


Figure 46. The Cyber-Physical-Social Eco-System (CPSeS) Framework.

The use of immersive technologies, XR environments, and Cyber-Physical-Social Educational Eco-Systems can offer opportunities to support and enhance the current teaching and learning practices. Educators can design and develop multimodal and interactive educational experiences and situations which until recently were difficult or even impossible to develop. The emerging XR technologies and CPSeS can provide access to a range of immersive learning situations to disrupt the current ways students experience and interact with educational materials, their educators, and with each other, fostering the ongoing implementation of emerging digital technologies in education, the digital transformation of our lives, and the society in general.

6.3 The New Jobs Landscape

The Digital Transformation, DX, is having a profound impact on jobs by:

- Replacing human workers with automation
- Removing the need for some type of jobs
- Changing the way jobs are performed, usually requiring different set of skills
- Creating new job opportunities in new emerging sectors
- Increasing the demand for DX support

These changes are happening everywhere, although the pace of change is different depending on the geographical area (see section 5) and the market segment. This different demand creates a worldwide competition for skills made stronger by the possibility of offering (part of) those skills from remote. In turn, this may accelerate the DX since the access to remote skills requires the shift of activities to the cyberspace where geographical distance is no longer a factor.

6.3.1 Replacing human workers with automation

The replacement of blue collar workers with machines is an old story. The Industrial Revolution did that, but the “replacement” was totally obscured by the flanking of machines to human workers and the amazing increase of human labor needed to complement machines’ activity. The increased productivity, in turn, increased wealth and stimulated demand driving further increase of jobs to sustain production.

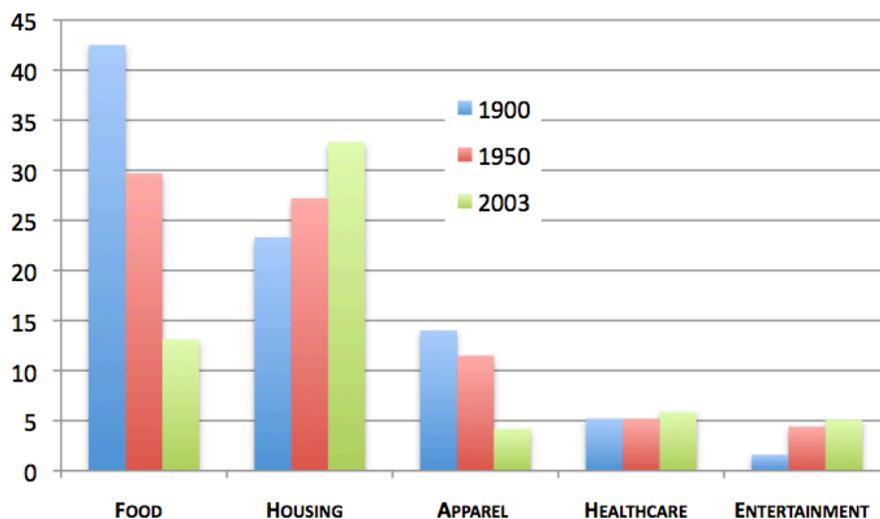


Figure 47. Image and data credit: US Bureau of Labor.

Consumer spending (average) did not change significantly over the centuries until the modern times. If we look back at the last century, we can see an amazing shift, shown in the graphic. In the US, food amounted for 42% of expenses in 1900 but only 12% in 2003 (today is below 10%). On the other hand, entertainment went from 1% to over 5%.

At the turn of the last century, robots started to make a dent into the assembly lines job, leading to job losses. Automation spread beyond the assembly lines of factories. Automatic Teller Machines (ATM) made a dent into bank white collars, and so on. At the same time, a booming service industry and a rapidly surging tourism, entertainment, and leisure industry, fuelled by increasing free time and availability of money that could be diverted from basic needs (these having become way cheaper) sustained the job market. As shown in figure, the pattern of consumer spending in the US²²¹ (representative of most Western Countries) changed significantly in the last century. Notably, considering expenditures on food, housing, apparel, healthcare, and entertainment, there is a significant shift (sharp decrease in food and apparel, sharp increase in lodging and entertainment).

What is even more notable is that whilst in 1900 “other” areas of expenditure totalled 13%, in 2003 these reached 39%, and the trend is still going on today.

The sharp decrease in food expenditure does not mean that people are eating less today than a hundred years ago. Actually, they are eating more and better quality food. The point is that on the one hand the productivity increase in the food value chain is decreasing the cost, and on the other hand people earn more money today than hundred years ago. However, productivity increase goes hand in hand with labor cost decrease, and since workers earn more money today, it means there are many less workers in that value chain than hundred years ago. The job losses in agriculture²²², courtesy of automation, have been staggering: up to 76% of jobs were in agriculture back in 1,300, that dropped to 60% in 1,800, 40% in 1,900. Today, the percentage is around 2%. The drop in the last 100 years has been incredible and has been matched with an incredible increase in productivity.

Interesting to note that in the last 50 years productivity in manufacturing²²³ in the G7 Countries has been around 4% per year, with a bigger increase in the 1950-1973 period that reached, in Japan, 10% yearly. This productivity increase resulted in increased jobs between 1 and 4% (Japan) in that first period followed by a shrinking between 0.5 to 3% in the following periods. This is the result of an expansion of factories in the first period and expansion of automation in the second that led to a first wave of job losses.

Responding to job losses, assembly line workers reinvented themselves as waiters, guides, taxi drivers, and others trained for new skills.

Automation is far from being complete and will continue in this decade, although at a slowing pace for blue collars (on factories floor most of menial work has already been automated). The application of AI is leading to white collar job automation, first in line being telemarketers, receptionists, legal assistants, back office workers, data analysts, and data harvesters. If in the past the highest impact was on lower

²²¹ <https://www.theatlantic.com/business/archive/2012/04/how-america-spends-money-100-years-in-the-life-of-the-family-budget/255475/>

²²² <https://ourworldindata.org/employment-in-agriculture>

²²³ <https://www.bls.gov/opub/mlr/2002/06/art4full.pdf>

salary jobs, repetitive jobs usually held by low education workers, now the impact is expected on better paid, better educated workers.

A recent study²²⁴ by the Metropolitan Policy Program at Brookings is showing the foreseen impact of AI in a variety of white collar jobs, pointing out that whilst robotics and computers automated the factory floor and the repetitive tasks of white collar workers, AI is clearly bent over high paid, high educated workers.

6.3.2 Removing the need for some types of jobs

In the last century, automation has resulted in a loss of jobs because machines could replace human workers. On the contrary, in most cases the Digital Transformation results in a loss of jobs because those jobs are no longer needed. There is not a machine (robot or software) that is replacing a human worker in performing an activity, rather, that activity vanishes.

Think about remote working. This keeps workers at home and the lunch break takes place locally. No more need to go to a Pret-a-Manger. The lockdown has seen millions of workers working from home and restaurants around major business hubs in cities went into lockdown as well. Once the lock down was removed, most people continued to work from home. Facebook and Google offices in London King's Cross, St. Pancras, will remain closed till Spring 2021, and the many restaurants in that area, mostly catering for those employees are going bankrupt²²⁵. This example shows how the DX in one area can dramatically impact another, removing the value it delivered.

One of the points made clear by the change in the way of performing activities during the lockdown is that the supporting technologies (for remote working, transactions monitoring and authentication, digital signatures, cloud support) are available. However, the organizational processes were designed for a different way of working, and they don't fit well with the new one.

Several CEOs have realized that those processes have to be changed (and this is one of the major hurdles facing the transition). It happened in the 90s with business process re-engineering²²⁶ as result of the pervasive use of computers in the office. It is going to happen again as the value chains shift to the cyberspace and resources interact via the cyberspace.

According to a McKinsey study, 60% of all occupations have at least a 30% of activities that can be shifted to the cyberspace or performed by machines. This, in other terms, means that 1.2 billion workers will be affected by the DX over this decade impacting on 14.6 trillion in wages. A good portion of wages will be shifted to investment in DX, but that means that workers will lose that part of wages to the DX.

Whether these figures will turn out to be accurate or not is not really the point. They show a trend that is creating huge issues at societal level. Those countries that, through policy and subsidy, will slow down the change can decrease the societal friction over the short term but may be facing even bigger challenges in the medium long term as their industry loses competitiveness.

²²⁴ https://www.brookings.edu/wp-content/uploads/2019/11/2019.11.20_BrookingsMetro_What-jobs-are-affected-by-AI_Report_Muro-Whiton-Maxim.pdf#page=11

²²⁵ <https://www.wired.co.uk/article/kings-cross-google-facebook>

²²⁶ https://en.wikipedia.org/wiki/Business_process_re-engineering

It is not the point here to take a stand on one side over the other, just to set the stage. In Italy, as an example, the approach towards recovery from the economic downturn created by the pandemic is mostly focussing on subsidies, including a government ban on lay-offs. In the US, the approach has been quite different letting private companies play with the rule of the business (with some forms of Government support to people losing their jobs).

Clearly, the goal should not be to preserve jobs that no longer create business value but to leverage on the resources that are becoming available (people looking for jobs) to create new business. Of course, this is easier said than done (See 6.3.4).

6.3.3 Changing the way jobs are performed

In March 2019, the OECD published a report “Preparing for the changing Nature of Work in the Digital Era²²⁷” analyzing the various impacts of digitalization on current work activities. It pointed out that 14% of jobs may disappear as processes and activities (particularly “white collar” activities) move to the cyberspace and become automated by software. Even more important, the OECD report foresees 32% of current jobs will be facing major changes in this decade requiring different sets of skills and knowledge, thus resulting in needs for significant retraining or for laying off current workers and hiring new ones.

Artificial Intelligence is going to become a sort of brain screwdriver: like factory workers considered the screwdriver an extension of their hand, this decade’s workers will get used to having artificial intelligence assisting them every step on the way. The crucial change here is that workers will no longer interact with a “machine” to get help, hence perceiving the existence of a machine, rather through augmented reality or smart interaction made possible by the embedding of intelligence in the environment, in tools they use, and in objects, they will simply operate in an augmented way.

Notice the crucial difference: the shift is from using (and being aware of using) smart tools to becoming augmented with no perception of an external entity.

As a simple example, imagine having electronic contact lenses that can transform infrared light-waves into the visible spectrum. A worker can now “see” with his own (augmented) eye that an engine is overheating. A more articulated example is one where that worker, still using those contact lenses, will perceive a number of characteristics of an object, its operation, and the overall context that will lead him into taking a specific decision. That decision will be perceived as emerging from his brain, although it has been constructed by an external intelligence flanking the worker’s brain.

Indeed, augmented reality mediated by seamless devices (like electronic contact lenses²²⁸, ambient video projectors, display capable surfaces, and more down the lane embedded actuators for direct senses/brain stimulation) will be a key component of this decade DX and in changing perception of the workplace and the way work is done.

In the longer time frame, possible already in the next decade, there will be a symbiotic co-existence of humans and machines, starting from the workplace.

²²⁷ <https://www.oecd.org/going-digital/changing-nature-of-work-in-the-digital-era.pdf>

²²⁸ <https://spectrum.ieee.org/view-from-the-valley/consumer-electronics/portable-devices/ar-in-a-contact-lens-its-the-real-deal>

In the transition, the access to artificial intelligence and cooperation with autonomous, smart systems, will require new sets of skills and the capability to share knowledge with machines. In turn, this brings issues of transparency, accountability, and auditability to the forefront (discussed in section 6.1).

The OECD report identifies the following policy implications:

- Prepare workers for new jobs and for changes to existing ones
- Empower people with a mix of skills to succeed in a digital world of work
- Get ready for a massive training challenge
- Improve social protection to ensure that no-one is left behind
- Address concerns about emerging forms of work

IEEE is committed to provide training to its members and to the world of professionals to help meeting these challenges.

6.3.4 Creating new jobs opportunities in emerging sectors/Countries

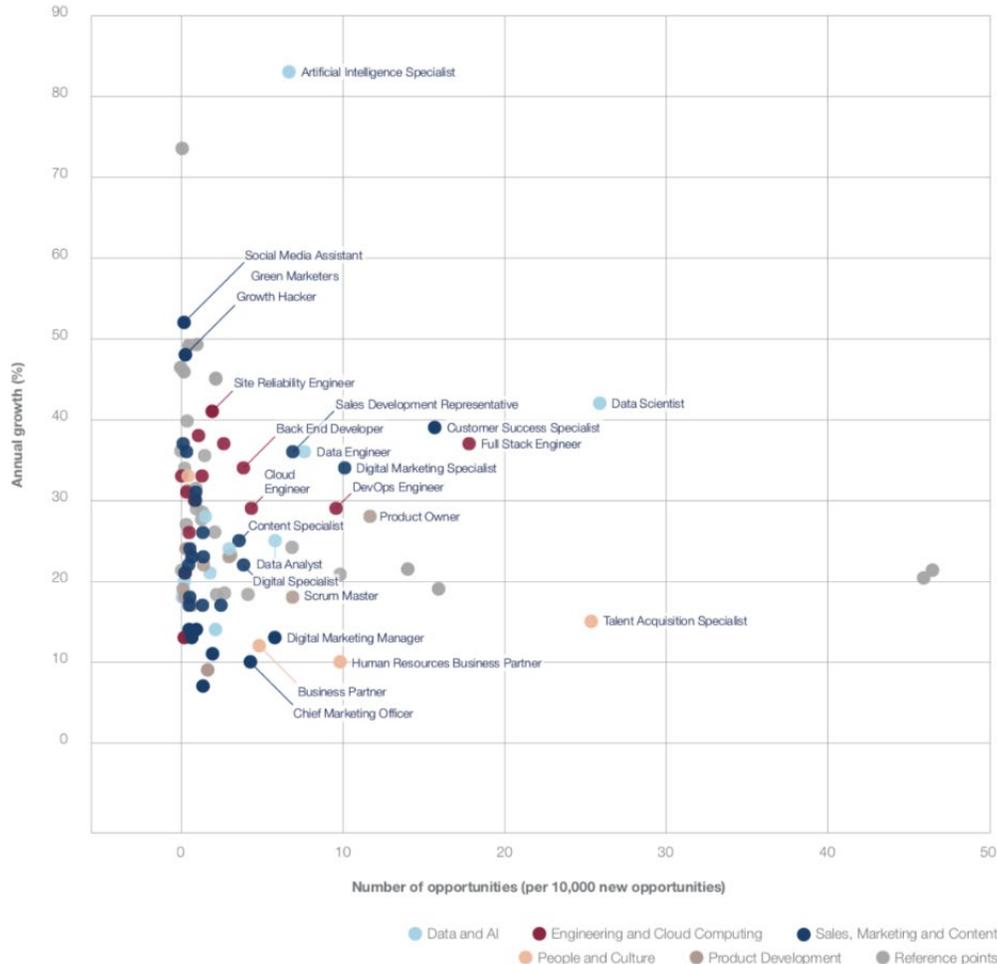


Figure 48. Types of emerging jobs, fostered by the Digital Transformation in the coming 2 years (2020-2022). The Y axes shows the yearly growth; the X axes the number of opportunities per 10,000 job posts. The colors of the dots relate to the 7 clusters of new jobs identified in the World Economic Forum report. Artificial Intelligent Specialists is the job with the highest expected growth. Image Credit: WEF.

The Digital Transformation, by drastically flattening the value chains, stimulating the aggregation of ecosystems (much easier in the world of bits), and accelerating the obsolescence of knowledge, drives the emergence of new types of jobs and new ways of offering one's expertise. This has already been pointed out in section 4.8, the Gig Economy.

Some of the big beneficiaries of the result of the Digital Transformation will be developing countries that will be able to develop business locally and reach a worldwide market. This has already started in the last decade with companies in developing countries offering their skills (as an example in software development). What happened with the offshoring of manufacturing is now happening with the offshoring of brains.

In addition to this, there are a number of new jobs that are emerging, and many more are expected in this and subsequent decades.

The Economic World Forum has published a report²²⁹ (January 2020) on the new jobs landscape in this decade as a result of the ongoing DX and of the new challenges being faced (Climate, Resources, and Population increase). The report pre-dates the pandemic but it includes a few points that are in sync with the issues raised by the pandemic.

The report identifies 7 emerging professional clusters and 96 new jobs. The report compares the new jobs opportunities against the whole labor landscape. In 2020, the report foresaw 506 new jobs opportunities over 10,000 jobs (5% of jobs in 2020 will be new types of jobs), growing to 715 per 10,000 in 2022 (7%). This account for 6.1 million of new types of job in the period 2020-2022; of these, 37% will be in the "Care Economy" cluster (this is possibly an underestimate given the healthcare crisis generated by the pandemic), 17% in Sales, Marketing, and Content, 16% in Data and AI, 12% in Engineering and Cloud Computing, 8% in People and Culture, and a very low 1.9% in Green professions.

An interesting point of the report is the identification of the types of skills required for these new jobs. All clusters require basic technology understanding (in Engineering, Data/AI, Product development, Cloud computing this exceeds 50% of the set of knowledge required, content production requiring over 30%). Three clusters, Data/AI, Cloud computing, and Engineering, also require over 30% of knowledge on disruptive technology.

This clearly points toward the growing need for STEM education as well as for continuous technical education. In fact, most of the emerging jobs are either having a short lifetime or they require a continuous refresh of the knowledge and skills supporting them.

This is the area where IEEE can be mostly beneficial to the new professionals and where initiatives like Knowledge-as-a-Service (KaaS) are crucial.

²²⁹ <https://www.weforum.org/reports/jobs-of-tomorrow-mapping-opportunity-in-the-new-economy>

6.3.5 Increasing the demand for DX support

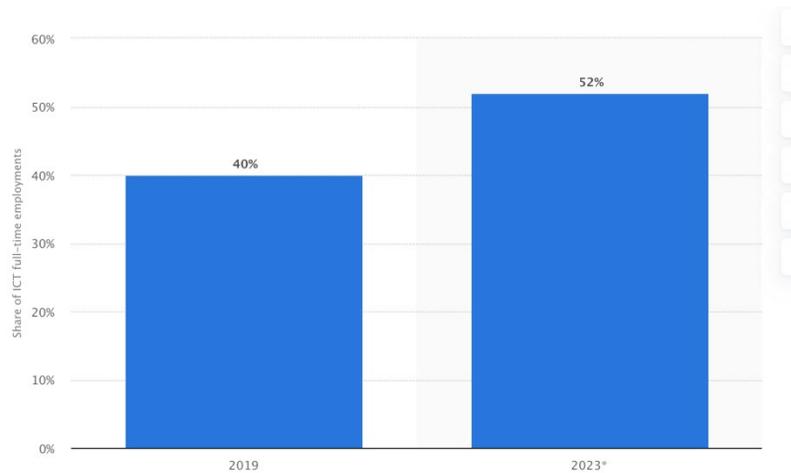


Figure 49. 40% of ICT jobs in 2019 were somewhat connected to support the Digital Transformation. These included data harvesting, data analytics, artificial intelligence, cloud, network service infrastructure. By 2023 this percentage is expected to exceed 50%. Image credit: Statista 2020.

Although the Digital Transformation is sharply decreasing cost by moving activities to the cyberspace, the cost of maintaining the cyberspace is growing and part of it relates to the increased number of jobs needed. In several areas, the shortage of skills is one of the main hurdles faced by companies and institutions alike. In some countries, the job market is static, meaning that it is difficult to change workers (this is in principle good from the point of view of social security, but it clearly slows down the evolution and hampers company productivity).

The COVID-19 pandemic has resulted from massive economic losses in almost all countries. Some having a flexible job market responded with major lay-offs, 40 million jobs were lost in the US, 600,000 in Italy. As the economy recovers, parts of these jobs will lead to a reinstatement of workers. However, several companies will see this as an opportunity to hire different sets of skills, changing their knowledge/skill mix. Some companies will have found ways to meet demand with a lower number of workers, and therefore will not need to reinstate all pre-epidemic positions once the economy will pick up again.

These companies are likely to have permanently moved part of their activities to the cyberspace. What they will need will be people able to manage the activities in the new space, hence, the expectation of an increase of job positions to support the DX. This is what studies²³⁰ from Statista are pointing out an expected increase in the percentage of ICT jobs taking care of DX support (see figure) from 40% in 2019 to 52% in 2023.

The increased volume of conference call, tele-working, eCommerce, customer care mediated by machines, plus the increased use of virtual and augmented reality expected in the coming years will result in increased demand for jobs in those areas.

²³⁰ <https://www.statista.com/statistics/1126689/it-employment-dx-worldwide/>

New job positions in the DX support area are emerging, like:

- Change Manager
- Digital Adoption Manager
- Digital Transformation Manager
- Digital Transformation consultant
- Digital Training specialist
- HR specialist in DX
- Third-party specialists in digital transformation
- Digital strategies developer
- Digital Solution Architect

There are already a number of job postings specifically targeting these new positions.

6.4 The Digital Divide

In this section, we discuss the growing challenges of the Digital Divide.

We begin by exploring the accelerating rate of technological progress. We then show that an accelerating rate of development inevitably leads to a widening gap between technology adopters and those that fall behind. Using both history and recent studies as our guide, we explore the potential impact of this technology gap. We also demonstrate how the very notion of a “Digital Divide” fails to recognize the breadth of technological development, culminating in our proposal to refocus the discussion on the broader Technology Divide. To aid understanding, we imagine how the lives of two similar individuals might evolve in the near future. The only difference between the two is their use of, and access to, technology. While the individuals are imaginary, the predictions we make are grounded in reality. Finally, we explore the effectiveness of programs that have targeted the Digital Divide and suggest ways to address the broader technology divide.

6.4.1 Skyrocketing Technology

6.4.1.1 *The Law of Accelerating Returns*

In 2001, Ray Kurzweil published an essay called, “The Law of Accelerating Returns”²³¹. Kurzweil is a pioneer in the field of pattern recognition. He is also a technologist and futurist, known for thoughtful essays. In this particular, he suggests that the rate of technological change is not linear, but exponential. His conclusion is startling.

“We won’t experience 100 years of progress in the 21st century — it will be more like 20,000 years of progress (at today’s rate).”

²³¹ <https://www.kurzweilai.net/the-law-of-accelerating-returns>

Twenty thousand years! Let that sink in for a moment. Twenty thousand years ago, humans were living in the late Stone Age. The wheel was a crazy futuristic dream. Thousands of years would pass before its invention. The peak of human technology was a sharpened rock.



Figure 50. The peak of Stone Age technology. Photograph by José-Manuel Benito Álvarez.²³²

The difference between 20,000 years ago and today is unimaginable. And yet, that represents the magnitude of change Kurzweil predicts in the next 100 years. As you read this, and the idea sinks in, you may think it all sounds absurd. But there is a reason why you may not be able to judge the situation clearly. Writer Tim Urban explains the issue in a blog post about Artificial Intelligence²³³. Any curve, no matter how steep, looks flat when you zoom in close enough.

We all live in the present. Change is all around us. In terms of history, we are all zoomed in and close to the curve.

In the same blog post, Tim proposes a thought experiment. He suggests we build a time machine. We use the machine to kidnap someone from just before the industrial revolution. We bring them to the modern day to see what they think of our world. He points out that our whole society would be utterly confusing to them. A person from 1750 would recognize almost nothing, from cities to cars to electronics. Many things would seem magical and beyond all explanation.

Tim then proposes that the person we kidnapped decides to get their revenge. They steal our time machine and play the same trick on someone from 1500, bringing them to 1750. The person from 1500 recognizes almost everything. Society as a whole is not that different.

This illustrates Kurzweil's point. Far more technological change happened between 1750 and 2000 than 1500 and 1750.

Let's look at more recent history. The past twenty years have seen massive change, far more than the previous 20. In 1980, computers were still expensive and large. The world wide web didn't exist. ARPANET, the precursor to the internet, had begun to use TCP/IP. Metal-oxide Integrated Circuits, the foundation of most computing devices today, were rare. Most consumer products had little or no processing power. Not even the military was using GPS. Genetic editing of any kind was new. Genetic testing didn't exist. Black holes were still theoretical. It was a very different world.

The point is that technology development compounds over time. One development begets many more. It's like compound interest gone berserk. If you have ten breakthroughs today, each one can lead to ten new breakthroughs tomorrow. Those hundred lead to a thousand. And so it goes on.

²³² https://en.wikipedia.org/wiki/Late_Stone_Age#/media/File:Pieza_foli%C3%A1cea_africana.jpg

²³³ <https://waitbutwhy.com/2015/01/artificial-intelligence-revolution-1.html>

In every field of human study, technological development is accelerating. And that presents some enormous societal challenges.

6.4.1.2 Falling Behind the Curve

We are all familiar with the stereotype of a child helping a grandparent use the internet. In the 1980's, it took a child to program a VCR. Presumably, in 20,000 BCE, it was Ugg's granddaughter that demonstrated how to use a sharp edged rock.

Younger generations typically have a better grasp of new technologies than older generations. It takes considerable effort on the part of older generations to stay up to date. But age is not the only reason why some people are technology laggards. Economic and societal challenges play a role too.

The economic challenges are obvious. New technology usually costs money. Furthermore, access to new technology often relies on foundational infrastructure. Someone who wants to use Wikipedia has to have access to a computer, smartphone, or similar device. That device needs an internet connection. The internet connection requires infrastructure. And so the list of requirements goes on. Similarly, the latest smartphone apps need a recent model smartphone. The latest medical advancements are unusable without supporting infrastructure.

Societal challenges also contribute to the problem of falling behind.

Some societies limit access to, or use of, technology to certain groups, or they reject technology entirely. Examples include restrictions based on gender²³⁴, ethnicity²³⁵, religion²³⁶, and sexual orientation²³⁷.

But societal challenges aren't always imposed by third parties. Many of us know individuals that "can't use" or "won't use" technology. Every generation has groups that pride themselves on wilful ignorance and rejecting change. In the 1800s, it was the Luddites destroying machinery²³⁸. Today, we have 5G conspiracy theorists²³⁹ and Flat Earthers²⁴⁰. In the latter case, it is ironic that the tools they use to spread misinformation can only work if they are wrong!

Regardless of *why* someone falls behind the curve, the effect is the same. It is a simple truth that the further behind an individual is, the more difficult it is to catch up.

Falling Faster

Picture yourself in a broken down car by the side of a road. Another car passes and accelerates away from you without stopping. Not only are they getting farther away, but they are getting farther away

²³⁴ <https://www.aljazeera.com/news/2016/02/india-banning-women-owning-mobile-phones-160226120014162.html>

²³⁵ <https://www.wsj.com/articles/u-s-adds-chinese-firms-to-blacklist-citing-repression-of-muslim-minorities-11570488642>

²³⁶ <https://www.britannica.com/topic/Amish>

²³⁷ <https://www.theguardian.com/technology/2019/sep/26/tiktoks-local-moderation-guidelines-ban-pro-lgbt-content>

²³⁸ <https://www.history.com/news/who-were-the-luddites>

²³⁹ <https://www.snopes.com/news/2020/06/12/how-the-5g-coronavirus-conspiracy-theory-began/>

²⁴⁰ <https://www.cnn.com/2019/11/16/us/flat-earth-conference-conspiracy-theories-scli-intl/index.html>

from you faster. Their speed continues to increase relative to you. Every second, they cover more ground than the second before. They quickly disappear out of sight.

It is the same with technological progress. If the rate of technology development is accelerating, it is easier than ever to fall behind. Not only is it easier, but it will happen faster and the separation will become greater, faster. The gap between technology adopters and laggards will grow exponentially.

It is hard to predict how long it will take for the gap to become irrecoverable. However, it is relatively easy to predict many of the impacts such a gap will have.

6.4.1.3 History as Precedent

The Digital Divide is a relatively new concept. It has received increasing attention with the rollout of computers in schools and the availability of broadband internet access. However, there is a clear historical example of a government directly funding the education and technological advancement of a significant percentage of the population. That example is the USA's GI Bill.

The GI Bill

The Servicemen's Readjustment Act, now known as the GI Bill, was passed by the U.S. Congress in 1944. It was by far the largest direct intervention to improve education and skills in the country's history. It aimed to help World War II veterans by giving them money for educational and vocational training, as well as access to low interest mortgages. The GI Bill is broadly credited with the increase in college attendance, homeownership, wealth, and birth rate in the United States. In the first seven years of the bill's existence, around eight million veterans took advantage of it.²⁴¹

While the U.S. government wrote this bill to help veterans, many were left behind. The implementation of the GI Bill was decided at a state level, which led blackest veterans to not receive the same benefits as their White counterparts. Many banks refused to give loans to Black veterans. This left many Black veterans to live in decaying inner cities, while their white counterparts lived in the suburbs commonly associated with the American 1950s.²⁴² Many believe the exclusion of Black World War II veterans has led to the current socio-economic gap in the USA. The effects have lasted across multiple generations due to White World War II veterans passing on their acquired wealth to their children.

The GI Bill was designed to stimulate learning and training. It was incredibly successful for those who were allowed to take advantage of it. However, it is also an example of the impact of wide scale exclusion of a group of people. It showcases what happens to those who are left behind by education and technology, and the corresponding socio-economic impact.

6.4.1.4 The Digital Divide Examined in the Modern Era

Numerous studies have been conducted in the USA by groups such as the Pew Research Center²⁴³ and other research teams. Their conclusions are clear:

²⁴¹ <https://www.defense.gov/Explore/Features/story/Article/1727086/75-years-of-the-gi-bill-how-transformative-its-been/>

²⁴² <https://www.khanacademy.org/humanities/us-history/postwarera/postwar-era/a/african-americans-women-and-the-gi-bill>

²⁴³ <https://www.pewresearch.org/fact-tank/2018/10/26/nearly-one-in-five-teens-cant-always-finish-their-homework-because-of-the-digital-divide/>

- “Teenagers who have access to home computers are 6–8 percentage points more likely to graduate from high school than teenagers who do not”²⁴⁴.
- Students with internet access at home earn \$2 Million USD more over their lifetimes²⁴⁵.
- In 2009, broadband internet access accounted for \$32 Billion USD in net consumer benefits, including annual savings on purchases of more than \$11,000 USD per household²⁴⁶.
- 82% of middle skill jobs require digital skills²⁴⁷.

Similar studies conducted in Europe²⁴⁸ and elsewhere broadly agree with these findings. As demonstrated by the GI Bill, the advantages and disadvantages of one generation are often passed on to the next. In this case, that translates to a lasting, multi-generational, socioeconomic impact.

6.4.2 Exponential Challenges

Predicting the future is always difficult. Predicting future problems is even more so. Yet the scale of the problem is greater than implied here. This is likely to be true for one simple reason: our definition of technology.

Throughout this article, we have used a limited definition of technology. The implied focus has been computers and computer-related applications. But if the rate of technology development is increasing, so is its breadth.

We have already seen broad adoption of early versions of wearable technology. Consumers have access to devices like fitness trackers, smartwatches, and cameras. More exotic wearables, like smart clothing²⁴⁹ and exo-skeletons²⁵⁰ seem right around the corner. Researchers have already demonstrated glasses with autofocus²⁵¹. Many other novel devices are in active development.

Robotics also seems to be on the verge of much broader adoption. Quantum Computing, Quantum Simulators, and Quantum Sensors are developing rapidly. And yet even these examples stick with a familiar computing paradigm.

What about implantable technology? Implants without technology have existed in many forms for decades. Examples include hip and knee replacements, bone pins, and many others. Implants with technology, such as pacemakers and Cochlear implants are still somewhat rare.

But many more implants are under development²⁵². Examples include in vivo biosensors and brain-computer interfaces. There are also a growing number of "bio-hackers" exploring implantable technology.

²⁴⁴ <https://onlinelibrary.wiley.com/doi/abs/10.1111/j.1465-7295.2009.00218.x>

²⁴⁵ <https://www.federalreserve.gov/pubs/ifdp/2008/958/ifdp958.pdf>

²⁴⁶ <https://publicpolicy.wharton.upenn.edu/live/news/2420-bridging-the-digital-divide/for-students/blog/news>

²⁴⁷ <https://www.burning-glass.com/research-project/digital-skills-gap/>

²⁴⁸ [https://www.europarl.europa.eu/RegData/etudes/BRIE/2015/573884/EPRS_BRI\(2015\)573884_EN.pdf](https://www.europarl.europa.eu/RegData/etudes/BRIE/2015/573884/EPRS_BRI(2015)573884_EN.pdf)

²⁴⁹ <https://www.lifewire.com/what-are-smart-clothes-4176103>

²⁵⁰ <https://www.nbcnews.com/mach/innovation/robotic-exoskeletons-are-changing-lives-surprising-ways-n722676>

²⁵¹ <https://www.sciencedaily.com/releases/2019/07/190701144250.htm>

²⁵² <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4987398/>

It was not long ago that using a headset with a smartphone seemed unusual. Now it is commonplace. Some of the acceptance and normalization of headsets is generational. Is it a huge jump from a wearable headset to an implanted device that performs the same function? History implies that "no" is the likely answer.

Another emerging field to consider is genetics. Genetic testing is now routine during pregnancy in many parts of the world²⁵³. The Human Genome project cost more than \$2.7 Billion USD. Today, an individual can get their genome sequenced for less than \$200²⁵⁴. Gene editing techniques such as CRISPR are becoming quite accessible. CRISPR appears to be useful for everything from pest control²⁵⁵ to alternative fuels²⁵⁶. It may even help with allergies²⁵⁷.

Some surgical procedures are now considered routine. Cosmetic procedures like tattoos and body piercing are all routine. Are implantable technology and genetic engineering a giant leap? It would seem not. Pharmaceutical technology is also developing rapidly. Commercially available drugs have been shown to improve memory, focus, and cognitive function^{258,259}. Considerable resources are focused on developing drugs to prevent or even reverse the effects of aging. For an increasing number of diseases, odds of survival correlate directly with access to technology and adequate financial resources. Furthermore, technology often takes unexpected turns.

One small example of an unexpected technology that is now mainstream is the consumer drone. The rapid rise of consumer drones owes much to the smartphone. Smartphone adoption drove rapid technology development in several key areas. Some components became dramatically cheaper, more functional, and more reliable. Around 2010, low cost drones became a practical consumer proposition. Today, you can find the technology that once cost millions embedded in a child's toy that costs \$30 USD. As late as 2005, such an outcome within 15 years seemed inconceivable.

Any discussion of the digital divide has to look beyond computing in today's sense of the word. Humans will soon have opportunities to upgrade themselves. These upgrades will seem straight from the pages of a sci-fi novel. They will go far beyond anything we currently expect or imagine. The people that stand to benefit the most are those that can afford the technology and have access to it.

6.4.3 The Haves versus Have Nots

As discussed, the digital divide transcends our traditional notions of "digital technology." For the purposes of clarity, we propose a new, broader term: *The Technology Divide*.

For those of us deeply embedded in the world of technology, it can be hard to picture the impact of the Technology Divide. To help illustrate its potential effects, we imagine two individuals. The first, Alex, has every opportunity to embrace technology. The second, Charlie, is born into less technologically advantageous surroundings. They are otherwise from similar socioeconomic backgrounds. To stay

²⁵³ <https://www.webmd.com/baby/pregnant-genetic-testing>

²⁵⁴ <https://www.wired.com/story/whole-genome-sequencing-cost-200-dollars/>

²⁵⁵ <https://www.wired.com/story/heres-the-plan-to-end-malaria-with-crispr-edited-mosquitoes/>

²⁵⁶ <https://www.sciencealert.com/gene-editing-algae-doubles-biofuel-output-potential>

²⁵⁷ <https://www.abc.net.au/catalyst/gene-editing-made-simple/11016800>

²⁵⁸ <https://www.scientificamerican.com/article/a-safe-drug-to-boost-brainpower/>

²⁵⁹ <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2690227/>

focused, we will ignore the potential impact of factors such as gender and ethnicity. We will also avoid atypical outcomes, and focus instead on the idea of a “normal” life.

The point of this exercise is to highlight how seemingly small differences in access to technology will have a compounding effect over time. The technology referenced is either available, or likely to be available within the decade. Many of the circumstances, both advantageous and disadvantageous, already occur in some form in today’s society.

6.4.3.1 Early life

From an early age, Alex has access to a variety of enriching technologies. They develop an early love of music and art, and quickly begin learning about their world. Via tablets and similar devices, they experience snippets of many cultures. By the time they reach school age, they are familiar with common devices and ready to learn.

Charlie has few such opportunities. While hardly neglected, they have very limited interactions with technology. Their world is far smaller than Alex's, but arguably more social and tactile. By the time they reach school age, they are still unfamiliar with common devices. They have better social and physical coordination.

6.4.3.2 K-12 Education

Technology at home enhances Alex's formal education. They are able to use online resources to help with homework. They can also video chat with distant relatives who provide help and encouragement. Alex’s high school implements a new augmented learning portal that requires the use of a headset. Fortunately, the headset Alex has at home is significantly more advanced than the model used by the school.

Beyond formal education, Alex develops a strong interest in electronics and music. They are able to undertake many projects guided by customized online tutorials and courses. They build a network of friends and acquaintances in various online communities. This enrichment leads to many opportunities and extracurricular activities. Alex receives recognition in Science Fair and Performing Arts. Along with a growing sense of self-worth and agency, Alex gains scholarship opportunities.

In contrast, Charlie struggles with school. They have few resources beyond what the school provides. The limited online resources they can access are one-size-fits-all, not customized to Charlie’s specific needs. Things get more difficult when Charlie’s school implements the same augmented learning portal as Alex’s school. Unlike Alex, Charlie does not have access to a headset at home and is forced to rely on the school’s resources. Academic assignments become increasingly challenging to complete and Charlie’s grades suffer. As a teenager, they finally gain access to their own smartphone.

This improves Charlie's social life immensely. Charlie's outside interests include various sports, which they are good at. They are far from confident with technology, but they too have a growing sense of self-worth. Charlie also gains scholarship opportunities from their extracurricular activities.

6.4.3.3 College

Alex quickly adapts to college. Some of the acquaintances Alex made online attend the same school making social integration easier. The greater depth required by college classes presents relatively few challenges. Alex was able to upgrade their personal technology before starting college. This has many benefits. Alex does not have to rely on public technology provided by the library. This reduces the time

wasted waiting for resources to complete an assignment. Alex also has better tools to visualize complex problems and explore ideas.

Their work attracts the attention of a Professor. This leads to mentorship and many new opportunities. As finals approach, Alex takes advantage of a new drug that helps with cognitive function. The drug significantly improves memory and focus. The drug is considered safe for short term usage, but is relatively expensive. The college does not differentiate between students taking the drug and those that do not. Alex graduates with honors and has a variety of opportunities to choose from.

Meanwhile, Charlie is struggling. The demands of college coursework have proven challenging. Charlie relies on publicly available technology. Many hours are wasted waiting for access. When they do get access, their time is cut short by others who also need access.

Charlie works hard, but they are an unremarkable student in the eyes of their professors. Charlie does not get the same mentorship and opportunities as Alex.

As finals approach, Charlie has to rely on traditional studying techniques. The publicly accessible technology is rarely available. Even when it is available, the machines are slow and unreliable. Charlie also does not have access to any performance enhancing drugs.

Charlie graduates with a respectable, but average degree. They leave college with few clear opportunities.

6.4.3.4 Job Interview

Company X is hiring. By pure happenstance, both Alex and Charlie apply and are granted interviews. Alex is able to review the company, its history, and its products. They use the analytical skills they have acquired to build a simple model of the company. The model shows a disparity between the success of a product and its effect on the company's revenues. This provides Alex with a fantastic interview question. Charlie still relies on publicly available technology. They have a limited grasp of the company and some of the information they have is out of date.

While waiting for the interview, Alex receives a notification. It's from a Digital Twin they created that monitors Company X for news. The company has made a public announcement about the product Alex planned to ask about.

Charlie notices a change in the activity in the office, but is unaware of the reasons for it.

Alex's interview goes well. The interviewer is older and impressed by Alex's up to date information. The interviewer is a distant acquaintance of Alex's mentor. They spend several minutes talking about the mentor's research. Alex is able to seamlessly interject up to date information that is being supplied in real-time by another digital twin.

Alex has multiple job offers and chooses to work for Company X.

Charlie's interview does not go well. The same interviewer perceives that Charlie is capable. However, they misinterpret Charlie's lack of information as laziness and disinterest. The interview is short and unsuccessful.

Unfortunately for Charlie, this experience repeats itself. They take a low-wage job outside of the field of their choice to pay the bills.

6.4.3.5 Effectiveness at work

Alex is doing well. Using their disposable income, they recently upgraded to the latest augmented headset. It has an amazing array of features and the battery lasts all day. They also increased their fog computing budget, so they have far more processor cycles to use.

Using facial recognition and intelligent search, Alex recognizes every executive in the company. Digital twins monitor the most important, as well as the company as a whole. Alex also monitors the competition. Alex is able to synthesize vast amounts of data. They are quickly recognized as a "rising star" in the organization.

Efficiency at work leaves Alex with liberal amounts of free time. They continue to pursue their music and tech interests and have an active personal life. They are also able to afford an apartment near Company X, reducing their commute. Despite the higher apartment cost, Alex is able to rapidly pay off their student loans, becoming debt free in their late 20s.

Through dogged perseverance, Charlie has managed to gain an entry level position. They are working for Company Y, the primary competitor to Company X.

They are a couple of years older than their peers at the company. A majority of the younger people have headsets that aid them in their work. Charlie does not. It takes Charlie six months to accumulate the disposable income to buy a headset. By that time, most of Charlie's peers have been promoted or left the company. Charlie is seen as reliable, but unremarkable.

Determined to overcome this reputation, Charlie works as many hours as possible. But they struggle to keep up with staff that have better headsets, access to more computing resources, and other performance enhancements.

Charlie has little time for a social life. Their entire life centers around work and they have little disposable income. Unlike Alex, Charlie lives some distance from work and spends multiple hours per day commuting. Their credit history was not good enough to qualify for fractional car ownership, so they are forced to use public transit. Charlie is still paying off student loans well into their 30s.

6.4.3.6 Health and well-being

Alex has a fulfilling life. They have invested in a variety of implants and minor genetic alterations. Their day to day wellbeing is monitored and optimized. For the few ailments they have, they receive customized care based on the data they can provide. Their biological aging has been slowed by genetically tailored pharmaceuticals. Their diet is continually adjusted, resulting in higher energy levels and all around better health. Implanted devices measure stress and hormone levels. Alex is prompted into action whenever levels are too high.

The result is a biological age far below their actual age. This reduces the cost of healthcare, life insurance, and driver's insurance. It also improves Alex's mental wellbeing. This allows them to concentrate on work-life balance.

Charlie is struggling. Their career has progressed, but at a far slower rate than Alex's. Their disposable income continues to be limited. Charlie has not been able to invest in implants, or any genetic alterations beyond basic vaccinations. Charlie has no routine health monitoring. In their early 40s, they develop symptoms common for the over-stressed. These include hypertension, digestive issues, a weakened immune system, and cardiovascular degeneration.

Charlie does not receive tailored medical advice as they have little data to provide. They also cannot afford any of the more effective, genetically targeted medications.

The result is a biological age slightly ahead of their actual age. Charlie faces increases in the cost of healthcare, life insurance, and driver's insurance. They also increasingly miss days at work due to illness. This leads to fewer promotions and Charlie's career stagnates.

Charlie still works hard, but work life balance is unobtainable. Their stress level is high, which of course makes the situation worse.

6.4.3.7 Elder care & mortality

Alex has had a successful career. They amassed more than enough money to retire gracefully. Thanks to the technology they have continually invested in, they are remarkably healthy for their age. Alex can travel freely, knowing that their health is good. In the event of any health related incidents, they can quickly provide a lifetime of medical history.

As old age finally starts to catch up with Alex, they are able to continue an independent lifestyle. Alex purchases sophisticated in-home monitoring. They also buy a personal exo-skeleton to help with everyday tasks. Their home includes a variety of other assistive devices that ensure Alex's wellbeing. Alex is able to live in an unassisted environment well into old age.

Charlie continues to work well into old age. Their career entered a downward spiral of demotions and lateral moves. Their income has decreased in real terms. Charlie's health issues have worsened, limiting their mobility and making travel difficult.

When Charlie experiences a major medical incident, doctors make poor decisions based on limited data. This leaves Charlie with lasting complications.

As old age approaches, Charlie is forced to move in with a family member. Their health deteriorates further, limiting their social interaction and affecting their mental wellbeing. Without the many technology advantages used by Alex, Charlie's life becomes difficult and comparatively short.

While Alex and Charlie are fictitious, the likely impact of technology is not. Alex lives longer, has a better quality of life, and amasses significantly more wealth than Charlie. Should Alex have children, it's clear that Alex's advantages would provide them with a considerable head start.

6.4.3.8 Conclusions

The conclusion that our fictional character and their children would have significant advantages is supported by the outcomes seen with the beneficiaries of the GI Bill, and their children. The GI Bill also supports the notion that investment in the future pays great dividends. But the GI Bill is hardly the only source of such evidence. In an increasingly technology-driven society, it is inevitable that socioeconomic success is tied to technological advantage.

Individuals with socioeconomic benefit can invest in additional technology, further enhancing their advantages. It is obvious that this effect compounds over time and can be significant.

Given the clearly accelerated rate of technology development, it is also clear that getting left behind will become more commonplace. This will be particularly true for those with socioeconomic disadvantages and marginalized groups. For example, individuals requiring assistive technology are often inadvertently excluded and left behind²⁶⁰.

In other words, those that are ahead will get further ahead, faster. Conversely, those that are left behind will fall behind further, faster.

The impact of our rate of technological advancement will dwarf the effects of the industrial revolution in every respect. The gap between rich and poor will be magnified to an almost unfathomable degree. Without radical course correction, it would appear that humanity is well on its way to a dystopian future. One group will increasingly accrue advantages, while the other falls further and further behind.

Given the rapid rate of technological advancement, the window of opportunity to remedy the situation is likely to be quite small. However, there are some bright spots to consider. Again, history can be our guide.

6.4.4 Improving the Future

In 2010, the European Union adopted the “Digital Agenda for Europe”²⁶¹. The agenda identified improvements in broadband internet access as a critical step in addressing the digital divide. It also set targets for internet usage and digital inclusions. While not entirely successful, this program has had a significant impact³⁰.

The South Korean government has made technology access a key part of the country’s culture. Internet usage rates are some of the highest in the world. As much as 89% of the broader population routinely uses broadband internet. South Korea claims to have the smallest digital divide among 40 major countries²⁶².

Other countries such as Singapore, Finland, and Sweden²⁶³ have also made shrinking the digital divide a priority.

The term “Digital Divide” was first used in the early 2000s. Interestingly, all four countries with a strong focus on the Digital Divide have shown significant growth in GDP per capita since then. It is unclear whether there is a direct causal relationship, but it would be an interesting topic for further explanation.

While programs addressing the Digital Divide have shown some success, their focus has been very narrow: internet access and computer usage. We must expand our approach to consider and address the broader Technology Divide. This will be a far more difficult challenge to overcome.

²⁶⁰ <https://www.pewresearch.org/fact-tank/2017/04/07/disabled-americans-are-less-likely-to-use-technology/>

²⁶¹ <https://ec.europa.eu/digital-single-market/en/broadband-europe>

²⁶² <http://m.koreatimes.co.kr/pages/article.amp.asp?newsIdx=199287>

²⁶³ <https://www.weforum.org/agenda/2015/04/which-nations-are-top-for-digital/>

It is clear that just supplying tools is not enough. The Technology Divide will only close if, as a society, we provide the tools, training, support, and encouragement for individuals to succeed. This can only be done with a significant overhaul of public policy and educational systems.

However, to be successful, we must start with small goals.

The first step, as individuals working in technology, is simply to be aware of the issue.

The next step is for all of us to make a conscious effort to explain our work and its benefits to broader, more diverse audiences. Proactively embracing diversity and youth is a key component in addressing the broader issue.

Furthermore, our organizations, like IEEE, must take a leadership role in bringing science and technology back to the forefront of society in a meaningful and engaging way.

We must all make a long-term commitment to education, engagement, and enlightenment. Simply publishing information is not enough. We must proactively encourage and support engagement with technology in all of its forms. While the level of complexity in every field encourages separation between disciplines, we must fight against the silo-ing of information. The idea of a “Renaissance Man”, albeit inappropriately gendered for today’s world, is a useful model to follow. Our goal can only be achieved with a significant overhaul of public policy and educational systems. And that has to start with each of us.

Like climate change and a global pandemic, addressing the Technology Divide requires unprecedented coordinated action. As a society, we must start a meaningful conversation about its potential impact and how it can be addressed. Failure to do so will create an unsolvable problem that could dramatically rewrite the structure of society. The time to act is now.

6.5 The Transformation of Capitalism

Capitalism has changed significantly over the last decades, and for the better. Economic growth and wellbeing have spread all over the planet. The increase of productivity led to a better balance between work and private life. Technology has fostered access to knowledge and to sophisticated services. The democratic processes have been strengthened, and there are a number of safeguards stopping those holding the economic power to abuse from it. This has happened in one of the longest periods of peace and prosperity known to Earth. Famine has been fought and won. Healthcare has improved, and people can spend more time outside work activities. Clearly, there are plenty of exceptions to this rosy representation, but on average the progress is undisputable.

Thanks to technology, the access to information and social interaction has increased immensely. The opening of physical and cultural borders has seen the spreading of capitalism as a model to consider also to those countries that opposed it.

However, in this last decade this progress has been challenged because of the failure, notably so in Western Countries, to provide opportunities of further bettering life conditions to the point that the new generations have lost faith in the future. Yet, the progress is still visible as it was a hundred years ago. What is different is the pace of change. This rapid change is affecting the society, the politics, the economy (in particular the perception of value), and this has created frustration in many people. The society, particularly so in developed countries, hasn’t had the time to adapt. Politics have been unable

to provide an appropriate representation of what was happening nor to offer a vision for the future. Reference points have been lost and uncertainty fuelled fear.

A good thermometer of development is provided by inflation. Like for the human body, there is a sweet spot for inflation: if it is too high or too low, it is not good and something is wrong.

What is seen today are both cases of high inflation and too low inflation (to the point of deflation). Central banks are attacking the low inflation by increasing the “printing” of money, to stimulate the demand (which in principle should lead to increased prices and higher inflation).

The reasons for the low inflation are the same that have steered the progress in the last three decades: globalization, opening of international markets, increased productivity resulting from scale and technology evolution, and increased market competition resulting from liberalization and privatization.

The opening of international markets with the creation of the WTO has not just increased goods exchange, it has also stimulated the flow of investment in new markets, fostering the shift of manufacturing from developed countries (high salary cost) to developing countries with low labor cost, and this fostered the growth of education in those countries. Technology evolution also contributed to the decrease of manufacturing cost. All of this results in lower cost of products benefitting the end customers, but it also leads to a loss of jobs.

Whilst in the previous economic evolution, the efficiency has affected, mostly, the production, now it is affecting the whole industry organization, and with the Digital Transformation, it is affecting the whole value chain. Industry 4.0 is not about changing a single company, it is about changing everything, from the supply chains to manufacturing to delivery chains and the value proposition of the offer itself (see section 4).

The ongoing Digital Transformation moves organizations in the cyberspace, automating processes. Actually, the main challenge for today's companies as the Digital Transformation accelerates is the rethinking and redesigning of processes. Remote working, as it has been demonstrated by its rapid uptake during the pandemic lockdown, is a no brainer from a technology point of view, but it requires a redesign of the organization processes and a redesign of the company culture, something that is much more challenging than using the cloud to connect people working from remote.

This shift and the redesign of processes is decreasing the need of white collar workers (particularly those with low/middle skills). This is also affecting the public administration workforce (or, alternatively, in case no action is taken, it is decreasing the effectiveness of the PA).

This increased gain in efficiency could be spent in increasing social responsibility of the enterprise (sustainable economy), and this is now becoming a leit-motif in the political discussion.

Why has the virtuous circle of progress come to a stop?

The virtuous circle where an increase in productivity had good feedback on jobs and wealth of family, which in turn increased the global demand, hence calling for more increase in productivity seems to have come to a halt in Western Countries.

One of the reasons is the technology progress. Differently from previous periods of progress, the shift to the cyberspace has brought efficiency and plenty of new services, but it has not been able to replace those goods, like cars and appliances that have been the engine of economic growth in the past fostering the demand of the middle class. The diffusion of the smartphone, instead, has contributed to decrease the demand of material goods to the advantage of demand of immaterial goods and sharing of services.

The shift accelerated by the Digital Transformation is less effective in growing jobs than decreasing them. Also, consumption is increasing in the cyberspace, but that does not offset the decrease in other sectors, particularly when looking at the economic value. It should also be noted that a lot of impact goes into processes.

The Sharing Economy that is clearly fostered by the shift to the cyberspace (it is so much easier to share bits than atoms), like car sharing, makes less important the ownership of material goods (the car), and thus reduces the workforce required.

The increased production in the cyberspace, particularly as AI plays a bigger role, is so huge to cast a shadow on social sustainability in the long-term unless a new paradigm for wealth sharing is found. It is not just the long term perspective. It is also the transition period, even more so as this is being played with the technology of the cyberspace and the economy of physical space.

The drive towards forms of universal/basic income reminds the description of the communist utopia described by Marx and Engels in *The German Ideology*: *“no-one will have a reserved area of activity but everyone could play in any area he so wishes; the society will be in charge to regulate the global production, allowing any person to engage in an activity today and in a different one tomorrow, hunt in the morning, fish in the afternoon, ... without having to become a hunter, a fisher ... for life.”*

In a way, it is paradoxical that it is capitalism that has set up the conditions to make Marx and Engels utopia possible (gig Economy, see section 4.8). However, we are still far from the moment when this will become a socially acceptable behavior and, most importantly, economically viable.

In the meantime, capitalism, particularly in Western Countries, needs to be reformed to remain a force of progress.

7 The Players

The Digital Transformation landscape is fairly complex: it has many players, some operating worldwide, others focussing on a specific region. Some players are making the Digital Transformation possible by providing the required infrastructures (like communications networks both long distance and local area networks or Clouds where data are being stored and processed or Platforms bridging data with applications and connecting players with each other through the cyberspace), others are providing tools for leveraging the DX, like AI, Blockchain, Data analytics, simulation, and AR/VR.

Other players are developing applications/services, whilst others are providing system integration. Finally, many companies, and institutions/governments are exploiting the business world resulting from the DX.

The goal of this section is to provide a short overview of this complex landscape that is continually changing as DX progresses and as it is applied to new sectors.

The market addressed by these players can be structured in many ways, based on technology used, on the type of the end users addressed (who's footing the bill), as well as by the process transformation involved. Additional categorization might take into account the size of end customers addressed (small, medium, large industry, institutions) and of course market segmentation by geography.

In this section only the first three are considered:

- split by technology
- split by end users
- split by process transformation.

Across all of them there are of course players providing consultancy, education, etc.

7.1 Players by End-Use Sector

7.1.1 Government & Public Sector

The Government and Public Sector have a tremendous power, and responsibility, in fostering the DX. They are not constrained by meeting quarterly results, can plan investment over several years, and are led by the wellbeing of citizens rather than by the bottom line.

Although most governments are declaring their commitment to the DX, and have been forced to adopt the DX in the pandemic crises (see section 9) only a few have a well-structured, comprehensive master plan for the DX and are consistently executing it. In this part, we are addressing three examples (out of many, of course) that have the plan, are executing it and can show results, the city of Singapore, the Provincia Autonoma di Trento, and the European organization EIT Digital having as goal the acceleration and support of the DX from a business point of view.

7.1.1.1 Singapore

Singapore has been on the forefront of DX applied to Smart Cities. It has been the first city to be mirrored by a Digital Twin, back in 2019²⁶⁴.

²⁶⁴ <https://www.smartcitylab.com/blog/digital-transformation/singapore-experiments-with-its-digital-twin-to-improve-city-life/>.

Starting January 2019, the Singapore Government has activated the City's Digital Twin incorporating a broad set of data, cadastral, infrastructure (roads, transport, waste), citizens, and much more. These data can be used for simulation as well as for getting a real time snapshot of the city. As an example, in case of an accident, it is possible to evaluate the impact on traffic, re-route vehicles, provide information to emergency teams, and so on.

Most importantly, companies having to access "digital Singapore" are required to do so online both for queries and for submitting request. As an example, a private corporation seeking permission to build a new mall shall present the request along with the Digital Twin of the mall. This will be used by the appropriate office for simulating the impact, and once permission is granted and the mall built, its Digital Twin will be used for monitoring and for support in case of need.

There is a growing number of data sets, provided by IoT, including safety and security cameras that are being embedded in the Singapore Digital Twin. Citizens seem to appreciate the enhanced safety and efficiency of the city and do not seem to be concerned, as in other cities, on the privacy issues that all this monitoring can raise.

The city of Singapore is mentioned in this report because of its accomplishment in the area of DX, but it is by no means unique, although it is probably one of the most advanced. It has been ranked second in the top 50 in terms of government²⁶⁵, slightly following London because of the innovation ecosystem. However, it ranks first in terms of policies.

7.1.1.2 Provincia Autonoma Trento

Since 2012 the Provincia Autonoma di Trento (PAT) has created an Open Data Platform accessible to any party²⁶⁶ wishing to develop services for citizenship. Additionally, these data can be used by companies to develop their business. An appropriate legislation was set up to:

1. require any party providing services and ICT support to the PAT to open the data related to those services
2. protect those companies that open their data through the PAT platform from any legal dispute (data provisioned through the PAT platform are encapsulated, monitored and certified)
3. provide monitoring information on use of data so that the company providing those data can leverage on their market value.

The platform contains over 200 data streams, part of them provided by third parties and has stimulated the creation of services and new business. Every year in cooperation with the University of Trento, a OpenData Hackabot²⁶⁷ is organized with thousands of people participating to leverage on the Trentino Open Data to create services and to show their applications.

Additionally, Trentino is experimenting with the FIREWARE platform (see 7.2.2.3) to develop smart city services.

The interesting point with PAT is that they are striving to create an ecosystem that is supporting DX for business and able of attracting more companies from other regions and countries. This is done in

²⁶⁵ <https://www.smartcitygovt.com>

²⁶⁶ http://www.provincia.tn.it/progetto_open_data/

²⁶⁷ <http://www.odhb.net>

cooperation with FBK²⁶⁸, the University of Trento, and EIT Digital that has the Italian Headquarter²⁶⁹ in Trento.

7.1.1.3 EIT Digital

EIT Digital aims at global impact through European innovation fuelled by entrepreneurial talent and digital technology. EIT Digital strengthens Europe's position in the digital world by delivering breakthrough digital innovations to the market and breeding entrepreneurial talent for economic growth and improved quality of life. EIT Digital helps businesses and entrepreneurs to be at the frontier of digital innovation by providing them with technology, talent, and growth support.

EIT Digital is a leading European digital innovation and entrepreneurial education organization, driving Europe's digital transformation. Its way of working embodies the future of innovation through a pan-European ecosystem of over 200 top European corporations, SMEs, start-ups, universities, and research institutes where students, researchers, engineers, business developers, and entrepreneurs collaborate in an open innovation setting. This pan-European ecosystem is located in Amsterdam, Berlin, Braga, Budapest, Brussels, Eindhoven, Edinburgh, Helsinki, London, Madrid, Milano, Munich, Nice, Paris, Rennes, Stockholm, Trento, and San Francisco.

Through ARISE Europe, EIT Digital is active in countries located in Southern and South-Eastern Europe, EEC, and the Baltics to pursue its activities in regions as well where the organization doesn't have a brick-and-mortar office.

EIT Digital invests in strategic areas to accelerate the market uptake and scaling of research-based digital technologies (deep tech) focusing on Europe's strategic, societal challenges: Digital Tech, Digital Cities, Digital Industry, Digital Wellbeing, and Digital Finance. EIT Digital breeds T-shaped entrepreneurial digital talent focused on innovation through a blended Education Strategy that includes a Master School, an Industrial Doctoral School, and a Professional School."²⁷⁰

7.1.2 Healthcare

Healthcare is possible the area that will be most impacted by the DX and many companies are repositioning themselves to address the opportunity.

Interestingly, in addition to the companies that are already operating in the area, we are seeing newcomers as well as companies that operated in different sectors. Among the latter, it is worth mentioning Apple that is now consistently addressing the proactive healthcare market (Apple watch), among the former it is interesting to look at the steps taken by companies like 23andMe²⁷¹, that having harvested a huge amount of data (DNA sequencing) are now trying to leverage on those in partnership with Pharma.

7.1.2.1 GE Healthcare Division

GE Healthcare division is committed to leverage on data for the future of healthcare. They are also exploiting Digital Twin technologies (already applied to facilitate hospital infrastructures monitoring and

²⁶⁸ <https://www.fbk.eu/en/>

²⁶⁹ <https://www.eitdigital.eu/about-us/locations/trento-clc/>

²⁷⁰ <https://www.eitdigital.eu/about-us/>

²⁷¹ <https://www.23andme.com/?cvd1=true>

operation) and expanding them into Personal Digital Twins. For an in-depth view of their vision and plans, refer to their white paper²⁷².

7.1.2.2 Philips

Philips is a major player in the healthcare arena in Europe (plus a worldwide footprint). One of their selling point is healthcare 24/7²⁷³, a continuous service that requires a shift to the cyberspace of several processes, with cloud based knowledge of the whole landscape and of individual patients/persons. Through the cloud, tele-health services are made available.

Philips is offering a HealthSuite digital platform to support healthcare ecosystems and provides a number of customizable services to operate on the platform, like the eCare Companion and eCare Coordinator²⁷⁴.

Interestingly, the Philips platform has been designed to be open and to support the open access to data, as an example, to increase medical research effectiveness.

7.1.3 Utilities

Utilities (electricity, water, waste management) are rapidly adopting IoT to manage their infrastructures and are learning to leverage on data for decreasing operation cost and move into proactive maintenance. Although the data harvested have the potential to be beneficial to several businesses and constituencies, so far very few utilities have considered opening them (exceptions are found in those utilities serving smart cities where there is an open data framework established by the municipality forcing them to open the data).

7.1.3.1 Enel

Enel is the major electrical power utility in Italy, and they have been among the first to deploy digital meters to be able to measure power consumption from remote. Over 32 million digital power meters were deployed starting in 2010. In 2017, a new generation of power meters became available (digital power meters 2G) and as of 2020 most of the older one have been replaced. This new generation detects power consumption in 15-minute intervals, and a special screen is available (optional) to use inside the home and get various types of usage statistics.

So far, Enel has not opened up the data and it is not releasing analytics beyond statistical analysis (i.e. they do not provide digital signatures of appliances in a home).

The volume of data harvested is huge and has the potential to be leveraged by Enel and third parties. A new regulatory framework, however, would be needed.

7.1.4 Manufacturing

Digital Industry, Society 5.0 and Industry 4.0 are three equivalent names for the DX of Manufacturing (US, Japan and Europe).

²⁷² https://landing1.gehealthcare.com/EUR-GA-19-10-HCD-EDS-NN-LP.html?utm_source=website&utm_medium=banner&utm_campaign=EUR-GA-19-10-HCD-EDS-NN

²⁷³ <https://www.philips.com/a-w/about/news/archive/standard/news/articles/2019/20191031-healthcare-innovation-in-the-cloud.html>

²⁷⁴ <https://www.philips.com/a-w/about/news/archive/standard/news/press/2014/20141001-Philips-secures-510k-clearance-to-market-the-first-clinical-applications-for-its-new-digital-health-platform.html>

It is well accepted that the new wave of manufacturing evolution is already in the making and will result in a radical change of many aspects of business and society, i.e. it goes well beyond the operational processes in manufacturing. It involves changes in the way raw materials are used and how products are recycled at the end of life; it results in a fading boundary among atoms and bits with many features of products relying on bits rather than on atoms.

It also requires a robust infrastructure, supporting the various phases and the interactions among different players, some in the value chain, some in the ecosystem (the former having mutually agreed contractual obligations, the latter just flanking one another biz without engaging in any contractual obligation). In this part we look, as examples at two companies, one for its innovation processes fully based on DX (Mevea), the other being a behemoth in industry support tools and as such able to influence the evolution of thousands of industries around the world (Siemens). In addition, we refer to EIT Manufacturing as a leading European Organization promoting the DX of Manufacturing.

7.1.4.1 Mevea

Mevea²⁷⁵ is a Finnish company leader in the Digital Twins space applied to the full product lifecycle. It is active in the construction machinery industry (backhoes, cranes, etc.). It starts the creation of the digital twin to capture the client's specs and then uses it for interacting with the customers to validate the project. The digital twin gets enriched throughout the manufacturing phase, and the products are connected through IoT and wireless communication to its digital twin, allowing remote supervision and fine tuning. Also notable is the use of the Digital Twin by the client for training, even before the product is delivered. The training makes use of virtual reality.

Mevea is likely the most advanced company in the use of digital twins, and it is worth reading their case studies available from their website.

7.1.4.2 Siemens

Siemens²⁷⁶ is a German company with a worldwide footprint that allows many companies around the world to manufacture their wares. It produces the tools used in manufacturing in a variety of verticals. One of the key enabler is their MindSphere²⁷⁷ platform supporting IoT as a service and supporting the use of Digital Twins.

Siemens is very important for its huge footprint and for establishing de-facto standards in manufacturing and its Digital Transformation. It is one of the forces steering Industry 4.0 and a founding member of both EIT Digital and EIT Manufacturing,

7.1.4.3 EIT Manufacturing

The manufacturing industry is a global base for prosperity and key to Europe's economic, social, and environmental sustainability. Manufacturing is a main driver of industrial innovation, job creation, and growth for the European society. It stands for over 2.1 million manufacturing enterprises in Europe, providing over 32 million jobs, which corresponds to 16% of the total EU working population, including approximately 13 million jobs in the growing high-tech manufacturing industry. In 2016, the share of EU-

²⁷⁵ <https://mevea.com>

²⁷⁶ <https://new.siemens.com/global/en/markets/machinebuilding/machine-tools.html>

²⁷⁷ <https://siemens.mindsphere.io/en>

28 GDP originated by manufacturing was 16.1% (Eurostat, GDP percentage of total, industry breakdowns, 10.01.2018), corresponding to a total turnover of EUR 7.11 trillion (European Commission, Factories of the Future Manufacturing in Horizon 2020 and beyond, 2017).

EIT Manufacturing²⁷⁸ is an Innovation Community within the **European Institute of Innovation & Technology (EIT)**²⁷⁹ that connects the leading manufacturing actors in Europe. Fuelled by a strong interdisciplinary and trusted community, it adds unique value to European products, processes and services and inspires the creation of globally competitive and sustainable manufacturing. EIT manufacturing has defined four transversal flagships that include important development areas for manufacturing industry today as:

People and robots for sustainable work

Industrial robots, capable of collaborating and interacting with humans are key enabling technologies to simultaneously achieve human well-being and manufacturing performance. “Made by Europe” has unique strengths in its robot-manufacturer partners. It offers a broad spectrum of industrial applications as well as expertise in human/robot collaboration, mobile, connectivity, exoskeletons, etc. This flagship is highly attractive for young people and entrepreneurs.

Additive Manufacturing for full flexibility

Additive manufacturing of multiple material combinations enables personalized products and advanced servitization, meeting both economic and environmental challenges. This flagship will develop “push-button” additive manufacturing technology in highly flexible manufacturing systems. Also, dynamic value networks with “supply & produce on demand services.” This includes emerging technologies such as multi-material printing and one-step printed sub-assemblies.

Waste-free manufacturing for a circular economy

Waste-free manufacturing enables a circular economy by minimising waste and resources use in the entire product lifecycle. Digitalization of zero-defect manufacturing increases the efficiency of industrial processes, reducing stocks. Digital twins facilitate eco-design and additive manufacturing boosts dematerialization. Our programs will boost technical advancement and shifts in skills, mindsets, and behavior to innovative and promote responsible production patterns.

Platforms for digitalized value networks

Value networks for digitalized manufacturing companies need a strong base of digital platforms to enable an efficient digital marketplace. Platforms and integrator companies are key enablers to European manufacturing innovation. Such capabilities are critical to capitalise on the potential of AI for SMEs, which requires a strong digital backbone. It will support manufacturers’ use of digital platform integrators to create high-value manufacturing in value networks across Europe.

7.1.5 Constructions

The world of construction is rapidly adopting the DX by using the cyberspace to record the construction phases, all the players and materials involved and more and more the status of the building (its infrastructure). Data accrued from buildings are used for proactive maintenance and prompt intervention. They are also used to evaluate the resilience of construction materials over time and the optimal engineering solutions. This is a sector characterised by a few big players that have or are in the

²⁷⁸ <https://eitmanufacturing.eu>

²⁷⁹ <https://eit.europa.eu/>

process of leveraging the DX and a huge number of smaller players that are so far quite disconnected from the opportunities of DX.

It should be noted, however, that companies providing the basic components for building infrastructures, from power to water, from heating/cooling to waste are offering them with embedded IoT and some have initiated specific training programs to let small/one-person companies get acquainted with the new technology.

7.1.5.1 ARUP

ARUP²⁸⁰ is a multinational engineering company, with presence in 143 Countries, that has been at the forefront of innovation. They have embraced ICT in their processes and embedded it (IoT) in their constructions where they are committed to leverage the DX.

Recently, they have adopted Digital Twins technology²⁸¹ and created a framework for their adoption and use in the construction sector. By having a digital twin for each of their construction they can offer maintenance and operation services, monitoring the status of the building and of its infrastructures. The Digital Twin is created as part of the design process and the required connections to the building are ensured through the embedding of sensors in the building construction.

7.1.6 Insurance

Unipol²⁸² is an insurance company in Italy that is undergoing a (slow) digital transformation in their relation with their customer base, moving to the cyberspace several processes (a trend accelerated by the recent epidemic). They are pushing for a digital monitoring of cars to decrease their risk exposure and at the same time they try to leverage on the accrued data to provide additional services to their clients.

This is the reason why this company is mentioned here, as an example of leveraging on data to expand their services.

7.1.7 IT & Telecom

The whole sector of IT& Telecom is looking at the DX as an opportunity for offering their infrastructure and services. However, we are seeing significant differences in adoption of DX by different players with the incumbent (Telecom Operators) often preaching the DX to sell their services but not adopting it in their internal processes, whilst new Operators, particularly (Mobile) Virtual Network Operators (in rapid growth, with a 2020-2025 CAGR of 7.3% leading to a \$89.9 Billion of turn-over in 2025²⁸³) are eager to ride the DX and leverage on it. Iliad²⁸⁴ is a case in point, a new Telecom Operator (born in France and rapidly extending to other Countries) that can offer its services at very low cost by having moved most of its processes to the cyberspace.

²⁸⁰ <https://www.arup.com/our-firm>

²⁸¹ <https://www.arup.com/perspectives/publications/research/section/digital-twin-towards-a-meaningful-framework>

²⁸² <https://www.unipolsai.it/homepage>

²⁸³ <https://www.globenewswire.com/news-release/2020/05/29/2041094/0/en/Global-Mobile-Virtual-Network-Operator-MVNO-Market-is-expected-to-reach-USD-89-9-billion-by-2025-witnessing-7-3-CAGR-during-the-forecast-period-2020-2025-VynZ-Research.html>

²⁸⁴ <https://www.iliad.fr>

7.1.7.1 Ericsson

Ericsson²⁸⁵ is a world player in telecommunications equipment and one of the big players for the next generation network and 5G. In addition, it has a specific branch²⁸⁶ providing Digital Transformation consultancy addressing the technology/infrastructure layer, the operation layer, and the organization layer.

7.1.7.2 TIM

TIM is the incumbent operator in Italy and has been facing tough competition, first from the open market, then by MVNO, and, most impactful in the service area, from OTT. As pointed out in the following, they see the Digital Transformation major challenge in the need to redesign processes and change the company (people's) culture.

A **Telecommunication Operator** is historically an **Infrastructure** player, who moved into **Services** and finds itself in the **Data** Industry, but with especially strict rules. Once a monopolist with Very Real and very demanding Networks to build and maintain, it saw its revenues and margins decrease as many Digital Service Providers started building their business on top of its commoditizing bandwidth. Then the Era of Data came about, and Telcos found themselves rich in Digital Data and looking for the ability to profit from them. However, despite having enabled Digitization since the very early days, they are still bound by old economy rules and brick-and-mortar organizations. The organization being what actually needs to change the most, in order to exploit Digital Space perks.

Organizations are made of people and processes. You cannot always change people that freely, which bounds Telcos, as so many other old companies, to focus on **Processes**. Processes look easy to steer as long as they stay on intangible flowcharts, but you soon realize they are built on very solid mental, societal and power structures. That's what you need to change in order to adapt an organization to the demands of an ever increasing transformation pace. It is actually very impressive how fast companies have become in realigning their organization to chase new and often fuzzy goals—so fast actually, that people and activities cannot match the pace. It is so fast, that you could end up with not enough time to adjust processes and mindsets, and therefore moving around blocks of skills and actually leaving behind a significant part of activities.

A better way of coping with fast changing environments is necessary, a way that would allow people in the organization to understand what is needed and to find the best way to match that need: that is the fastest way to realign your procedures to present and future demands. We could call it **collective intelligence**, and it relies entirely on **communication** – think of Planet Gaia from Asimov's Foundation. To achieve it, you need to share the goal rather than the means to reach it, as those means could be old as soon as you finish defining them. Can you afford to spend months designing a process that could last a week and which will be almost certainly outdated in a year's time?

You need continuous and fast improvements, but you also need a common direction. A **vision**, which is both the most difficult and the easiest thing to communicate: it is difficult if you focus on details and measures, but it is easy if you can talk to common knowledge and shared experiences.

²⁸⁵ <https://www.ericsson.com/en>

²⁸⁶ <https://www.ericsson.com/en/portfolio/digital-services/transform-business/digital-transformation-consulting>

Could **Artificial Intelligence** help? It can and it will: analyzing your data, finding patterns, making connections, uncovering critical points, and recognizing possibilities. It will be a powerful tool in exploring alternative design solutions and forecasting the outcomes. It could also act as an excuse to disrupt deep-seated bad practices, often hard to dismantle despite being recognized. Clearly, processes need to leave meaningful digital traces for AI to step in, using tools which can be various throughout the company, provided they give comparable information.

What AI and even the best designed processes won't do is create a **shared vision**, a vision that will have to be communicated, by humans to humans, because an organization is still made of **people**—not data, people.

7.1.7.3 Huawei

Huawei²⁸⁷ is a leading global provider of information and communications technology (ICT) infrastructure and smart devices. It is a major player in several areas, making its technology available in a variety of application areas. Although it is often associated by the lay person to smartphones and telecommunications equipment, it is a major player in several areas, making its technology available in a variety of application areas.

As leader in ICT solutions it is also exploring DX in partnership with its clients. In the following is an interesting example of DX applied to Shenzhen urban railway system²⁸⁸ planning and operation based on the use of Digital Twins (in their lingo BIM: Building Information Model).

The Digital Transformation relies on the mirroring of various attributes of the physical entities to the digital entities through design tools, simulation tools, and other digital technologies. In the digital transformation of urban rail transportation, for example, digitalize the entire life cycle process information such as planning, design, construction, and acceptance, could make multi-dimensional statistics and display the data in each process of subway construction, and retrieve and analyze the event-related data using the technologies like video surveillance, BIM (Building Information Model), Internet of Things, big data, AI, GIS, etc.

An effective digital construction site management system is able to promote the digital transformation of urban rail transportation. The basic concept is to integrate the data generated in the process of design, construction, operation and maintenance, and supervision of the smart construction. The status of personnel, equipment, materials, construction methods, environment, measurement, and monitoring of the construction site is reflected in the construction site management system through digital form, which realizes the digital and intelligent supervision of on-site construction work of the work team, as well as the continuous accumulation and application of construction site data assets. This system will improve the sharing of engineering information, management collaboration, rapid response, process specification, behavior traceability, and decision support capabilities in the smart construction.

The following figure describes an example architecture of the digital construction site management system, which is composed of four layers: application, model layer, data layer and physical layer. In each layer, there are some examples of the functional components.

²⁸⁷ <https://www.huawei.com/en/>

²⁸⁸ <https://www.railwaygazette.com/technology-data-and-business/shenzhen-tests-5g-for-smart-metro-applications/48630.article>

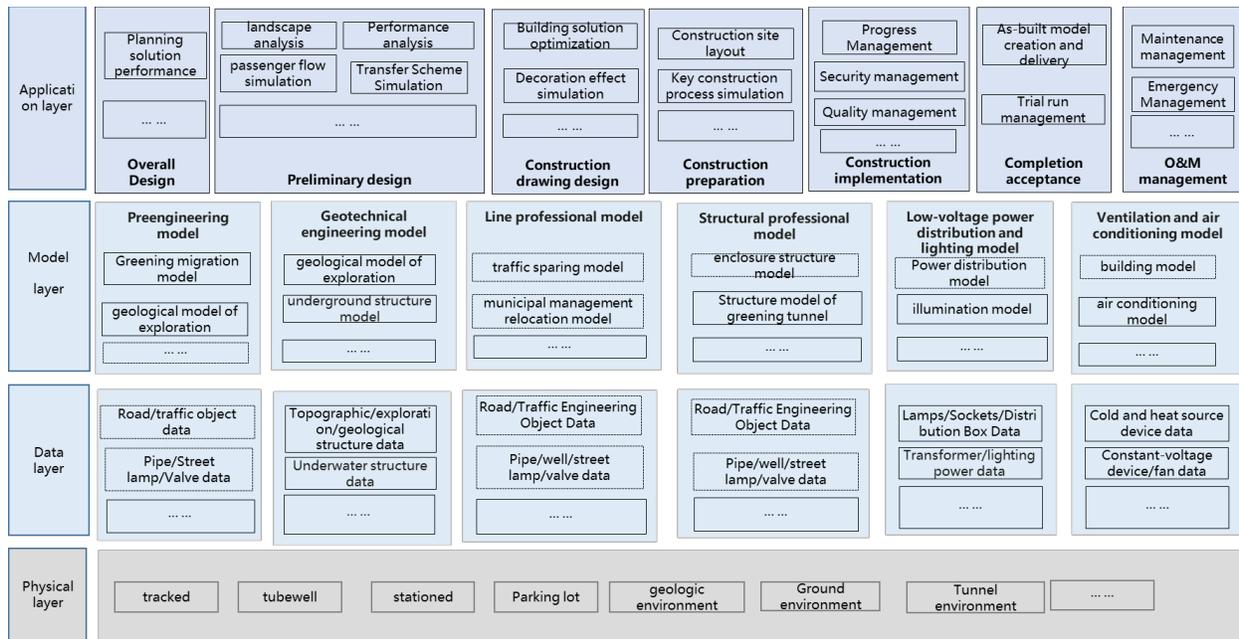


Figure 51. An example of the digital construction site management system.

Based on the GIS/BIM, the indicators such as security, progress, and civilized construction in all elements are displayed to facilitate management and decision-making support.

The data related to the BIM model may include: personnel management, mechanical management, progress management, security and quality, material management, environment and power loss, measuring, and detection.

Services

GIS-based AI video surveillance system:

- 1) Support real-time video monitoring of widely distributed projects based on GIS integration.
- 2) Support the extraction of key information in the video from the surveillance video data of urban rail construction sites for analysis. When safety violations and emergencies occur on the construction site, they will be monitored in real time and processed quickly. The alarm information, location information, and the location of the relevant video images in the GIS map are displayed in detail, and relevant information will be pushed to the handling personnel of different areas and different management departments, fully realizing the multi-level linkage of the management center, the safety and quality department, and the on-site management personnel.

BIM-based schedule planning and simulation

The application of BIM in construction project schedule control covers the whole process of the project implementation stage, mainly through virtual construction to guide the planning, promotion, inspection, correction, and evaluation of the project schedule. The specific method is as follows: first construct various components and professional information models through three-dimensional simulation software, and then carry out a detailed schedule plan according to the resource and total duration of the project. Then, by connecting the 3D model and the progress information, a 4D model is formed to visually display the construction progress of the entire project from the time dimension.

7.1.8 Banking & Financial Services

7.1.8.1 *Poste Italiane*

Poste Italiane²⁸⁹ is one of the biggest companies in Italy by workforce headcount and by the variety of businesses addressed. It is a post service, a bank, a mobile virtual operator, an insurance, and much more. They are also one of the issuers of the digital identity (SPID) for Italian citizens.

Their transition to the cyberspace started at least 20 years ago through automation and computerization. Now they serve as one of the European hubs for cybersecurity, and their Rome center is monitoring billions of transactions a day looking for potential cybercrime.

They have a very important role in the culture transformation of Italian people, particularly the elderly population that uses them as their bank for the monthly retirement checks.

7.2 Players by Process

7.2.1 Operational Transformation

One of the most difficult parts for DX is the transition of business from a classic economy to a digital economy. There is a need for applying technologies that might not have been used by that company/institution, but the crucial point is to re-engineer the processes and to leverage on data for and beyond the enterprise boundary.

There are many companies that address this specific need of Operational transformation. The ones following are just mentioned as examples and by looking at their website one can have a good idea of the challenges addressed.

7.2.1.1 *Hakuna Matata Solutions*²⁹⁰

This is a relatively small Indian enterprise created to help Indian companies to execute the Digital Transformation. It is mentioned here as an example of the interest in DX in emerging and developing Countries.

7.2.1.2 *Reply*

Reply²⁹¹ is a multi-country company headquartered in Italy operating as system integrator and deploying innovative solutions to help companies transition into the Digital Economy.

They have been very active in several parts of the Digital Economy, from the IoT, Cloud, and Artificial Intelligence to application services and process re-engineering. They span several vertical sectors, from Industry 4.0 to automotive, from Healthcare to Supply/delivery chains and eCommerce.

They are also active in the area of virtual and augmented reality and, notably, have been able to create an engaging virtual event with expo to make up for the impossibility to hold their customary meeting with clients in Spring 2020 with thousands of virtual participants.

²⁸⁹ <https://www.poste.it>

²⁹⁰ [https://www.hakunamatatech.com](https://www.hakunamatatatech.com)

²⁹¹ <https://www.reply.com/en/>

7.2.1.3 Engineering

Engineering²⁹² is an Italian company with presence in a few other Countries that has been very active in the area of Digital Transformation, particularly supporting Public Administrations.

They have been one of the founder of the FIWARE Foundation to promote the use of the FIWARE Platform, a European funded initiative²⁹³ aiming at accelerating the Digital Transformation by providing a platform to aggregate data and support services that would be easily customizable to fit specific needs.

²⁹² <https://www.eng.it/en/>

²⁹³ <https://ec.europa.eu/digital-single-market/en/future-internet-public-private-partnership>

8 Fostering a sustainable Digital Transformation

As stated in the European Digital Infrastructure and Data Sovereignty: a Policy Perspective²⁹⁴:

Digital infrastructures and data are at the heart of digital platforms driving the digital transformation in both consumer environments (such as for example Social Media), and industrial environments (such as for example the IV Industrial Revolution).

The data-driven digital transformation is a main source of innovation and produces wide benefits for consumers that escape GDP measurement, since many digital goods have zero price and as result the welfare gains from these goods are not reflected in GDP or productivity statistics.

Fostering a sustainable Digital Transformation requires a 360° approach, taking into consideration enabling factors, definition of culturally acceptable framework that provide a level field for competition, the establishment of standards to decrease industry cost and speed up innovation and deployment (think about the standards on communications infrastructures like 4-5-6G). Additionally, as pointed out in the quote from the European document, the establishment of platforms for processing and data is crucial. Unfortunately, there are significant differences among 5 broad clusters of geo-political players:

1. Europe

In spite of the European Union, Europe is a fragmented market (and different languages play a role in this, with Governments protecting diversity and local interest). Europe is placing the accent on ethics and privacy (GDPR is a clear framework for placing privacy on top). The Article 102 of the European Treaty regulates competition and is strong on anti-trust initiatives on dominant firms.

2. US

The US market compares with the global EU market, but it is not fragmented. The average level of prices can be a bit higher, given the higher average salary, and this favors infrastructures owners, like the Telcos. This, in turn, makes higher investment levels possible (like faster deployment of the 5G infrastructures) and benefits all industry sectors.

The cultural underpinning is rooted in “liberty” and violation of privacy is seen, and treated, as a tort. This provides more latitude to firms to exploit data and try out innovation on the market. If they use private data and are able to deliver services benefitting the market (in addition to generating revenues), the market will not pursue privacy infringements since it considers that more than offset by the benefit received.

There is no federal unified framework on data protection (mostly based on State laws). However, the situation might change with growing pressure to adopt GDPR-like regulation at federal level.

3. China

The Chinese culture (“shame” rather than the Western Countries “sin”) goes hand in hand with centralized government control under which the big Chinese companies supporting the Digital Transformation (Baidu, Tencent, Alibaba) operates.

The Chinese market is bigger than the US/EU ones, and in addition it can act as a buffer to level out international demand oscillation (when the foreign market slows down goods are sold internally, VV when demand from the foreign market is up goods can be directed to it).

²⁹⁴ <https://www.eitdigital.eu/fileadmin/files/2020/publications/data-sovereignty/EIT-Digital-Data-Sovereignty-Summary-Report.pdf>

An additional advantage of the Chinese environment lies in its manufacturing capability (although it is dependent on some foreign raw materials and components, but to a much lesser extent than the other markets). This capability is supplemented by strong availability of high education and high level skills.

The Chinese market and environment generates and aggregates many more data than any other areas, both in volume and diversity. Data protection is focussing on security and on Government, not on the single citizen (this is in accordance with the local culture so it is not perceived –on the average- in negative terms).

Given the present status of AI technology, the availability of large volumes of data and the possibility of integrating them favors the rapid evolution of AI in China.

4. Japan, South Korea

Japan and South Korea may be seen as inheriting some characteristics from all the three previous market areas. Culturally they share the Confucianism roots with China, they have an education level au par with Western Countries and a competitive market that is close to the US one.

In Japan, there is no equivalent to the GDPR. Privacy online is subject to general law of Act of Protection of Personal Information²⁹⁵. Overall, the approach is to have business auto-regulating itself (which plays well with the concept of “shame”).

An overview of Japan’s Digital Transformation policies is provided in a OECD brief²⁹⁶. South Korea has a number of authorities²⁹⁷ in charge for information rights and privacy protection:

- PIPC: Personal Information Protection Commission
- MOIS: Ministry of the Interior and Safety
- KCC: Korea Communications Commission
- FSC: Financial Services Commission
- National Human Rights Commission
- KISA: Korea Internet and Security Agency

A comprehensive description of South Korea Digital Transformation policies is presented under their Innovation Policy Agenda²⁹⁸.

5. Developing world

The Developing world presents a very varied approach to Digital Transformation policies and to privacy protection.

Although some progress is underway (11% increase in the 2015-2020 period), a recent United Nation conference on Trade and Development pointed out²⁹⁹ that over one third of Countries do not have any provision for data and privacy protection.

²⁹⁵ <https://www.loc.gov/law/help/online-privacy-law/2012/japan.php>

²⁹⁶ <https://www.oecd.org/policy-briefs/Japan-Policy-Brief-Digitalization.pdf>

²⁹⁷ https://www.privacy.go.kr/eng/about_us.do

²⁹⁸ http://www.innovationpolicyplatform.org/www.innovationpolicyplatform.org/system/files/Session%201_3_Park_STEPI/index.pdf

²⁹⁹ <https://unctad.org/en/pages/newsdetails.aspx?OriginalVersionID=2348>

A few Countries, like Brazil and Thailand, are considering adopting GDPR at the core of their legislation framework.

8.1 Policies

Technology and digital transformation are applied for the betterment of society, in areas such as healthcare, mobility, and smart cities. These changes result in societal and ethical impacts, and these challenges may become pervasive throughout these areas. In order to address the ethical and societal issues, policies are put in place to address the questions to find the best balance. IEEE engages in multiple public policy activities in order to advance its mission and vision of securing the benefits of technology for the advancement of society.

8.1.1 Intelligent, Connected & Autonomous Vehicles

Connected vehicles, autonomous driving, intelligent transport systems, and the Internet of Things (IoT) have emerged as major driving factors of automotive digitalization. With a global economic potential of over EUR 100 billion revenue per year in connected vehicles equipment (both hardware and software), the digitalization of the automotive industry is set to radically transform our transport and mobility behaviors.

The expected future development and large-scale deployment of intelligent, connected, and autonomous vehicles has led to a new paradigm of road traffic that focuses not only on public safety and environmental sustainability but also on how to ensure an adequate level for privacy, security and protection of the collected data, while improving the driving experience. With the evolution of digital technologies impacting all sectors of the economy, vehicles and the automotive industry are changing rapidly too.

The European Union (EU) has long addressed comprehensive responses to emerging technology issues, recognizing that complex and interdependent challenges require action at multiple levels and over extended periods. Over the past years, the European Commission, EU Member States, and industry in collaboration with other stakeholders, have worked together to achieve the EU's vision for connected and automated mobility in a Digital Single Market and to shape more incisive policies relating to privacy, data use and protection, connectivity, cybersecurity, road and vehicle safety, and liability.

These efforts have included both policy and legislative initiatives, as well as funding of research and innovation projects, and the development of standards³⁰⁰. Examples include the "Europe on the Move" mobility packages for a safe, connected, and clean mobility; the Road Safety Policy Framework for the period 2021-2030, which includes two legislative initiatives on vehicle and pedestrian safety, and on infrastructure safety management; a dedicated strategy on connected and automated mobility; the Cooperative Intelligent Transport Systems (C-ITS); the 5G cross border corridors; the 2020 European Strategy for Data; as well as proposals for equipping vehicles with advanced safety measures and funds of over EUR 450 million to support projects contributing to road safety, digitization, and multimodality.

The Position Statement of the European Public Policy Committee aims to offer specific recommendations to policy makers and other policy stakeholders in Europe with a view to further

³⁰⁰ See https://ec.europa.eu/transport/modes/road/news/2018-05-17-europe-on-the-move-3_en for the full spectrum of recent initiatives by the EU in the area of mobility.

promoting the full-scale development and deployment of intelligent, connected, and autonomous vehicles. Not only technologies that are potentially applicable for this future generation of vehicles³⁰¹ are relevant to the engineering profession and within the technical interest of IEEE, but their development will also be instrumental in making Europe a leader in smart cities, achieving the objectives set out in the European Green Deal, and ensuring an adequate level of European digital and industrial strategic autonomy.

The debate about pathways towards the future of mobility is ongoing, and its outcome will inform EU policy and legislative options, including the development of a common European data space for mobility to allow for data sharing and the EU Strategy for a Smart and Sustainable Mobility to be presented later this year. Just as the transport sector is cross border in nature, so too needs to be the approach to it.

Against this backdrop, five major issues and axes of action are highlighted, and possible solutions that have been agreed with the wider IEEE membership are put forward. These include:

Issue #1 – Privacy and Data Protection

ICAVs may exchange and store large amounts of data through current and next generation technologies and infrastructure, e.g. 5G and beyond as well as IEEE 802.11xx. This data may be available for sharing by authorized agencies. This feature raises a number of concerns in terms of the following data attributes: ownership and sharing, privacy and protection, as well as security and management of repositories. Addressing these issues and developing a more robust framework can be facilitated through:

- restricting data sets and levels of data access to a limited number of authorized parties or applications such as:
 - disaster recovery, emergency services and public safety;
 - car health monitoring and maintenance services; and,
 - intelligent transport infrastructure which continuously collects data from and exchanges with all involved vehicles.
- encrypting all data collected for storage, transmission and processing; independent of the nature of the data sets and their access levels, and this includes e.g. shunting past data to an encrypted storage if only currently collected location data are used;
- protecting data from unauthorized tracking, e.g. making data anonymous without revealing sensitive and personal data of drivers and passengers;
- adhering fully to European regulations (e.g. GDPR) and guidelines with respect to data protection and management³⁰²; and,
- preventing the collection of data, which are irrelevant to the requested service, without the consent of the data owner.

Issue #2 – Cybersecurity

Increased connectivity of ICAVs and interconnection amongst systems, including the grid and communication infrastructure, increase the risk of cyber-attacks, as attackers would have a larger

³⁰¹ There are six stages of AV development (SAE levels 0-5), today level 2 vehicles are commercially available. For more information, see <https://www.sae.org/news/2019/01/sae-updates-j3016-automated-driving-graphic>. For further extensive details, see also https://www.sae.org/standards/content/j3016_201806/

³⁰² The Information Technology Policy Unit of the European Data Protection Supervisor (EDPS) and the European Data Protection Board (EDPB) https://edpb.europa.eu/sites/edpb/files/consultation/edpb_guidelines_202001_connectedvehicles.pdf

number of individual nodes and weak points to access. To address potential cybersecurity threats and prevent unauthorized access, specificities of the cybersecurity risks and vulnerabilities of ICAVs need to be identified and effective solutions put forward.

Cybersecurity is a relatively new challenge for the automotive industry. It is recommended that the ICAV players liaise with industry partners, who have experience and expertise like e.g. Telcos, defense, banking, and public transport. Together, all parties can benefit from resources, skillset and common activities which can lead to an exchange of best practices, latest cyber-attacks and countermeasures. In addition to recommendations noted in this paper, the Cybersecurity Position Statement of the IEEE European Public Policy Committee can be leveraged.

Issue #3 – Public Safety

Improving and assuring safety, including that of pedestrians, drivers, passengers, animals, goods etc., is imperative, and ICAVs at all levels of driving automation will need to adhere to these requirements just like traditional cars. The highest design objectives for ICAVs must be to guarantee these needs under all circumstances. This requires that information provided under any weather conditions by every sensor, satellite assisted navigation systems (e.g. GPS and GNSS) and/or Inertial Navigation Systems (INS), RADAR, LiDAR and cameras must be interpreted correctly; taking into account other assisting information such as maps, V2V communications, and car connectivity.

Based on these inputs, the decision logic needs to take into account the safety of the pedestrians, driver, passengers, and any other persons, animal or goods potentially involved. The IEEE EPPC recommendation is to: build upon existing policies and initiatives; ensure that the identified areas are being addressed; and, benefit from lessons learned for technology advancement (e.g. Artificial Intelligence, Blockchain) in ICAVs that continue to safeguard all public safety issues.

Issue #4 – Product Safety (Guarantee of Intelligent, Connected and Autonomous Vehicles, test specifications and lifecycle management)

A number of products available in the market require certain types of licenses to become authorized (e.g., factory and household machines, etc.). To guarantee the safety of ICAV products and equipment, a series of tests based upon well-defined specifications and standards should be conducted, with authorizing entities providing certifications of compliance.

Examples of key testing areas to consider, but not limited to, are: static tests e.g. sensing, perception and planning components or systems; dynamic tests in closed environment e.g. integration, actuation and control; and, specific designed situational tests defined by external parties. These tests must be conducted under worst-case conditions, e.g. for all operational design domains (ODD)³⁰³. Importantly, safety should be considered for the entire life cycle of ICAVs, and covers the conformity of component- and system-level specifications and regional requirements.

Issue #5 – Liability

A public debate that clarifies driving automation levels, how ICAVs function, their sub-system roles, and their interactions; can offer guidelines to lawmakers and help build a regulatory framework that gives legal assurance to all parties concerned.

³⁰³ For details: https://www.sae.org/standards/content/j3016_201806/

Depending on the SAE driving automation levels, driver responsibilities for levels 0-2, and system responsibilities for level 3-5 need to be explained and distinguished. In addition, dependencies on external factors, such as telecom network and/or V2V communication failures also need to be considered in the regulatory framework. As an example, existing guidelines and regulations for the aircraft industry could be considered as a reference.

The concept notes for a future position statement of the IEEE European Public Policy Committee (EPPC) on Intelligent, Connected, and Autonomous Vehicles as detailed earlier in this section is currently under review and is not a final concept note and position statement by the IEEE EPPC.

8.2 Standards

Standards are crucial for the commercialization of new technologies as they encourage innovation in the industry and shorten the time-to-market of products and technologies. IEEE is not only the world's largest professional organization but also one of the most influential standards developing organizations (SDOs) globally. As of today, 1,300+ IEEE standards have been published and another 900+ are being developed. Unlike those national-body based SDOs, IEEE's standards development is completely market-driven and industry-oriented that makes IEEE the go-to platform for many companies and institutions to develop global standards.

Standards Projects and Working Groups

In IEEE, standards under development are called Standards Projects. The organizational unit that takes the actual work of drafting standards is called Working Group. There could be multiple projects under the same Working Group. Although, in most cases, a Working Group is responsible for a specific project.

There are two different ballot types for each project and the corresponding Working Group: individual-based vs. entity-based. The participants of individual-based projects and individual-based Working Groups are individuals; however, they could claim that they are affiliated with entities (companies and institutions) or themselves. The participants of entity-based projects and entity-based Working Groups are representatives of entities that are also required to be IEEE SA entity members (also known as IEEE SA corporate members).

A project proposer is free to choose the ballot type between individual-based and entity-based. Typically, entity-based projects would have less participants than individual-based projects, since the IEEE SA entity membership fees may be considered as a barrier by some small and medium entities. However, for those who are willing to afford the IEEE SA entity membership fees, entity-based projects usually mean smoother balloting and faster development.

To officially propose a project, the proposer needs to submit a Project Authorization Request (PAR), which is basically a questionnaire no longer than a couple of pages after completed.

Standards Committees

Before you start composing a PAR, the first thing is to find a Standards Committee to sponsor your PAR. According to the IEEE SA Standards Board Bylaws, the Standards Committee shall be one of the following:

1. A Technical Committee within an IEEE Society/Council
2. A Standards Committee or Standards Coordinating Committee of an IEEE Society/Council
3. A Standards Coordinating Committee established by the IEEE SA Standards Board
4. A Standards Subcommittee organized by or reporting to one of the above

5. A Standards Committee within the Corporate Advisory Group (CAG)
6. Other organizations as recommended by the IEEE SA Standards Board and approved by the IEEE SA BOG

The Standards Committee shall be responsible for the development and coordination of the standards project and for supervising the standards project from inception to completion. The Standards Committee also shall be responsible for the maintenance of the standards after their approval by the IEEE SA Standards Board. In other words, the Standards Committee will oversee your Working Group and your project throughout the standards development process.

As of today, there are totally 97 Standards Committees within IEEE. 89 of them are under different IEEE Societies and Councils, and another 8 are directly under IEEE SA.

Group Name	Committee	Group Type	Groups I Am Interested In
+ IEEE Aerospace and Electronic Systems Society	AES	Society	
+ IEEE Antennas and Propagation Society	APS	Society	
+ IEEE SA Board of Governors	BOG	Society	
+ IEEE Broadcast Technology Society	BTS	Society	
+ IEEE Computer Society	C	Society	
- IEEE Consumer Electronics Society	CES	Society	
+ Blockchain Standards Committee ⓘ	CES/BSC	Standards Committee	●
+ Digital Finance and Economy Standards Committee ⓘ	CES/DFESC	Standards Committee	●
+ Standards Committee ⓘ	CES/SC	Standards Committee	●
+ Smart Devices Standards Committee ⓘ	CES/SDSC	Standards Committee	●
+ Virtual Reality and Augmented Reality Standards Committee ⓘ	CES/VRARSC	Standards Committee	●

Group Type Legend: Society Standards Committee Subcommittee Working Group Project/Task Group Study Group

Figure 52. A full list of IEEE societies and committees can be found online.

All the Standards Committees can be easily browsed in myProject, which is an online system used by IEEE SA to manage all the projects and standards. From the technical perspective, you should make sure that your PAR falls into the scope of the Standards Committee that you identified. And you should talk to the Standards Committee chair or another officer before you submit your PAR in myProject.

NesCom, RevCom, and PatCom

NesCom, RevCom, and PatCom are the three committees under the IEEE SA Standards Board (IEEE_SASB) that are directly relevant to the development of a standard.

NesCom (New Standards Committee) shall examine Project Authorization Requests (PARs) and make recommendations to the IEEE SA Standards Board regarding their approval. Such forms shall be reviewed in detail to make certain that all necessary information has been properly provided. Your PAR will be submitted to NesCom after the submittal is authorized by the sponsoring Standards Committee.

RevCom (Standards Review Committee) acts in an advisory capacity to the IEEE SA Standards Board by making recommendations on the approval or disapproval of standards submitted for IEEE SA Standards Board approval or adoption. Approval or adoption of a standard requires a consensus of RevCom that the requirements of the procedures of RevCom and those of the IEEE SA Standards Board have been satisfied. Specifically, this means that the final results of the Standards Association ballot and

statements submitted by balloters who participated in the development of the standard indicate that consensus has been achieved and unresolved negative ballots have been properly considered, together with reasons why the comments could not be resolved. After your Working Group completes the standard draft, you need to request the sponsoring Standards Committee to authorize the SA ballot for your standard draft. After the SA ballot, a package including your standard draft and the ballot statistics should be submitted to RevCom.

PatCom (Patent Committee) reviews patent letters of assurance and other patent information submitted to the IEEE Standards Department. It examines issues brought to its attention regarding IEEE Standards development and patents, and makes recommendations as appropriate. During the standards development in your Working Group, whenever someone wants to put a patent into the standard and make it an SEP (Standard Essential Patent), a letter of assurance will be requested from the patent owner.

ICCom (Industry Connections Committee) reviews proposals from industry and the academic community that ICAIDs for consideration and approval with oversight and guidance by the Committee for a period one or two years. ICAIDs offer individuals the opportunity to develop a topic or association associated with a rapidly developing technology. For some of these ICAIDs, the body of work serves as the basis for a new PAR that leads to a standard.

Most FDC Initiatives have established PARs through an IEEE TA Society or Council Standards Committee. This also provides members with an avenue to contribute and participate in other IEEE-SA efforts, such as the IEEE-SASB and standing committees of the Standards Board. Standards development is essential to developing and establishing the technologies coupled to the Initiatives. Members of IEEE TA Societies and Councils can participate on the TA Committee on Standards that provides oversight on standards development within SCs.

A list of PARs focused on Digital Transformation, VR/AR and Digital Twin are provided in the appendix. An IEEE volunteer can join standard development efforts within a S/C SC or an FDC Initiative and contribute. The FDC Initiative offers the members options to contribute in broad range of efforts within the Initiative itself, through S/Cs, IEEE-SASB, and standards committees using their technical knowledge and experience to establish a standard.

9 Roadmaps

This section outlines the information on the expected roadmaps of digital transformation. As pointed out in section 5, there is a significant variety of situations in different geographical areas. Hence for specific roadmaps, one should refer to the geographic area of interest.

What is found here are:

- technology roadmaps for the technology enablers discussed in section 3.1
- economic sectors roadmaps for e-Government, entertainment, manufacturing, logistics, retail, real estate, healthcare, communications infrastructures, education
- cultural roadmaps

9.1 Economic sectors roadmaps

9.1.1 Education

New skills and education – XR and Cyber-Physical-Social Eco-Society Systems in Education

Education is an important societal component and a vital area for the future development. Organizations, governments, scholar communities, and individuals are committed to keep leveraging new and emerging digital technologies, for instance Augmented (AR), Virtual (VR), Mixed (MR), Extended (XR) Realities, Digital Twins etc. to deliver knowledge to students and to the industry. The education market worth billions, and it will continue to grow and is crucial to ensure efficient access to knowledge and its delivery, and exploit knowledge as a service. Learning using immersive technologies has never been more exciting than nowadays. A wide range of immersive tools and hardware devices are at the disposal of educators, enriching their teaching toolbox with solutions that can support and enhance current teaching and learning practices. Over the past few years, there has been a significant increase in the use of XR environments to support and enhance learning, and the focus of this section is to highlight the main directions in the utilisation of Extended Realities in education at present.

VR in Education

VR has drawn significant interest in its use and application for educational purposes. The Oxford dictionary defines VR as a *“computer-generated simulation of a three-dimensional image or environment that can be interacted with in a seemingly real or physical way by a person using special electronic equipment, such as a helmet with a screen inside or gloves fitted with sensors.”* VR is frequently employed in education to enable the development of immersive learning environments in which learners can interact with and be part of the lesson instead of than the tool. After decades of expensive hardware requirements and technical glitches and issues hindering VR mainstream implementation, it is now a mature and customer-ready technology. Powerful computers that can support high fidelity VR experiences are now at reasonable prices, in portable and lightweight sizes. According to Hussein & Nätterdal, *“the differences between modern VR compared to the concept of VR presented two decades ago is that the technology is finally at the stage where it can be adapted to any mobile phone.”* Students have powerful computing devices in their pockets, their smartphones, and mainly use them for recording and share videos and multimedia, experiencing face filters, playing games, watching videos, social networking, etc. Smartphones have become an integral part of our everyday lives and can be even considered an ‘extension’ of our brain.

As previously indicated in our [Symbiotic Autonomous Systems White Paper III](#), we are using on average ten different applications every day and as much as 30 different applications every month, with the app market increase expected to reach \$188 billion in 2020. Considering the familiarity, daily usage, and to an extent, reliance on our smartphones, many opportunities for utilizing the computational power and visualisztion capabilities arise and are ready to be exploited. Considering that there are more than 3.5

billion smartphone devices, as much as 50% of the world's population possess one or more, and each device is composed by at least 10-15 sensors. We are becoming part of a cultural digital transformation.

Utilizing the smartphone technology that students have in their pockets, especially with the use of low cost headset devices like Google Cardboard and Samsung Gear VR, VR can now become mainstream in education. This would allow students to use their smartphone devices to immerse in high fidelity virtual environments and participate in educational activities. In fact, a report on technology trends in higher education has predicted that VR technologies will be adopted in the higher education sector in the next few years. Recent studies indicated that as much as 94% of all teenagers are using the internet daily and 91% use a mobile device to get online, as well as that student ownership of smartphone devices has exceeded the ownership of laptops. These findings demonstrate that the increased use of mobile devices and technological advancements of hardware and the internet offer opportunities to be harnessed for educational purposes in a wide range of educational topics.

AR in Education

The use of AR in education also drew a lot of attention over the past few years. AR aims at connecting the real with virtual worlds by creating realities that are enhanced and augmented, creating the illusion that computer generated virtual elements exist in the real setting in real time. AR is defined as *“a form of virtual reality where the participant's head-mounted display is transparent, allowing a clear view of the real world.”* It is *“a situation in which a real world context is dynamically overlaid with coherent location or context sensitive virtual information.”* AR is a variation of VR that rather than replacing reality for the user entirely. It uses the existing physical environment in a MR mode in which the physical and the virtual environment are presented together. AR allows the coexistence of virtual and physical objects, enabling learners to visualize spatial components that are difficult or even impossible to reproduce in the real world. It also enables interaction with 2D and 3D objects in a MR mode that blends the real with the synthetic world. This allows the development of practices that the traditional technology mediated learning tools and technologies cannot provide.

AR can be used through a number of technologies such as computers, immersive glasses, HMD's, backpack computers, projected walls, and others, but the educational value depends on the AR experience rather than the implemented technologies. In education, students can use such technology to overlay virtual elements on devices to manipulate and interact with them. Especially with the mobility offered by the use of the smartphones students already possess, this provides authenticity of the learning environment and increase students interactions with the environment and with each other. The use of AR can provide opportunities to teach and learn content in 3D, establish collaborative and situated learning, offer opportunities to visualize invisible artefacts, and to bridge formal and informal learning.

MR, XR and Cyber-Physical-Social Eco-Society Systems for Immersive Learning

Mixed Reality (MR) is an experience that blends the real world with digitally created content, and enables both environments to coexist and interact with each other. The Reality-Virtuality continuum as defined by Miligram et al. describes and can help understanding the different levels of reality.

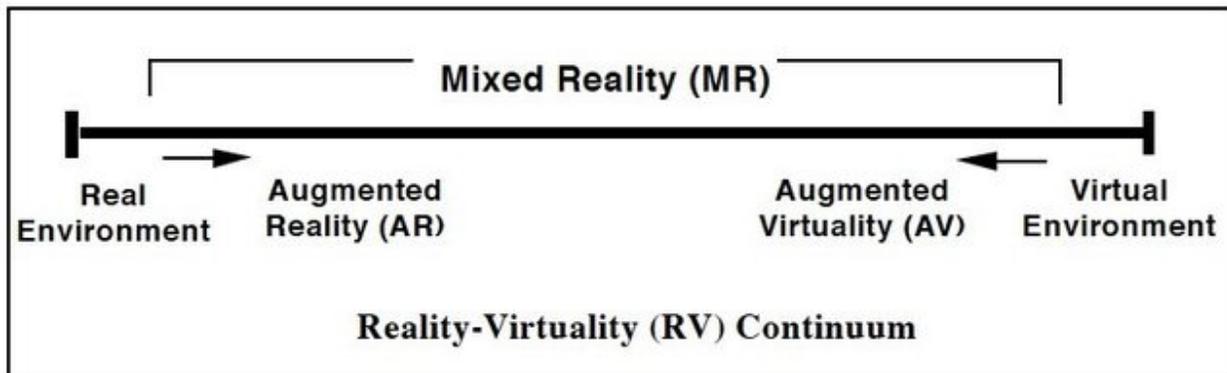


Figure 53: Milgram and Kishino's Mixed Reality on the Reality-Virtuality Continuum. [From Medium.com](https://medium.com)

This is ranging from a completely real to a completely virtual environment, where MR is a situation in which real and virtual objects are presented together, introducing the concept of AR and Augmented Virtuality (AV) in one frame. According to this concept, AR involves the real world more than the virtual elements by projecting virtual objects to a real environment, whereas AV involves more virtual elements than real that project real objects in a virtual environment. The weight of augmentation should also be considered and it has been put on a spectrum by Klopfer, ranging from light to heavy augmentation. A lightly augmented reality is a situation using predominantly a large amount of information from the physical world with little virtual information. In heavily augmented situations, the use of presentation devices such as HMDs is employed to generate the immersive environment.

Extended (or Cross) Reality (XR) is an umbrella term that represents these artificial digital experiences and the fusion of real and digital environments, and encapsulates the hardware, software, methods, and experiences that make VR, AR, and MR a reality. XR in education provides academic flexibility to deploy immersive technologies to support students learning in engaging, interesting, accessible, and experiential forms.

Going beyond the use of XR in education, the use of a new type of conceptually led Cyber-Physical-Social Eco-Society (CPSeS) systems has been recently introduced to support immersive learning. CPSeS are intelligent systems constituted by physical space(s), real and artificial agents and elements, the virtual space that seamlessly connects them, and are influenced by users and their intentions. CPSeS systems blend the real with digital worlds using Immersive Technologies, Robots, and Social Networking technologies, providing opportunities for formulating innovative social XR experiences to support education. In such systems, students can interact with elements from the physical and digital worlds, with educational content and with each other, and their interactions and intentions influence the system.

Students also interact with real and digital robots placed either in the real or in the digital world(s), or in both. These robots form networks of stationary and mobile agents and their corresponding Digital Twins are used as intelligent tools to support students while participating in learning activities in the digital and real spaces. Students use low cost HMD's and their smartphones to connect, synchronously coexist in the same-shared spaces or participate in individual activities, interact and apply the concepts they have learned in risk free XR environments and participate in collaborative activities. An educational CPSeS can facilitate the symbiosis of robots, their digital twins, students, teachers, and their avatars, in a

multifaceted intelligent system which they are all learners and collaborators, offering opportunities to experience interactive and multimodal immersive learning situations and activities.

9.2 COVID-19 impact on the deployment of Digital Transformation

COVIDs-19 has become a catalyst accelerating the Digital Transformation. Basically, nobody predicted the impact of this epidemic, although several organizations in the past decade have warned of the possibility of a pandemic. From a Digital Transformation point of view this has generally resulted in an acceleration. In turn, this acceleration has made several issues emerge. Whether the changes forced by the measures to contain the epidemics will result in a permanent change remains to be seen. With respect to Digital Transformation, the consensus is that there will be no going back since the path was already in place.

Take Italy as an example: it is doubtless that this crisis has forced a shift to the cyberspace, pushing the Digital Transformation several steps forward. In Italy, all the governments (in the plural to highlight that the many parties and coalitions that took the helm in the last 20 years have all sung the same song) have been speaking about implementing the DX for citizen services, for business and business to bureaucracy, in education, in healthcare, you name it. Basically very little happened, although lot of money has been spent (wasted) to create several digital identities, plenty of ways to digitally access various government agencies and so on.

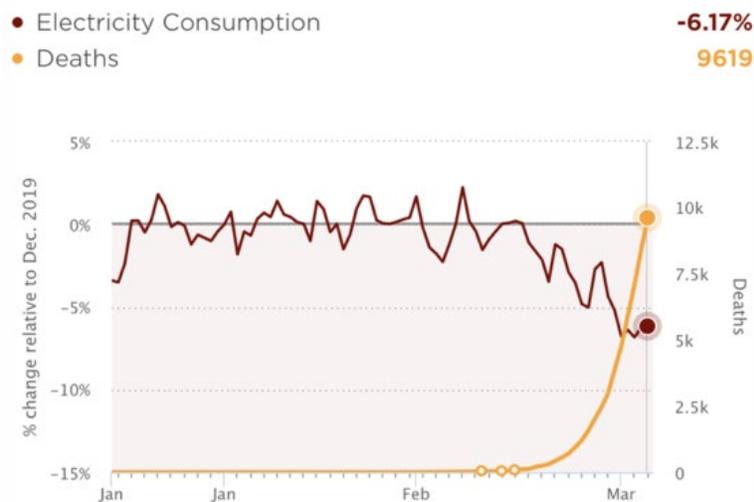


Figure 54. The decrease in electrical power consumption in the US mapped against the rising toll in death by COVID-19. Notice the plunge close to 7% in electrical power consumption. Image credit: EPIC – Energy Policy Institute at the University of Chicago.

As the epidemic struck, we have seen, in just a couple of weeks, a shift to the cyberspace, like:

- medical prescriptions turned electronics and now we receive them by mail and can get them from any pharmacy just by showing the code on our smartphone;
- interaction with public offices is now possible, like magic, online for many daily needs;
- teleworking that previously required lots of paperwork and lengthy approval processes can now be implemented in a matter of hours;
- schools, from primary to university, have all moved to the cyberspace teaching and exams;
- provisioning of computers, tablets to families that did not have them was, through various channels, implemented in less than a month;

- teaching computer literacy (a year-course in the secondary school) has become a crash course for all students from primary on, and that took a week to deliver; now all students use email, Google Drive, Zoom, MS Teams and the likes;
- the network capacity has been upgraded (increased by 50% on the backbones) in less than a week and major Operators have upgraded all mobile subscriptions to an all-you-can-eat to enable people access to the web with no volume constraints.

The list can go on and on. Now, I perfectly understand that all this was possible because of the work that took place in the previous twenty years but the emergency turned the switch on. Without it, in Italy, we would still be discussing and talking about it. Today, all students are learning online, and some 40% of the workforce is working from home.

This is, at least to me, an upside of the epidemic. However, if we look closely to the new “world,” there are several grey areas that will need attention in the coming months as everybody is saying that they will bring us into a “new” normality, a new way of life.

Let’s consider energy use. As shown in the graphic the US has seen a decrease of about 7% in electric power consumption. Now, this is strange, thinking about it. Wouldn’t we have expected a much sharper decrease in electricity consumption? Notice that in the same period the consumption of gasoline collapsed by 30%! The widespread stop of industry, well documented by the decrease in CO2 emissions (-25% in China), should have resulted in a similar drop in electricity usage.

Yet it was not so. The 7% decrease is actually representing a major shift of electricity use and it actually marks an increase of use to power the cyber world.

Our shift to online education and work has increased the demand on communications networks and, most importantly from an energy point of view, on the Cloud (data centers). Although, twenty years ago we used to say that data infrastructures use an amount of energy that is independent of the demand volume (in the end sending a “0” cost as much as sending a “1”), the situation has changed dramatically. As power demand in data centers and communication networks increased, engineers have found ways to decrease it by placing dormant all those components that are not needed. Even cellular antennas decrease their radiation energy when the traffic demand slows down. This savvy use of energy starts from the single chip where each par is powered up only at the time it is needed, all the rest remains dormant, and goes up to the big data centers where racks and pods are put to sleep when the demand slows down.

As demand surged, so did the energy use, and this accounts for the huge increase we have seen in these weeks on the cyberspace support infrastructure.

It is not just about the infrastructure. Applications may be power hungry, and AI is clearly leading the pack. It is estimated that the pattern learning phase of an artificial intelligence service may require the equivalent energy of that used by 10,000 cars for a day.

The cyberspace demand of energy does not fit well with renewable sources, and this may be an issue in the coming months and years. Assuring a constant supply 24/7 of energy to a data center using only renewable may increase its energy cost by 400%. The economic downturn started by the epidemic might lead to a reconsideration of investment on renewable (not to be taken for granted but a real possibility,

particularly in a period when the cost of oil has plummeted), and clearly this is not a good news for our climate.

Another bad twist is the likely behavior of people as life will slowly go back to (the new) normal. As we are seeing in China, people tend to use much more their private car rather than the public transportation to decrease contagion risk. This is the opposite of what we have been advised to do in the past, increase use of public transportation to decrease pollution. Check the Moovit report.

9.2.1 Forced shift to Teleworking

Teleworking has spiked in most COVID-19 affected countries, moving from a single digit percentage to double digit in a matter of weeks. In Italy, all clerical work, both in private companies and in the Public Administration, moved to the cyberspace in a matter of days.

Clearly, it is too early to have an objective assessment of this shift in terms of productivity; some early research, like the one mentioned in the figure, seems to indicate that the teleworkers perception of productivity has decreased (it would be more effective to work at the office). However, as people get better used to cooperative online tools, this perception may change. Besides, the teleworker perception of productivity may be different from the actual productivity measured in objective terms (although, it provides a significant estimate). For sure, the productivity plummeted in those areas where teleworking was not possible.

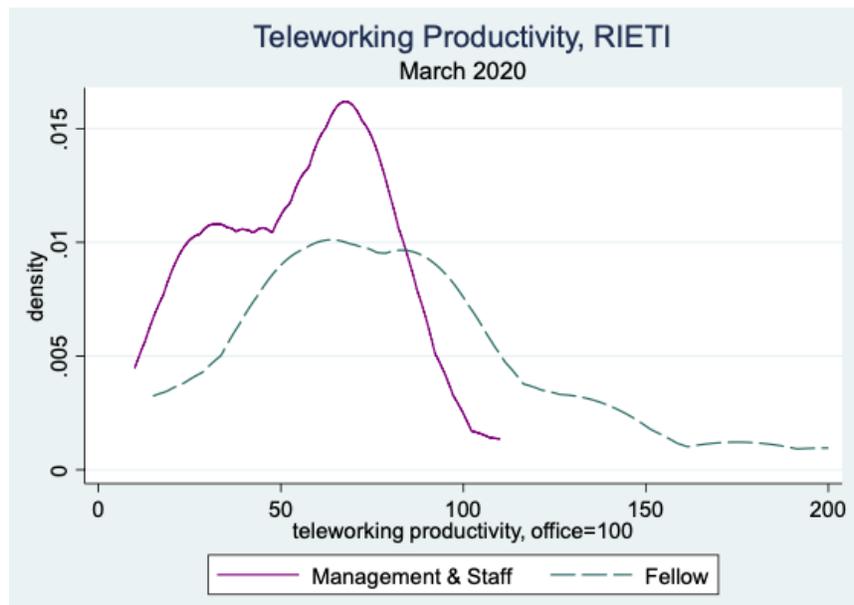


Figure 55. Teleworking Productivity chart. A research, published on April 10th, analyzing the productivity perceived by teleworkers in a research organization in Japan that spent the whole of March 2020 teleworking from home. The purple solid line represents manager perception of their own productivity and peaks at 63% indicating that the feeling was a decrease of 37% of perceived productivity. The dashed line represents researchers perceived productivity and peaks at 81%. However, notice that a significant portion of researchers perceives an increased productivity at home in comparison to the office. Image credit: Masayuki Morikawa, RIETI

What is emerging, however, is that a number of people, and companies, are now much more seriously considering teleworking as an option to keep using once the epidemic will be over. The epidemic had the effect of forcing experimentation and at the same time of pushing for better tools to manage remote working. It also, most importantly, forced a re-engineering of processes to make teleworking possible. Part of this re-engineering (and this can be a bad news to many) lead to disintermediation of functions, basically rendering some jobs irrelevant (read: killing them). Obviously, this is not because of the epidemic, it would have happened once a company would have implemented teleworking. It just happened in a matter of days as the companies had to shift to teleworking.

It is actually the speed of change that may be problematic. We know very well (although sometimes we pretend not to) that the Digital Transformation decreases the market value (because it decreases transaction cost, shortens the value chain, makes some activities irrelevant). Whenever we apply the Digital Transformation, we increase efficiency, and this in a competitive market leads to a decrease of price to the end customers, hence to a decrease of the market value.

Usually, the Digital Transformation takes time, it is actuated on niches that expand over time. This give time to manage the value squeeze, to reallocate resources. As it is happening today, not in years but in days, we no longer have the luxury of time to implement countermeasures.

Add to this the decreased demand, following the decreased market liquidity as people lost their jobs and companies had to reduce their offer, and we are facing a perfect (economic) storm.

On the upside, we are seeing that demand for online education has increased exponentially. People finding themselves out of job and those that moved to telework need to learn the new tools of the trade to remain competitive in the new environment. The good news is that such tools exist and are easier to reach in the cyberspace. The bad news is that competition is no longer confined/constrained by geographical proximity. Now, a person can offer her services/skill/knowledge to whoever might need them independently of the geographical location.

In these last weeks, I have received several offers of services from people/companies thousands of miles away from my home base.

As competition increases at the level of single people and small medium enterprises, we are seeing the lock in of the market by the top guns. The provisioning of infrastructures in the cyberspace is very costly (read: data centers), and the value of these infrastructures follows the Metcalfe Law. Originally born to quantify the value of a network (telecom, computer), the Metcalfe law has expanded to quantify the value of business and social networks. This value grows exponentially with the growth of nodes (read: users). These infrastructures decrease the users cost (transaction cost) and ensure interoperability within themselves. In turn, this creates the lock-in. You end up using an infrastructure because of the advantage you get in cost decrease, but at the same time you get interoperability with those that are part of that ecosystem but not with those outside so you are forced to stay in that ecosystem.

If you buy a Canon, you are most likely to remain with Canon: moving to Nikon would mean to change all your lenses since the ones working on your Canon camera cannot be used on a Nikon. With software, it is a bit easier: if you are in a Windows ecosystem you can find ways to convert your stuff to the Apple ecosystem (and vice versa), but it is pretty inconvenient and most people don't change ecosystem. Once you are in one, you are basically stuck with it.

The Digital Transformation is enabling a gazillion small companies to access the marketplace by decreasing the entry level hurdles and at the same time makes the big companies bigger and more self-referential.

The rapid uptake of the Digital Transformation under the pressure of the epidemic is robbing companies, and institutions, of the time to evaluate choices. This is probably one of the reasons why we hear a lot of concerns in the sudden adoption of tracing apps that might trade too much privacy for safety.

9.2.2 Digital Imaging exploited for enforcing social distancing

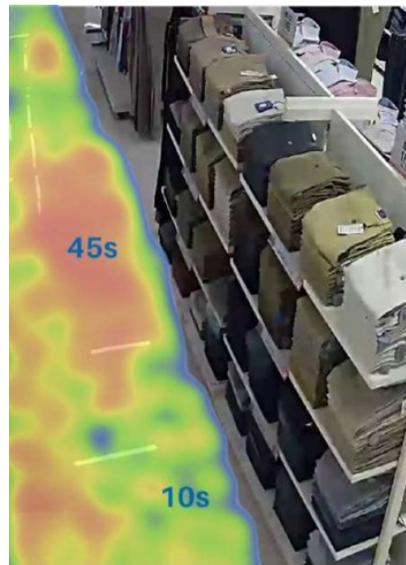


Figure 56. Use of analytics on video camera images to detect the time people stands in front of a shelf. Redder areas are those where people on average stay longer. Image credit: Glimpse Analytics.

We already have plenty of data that are captured at any time in many places. As shown in the picture, department stores are using analytics on images captured by video cameras to assess the average time customers spend in a specific location, like looking at products on shelves. Based on these data, the store managers try to move products in different positions, evaluating how this would impact the attention span of customers and their willingness to buy a specific product. Notice that department stores have the goal of selling all their merchandise (they use data on saleability of items for re-stocking policy, but they want to sell whatever they have on the shelves!) and therefore try to readjust the merchandise in ways leading to the complete sale of all stock (this is obviously the case of grocery and dairy products where you want to have everything sold out before it rots!).

Companies like Glimpse Analytics are in the business of providing intelligence based on video camera images, and these companies are now expanding their analytics to serve the needs of social distancing. Video cameras feeds are analyzed to check that people wear masks and keep their distance from one another. Robotised attendants can be directed, automatically, to warn people of their lack of compliance.

This reduces the cost to control people’s flow and potentially makes it more effective since a few (affordable wireless camera) can be deployed to provide full coverage of a shop floor plan. Similarly, cameras and analytics is being applied to monitor plants and workers movements.

The side effect of these measures is to create a platform for the digital transformation of retail, where more and more AI can be used to deliver services to customers. As I mentioned, this is not necessarily new since many department stores are already making use of data analytics. However, the pressure placed on storekeepers to help in containing exposures is multiplying video camera presence and transforming the use of data they harvest.

As always, there may be a downside to this: privacy activists are ready to point out the privacy intrusion of these systems, and they fear that it will not be for a limited time only. Once the epidemic needs are over, will shop keeper remove the cameras? Most unlikely. On the one hand these cameras have been used to deter shoplifters and will remain in place. On the other hand, the leverage of data through AI will prove quite useful to those shopkeepers that were not using them for analytics, and therefore, will remain in place.

There is something more. Once you have all those cameras deployed and they will no longer look at people’s face to make sure they wear protective masks, since the need will be over, the software will be able to look directly at customer faces and detect their mood from their expression. The use of AI will make profiling much more effective, and I doubt shopkeepers will not want to take advantage of it.

9.2.3 Air travel, hit as never before, is turning to Digital Transformation

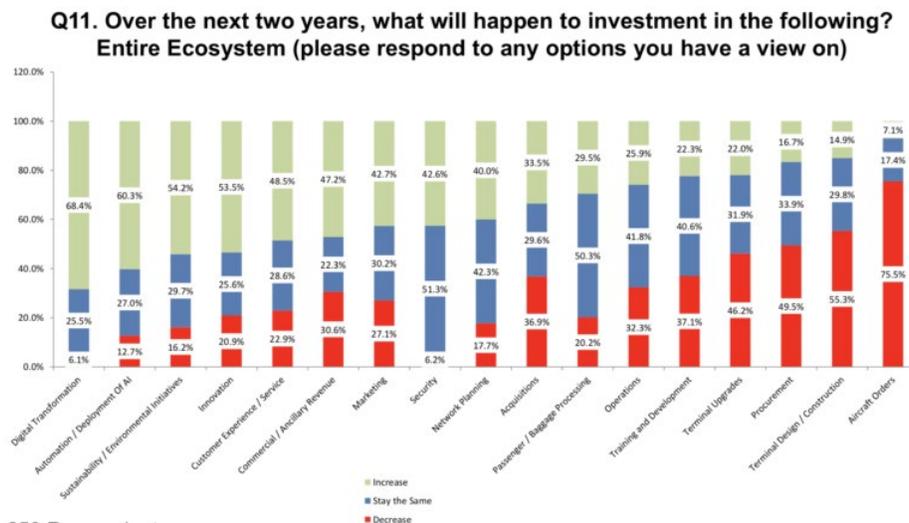


Figure 57. Expected impact of the epidemic on investment in the air transport area. Notice how Digital Transformation is expected to grow whilst aircraft orders are expected to decrease according to the majority of people interviewed. Image credit: Rohit Talwar – Fast Future Publishing

Among the different aspects addressed, there was the impact of the epidemic and the economic (dramatic) downturn on future investment. Many experts (not just the ones on the panel) are expecting a slower recovery than the one we saw after 9/11 (and that one was not particularly fast). The air traffic now is down some 80 to 90% (depending on the areas), and airlines are getting rid of planes to decrease cost (American, as an example is retiring all its 757 and 767 plus some old planes in the fleet).

Unfortunately, the air transport business has significant fixed cost, from keeping a plane parked on the tarmac to labor cost. Lufthansa, by having over 90% of its planes grounded, is losing 1 million € per hour, and of course if an airplane is not flying it is not making money. The long recovery time that is expected will lead to planes flying with fewer passengers (airlines, on the average, need to have planes at least 85% full to generate a margin) for quite some time, and this is another force pushing airlines to reduce capacity.

In the US, the expectation is of a reduction of 10 to 15% in capacity this year. Since a plane uses roughly 100 people to operate (it needs much more than the crew!), this reduction may lead to some 100,000 people losing their jobs by year end (airlines that are receiving government funds have agreed to save jobs till October).

All in all, there is the expectation of lower investment in aircraft orders (Boeing and Airbus are expecting significant losses by year end) as well as in other areas like facilities upgrading/constructions and procurement as you can see in the graphic. The areas that are expected to see a growth are the ones that can lead to cost decrease by increasing effectiveness, such as automation (also making use of AI) and innovation as well as customer service. In particular, those actions that can accelerate the uptake of business (like increasing the perception of safety to prospective passengers).

Top investment increase is expected in the area of Digital Transformation. Airlines, as well as facility operators (airports, catering, transportation) are looking at ways to dematerialize as much as possible their processes. It is an ongoing process, the boarding pass has moved from a paper form to a QR code on our smartphone, and in some airport, it is no longer required. A video camera picks up your face, cross checks the biometrics with the one coded in your passport and let you board the plane.

Bags are more and more self-tagged by the customer with no operator attendance; meals are pre-ordered and delivered to your seat thus cutting on waste (this is particularly advantageous in business and first class where a meal is pricey and there have to be a sufficient number of extra servings to accommodate passengers' choices by having passengers pre-selecting their meal airlines can cut cost and give the passengers the perception of a better service).

Entertainment is more and more based on BYOD, bring your own device/screen. That makes for a cheaper and lighter aircraft. In the coming years, we might expect airlines starting to offer "office-in-the-sky" by creating a virtual enterprise environment that connects business passengers to their company by data shadowing and mirroring (this will be a significant improvement on today's lousy internet connectivity as the data you need will travel along with you).

Here again, we are seeing the COVID-19 accelerating the implementation of the Digital Transformation, a good thing if you look at the increased efficiency (both of airlines and of their passengers), a bad one if you think about the loss of jobs that this implies.

9.2.4 Digital Transformation in the Movie Theatres business



Figure 58. *The Trolls World Tour couldn't make it to the movie theatres, but Universal found an alternative to reach its audience. Image credit: Universal*

The success of the distribution of the movie “Trolls World Tour” has made the headlines of many newspapers. It has generated more revenue (over \$100 million) to Universal than the first movie, a hit in 2016 during the first 5 months in movie theatres.

AMC theaters protested, stating that their theaters in the US will no longer show Universal movies in retaliation of having been cut out from the Trolls distribution also made the headlines.

What we are seeing is the replica of what happened to the music world as music used internet as the main distribution channel (first as an additional channel but it rapidly became THE distribution channel). Notice that we have had music “pirated” via Internet (and before through physical copies) well before the iTunes age, but there lies the disruption. Until the distribution was illegal, the rules of the game did not change. The Digital Transformation, that is the changing of business models, hit when the distribution over internet stores became legal. That changed the music industry and led to more people listening to music as well as to the shrinking of the market value (plus the disappearance of CDs and the like that further decreased the ecosystem value) and the emergence of new players along the disappearance of previous ones.

People got Trolls directly from Universal (using the AppleTV platform) for \$19.99, a tad more expensive than watching it in an AMC theater (but not that much once you consider the petrol and time wasted to go to the theater, and definitely cheaper if there were two of you watching it, most likely the case). Universal, in turn, by going direct to consumer and skipping AMC generated more net revenues.

Now, we have been saying that the user experience does not compare. At the theater, you get a big screen, and it gives you a sense of immersion that you can't get at home. True, but the situation is changing. Television screens are getting larger and larger (I am receiving more and more advertisement from Sony, Samsung and the likes to get their latest 75-inch and larger screens in these weeks. They are probably sensing that by being forced at home, I might feel the need for better entertainment).

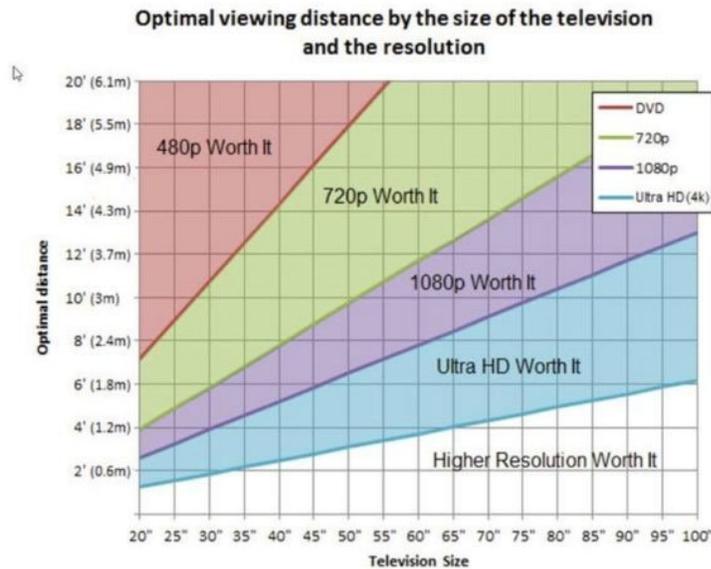


Figure 59. Viewing distance as a function of screen size for different screen resolutions. Image credit: *rtings.com*.

It used to be that the larger the screen the further away you needed to be from the screen (a rule of thumb was 5 times the diagonal, if you were among the lucky guys who could afford a 27-inch CRT, you had to watch it from 3m, 10 feet, away), but that was in the 90s. With HD television, the rules changed, and they changed even more as we move to 4k and 8k (see the graphic).

The change is because of the resolution of the screen. The bigger the screen, the further away you have to stay BUT the higher the resolution and the closer you have to be for perfect viewing. So, with a 75" HD screen, you have stay between 3 and 4.5 meter (8-12 feet) and with a 75-inch UHD (4k) screen you have to watch from 1.5 to 3 meter (5-10 feet). Whereas in the last century, we had the problem that a large screen would not fit in our living room (it was "thick" and we had to stay far away from it). Now, the only issue is to find a wall large enough to accommodate it (and sometimes to get close enough to appreciate it).

An interesting twist is that the larger screen gets (keeping fixed the distance you are watching it) the larger view angle. Our eyes have a field of vision that is about 124° on the horizontal plane and 110° on the vertical plane (70° downward and 50° upward). Our brain horizontal field of vision is broader, close to 170° thanks to the eyes saccadic movement. Now, the field of view is crucially important to deliver the perception of being inside the scene. Take the IMAX theater where you are placed close to the screen and the screen is very large, it feels like being there. The movie theaters trick our brains by keeping the whole ambient dark so that what our brain actually perceive is just the screen and that limits the saccadic movement to the illuminated part. It is not as good as an IMAX, but it may get close (panoramic screens are even better because they create a larger field of vision).

You see, the critical word is "perception": making the brain feel like it is part of the scene, by having a larger screen at home and getting closer to it we may create this immersion perception (watching in a dark room improves the feeling).

Popcorns and candies might be missing at home but this is something one can take care of. Friends might be missing, but again, if you have a spacious living room (likely if you have bought a large screen), then you might have your friends joining you.

I am not saying that once the epidemic is over, we want be going to theaters to watch movies, but clearly the longer the lockdown, the more we will get used to watch prime movies at home. It may also well happen that I may have the itch to watch the latest movie, and I do not have the time to go to a theater while I can surely find two hours to watch it at home.

Besides, if movie producers will make more money by going direct to the consumers, they most likely will. I discussed this news because it is just another point in case of the upside and downside of the Digital Transformation and evidence of the abrupt adoption caused by exceptional circumstance, like this epidemic. Because of it, companies are forced to explore new ways to reach customers and going through the cyberspace wherever possible is a no brainer. Yet, this shift to the cyberspace kills market value and affects those players that made a living out of that lost value.

9.2.5 Electronic payment boost in the long term

The whole world is experiencing a significant slowdown of business because of the ongoing lock down in several countries, and people have decreased their spending spree (I can vouch for my wife!), so it is no wonder that Master Card (as other companies in that business) has seen a sharp decrease in transactions (and earnings) as shown in the graphic.

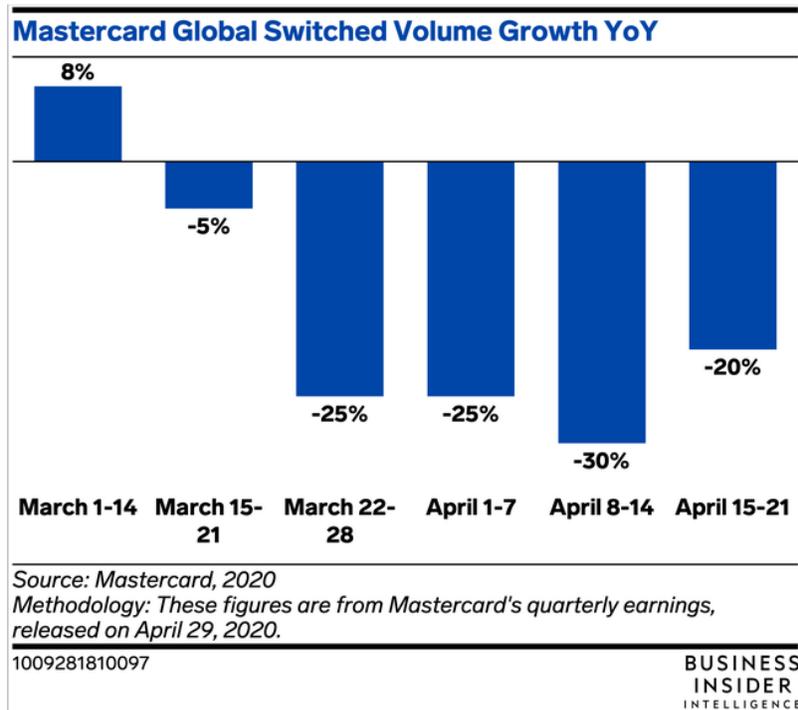


Figure 60. Image credit: Business Insider intelligence based on Mastercards quarterly earnings data published on April 29th, 2020.

The graph shows the sharp decrease in switched transaction for Mastercard (Amex, Visa, and other cards are likely to show similar pattern). This is a direct result of the epidemics with lower number of transactions all around the world.

However, the expectation is that once the lockdown is removed and given sufficient time to the economy to recover (here the expectations vary, from the more optimistic V economy that would result in a full recovery by year end to more conservative forecast in between U/W and L economy that will expect full recovery in 2023), the outcome might be rosy for the Mastercard-like companies. The reasoning is that the scare of contagion will linger and will steer consumers to use contact less payment methods (that are leveraging on credit cards). I have already seen in a few shops here in Turin, Italy, a notice saying “we prefer contact-less payments.”

If that will turn out to be true, it will be another sign that the epidemic has accelerated the digital transformation in yet another sector. I do not expect that credit card transaction data will be used to trace contacts among people (here the concerns on privacy are too strong in the Westerns world). Although, we have seen that credit card transaction data have been used in some countries for that.

A cash-less world is surely possible, and a few countries, like Denmark, are well ahead in this direction. We might discover that COVID-19 is pushing many more on the same path.

9.2.6 Dating Services

The epidemics is locking down, either by government imposition or by people’s fear, whole countries around the world, and therefore, you would expect that those companies that have leveraged the cyberspace to connect with brick and mortar services would suffer from the impossibility to deliver. Indeed, TripAdvisor (25% jobs cut), AirBNB (25% jobs cut), Trivago, Booking, and Expedia started cutting jobs in February and secured new funds to weather the storm. They are all suffering, and as result, have announced significant cuts in their workforce.



Figure 61. How can a dating service survive in time of quarantine? It looks like they are not just surviving, they are actually growing! Image credit: Giorgos Moutafis/BILD

So, on the one hand we can see, as I mentioned in the previous posts, that the Digital Transformation is picking up steam under the epidemic pressure, but on the other hand, the epidemic is hitting those companies that had used the digital transformation to create a business. Yet, in this light and shadow scenario, there are companies that one would assume to be severely hit by the lock down that see a surge of business, like online dating.

I have to say I was really surprised looking at the latest figures on Tinder (probably the most widely used dating app), Bumble, Plenty of Fish: they all show a significant increase of usage and subscription. They

are also scrambling to add tools to their apps to take into account the need for social distancing, most notably the video chatting feature. Hinge, part of the Match Group, has released “Date from Home,” an app designed for these times of living apart together.

Tinder announced its new record of contacts in a single day, 3 billion on March 29. OKCupid announced a 473% growth of virtual encounters in April, and Bumble (ladies first) indicated a growth of 26% in April.

I am no expert, but it looks like the seclusion in our homes stimulates the need for, at least, virtual encounters (possibly hoping to have them turning into real ones in the future). People who had to go into quarantine and are single have seen their social life put to a screeching halt in the real world and had to turn to the cyberspace. The increase in conference call tools is surely one side of it but the other might be turning to online dating. What remains to be seen is if this will result in an overall increase of use once the lock down will be over. In other words, this is what the “new normality” will look like.

9.2.7 Government policies

During the COVID-19 pandemic, I was asked a few questions related to the expected UK Government directives that were issued on May 11th to shift the country into phase 2, for a controlled return to business and societal interactions.

1. How do you think the new office COVID-19 guidance will impact companies from a technology standpoint?

Most of the guidelines are aiming at in-office separation, social distancing. Some of the activities involved will be difficult to execute in this framework, and although in the short term it may be difficult/impossible to have compliance, in the medium term this will stimulate a rethinking of interactions, i.e. process re-engineering and automation. Both of them lead to increased use of technology. A few companies are developing affordable robots targeting SME, both to ensure sanitation and for taking over menial tasks thus reducing interaction among workers.



Figure 62. Violet is a robot designed to help in sanitation of hospital rooms and can be used in closed spaces like stores and in offices. Using UV light, it can kill the coronavirus and has a smart detection system to switch off the UV light if a human shows up. Image credit: Akara Robotics

An example is Akara Robotics. They developed Violet, see the photo, targeting the sanitation of hospital rooms, but it can be used in a closed environment. It kills germs using UV light that is also dangerous to humans. Hence, the robot uses sensors to detect the presence of humans, in which case it switches off the UV light. Another example is a robot (prototype) using chemicals to disinfect closed spaces by Rubedo Systemos, a Lithuanian company designed for large spaces like train stations or department stores.

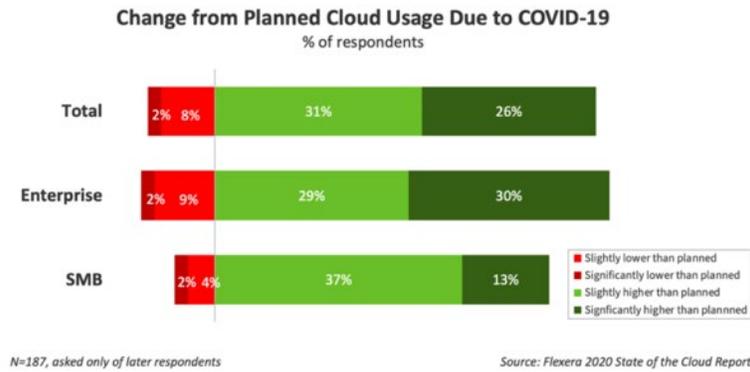


Figure 63. Change from planned cloud usage due to COVID-19. The latest Flexera “State of Cloud report” indicates a significant growth in Cloud usage. The graphic results from an April 2020 survey and shows the majority of respondents foresee an increase in cloud usage as consequence of COVID-19 that will continue even after the epidemic will be over, both for enterprise and small businesses. Image credit: Flexera

In general, we are seeing a drive towards automation. The current crises can serve both as a catalyst for change and an accelerator of a change that is already ongoing. This is the case of the extension of automation to small-medium enterprise and to the retail sector. Although liquidity is an issue, particularly for small business, government support can step in to foster innovation and restarting activities. Robotics is now a mature technology in terms of performance and flexibility, and the evolution is now towards the extension of affordability to smaller businesses. In turn, this is going to scale up the market making robots even more affordable. As it has been affirmed by Arun Sundararajan, a NYU Stern School of Business professor researching how digital technologies transform society, what is now being pushed into the business processes as a way to cope for the emergence will actually consolidate into a new tech paradigm. In other words: don’t think that once the epidemic is over, we will go back to the old times.

In the guidelines expected by the UK Government, there is a call for a continuation of smart/remote/tele working whenever this is possible. This is clearly going to benefit those companies providing the supporting technologies, and it is likely to foster their evolution. Besides, it is not an isolated call. Most countries are actively pressing on this with several providing incentive, and changes in the labor regulations to make teleworking easier. Unions have become fully involved and have been quick in pointing out dangers like Big-Brother control of workers (becoming so much easier since everything is digitalized, hence controllable) and the work exceeding the usual working hours. Take a look at the interesting article published by Bloomberg pointing out the dark sides of teleworking, when the boundaries separating work from home life fade away.

Use of remote cooperative tools and of cloud infrastructures (see graphic) is expected to stay after the

epidemic is over. It was an ongoing process that is now accelerated, and that is changing the work dynamic.

Robots are also more likely to be adopted in retail, both big department stores and small retail points. Self-serve dispensers are not new but are likely to become more flexible and common. Robots to pick up the wares and deliver them to a customer that asked for them via an app are also on the rise (they are common in several countries in the Far East already) as well as robots performing inventory functions.

A further push to adopt technology in Phase 2 (which is expected to last for several months, possibly over a year) is the need to provide a perception of safety in the interaction with the customers. This will become a competitive advantage in areas like retail, hotels, and entertainment. Again, the use of robot, like shop assistant or hotel concierge, may become a differentiator and push adoption. An article published on May 6 by the University of Surrey goes into interesting details on possible use of service robots in the hospitality industry to redefine leadership in that sector. A few hotels are using robots to care for people in quarantine, like in a Tokyo hotel completely dedicated to “coronavirus” guests.

Adoption of technology to intercept contagious employees and customers will also be fostered (infrared sensors, image recognition). However, this latter is fraught, particularly in Western culture, with privacy concerns, so it will have to be deployed in a regulated and transparent framework (there is already one in place to regulate the use of safety/security cameras).

2. Will ‘digital twin’ thinking play a role in facilitating the Government’s office guidance and, if so, how?



Figure 64. 66% of Italian people seem to be in favour of using a tracing app and just 24% say they would feel uneasy in using it. Image credit: Altroconsumo.

Several businesses are currently using sort of digital twins in profiling their customers. They trace their activity, perform data analytics on virtual communities (birds of a feather) to evaluate shopping and interest trends, and use this information for advertisement targeting (and sometimes for targeted pricing).

Increased availability of sensing, processing, storage, and analytics keeps pushing towards the creation of more and more comprehensive customer's records, and these may be the seeds for the implementation of "personal" Digital Twins.

The proponents of Personal Digital Twins are ready to point out the implication of "Personal": it should refer both to the fact that the Digital Twin is mirroring person characteristics AND is controlled/owned by the person (at least this is the Western culture interpretation). So far, all implementations of personal digital twin have been made by companies with the implicit/explicit consent of customer (most often implicit). A regulatory framework is needed, and governments should take the lead in the definition of a framework. So far, the approach has been towards the limitation of personal information capture and use (GDPR) rather than its exploitation. Both regulatory and standardization frameworks are needed, and the current epidemic can stimulate creation and adoption. The recent agreement between Apple and Google to agree on API for Bluetooth communications usable for tracing is creating a de-facto standard (although much more is needed, as an example to exchange physiological data from wearables to applications).

Notice how the creation of personal digital twins (an extension of the concept of personal identity that is now widely used) would have important applications in many areas, including a shift towards proactive healthcare.

Today, governments are facing an emergency and it makes perfect sense to turn to available tools and proved technologies. There is no time for inventing something new and even less for testing it. However, governments should take this emergency as a warning bell that something like this might show up again in a few years. Most governments missed the warning from SARS and MERS, and we are now paying the consequences. It should not happen again.

Whilst for SARS and MERS, most countries were not affected, and the general feeling among the population was "it is not affecting me, why bother." Now, everybody has been affected and awareness is strong. So, if 10 years ago it might have been difficult for a government to propose and pass a legislation that implied a change in culture, like sharing healthcare data, now it is easier, people may actually be expecting it.

I was surprised in these last week of the opposition, in Italy, by a few against tracing apps, with strong concern on privacy violation. These "opposers" made the headlines of national newspapers and were voiced in television talks giving the impression that the "majority" would be against a tracing app.

Just few days ago, a [polling](#) promoted by the National Consumers Association proved that the Italian sentiment towards a tracing app is quite positive, with just 24% of people saying that they would feel uneasy in using such an app. This is a clear demonstration that the COVID-19 has left quite a mark in people's perception and that privacy concerns come after safety perception.

Governments should leverage on this favourable feeling from "voters" to move more decisively towards the Digital Transformation of healthcare. Part of it is the creation and use of Personal Digital Twins. We

already have (in many Countries) digital health records. Often, we lack interoperability (standards and standardised API) to access and exchange these records. The impulse we have seen in these weeks towards tele-medicine to expedite triage and to provide cure-at-home means that more and more data will be generated “on the patient,” and these data can remain under the patient control (possibly in her smartphone!). This may be another force towards the creation and use of personal digital twins. For these, we also need an architecture for data management.

There is quite a bit of work, and research, to come up with a worldwide healthcare safety network. This epidemic may provide the initial push in this direction. Let’s hope we are not wasting this opportunity. Of course the Digital Transformation of Healthcare will not succeed unless it takes into account privacy, but this should be done balancing benefits with the little sharing of data that is required. All of our Society is a compromise between personal and societal benefits. A healthcare safety net is nothing different.

3. *Would there be any challenges or barriers for companies using digital twins to navigate the guidance around COVID-19?*



Figure 65. The COVID-19 Host Genetics Initiative provides an environment to foster the sharing of resources to facilitate COVID-19 host genetics research. Image credit: COVID-19hg.

As mentioned, today we do not have real implementation of personal digital twins. We have profiling, but this is just a tiny part of the overall data set characterizing a digital twin. In our Western culture, the development of personal digital twins is unlikely without an accepted/regulated framework. The current GDPR scheme is usually applied in a restricted way and this basically hampers their development. In the context of the guidance around COVID-19, personal digital twins may provide a way for effective tracing, but the very concept of tracing is looked upon with suspicion by several constituencies. This, however, as pointed out in the answer to the previous question, is for tomorrow, not for today, Nevertheless, tomorrow will not come, unless we start working today to make it happen.

4. *In addition to the previous questions, any other comments?*

The fight against COVID-19 is being fought on several directions:

- decreasing the probability of contagion, usually through social distancing and isolation of potential foci of infection. Technology can help through sensing distance (Bluetooth based

apps), data analytics (tracing of people's movement and broadcasting of warnings when an increased risk of exposure is detected), and quarantine enforcement surveillance. Technology is available now, we do not need to wait for any evolution, as it has been shown by the adoption of tracing and tracking apps in China, South Korea, and Taiwan first (and now in several other countries). The problem is not tech, rather its adoption and this requires a conducive cultural/societal environment. As it was remarked by Derrick the Kerckhove in the IEEE webinar we held last April, the cultural set in the Far East Asia is quite different from the one in the Western World countries, our being based on the mindset of "sin" (a personal issue) there on the mindset of "shame" (a societal issue). Hence, in the Far East Asia requiring people to use a tracing app is a societal demand, and as such, it is culturally accepted. On the other hand, in the Western world, governments have to "suggest" the use of the app whose adoption has to remain voluntary. This, in turn, creates the issue of ensuring a sufficient adoption to make it effective. Adoption shall be driven by (guess what?) advertisement, through the use of "influencers" since imposition is almost impossible. Technology is not the issue. Let me put it bluntly: most people (I am part of those) do not understand the technicalities of ensuring privacy, of having data in a central location or distributed at the edges, of cryptography applied to the data storage versus applying it to the transmission channel, and so on. People react on hearsay and perception. With part of the social and press screaming about privacy violation, democracy in danger, only advertisement can work (I feel sad stating this, I would love to be proved wrong, please comment).

- finding possible preventative measures (specific vaccine, pre-existing vaccines able to decrease susceptibility). Technology can help in various ways and it is already widely used. The sharing of information/data is crucial to speed up the process both in discovery and testing effectiveness and safety. There are now several unanswered questions on why the COVID-19 seems to hit more certain areas than others, why its symptoms are severe in some people, and almost invisible in others. Some are speculating that specific genome characteristics may be at the root of these differences, and work has started to sequence the whole population genomes in Vo, one of the small cities hit in Italy. These data will be used by researchers to have some answers emerging (data analytics) and will feed into a transnational cooperation project to investigate the relations among the coronavirus and the genome, the "COVID-19 Host Genetics Initiative."
- balancing the above measures against economic and societal cost. This is actually the big issues facing political decisions and we can see the different approaches followed in different countries. Notice that most measures today are based on an over-reaction to the problem, just in case. We are using a cannon to hit a mosquito. If we look at figures, even though the number of affected people is staggering, the ratio of affected people vs population is very SMALL, and yet the measures implemented affect ALL the population. Technology may help in limiting the number of people affected by the containment measures, and this would decrease the economic and societal impact. The help comes from better tracing and focussed measures, as pointed out, as well as from the re-engineering of supply and distribution chains, from the reconfiguration of manufacturing processes. This latter is a very complex task since our society and its economic underpinning is very much connected. Stopping a cog is most likely affecting the whole machine. China has been able to halt activities in the virus affected region by fencing it because the rest of China could provision all required goods to that region. That involved significant reshaping and reorganization of supply and delivery chains. Not so in Europe, where basically each country was playing an independent game and the lockdown of a country could not be as strict as it was in China since you had to keep the essential logistics running. As an example, the lockdown in Italy kept 40% of the people on the move, just to ensure the provision of essential goods to the population.

- The re-engineering of supply and value chain will become a major topic in the post pandemic world, with plenty of technology (artificial intelligence, data analytics, data lakes, robotics) involved. It will likely become one of the main drivers for Industry 4.0. Whilst supply and delivery chains have been designed, and refined, for optimization, they will have to be re-designed for resilience and reconfiguration as well.

9.2.8 Re-invention of the Brick and Mortar

In all countries where the lockdown was in place, the brick and mortar shops saw their business plummet. At the same time, the Amazons of the world saw the demand for online shopping grow at double digit rate.

Back in 2019, 1.92 billion people shopped online at least once worldwide. The expectation for this year was for an additional 130 million to join the online bandwagon, but this figure most likely will be significantly higher because of the lockdown.

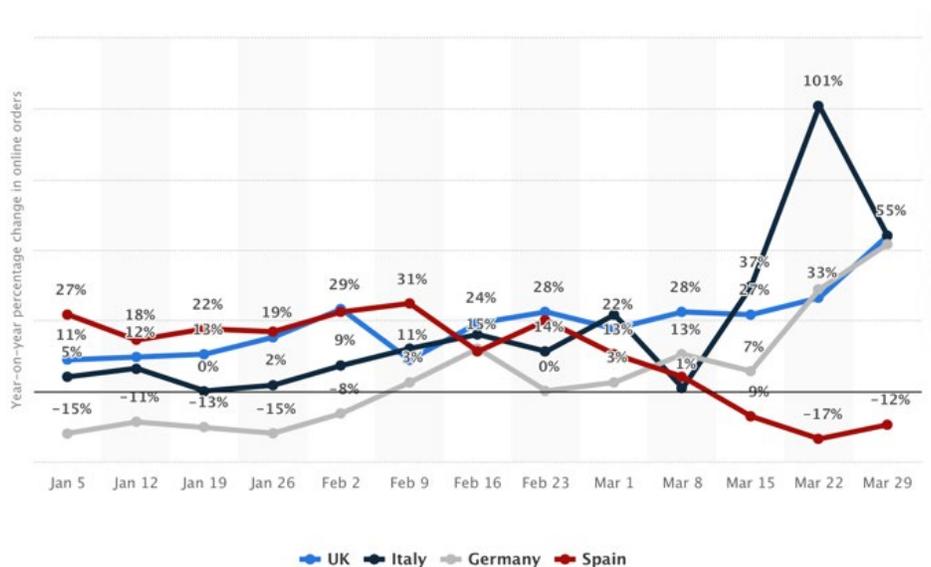


Figure 66. Online commerce changes in the lock down period in some European Countries. Image Credit: Statista 2020.

In this respect, it is interesting to look at the trends just published by Statista on the effect of the lockdown on online commerce in some countries in Europe. The graphic shows the significant surge in Italy in the week of March 15th (the lockdown in Italy was enforced on March 11th), leading to a doubling of online shopping and remaining high (50% increase) in the following week. The other countries represented did not enter into a lockdown until later in March, so the consumers' behavior is not reflected there.

Interestingly, in a statistics harvesting data as of May 10th, up to 30% of responders said they bought online because of the epidemic (meaning they would have normally shopped in a brick and mortar shop). The data differs country by country, with US customers seeming more ready to shift to online shopping than others (Germany data show an increase in between 10-20% whilst UK is in between Germany and US).

In the coming weeks, the picture will get clearer as more data become available. However, if you want to get an in depth analysis of the changing consumer behavior, there are already some impressive analytics available. One of the trends that impressed me is the uptake of online grocery shopping, showing a three to four-fold increase.

Now, one might say that this is nothing but a spurious spike. Once the epidemic is over, all will go back to what it used to be. Of course, it remains to be seen but many are feeling that the future will be different from the recent past.

First of all, the removal of the lockdown will be staged. Social distancing will remain enforced for a few months more, and this will continue to have an impact on shopping habits. Secondly, many shop keepers have been forced to embrace online shopping and set up home delivery to remain in business. Thirdly, people got familiar with online shopping: people who never shopped online have experienced it (saw that it works, and got used to it), and people who already shopped online have extended their online shopping to new categories of merchandise. The pre-epidemic expectations of an e-retail growth to reach \$4.8 trillion worldwide in 2021 (from the 2.8 trillion \$ of 2018) are most likely underestimated.

Several small shops will face a hit from this shift to online preference by customers and will need to react rapidly by moving their offer online. However, going online is basically adding a cost (although a limited one) to their brick and mortar operation, so the risk is to become even more stressed on the bottom line. Additionally, the online marketplace is an ocean where their little island may be insignificant (will not catch the customer eye). In the end, if you buy online, and if the stuff you are buying will reach you within a day, it makes little difference where that stuff is actually coming from.

Mom and pop stores will have to make clear to customers that such a difference exists. This can be done by creating a personal shopper experience, where the brick and mortar matters. As an example, even though one is buying online, products coming from a nearby store are associated to a well identifiable shopping clerk that one can always call upon to get a personalized interaction. Getting info on the product and assistance is surely easier if you can interact and “touch” a real person, like you do when you visit the store. The provisioning of this higher level of personalized customer service requires a higher engagement of clerks, but on the other hand, the online shopping will decrease their load. Why not take advantage of that to deliver better on-site service?

With social distancing, likely to be enforced for a while, shops will likely leverage on digital technologies to display their wares, and that means being able to display them from remote, reaching their customers living rooms. AR/VR are likely to increase their presence, both as devices (enhanced smartphones, expect some announcements in the coming months, and VR devices) and services.

This is likely to become a self-sustaining evolution, a virtuous spiral re-enforcing the shift to e-retail: better ways of providing online shopping experience, more effective value chain in the distribution push to further adoption by customers, and this reinforces the efforts of store keepers to be part of this.

9.2.9 Innovation in the Restaurant Business model

The lockdown of restaurants around the world may prove to be just the tip of the iceberg in the crises that this market area is experiencing. It was (in some cases it still is), but the idea that once the epidemic is over everything should be back to “order” is wrong.

For several months ahead, the situation may go from bad to worse. The social distancing is not compatible with most restaurant business models, they simply cannot operate in that framework. If you have a business model requiring to fill up at least 80% of the seats, and the social distancing rules impose a separation that decreases your serving capacity to 30/50%, it is clear that you won't be able to survive. This is not that much different from the case of airlines: asking them to travel half full is condemning them to bankruptcy. In the airline business, the break-even is achieved with a 77% seat occupancy. Enforcing social distancing would cap capacity at 62%, and several companies have already stated this would lead to a 50%+ increase in the cost of tickets, leading to a downward spiral with less passengers and even less filling rate. In practice, a "no-go."

Add to this the increased cost of sanitation and the need to ensure customers of their premises safety, and it is clear that the present way of doing business will no longer be viable in the coming months.

The expectation is for a massive decrease of restaurants. In the US, according to the National Restaurant Association, 3% of restaurants have closed permanently, and this figure may reach 11% in the coming weeks. That is some 110,000 restaurants in the US will go out of business. Already, 70% of the restaurant workforce has been laid off, and it remains to be seen how the reopening will be able to turn the figures around.

Most restaurants have considered food delivery as a temporary back up; however, the transition is not an easy one. It requires a change in the organization, a different way of preparing and presenting food, and a different business model.

Not all food is suitable for takeaway, and top of the line restaurants have menus that are not suitable for home delivery. Actually, for some of these, it would be more practical to deliver the cook for an on-site cooking! Besides, you guessed it already, there are companies providing exactly this service, and of course there is an App for this: "Hire a Chef."

The current crisis is pushing for innovation in the restaurant area and is leading to the emergence of new business models. Which will succeed remains to be seen, but there is a growing consensus that new restaurant experiences will be proposed and that many old timers will disappear.



Figure 67. The Robot Show at the Tokyo restaurant where robots are the main attraction. Image credit: RobotShow Restaurant.

An example could be the enrolment of robots to replace cooks and waiters. This has been tried already with mixed results. There is a restaurant in Tokyo, the RobotShow Restaurant, that has become in just

one year an iconic point in the international night life of Tokyo, attracting locals and tourists in such a number that getting a seat has become almost impossible. This restaurant has robots welcoming you, taking your orders, serving you, preparing (part of the) food, and bringing you the check (from \$100 up, including the robot show). However, the success of this robo-restaurant so far is more the exception than the rule. Several restaurants around the world, most notably in China, Japan, and South Korea, plus a few in the US, are using robots as cooks and waiters, but these are mostly in the fast food category and have not shown a significant business advantage over the human staffed restaurant.

Many restaurants have also adopted digital ordering, first using tablets on the table but more often asking patrons to download an App and use it for order and payment. This seems to work well and has increase efficiency/decreased cost, but it does not work for upscale places where the human touch is an integral part of the customer experience.

The push towards increased efficiency (cost reduction and space time occupation reduction) will continue, particularly in lower scale restaurants under the stress of the epidemic crises. The use of robots and automation in general, the decrease of interaction among customers and staff, may be perceived as an increased safety, and therefore appeal to customers.

At the same time, the unavailability of a profitable model to serve customers will decrease the number of restaurants, as noted, and that will create an opportunity for changing people habits in a few ways, including:

- getting pre-cooked food at a restaurant level quality from grocery stores, possibly home delivered
- using automated equipment at home to prepare a meal
- setting up restaurants on demand in specific location

Getting food with a quality that compares to the one of a very good restaurant is tricky. Food preparation, at those levels, is usually sophisticated (that's why you have to go to those restaurants and you cannot reach it at home). It involves specific ingredients, their preparation, the exact temperature in various stages of the cooking process, the mixing of ingredients at the right time after they have undergone each their specific preparation, and eventually the plating. A crucial aspect is also the time from plating to serving. Turning all of this into home delivery may be close to impossible. Yet, not all great tasting food requires this complexity, and food companies are hard at work to create pre-packaged food that can be delivered at home. The effort has been redoubled by the crises as food companies are seeing an opportunity (and a need as the trade towards restaurants decreases).

At the same time, the potential increase of just cooked food may call for the use of drone delivery, an area where we have seen some trial but no real significant uptake so far.



Figure 68. A, probably, futuristic use of robots in the kitchen to cook and clean. Powered by AI, this NVIDIA robot is at work in a mock up kitchen environment at the NVIDIA research lab in Seattle. Image credit: NVIDIA – IKEA.

Another approach is to prepare the food at home. Here, time availability may be an issue as well as the level of experience that may be required. Robot assistance may be a possible answer. More sophisticated robots are on the way, such as the ones being studied by NVIDIA. If you want to get update info in this area, read the report on 2020 Trending Robot Kitchen Market. The COVID-19, according to experts in the food area, is pushing the market of Robot Kitchen.

Finally, a rethinking of the restaurant paradigm may be in the making: rather than seeing the restaurant as a specific location, restaurants can morph into a catering paradigm, as organization that can provide customised food at any location. Differently from the catering of today, where there is a specific company providing the service, the restaurant may undergo a digital transformation becoming an entity in the cyberspace, accessible through an app and ready to deliver food services, customised to specific need. Differently from catering where you need to negotiate, pre-order, what you want and specify what you want, these cyberspace restaurants (actually an intelligent software gluing together several physical providers) will be constantly available. Are you finding yourself with a date in a park and longing for a nice restaurant to spend some time with your date? Pronto. A digital restaurant may be just a few click away to provide you with delicious food, compatible with the logistics involved, and all the trimmings (towels, cutlery, glasses). This is not catering since it delivers on a whim of the moment, nor is it a food delivery service that provides you with a menu that is not taking into account the logistics involved and is limited to bringing you the food.

9.2.10 Digitalization of the office space

On May10th, Twitter told its employees that they can choose to keep working from home even when the pandemic, and lockdown, is over. It is not the only company that is considering moving their office space to the cyberspace.

This shift to the cyberspace has significant implication on real estate assets value, as shown in the graphics created by Green Street Associates photographing the value decrease in just 4 weeks since the pandemic started to impact Western world countries. And the situation is just getting worse, as the lockdown progresses and as companies discover that they can work in a cyber-office as well as in a physical space, the difference is that the cyber-office is basically free.

As shown in the graphic, different kind of properties are seen different degree of value loss, with the greatest hit taken senior housing than almost halved its value. Student housing lost one third of its value, as student no longer need to attend school in person but rather follow lessons in the cyberspace.

Office space that used to be at premium is now becoming available as companies have lesser need for physical office space and others are closing down and releasing the space they used. A similar situation is seen in spaces used by shops and restaurants, as many of these businesses are closing down.

The latest data by Green Street Advisors show a further –average- 9% decrease in value in April.

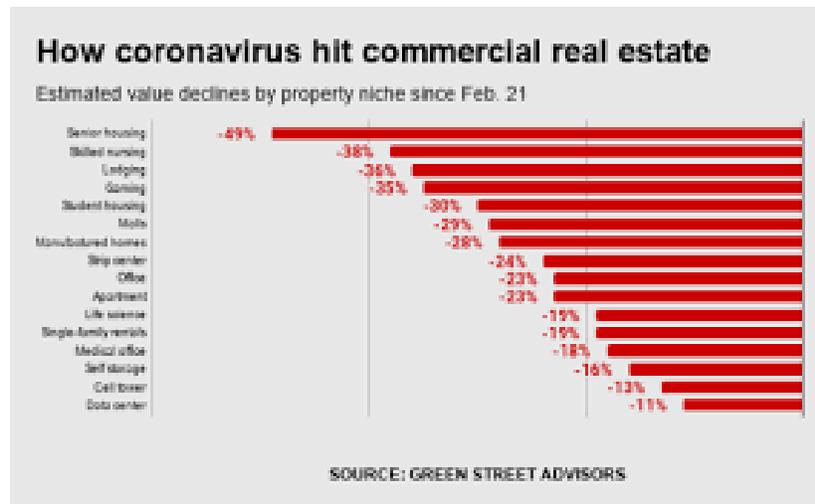


Figure 69. Graphic showing the estimated value loss of several real estate assets as consequence of the COVID-19. The decreased value is expressed in percentage in comparison to the asset value on February 21st compared to the value as March 15th. Image credit: Green Street Advisors.

Although not all the work in a physical office space can be moved to the cyberspace, keeping the same level of efficiency, companies are discovering that a significant portion can, and in most cases they are seeing increased productivity and worker satisfaction. From the worker’s perspective, just think about the saving in commuting time (in the US this averages to at least an hour a day and this figure compares with several major cities in Europe) and the saving in transportation cost, and it is easy to see why workers are usually happier. The drawback is the loss of personal interactions, sometimes serendipitous interactions that may take place in a physical office. This loss is being addressed, not solved, by a variety of initiatives like having a (voluntary) half-hour cyber mingling every day with colleagues in the cyberspace (IDEO, where my youngest son is currently working has adopted cyber-mingling), having social gathering organized in the cyberspace, having coffee break rooms in the cyberspace, and so on.

It can also be expected that the adoption of better cooperative tools will further increase the work at home efficiency. For sure, the latest data are showing an interest of companies in investing on cooperative support tools.

At the same time, we can expect that second generation virtual offices will become available. An interesting example is the one provided by VirBELA. This is a company that is offering working space in the cyberspace. You can use their web site to design the look and feel of your office, design the meeting rooms and the public spaces. Along with that, you get specific tools that can be tailored to your needs.

The cost? You can start experiencing their offering by setting up your office in an open campus for free. Alternatively, you can select their Team Suite package, suitable for companies with 10-100 employees at a starting “rent” of \$100 a month. If you are a bigger company, there is the option of Private Campus that can accommodate space for up to 25,000 workers at a starting price of \$2,500 a month.

We can expect this kind of offer to become more and more sophisticated, leading to a Digital Transformation of the office space.

For residential properties, it is too soon to see an impact. However, the first data derived from polling in the US, the perception of customers is almost evenly split, with some pointing to an expectation of a general loss of value and others that feel the residential market will remain unaffected, also taking into account the presently low mortgage rates.

9.2.11 Tele-learning gets serious

What is now being called the “Zoom Education” turned years of discussion into reality in a matter of weeks, sometime days. According to the Singularity University, 1.38 *billion* students shifted from the classroom to the cyberspace as the daily way of “going” to school.

In Italy, in just a week all classes from primary to university moved to the cyberspace. There was no single way of doing it. Teachers were most likely the ones more affected by the shift. Zoom (or other conference call tools) has in some cases being used by teachers and students for the very first time, sharing a document on screen was seen as a sort of conquest that generated quite a few “wow.” People tried, and failed, in installing apps that turned out to be incompatible with one another, Google drive was an unexplored world that all of a sudden had to become the black/whiteboard, and notebooks became files.

Yet, in spite of it all students and teachers managed and what was a challenge, has become the way of learning after 2 months of lockdown.

Some universities (in Italy) have already informed that the first semester of the next academic year will be online only, and a few have decided that the whole next academic year will be online.

In the following, I am considering the Italian framework, since it is the one I have direct experience (got 3 of my kids who are teachers plus one daughter-in-law, and 2 grandchildren going to school, plus I get daily exposure through friends). If you have different experiences in other countries, please share. The pandemic proved to be a tremendous push in the Digital Transformation of Learning, a success beyond expectation.

Yet, as we look closer, beyond the glitter, there are quite a few shadows:

- not all teachers and students have a really good broadband connection. Because of that, in several cases no real time/streaming of lessons could take place, and teachers opted for recording the lessons.
- Online teaching is quite different from face-to-face teaching. For many teachers, that was a surprise. It also led to a decreased teaching quality, not unexpected if you just apply the same approach of the real classroom to the virtual classroom.
- Students, particularly those from secondary schools upwards, were more familiar to the cyberspace, and for them, the shift was not that traumatic. However, many students

(particularly in the primary and secondary schools) didn't have their own PC, being used to share the home PC that now was used by their parents for teleworking.

- Primary school children found typing on a keyboard more challenging than writing with a pencil, and that led to longer time spent in doing their chores.

After the first few weeks, some of the above hurdles were solved or at least mitigated. The bandwidth has significantly improved, and we have seen the adoption of wireless connectivity for home connection (it is not what is usually called wireless fixed access, but from the user viewpoint, that is what it is), and the wireless network capacity has been almost doubled in a matter of weeks, thus sustaining better connectivity even in rural areas. Additionally, several national wireless operators removed the cap on GB, providing an all you can eat with no price increase.

Several students were given computers from their school to connect, and teachers learnt how to adapt to the cyberspace, changing their way of teaching and structuring their lessons in a different way, usually opting from smaller chunks that could be digested in 15-20 minutes.

At the same time, new issues surfaced:

- The absence of a common teaching and learning platform made difficult for teachers to exchange education material and lessons. This was not an issue in the classroom since basically no teacher felt the need to share their education material, but now that new material was needed, sharing would have been welcome.
- The approach to an online exam has to be different from the classroom exams. What I saw was an attempt (failed) to duplicate online the face to face environment. So, I have seen teachers asking their student to use the smartphone camera to show that they were alone in the room. Some even used AI based applications to detect and analyze noise to detect the possible presence of other person or the use of other devices.
- That the Italian school is not prepared to manage online exams was made clear by the decision of the Education Ministry to have the final college exams "in person," ensuring social distances at school.

The shift to online education has shown clearly that when you move to the cyberspace, you need to change your processes. A straightforward shifting from the physical space to the cyberspace does not work, and the attempt to recreate in the cyberspace the same environment you have in the physical space (i.e. the same processes and approaches) makes the whole cumbersome without reaching an equivalent situation.

Moving education to the cyberspace requires, at least to a certain extent, to get rid of exams. What is needed is to structure the lessons into chunks, containing exercises that are a continuous exams and the thread linking the various chunks can only be followed once a student has clearly understood and learned the previous one.

Obviously, this implies a rethinking of the structure of courses. It may also imply an increased effort in terms of tutoring to the point that a few observers are noting that moving education online will actually require more teaching staff than the one needed for a classroom-based teaching.



Figure 70. Face recognition AI can help in finely tuning online education. By detecting the student emotions, the teacher can adjust his presentation. This information can also be used by an artificial teacher, AI based, to provide dynamically customised lessons. Image credit: Affectiva.

Since it is difficult to imagine, a significant increase in the number of teachers to support remote tutoring several companies are working of developing AI based application to help. Affectiva, as an example, is using the forward facing camera of the iPad to detect interest, boredom, confusion, and stress by looking at a child's face as she is following the lessons.

Hence, it is no surprise that the edtech worldwide investment of 18.66 billion USD we saw in 2019 is now expected to grow to 350-400 billion in 2025, an unprecedented growth. This investment will cover all kind of education, in particular the continuous education that we have seen gaining steam during the lockdown as several companies asked their employees to take advantage of the forced free time to update their knowledge.

We can expect education to become a service that is being subscribed by many people through their lifetime, flanked by Knowledge as a Service (KaaS) where knowledge is distributed and the service is about making use of that knowledge in the most effective way, not to learn what you don't know!

The shift to distributed remote working will only intensify the interest towards KaaS, an area that is being addressed by the Digital Reality Initiative.

9.2.12 Virtual meetings in augmented physical spaces

Virtual meetings are not new, I started to have them long time ago. What is new is the stop to physical meetings forced by the pandemic. As many more of us are forced using them, we are also feeling frustrated by their shortcomings. What before looked like an opportunity that was added to physical meetings is now feeling like a bad version of a physical meeting.

On the other hand, companies that were providing the tools for virtual meetings are now finding themselves with a captive audience that is actively experimenting and exploring alternatives. This is stimulating evolution, and I bet we are going to see a leap forward in technology to support virtual meetings.



Figure 71. A visually more convincing virtual reality gathering in the cyberspace can improve effectiveness of online collaboration and speed up VR and AR adoption. Image credit: Spatial.

An interesting second generation tool for virtual meetings is provided by [Spatial](#). Their tool has been designed with VR and AR in mind, but given the current race towards effective and usable virtual meetings support tools, they are providing a version where people can connect through a usual PC screen.

I find the idea of using AR in virtual meeting a very interesting one. Rather than using a virtual space (even one that you can customise like the one offered by [VirBELA](#)), why not start with your "real" physical space and invite other people to join in your space? You can show them around and have them look at the mock up you have on your table.

Also, this approach may be of interest to professionals like educators supporting kids with cognitive disabilities. They could use as the virtual meeting place the playroom/bedroom of their kids and enter, virtually, into their room. The kids will be much more at ease, since they will meet in their familiar environment and can physically interact with their toys as well as with the virtual one provided by the educator. By having this ghost space, the educator can review the activity of their kids and monitor their progress. It is usual for educators supporting cognitive disabilities to solicit them to practice some exercises, and then they get feedback from their parents, sometimes they look at exercise sheets filled in by the kid (those with high function). By using AR, the monitoring can become much more effective, and there is even the possibility of "replay" the past activity together with the kid.

The big issue to really leverage this mixed space is the availability of AR devices making the interaction seamless. We do have some devices, like smartphones, that are affordable (basically because there is always one of them around), but their use is not really seamless, it requires some skill, both physical and cognitive, that may be missing in some kids with disabilities. Besides, the smartphone gets in the way; it turns the interaction in something perceived as mediated (that is different from when we use a phone to talk, this has become so natural that the phone fades away from our perception and we focus on the interaction). AR glasses would probably be much more effective, but they are not affordable and do have several shortcomings in their current version.

We might expect that, also under the pressure of the epidemic countermeasures, in the coming months, better products will become available. I am pretty sure this will happen pretty soon with the various

pieces of the AR puzzle falling in place now. At that point, we will have taken a big step into the Digital Transformation of our ambients.

This is likely to open a Pandora box of opportunities as well as issues, with privacy and security entering into our daily life. Once your home can be mirrored in the cyberspace, who knows what the implication might be? Remember those fairy tales where you entered your home and there was the boogeyman waiting there? Well, with AR and somebody hacking your data space, you may actually end up finding a boogeyman in your living room!

9.2.13 Supply and Delivery Chains

Supply and delivery chains are possibly some of the most complex and successful achievement of modern society. The computerization of their management has made possible an unbelievable effectiveness. With quite a bit of simplification (over-simplification possibly), we can recognize these stages:

1. Innovation and streamlining of transportation
2. Creation of warehouses and distribution hubs
3. Integration of the supply chain in the manufacturing process
4. Integration of the distribution chain in the manufacturing planning
5. Industry 4.0
6. Global supply chain intelligent workflow

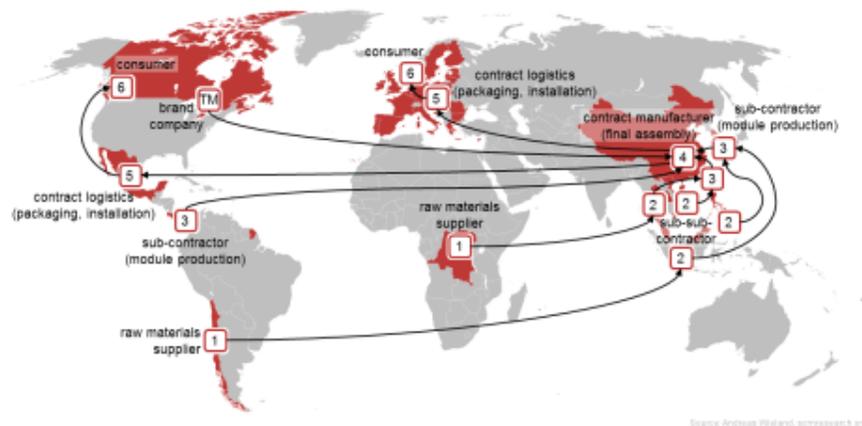


Figure 72. A macro view of the computer supply chain identifying the exchange of materials, components and final product. Notice how China is the main aggregator, at the core of the supply chain. Image credit: Supply Chain Management Research.

When we look at a container ship, we appreciate the kind of standardization and optimization that goes into shipping. Big ship can carry over 20,000 TEU (Twenty-foot Equivalent Unit, an ISO standard, containers are either 20 or 40 feet in length). 1 TEU can contain over 50 refrigerators or 400 42-inch flat screen televisions. By using container shipping load, time has decreased by 90% and can be completely automatized. Robotic cranes pick up containers from trucks and load them onto trucks at the destination port. There is plenty of software in the filling of containers. You don't want to ship a half full container. At the same time, the stuff you place inside has to be compatible and should make sorting easy at the destination point. You also need to know the time it will take a specific container to reach the destination hub and make sure that something will be available to pick up the content.

The whole transportation chain has been progressively standardized and automatized with a hub and spoke structure, warehouses that are more and more automatized. Shipping a PlayStation from Shenzhen, China, to Italy is likely to take the package first to the Netherlands to a warehouse conveniently located near Schiphol airport. From there, it may be loaded on a truck reaching a warehouse in Lombardy, after rolling through Germany and Switzerland, and from there on a different truck to a local warehouse serving the regional area of destination where it will be picked up for final delivery by a small van whose driver receive the driving instruction from a computer that optimize delivery. In the meantime, the end customer can track the position of her package that is updated in real time.

Warehouse costs and letting packages dormant immobilizes capital, thus increasing the overall cost. That is why in the last decade, computers have been used to synchronize the production needs with the availability of components so that these become available "just in time" to feed the assembly lines with no warehouse storage required. The mantra in the last two decades has been "just in time" and no warehousing. This requires a high reliability of the supply chain (you don't want to run out of components feeding the assembly line, that will create a huge loss of productivity and money). Again, the use of computer and sophisticated applications more and more making use of artificial intelligence has been crucial. We simply could not run a manufacturing plant today without computer networks connecting the plant to the suppliers.

Huge progress has also been made in connecting the distribution chain to the manufacturing plant to make sure that what is being produced is immediately taken to the market, and in particular to the market spots where that product is needed. This has required the development of applications and market sensors that can forecast the changing needs of the market. The Internet of Things, product tagging, and electronic inventory at cash out are more and more integrated to provide an almost real time pulse of the market. Furthermore, machine learning and forecasting leveraging artificial intelligence (like to take into account the impact of advertisement campaigns) are being used to finely tune the distribution chain. Just imagine preparing the manufacturing processes for the release of a new iPhone. How many million pieces should be produced in advance of the announcement? We are talking about millions of pieces that will have to reach stores all around the world in a week's time to meet customers demand. What will that demand be? Will it be a stampede or a low uptake? The distribution chain shall connect effectively with the factory(ies) and with the retail stores around the world.

We are now in the next stage of logistic sophistication, the one of Industry 4.0. Here, the customer (as a single and as a community of customers) is connected to the factory and influence the factory processes. The idea is to merge customization with mass production, on one end maximizing the perceived value (hence the price that can be charged), and on the other hand, the advantage of scale (minimising cost). This requires a rethinking of the way a product is manufactured. Most of the time, enabling customization at the retail point. Although, in some cases customization may also take place in the assembly line through robots that are fed with specific instructions resulting from specific customer choices. All of this should maintain the overall manufacturing and supply/distribution chain efficiency.

If we look back it looks almost unbelievable the level of efficiency that has been gained in the supply/manufacturing/delivery chain. This has led to an integrated system that is only possible through massive use of computers and software. At the same time, this efficiency has now clashed with the unprecedented situation created by the lockdown of entire areas and countries.

The continuous flow of components is crucial to the functioning of today's world economy. This is well known, and any company makes sure that there is always a "plan B" in case a disruption occurs at any stage in the value chain. There are alternative providers, alternative transportation means, and alternative resellers. However, no one could have predicted (or considered worth to take into account) a whole country lockdown. Here, the issue is that there is no alternative! If you need a sensor for your car or for your watering system, you will have to turn to a company in Wuxi, China. Yes, you have several alternatives. There are hundreds of companies in Wuxi that can meet your demand. However, 90% of sensors are produced by companies in Wuxi, just 10% by companies in other parts of the world.

A recent analysis has shown that close to 90% of Fortune 1000 companies have their supply chains involving tier-2 suppliers in the Wuhan region. When the Chinese Government locked down that area to contain the epidemics, they also blocked the supply chains feeding factories around the world. In 2003 when the SAAR epidemic started, China's GDP represented 2% of the world's GDP. Today, it represents close to 20% and a good portion of this GDP is in delivering "stuff" to the rest of the world. No one was actually prepared for such shattering of the supply chains.

This is why everybody is scrambling now to rethink the supply chains, making them less vulnerable, and here again the world is turning to digitalization and to a digital transformation of the supply chains, to what is known as digital workflow.

If you are interested in this area, read [the latest report](#) from the World Economic Forum on how global supply chains will change after the COVID-19.

9.2.14 Professional Healthcare at home

The ongoing pandemic is placing healthcare infrastructures under stress, and unless it is absolutely necessary, you are asked not to go to a hospital but stay isolated at home. Doctors will be providing support by phone, telling you what to do. Clearly, it is a different quality of care from being at the hospital where one can be monitored continuously.



Figure 73. A very simple to use medical exam kit can let your doctor visit you from remote. Image credit: Tytocare.

Here comes Tytocare, an electronic kit flanked by powerful software that lets a doctor perform a number of medical tests on your body, as he would be doing if he were at home with you.

Tytocare is a handheld device that can be coupled with a variety of sensors to examine ears, lungs, throat, heart, skin, abdomen, oximetry, and temperature. In addition, it couples to your smartphone to

establish a connection with your physician that will guide you in carrying out the exams and will get the data from them, prompting you to move them. In a way, it is like having your physician at home.

Tytocare was not designed as response to the current crises. It is part of a general trend in the Digital Transformation of healthcare. There are a number of companies that are exploiting the possibilities provided by tele-medicine as these are getting more and more effective as more and more sensors can detect data in a seamless way. Wearables for sure will accelerated this trend. Besides, the analysis of data generated by these sensors, sometimes continuously, as the ones that can be generated by a smart watch (like heartbeats coupled with the level of ongoing activity), can be performed by an AI algorithm that will take into account your medical history, along with the kind of drugs you may be taking and that will signal a red flag to your physician in case of need.

The pandemic is accelerating this shift. Remote monitoring can be used by people that are in quarantine, those that have been infected but whose clinical status does not call for an immediate hospitalization as well as people that are only indirectly affected by the pandemic, like those with some chronic condition that would normally require some periodical hospital checks and that now prefer to stay away from hospital given the risk of infection.

We can rest assured that professional healthcare at home will increase in the coming years and might be one of the inherited habits created by the pandemic.

In this decade, we can expect a growth of proactive healthcare as well as the uptake of a variety of remote medical services based on continuous monitoring and data analytics, with first level of interaction involving chatbots and only in a few cases involving a human doctor.

The flow of medical data and the specific analytics on these data will become an integral function of personal digital twins that we can expect playing a major role in healthcare by the end of this decade.

9.2.15 Economic aspects

In the previous posts, I highlighted the acceleration to Digital Transformation (DX) caused by COVID-19, resulting in both upsides and downsides.

However, what is seen today as a DX acceleration, the uptake of home working, home education, digital health care and so forth may end up in a slow down over time as GDP growth slows and less money is available to support investment.

A recent IDC study indicates a 10.4% growth of DX investment in 2020, a nice figure but actually almost half the growth experienced in 2019 (18%). Overall, the expectation is a loss of \$500 billion investment in DX over the next 3 years.

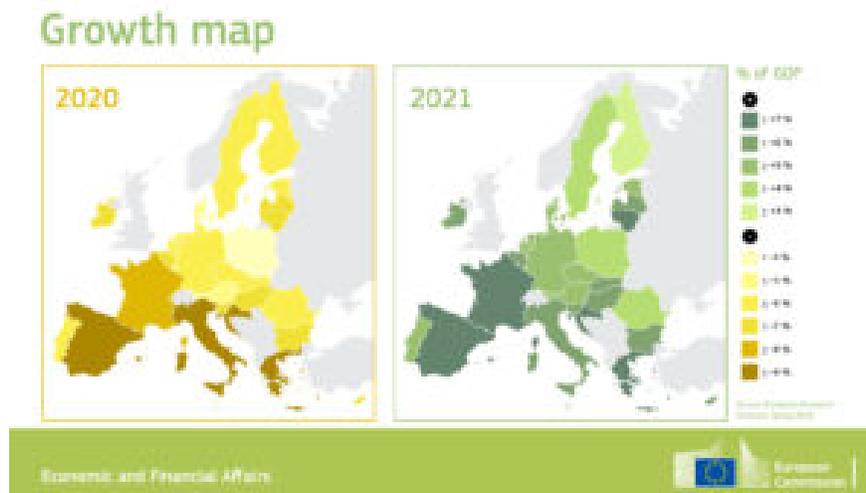


Figure 74. Image credit: EU.

The graphic shows the expected GDP variation across European Countries in 2020 and 2021. The decrease expected in 2020 is sharp and the recovery in 2021 may not be sufficient to restore the 2019 GDP in several countries. Moreover, there is the expectation of a significant shift in investment and in revenues that will be affecting jobs and values, including competitiveness value for companies and individuals.

The problem, of course, is not DX, per se, rather the impact of a decreasing GDP on DX. As shown in the figure, European Countries' GDP is expected to decrease in 2020 between 4% and 10% (some observers are even suspecting greater decrease values), and the rest of the world is not going to fare much better. According to the IMF, 160 countries were expected to show an increase in their GDP in their January forecast. In their latest forecast (April 2020), they expect a decrease of GDP for 170 countries.

Actually, one might say that the decrease of investment in DX is lower than the decrease of investment in other market sectors. So all in all, DX is faring better than the other sectors.

My concern is that what we are seeing now, and for the coming months in 2020, is a rush to transfer business processes to the cyberspace as these have been stopped in the world of atoms. This is not being done with a strategic view, rather as a patch, quick, and (who cares if it is) dirty. It is a bit like saying that we are experiencing a flooding, and we have rushed to get rafts to manage the current. We are not investing in building bridges or true solid ships. We have probably no time for doing that and, possibly, no vision. This is true at the level of companies (understandable, the mantra is "first survive"), but, unfortunately, it is also true for governments. Most of the money that is now being "invented" (i.e. created out of nothing) is being spent to patch up a very dire situation. I do not see a plan to spend the money to change the production fabric of the country, to transform this emergency into an opportunity.

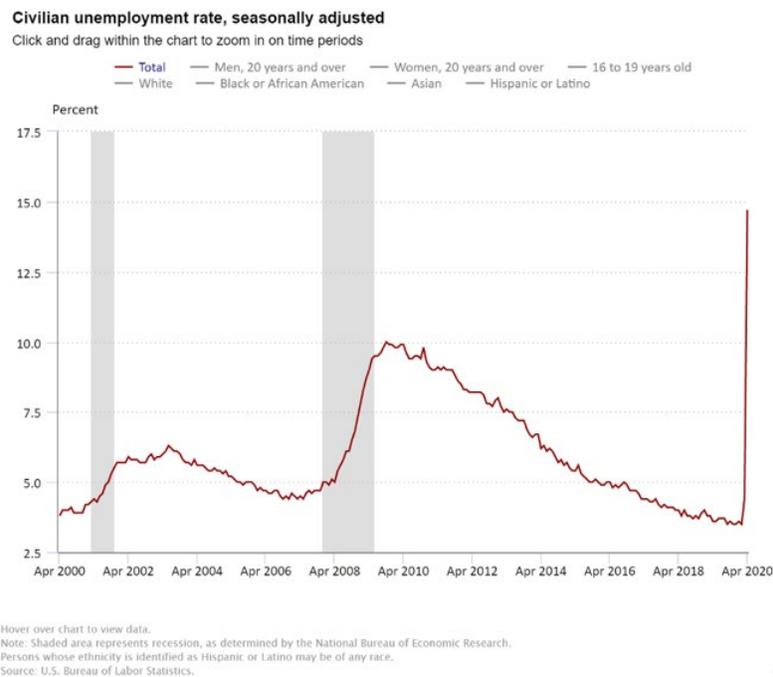


Figure 75. The sharp rise of unemployment in March 2020 in the US, compared with the job losses in the crises of 9/11/2001 and the 2008/2009. Image credit: US Bureau of Labor and Statistics Office.

Some companies are starting to learn from seeing patches that actually not just work. They can become stable parts of a new business and production environment. Companies like Twitter are seeing the advantage of teleworking and are considering to keep it once the pandemic will fade away.

Other companies are leveraging on the pandemic containment to deliver services that haven't been so successful when people were used to move around freely but that now have been forced to adopt. The increased adoption is not just increasing their revenues, it is increasing their understanding of scaling, of what customers really value and learn how to streamline their processes. Their target market has suddenly expanded and their audience has become used to their services. Think about online groceries, online restaurant, and the e-commerce in general. All of this may require a new regulatory framework, and I do not see Governments paying real attention in terms of a vision where the shift to the cyberspace of many services may become a normal way of life.

Plenty of jobs are lost, and in a very short period of time. Some will recover, but many will not. According to the Becker Friedman Institute for Economics at the University of Chicago, 42% of the jobs lost in the pandemic will not be recovered. That means that of the 20.5 million jobs lost in April in the US 8.5 million jobs will not be restored after the epidemic! In Italy, we have just moved into phase 2 with the reopening of all stores and restaurants (although enforcing social distancing). As of today, 90,000 restaurants haven't reopened.

This is leading to an unprecedented reshuffle of jobs (and skills) that I do not see in the governments' focus. It seems to me, at least from the Italian point of view, that governments are focussing their actions to "restore" the status quo, not realizing that the accelerated DX has changed the status quo!

9.2.15.1 Impact on the Sharing Economy

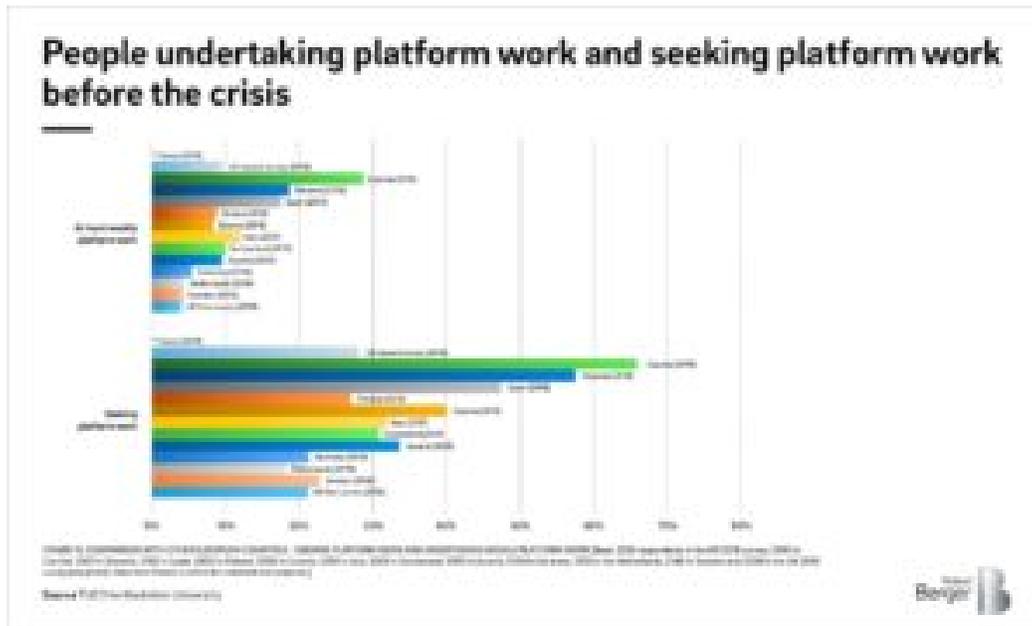


Figure 76. The "Platform Economy" has been hit by the COVID-19 containment actions. In the graphic, the "pre-COVID-19" percentage of people participating at the platform economy (both Gig and Shared Economy) in several countries (upper graphic) and the percentage of people looking to benefit from the platform economy. Image credit: TUC/Hertfordshire University.

In the World Economy, also thanks or because of the Digital Transformation, a growing role is played by the so called "Platform Economy." This is the economy enabled by digital platforms, and it supports both the Sharing Economy (like Airbnb) and the Gig Economy (like Foodora).

The Sharing Economy is still in the single digit of world GDP, but it is (was) growing rapidly. In China in 2020, it was expected to account for 10% of the GDP with an expectation to reach 20% of the GDP in 2025 (it is estimated to have involved some 800 million Chinese people through 78 million service providers in 2019, creating over 6 million jobs).

The Gig Economy (it partly overlaps with the Shared Economy) has reached a \$4.5 trillion value in 2018 worldwide (\$1.3 trillion in the US). These values are based on a study of 18 countries representing 90% of the Gig Economy market worldwide. In the US, 53 million people took on gig work in 2018.

These figures are relatively small with respect to the world GDP, estimated at \$86 trillion (2019 nominal world GDP, the parity adjusted would be around \$140 trillion - this latter value takes into account the different purchase value in different countries, but for comparison with the Gig and Shared Economy data it is better to refer to the nominal GDP). However, the expectation is to see an increasing weight of the Platform Economy on the world GDP. By 2023, according to a recent IDC report, we will see a digital economy supremacy, a threshold defined by companies having undergone the Digital Transformation producing 50% of world GDP.

COVID-19 has changed this scenario and has hit, hard, the platform economy. In particular, the Shared Economy has been hit in different degrees, depending on the sector, but overall the hit has been huge.

The **trust** factor is crucial in the shared economy, and the virus has laid a veil of suspicion of our everyday interactions. Travel has been disrupted, and companies like Airbnb have been hit hard. Just two weeks ago, Airbnb decided a 25% layoff of its workforce. The message sent by the Airbnb CEO to the workforce to explain the reasons leading to the layoff included this statement:

"we are faced two hard truths:

1. *We don't know exactly when travel will return.*
2. *When travel does return, it will look different. "*

Of the two points, it is the second one that strike me most: "travel will look different" once the pandemic is over. This is expected to be a permanent change in behavior, impacting the structure of Airbnb business and of course that of many other companies in this sector.

As I mentioned, trust is a crucial factor in the share economy, and trust is based on the perceived assurance that "everything is fine." This kind of assurance is associated to brand in the "usual" economy and to regulatory body supervision. This is something that is often missing in the sharing economy. At a time when trust is both dented and most valuable, there is a need for establishing acceptable framework in a world that by definition is chaotic and thrives fast differentiation and continuous change. Hence the challenge.

Look at the "phase 2" and how stores reopening is regulated to enforce safety measures. Now think about companies that have found opportunities in the "rentable fashion," attracting people to rent apparel with new business models proposing "subscription" that would provide a new set of clothes, apparels, every week. These companies started to carve a slice in the fashion market with analysts casting rosy expectation on a revolution in the apparel business. All this has been disrupted in just a few weeks. It doesn't really matter that the FDC keeps stating that the probability of contagion from objects is really low, people no longer trust renting an apparel that has been used by another person.

It will take some time before a change in perception occur, and in some sectors this may not happen at all.

As pointed out in a nice article analysing post pandemic business recovery challenges by McKinsey, those businesses that will be able to leverage the new "normal" will come up stronger and will likely aggregate more customers than before. This is particularly so in the Shared economy space because platforms scale much better than normal atoms based economy.

9.2.15.2 Gig Economy

The Gig economy has been hit by the COVID-19 containment actions like most other areas of economy, but here the people making a living out of the gig economy have found themselves without any protection. No severance pay, no Government help. This is something that was pointed out in the past few years. As gig work picked up steam, the issue of accepting this type of work in the global labor framework came up over and over. We have seen the protest of riders delivering food asking for some sort of labor protection. So far, very little has been done. The gig economy provided extreme flexibility to people engaging in it, but at the same time it was basically unregulated. Very little commitment on both sides (although the platforms used to connect offers and demand are tracking the gig workers much more than companies would track their employee, and automatic mechanisms are in place so that those generating more revenues are the ones getting more opportunities, thus inducing a very strong form of control and stress on the worker).

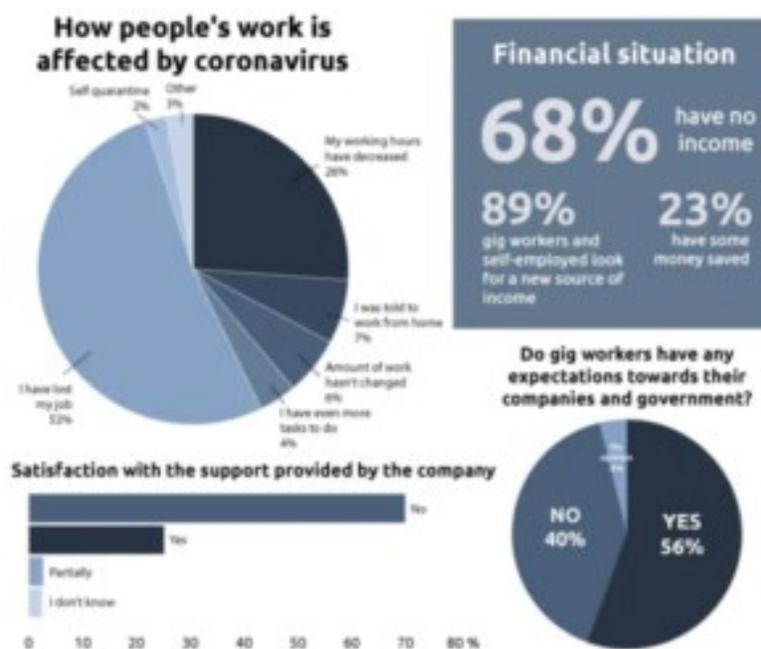


Figure 77. Although 4% of Gig workers saw an increased demand COVID-19 drastically reduced, even obliterated jobs in the Gig economy leaving most workers without any social protection. Image credit: AppJobs.

As shown in the graphic, a few gig workers have actually benefitted from the situation, seeing an increased demand and increased revenues, but this represent just a 4% of the total. Instacart has enrolled 300,000 gig workers (shoppers) to meet demand in the home delivery sector. 6% didn't noticed any change, but for the remaining 90% the landscape is sour.

Over 50% of gig workers lost their job, and a quarter saw a decrease of demand. The sectors of home cleaning, babysitting, and house-sitting have seen a 38% decrease in demand in the US in March. Overall, 68% of workers have been left with no income. 70% are also indicating they had no support whatsoever from their "platform." This is not a surprise, since basically the platform is providing a neutral meeting point of offer and demand. It is not a company taking responsibility on its workforce.

That the situation is dire is shown by an 89% of gig workers that are now actively looking for a job. They fear this may not be just a passing moment, but something that will linger for several months.

Just in the Seattle, WA, area, an estimated 1 million gig workers lost their revenues. If one extrapolates to the whole US gig economy, you get several millions job lost that are not officially accounted for in government statistics and a loss in economic terms close to \$1 trillion.

It is not just the effect of a decreased demand that is hitting the gig economy. It is also an issue of increased "offer." As many workers are losing their job in the "normal" economy, they turn to the gig economy flooding this sector and multiplying the offers. Increased offers and decreased demand don't make for an interesting marketplace!

It is reasonable to expect that once the pandemic will be over the demand will come back. However, there is also some fear that people might have become more cautious and may change their way of living for quite some time. During this time, they will be looking for alternatives, including the replacement of human labor with machines. In the home environment, there is an expectation of an increased demand for home robotics, autonomous vacuum cleaners, self-cleaning surfaces, robot cooks, and so on. This increased demand will result in increased volumes as well as better and more affordable products, starting a spiral towards increased automation.

9.2.16 Impact syntheses

It is obviously too early to draw conclusion on the long term impact of the pandemic. However, some trends are starting to emerge:

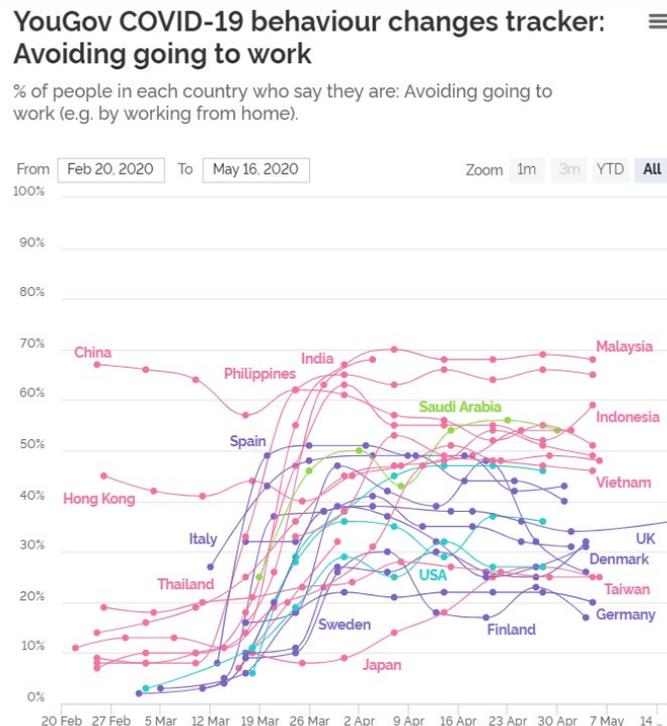


Figure 78. Acceleration of the Digital Transformation — and slow down. Image credit: YouGov.

People's behavior has changed significantly as result of the pandemic, partly as mandated by COVID-19 countermeasures and partly by the changing social behavior resulting from fear. In this graphic is the willingness of people to go to work in different countries.

The pandemic, as pointed out in the previous parts, has accelerated the execution of the Digital Transformation in several areas. In a way, one can say that it is accelerating the future, lights. At the same time, some slowing down is visible, like the foreseen uptake of robo-taxis that is now being delayed. The fear of contagion is leading people to avoid sharing transportation means. Ford is delaying the delivery of robo-taxi, previously expected in 2021 to at least 2022 and will evaluate the impact of the pandemic on consumers expectations; GM has shut down the Maven car sharing service. To stay in the automotive industry at all, the big guns have lost big bucks in the first quarter, and signs are not that encouraging for the next two quarters. The loss is in the order of billions of dollars, and this will affect investment on self-driving cars (notice that the first customers were supposed to be the sharing services, the Ubers of this world). Besides, it seems that technology and regulatory frameworks are not available for full autonomous cars, so better wait a few more years and focus on incremental driver assistance functionalities.

Decreased revenues and slower demand in the coming quarters are delaying/reducing investment, and this will be affecting the Digital Transformation in the coming two years.

Impact on jobs

The last few years have seen a significant decrease in unemployment (broadly speaking, with differences in different world's areas) that pushed up minimum wages (4.5% in the US in 2019). The pandemic has reversed this in just a month, leading to millions of job losses. According to the National Bureau of Economic studies, 42% of lay-offs will become permanent job losses. Part of this will be the result of a decreasing GDP, but part will be a side effect of the accelerated DX with more automated functions, more work in the cyberspace (less office space needed). Moreover, we are seeing first signs of increasing investment in robotization/automation, both as result of:

- increased labor cost/decreased efficiency because of social distance in the factory
- risk in off-shore manufacturing (when the Wuhan region was locked down as many as 80% of major worldwide manufacturing value chains felt the heat) that pushes towards in-shoring and this goes along with new automated factories to keep cost low
- massive deployment of AI to replace humans in call centers and other office activities
- use of robots in janitor/sanitation activities
- lower cost of automation as robots and AI gains volume leading to decrease cost and increased performances

The shared and gig economy have been badly hit, in general. However, in certain areas (like increasing the workforce to support the spike in ecommerce, in healthcare support) the gig economy has seen a tremendous increase. However, those who lost their jobs in the gig economy because of decreased demand did not have any social/government "parachute" and most likely are those that are suffering most.

e-commerce and retail

In just a month, there has been a 10% shift of commerce to e-commerce (in the US), deeply affecting major retail chains (several are closing in the US and 100,000 stores are forecasted to close in the next 5 year). However, at least looking at the US, although a 10% growth of e-commerce (from 15 to 25%) in a single month is unprecedented, one has to observe that 75% of commerce still relies on brick and

mortar, suggesting that people really like the physical shopping experience. In these two months of lockdown, most people simply stop buying (clearly the loss of jobs has been a factor), and from the first signs seeing in Italy as stores re-opened, people are now flocking back to make up for the time lost.

Telecom Infrastructures

Telecommunications infrastructures turned out to be reliable and “scalable.” In just a few days, most backbones have doubled their capacity and managed an increase in traffic that was unprecedented (100% in Italy). This has clearly made clear the importance of the telecom infrastructure for countries, both in terms of business and social continuity. Yet, very seldom we have heard praise on these infrastructures in these months. They are taken for granted. Operators did not see an increase in their revenues (whilst other infrastructures operators, like Amazon, did). Rather, they experienced an increase in their cost. This is going to slow down investment in the deployment of 5G (4G is ubiquitous and it proved it can meet demand).

Healthcare Infrastructures and services

The pandemic has developed quickly, and although there are several critics pointing to a tardy reaction in several countries, it has become clear that the scaling of “healthcare” requires a completely different approach. Hospitals and care centers cannot sustain an avalanche. There has to be a way to provide care at home, using remote diagnoses and monitoring. In the US, 11% of people used some form of tele-health in 2019. During the pandemic, the percentage has skyrocket to 46%, and according to McKinsey, 76% of people in the US are now interested in using tele-health. Companies providing tele-health services have seen the number of transactions growing between 50 and 175 times in April versus the number served last year. This means that they have been able to scale the services in the cyberspace. Most interesting is the forecast of revenue growth: tele-health care services harvested some \$3 billion in 2019 (US market) and may grow enormously since McKinsey estimates that some \$250 billion of today healthcare services can be “virtualized”, i.e. provided via the cyberspace.

The different severity of the disease in different people clearly pointed out the need for a personalized medicine, and here the role of genome-based medicine has become clear. We are already seeing accelerated investment in this area. Likewise, the need for a vaccine “as soon as possible, actually sooner” is leading to the adoption of new tools based on machine learning and AI. It is not known at this time if they will turn out to be as effective as hoped, but it is clear that the increased effort in this area is bound to create results.

17.6 Organizatons and Processes

As companies scrambled to adjust to the pandemic, they had to face the suitability of present processes to the new reality. Organizaton and processes are a crucial component of today’s business. They shape the company and provide the competitive advantage. Changing processes and the organizaton is more complex than changing people and suppliers because those are what define the company. Besides, they are the result of a long and continuous process of adaptation to changing markets, competitive context, regulatory framework, supply and distribution chains. They are shaping up to maximize competitiveness, hence if the context keeps changing they focus on a very flexible operation environment. If the context tends to be more stable, the focus is on continuous improvement (and usually leads to much more rigid operation environment). The sudden changes brought by the pandemic is requiring a re-thinking of the way processes and organizatons are designed.

Over time, a top down approach in redesigning business organizaton has become mainstream, but now there is a growing push towards a bottom up approach, the so called zero-based organizaton redesign.

This approach involves starting off a clean organizational sheet and filling it taking into account internal (people and other resources assets) and external factors (constraints and levers). Notice that knowledge in this approach is seen both as part of the internal and of the external sets, and it can remain such, i.e. leading to an organization based on operation distributed knowledge.

A few of the CEOs interviewed in the last two months are seeing the rethinking of processes as a crucial activity to survival in the short medium term, whilst innovation is seen more as a factor for long term competitiveness (hence not a priority at the moment).



Figure 79. Image credit: EY.

A four step response to the pandemic for companies: 1. Ensure people’s safety (both company employees and customers/providers). 2. Communicate with all parts of the value chain including end customers and retune interactions. 3. Maintain business continuity addressing liquidity, finding alternate supply chains, leverage institutional support. 4. Redesign the organization for recovery and learn from experience.

Communication across the cyberspace

In these two months, even people who never made a conference call became sort of experts. This does not mean that everybody is finding Skype, Teams, WebEx, and Zoom easy to use (not mention to master). It is just that people “had to” use them. The fact that there are several almost equivalent tools, each with its own user interface, is just adding to the confusion.

The lesson learned is that there are plenty of ways (most of them free) to communicate across the cyberspace, but probably none of them is the ideal one, none is really seamless nor able to recreate the feeling of being face to face. This is why companies working in the recreation of physical spaces in the cyberspace are now attracting attention and investment in hope that they can “crack” the recipe for effective communications.

AR and VR are promising technologies that might change the rules of the game. Improvement in devices, particularly in screens and cameras can surely help. Having a conference call on a 75” television screen delivers quite a different experience than using a laptop screen. However, a large screen is not enough. Today’s video cameras require a very good lighting to deliver good images, something that is usually not available in a home environment. Additionally, the sound is not “sounding” natural. One of the most obvious negative issue with conference call is the difficulty in “synchronizing” interactions. When communicating face to face, subtle signs tell that the person is about to finish speaking and that another

is getting ready to talk, hence one waits for his turn. This is not the case in a conference call where several people are usually starting to talk at the same time and then it starts “sorry, go ahead... no, you go ahead....” and so on. This is just a sign that today’s technology is not able to mimic a physical experience.

Sure, the experience is way better than what was experienced years ago, but this is something that is perceived only by those that have been using conference calls in the past. Most people who have discovered this service, forced by the pandemic, are usually feeling excited at first (something is better than nothing), but after a few calls are longing for in-person conversation.

Connection to the cyberspace: XR

As with other market sectors, there are lights and shadows for AR, MR, and VR. The overall shift towards a greater use of the cyberspace naturally favors an uptake of XR, and at the same time the connection and interaction with the cyberspace would benefit from XR. Having said that, the present situation of devices supporting XR is not satisfactory to the consumer market both in terms of performances and in terms of affordability. Solutions that are affordable, like use of existing smartphones, are not delivering credible perceptions of the artificial world. More sophisticated solutions are pricey and still do not feel like the “real thing.” The economic downturn is likely to affect the purchasing capability. However, the lockdown and the need to access the cyberspace, and to a certain extent to “live” in the cyberspace, can become a catalyst for innovation in this area. As shown in the graphic, the lockdown (outermost circle) is expected to stimulate XR hardware sales, development of Apps, use of enhanced video, more engaging e-commerce, and support to enterprise activities that have shifted to the cyberspace (green areas in the outermost circle).

Because of lockdown and the perception of unsafeness that will linger in the months ahead, location based entertainment is likely to suffer (red color), as well as Ads expenditure (apart from the lock-down period).

Supply chains have suffered and in several cases have been disrupted, and this is negatively affecting the whole area that is still relying for hardware components on a few manufacturers that are now focussing in, giving priority to different segments.

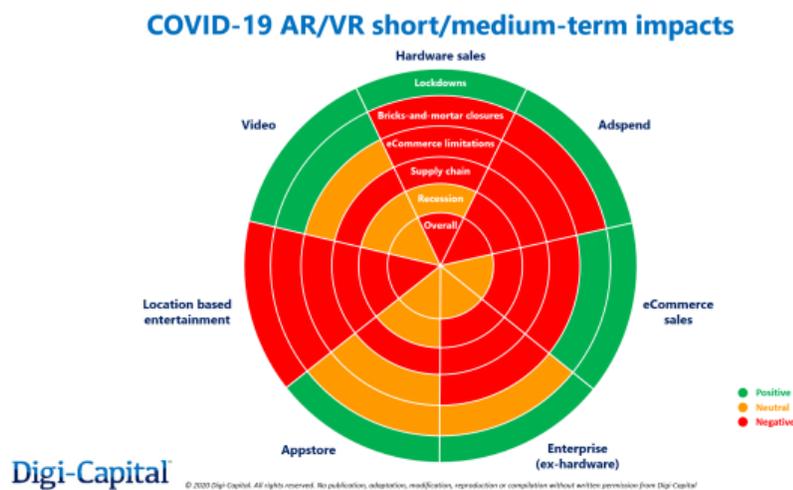


Figure 80. Forecast of impact of COVID-19 on the VR market. Red signals a decrease, yellow neutral and green an increase of market demand/sales. Image credit: DigiCapital.

On the bright side, the recent AWE conference saw several announcements of XR support, like the new XR Collaboration Platform, bringing several tools (and implicitly establishing a much needed standardization) to XR developers. Also, the prevailing sentiment at AWE 2020 (run in the cyberspace) was that in the next 2-3 years, AR and VR devices will meet the performance and affordability needs of the consumer market, and that will result in a rapid uptake of XR.

Touch-less technologies

Touch-less technologies are receiving a big boost by pandemic countermeasures and, possibly even more important, by the perception of people that touching something might be a source of contagion. This (perception) is particularly strong when one has to touch something that is being touched by many other people, like a handle or knob to open a door, a keypad to key-in a code, etc. This explains the rise of companies like Swiftlane and Clear that offer touch-less biometrics. Clear also has an interesting business model. One can enrol for an annual fee (\$15 as of May 2020) and have them manage the biometrics so that when one has to go through a barrier at an airport or any other controlled venue, they will check the biometrics and interact with the local authority that will be able to recognize/authenticate the person and grant access permission. This should result in a much quicker access and no need to touch anything (face scan-based biometrics).

Digital Identity and Personal Digital Twins

Digital identity and characteristics, aka Digital Twin, are also on the rise. The health passport that has been adopted in some countries and is being considered by many others is an example of a Personal Digital Twin. Again, as an example, Clear is offering a Health Pass and associates it to biometric identification (which, from a service and technology standpoint makes perfect sense). However, all these collections of personal data (biometrics, health parameters, contacts, places visited) are fraught with privacy and security issue (one surely doesn't want to have someone out there hacking into personal data). Imagine a lift that looks at a person's face and listens to the request to go to a specific floor. Cool! Well, in order to do that there should be a computer processing the voice and face. Sure, it can enable access control and avoid touching any button, but at the same time it can accrue data on when, what and even the mood changes as that person went up and then down. The point is that people are getting used to these interactions and even appreciate the possibility they offer, but at the same time they open up the flank to undesired big brother scenarios.

A common transnational framework would be needed.

10 Appendix

10.1 Standards

10.1.1 Standard for Digital Transformation Architecture and Framework

This standard provides an architecture and framework for digital transformation development, usage, implementation, and interfaces for applications. The architecture and framework addresses scalability, systems and interfaces, security, and privacy challenges for digital transformation applications.

Purpose: The purpose of this project is to develop definitions and a protocol for digital transformation implementations for applications.

Need for the Project: The rapid advances and developments in digital technology and market growth have created the digital transformation that resulted in new and complex challenges in information systems and technology, process automation, cloud computing, robotics, and artificial intelligence. No standards exist for digital transformation.

Sponsoring Society and Committee: IEEE Industrial Electronics Society/Industrial Electronics Society Standards Committee (IES/IES) P2023

10.1.2 Basic supporting technologies

10.1.2.1 Standard for Real-time Operating System (OS) for Small-scale Embedded Systems - IEEE P2050

This standard specifies a real-time OS for small-scale embedded systems such as systems with single chip microcomputer including 16-bit CPU, systems with small amount ROM/RAM, and systems without MMU.

Need for the Project: Small-scale embedded systems constitute the majority of IoT (Internet of Things) devices. This project is needed to make it easy to customize and optimize the implementation for small-scale embedded systems, and address the distribution and portability of device drivers and middleware.

Sponsoring Society and Committee: IEEE Consumer Electronics Society/Standards Committee (CES/SC)

10.1.2.2 Nomenclature and Taxonomy for Distributing Computing, Communications and Networking along the Things-to-Cloud Continuum - P1934.1

The development of Edge/Fog Computing technologies and systems among the industrial consortia and the research communities has created a rich set of concepts and constructs. This document aims to collect the terminology developed in these communities and identify the relationships between their use in the communication technology (CT), information technology (IT) and operation technology (OT) applications along the Things-to-Cloud Continuum. This document also introduces a high-level taxonomy of these concepts and constructs.

The primary goal of this standard is to establish common, generic nomenclature and taxonomy for distributing computing, communication, networking, storage and control along the Things-to-Cloud Continuum for the use in the IEEE standards, recommended practice and guides. It may also be used to refer to common elements, structures and practices in different application verticals.

Need for the Project:

The IT, CT and OT convergence will be accelerated with the use of a common set of terms and definitions to refer to the concepts and constructs developed in the Edge, Fog Computing and other related technologies. This effort will also promote the development and use of this nomenclature and taxonomy in multiple communities and thus serve as a catalyst in the next digital revolution.

Standards Committee:

IEEE Communications Society/Edge, Fog, Cloud Communications with IOT and Big Data Standards Committee (COM/EdgeCloud-SC).

10.1.2.3 Edge/Fog Manageability and Orchestration - P1935

This standard defines and harmonizes the manageability, management and orchestration for Edge/Fog Computing. It describes the capability, manageability, management and orchestration functions and services of ambient, self-aware resources. It also defines the membership and behavior of an ambient resource within an Edge/Fog community or neighborhood, as well as the structure and function of the Edge/Fog community or neighborhood itself.

Need for the Project:

This standard is needed to aid the understanding and define the common interoperability and data models for Edge/Fog computing

Standards Committee:

IEEE Communications Society/Edge, Fog, Cloud Communications with IOT and Big Data Standards Committee (COM/EdgeCloud-SC)

10.1.2.4 Intercloud Interoperability and Federation (SIIF) - P2302

This standard defines topology, functions, and governance for cloud-to-cloud interoperability and federation. Topological elements include clouds, roots, exchanges (which mediate governance between clouds), and gateways (which mediate data exchange between clouds). Functional elements include name spaces, presence, messaging, resource ontologies (including standardized units of measurement), and trust infrastructure. Governance elements include registration, geo-independence, trust anchor, and potentially compliance and audit. The standard does not address intra-cloud (within cloud) operation, as this is cloud implementation-specific, nor does it address proprietary hybrid-cloud implementations.

Purpose:

This standard creates an economy amongst cloud providers that is transparent to users and applications, which provides for a dynamic infrastructure that can support evolving business models. In addition to the technical issues, appropriate infrastructure for economic audit and settlement must exist.

Need for the Project:

The cloud landscape today consists of multiple independent and incompatible cloud offerings, based on both proprietary and open architectures. The growth of the Internet was facilitated by the creation of an interoperable service marketplace between Internet service consumers and Internet service providers. Clouds today do not interoperate, resulting in absolute limitations in geographical coverage, resource functionality, and resource scalability. A cloud provider may not have resources where a cloud consumer needs them; a cloud provider may not offer the type of resource needed; and a cloud provider's resources cannot be infinitely elastic. Intercloud interoperability and federation solve all these

problems. This is analogous to the interconnected economy that evolved amongst telephony service providers. This facilitated the original global long distance network for voice, and more recently today's cellular world where one provider's customers can "roam" on another provider's network.

Standards Committee:

IEEE Computer Society/Cloud Computing Standards Committee (C/CCSC)

10.1.2.5 Authentication Services for ISO 8583 - P1940

Create a collection of standard profiles that define integration of authentication services with ISO 8583 used for financial transactions (e.g., point-of-sale (POS), automated teller machine (ATM) cash withdrawal transactions, etc.). Such services include biometric authentication (as defined by IEEE Std. 2410), PIN-based, Fast Identity Online (FIDO), and One-Time Password (OTP) and Time-based OTP (TOTP) authentication methods including risk and presentation attack defense (PAD) measures. The scope of authentication includes primary authentication, second-factor authentication (2FA), step-up authentication (SUA), and multi-factor authentication (MFA).

Need for the Project:

The ISO 8583 standard is used globally for financial transactions at ATMs, including transaction authorization and authentication of the customer and device. Although current authentication methodology at the ATM is closely tied to use of traditional PIN-based authentication using card-based access, ISO 8583 provides capability for other forms and methods to be used. Thus, services that support protocols such as IEEE Std. 2410 and FIDO (and FIDO2) would be used for authentication for "cardless" and "PIN-less" transactions using a mobile app that provides: 1. proper cryptographic payloads (aka "cryptogram"); and 2. metadata regarding the authentication modality used for the transaction such that the issuer (e.g., a bank or fintech firm) has high confidence in the authentication session used in risk analysis; and 3. User behavioral confidence measures also for use in risk analysis. Note: The cryptographic payload in (1) could include an OTP or TOTP displayed to the user for input at the POS/ATM keypad optionally. This collection of profiles will detail use of various authentication methods (biometric, PIN, FIDO/FIDO2, etc.) to provide information needed for (1), (2) and (3). In the first case (1), the cryptographic payload (aka "cryptogram") standard is being developed by National ATM Council (NAC). In the second case, we refer to possible candidate existing standards, such as IEEE Std. 2410, RFC 8485 (Vectors of Trust), FIDO, FIDO2 and X9.117-2018, to encode metadata regarding confidence measures for authentication modalities including use of biometrics but not limited to these standards.

Standards Committee:

IEEE Communications Society/Edge, Fog, Cloud Communications with IOT and Big Data Standards Committee (COM/EdgeCloud-SC).

10.1.2.6 Privacy and Security Framework for Consumer Wireless Devices - P1912

This standard defines a privacy scale that shall be applied to data that is defined as personal identifiable information that is being collected, retained, processed or shared by or among applications implemented on networked edge, fog, or cloud computing devices. This privacy scale data provides input to assessment tools that developers or users of these applications use to develop, discover, recognize, or implement appropriate privacy settings for types or levels of personal data resident on these devices.

Need for the Project:

The Project develops a standard to define a privacy scale for businesses or organizations seeking to avoid the pitfall of failing to provide adequate privacy protection for consumer data. On May 25, 2018, the EU General Data Protection Regulation went into effect, marking a dramatic shift in the regulatory obligations of digital technology manufacturers and data managers as it relates to the protection of consumer privacy. The cost to an entity for non-compliance can be €20 million or four percent of annual turnover, whichever is greater. Following the actions taken by the EU, the State of California, on June 28, 2018, passed the California Consumer Privacy Act, which went into effect on January 1, 2020. This law protects the privacy of California residents by giving them the right to know what personal data companies collect on them, their consumer devices, and their children, the right to opt-out of the sale of personal data, and the right to sue companies for data breaches. Californians can also request that a business delete their personal information. To manage the new privacy legal landscape companies and organizations will need the standard developed by this project to help them to determine how to view consumer data practices and develop strategies to avoid costly privacy regulatory violations. In this new policy and legal landscape there are complications for organizations and companies seeking to adequately meet privacy regulatory obligations as they navigate enforcement of the California and EU privacy laws.

Standards Committee:

IEEE Communications Society/Edge, Fog, Cloud Communications with IOT and Big Data Standards Committee (COM/EdgeCloud-SC).

10.1.2.7 Standard for Biometric Privacy - P2410

The Standard for Biometric Privacy provides a biometric-agnostic security protocol for private authentication, identification, and liveness using one Application Programming Interface (API). User privacy including General Data Protection Regulation (GDPR) compliance is guaranteed through the use of homomorphic encryption."

Need for the Project:

With the increasing need to secure user access to their footprints of personally identifiable information (PII) in the Internet (e.g. financial and health records) and enterprise assets, the Standard for Biometric Privacy is designed to control communication with its clients via a two-way SSL/TLS homomorphic interface. Before users are granted access, users must authenticate their identity with an enterprise system that controls access to resources and assets. If authentication is successful, the user is authorized to access resources or assets (i.e., they are "granted access"). Otherwise, they are denied access. Identity must be established at some prior phase via registration of information (e.g. username, token or biometric) that identifies the user with an account in the system. Biometrics have a long-held hope of replacing usernames, passwords and tokens by establishing non-repudiable identity and providing authentication with convenience. Biometrics include a wide range of information taken from a person, for example, fingerprints, face, voice, and iris pattern; and his/her behavioral properties, for example, gait, date, time, and location. Convenience is driving industry and consumers toward the biometrics-based access management solutions, say studies from Ericsson, PayPal, IBM, and Microsoft. A study by Frank Stajano at the University of Cambridge together with Microsoft Research titled, "The Quest to Replace Passwords: A Framework for Comparative Evaluation of Web Authentication Schemes," similarly concluded that a vast passwords replacement transition should conform to the following criteria: nothing to carry, efficient to use, and easy recovery from a loss. The study goes as far as concluding such criteria could be achieved mostly in the biometric schemes. Recent increases in the processing power and sensor technologies allow algorithms to run in the time needed for a real-time authentication (similar to username and password login processing). Unlike passwords, however,

biometric data is considered highly sensitive due to its personal nature and unique association with users. Secure storage, transport, and processing of biometric data is paramount in the design and implementation of the SBP system. Over the course of various iterations, we changed the wording to highlight privacy. The reason is that users of the Spec said that we should highlight privacy because it has tremendous value and is not obvious. Standard for Biometric Privacy brings a new level of consumer privacy assurance by keeping biometric data encrypted at rest, in transit and in use.

Standards Committee:

IEEE Communications Society/Edge, Fog, Cloud Communications with IOT and Big Data Standards Committee (COM/EdgeCloud-SC).

10.1.2.8 Data Model for Nanoscale Communication Systems - P1906.1.1

This standard defines a common YANG [RFC 6020] data model for IEEE 1906.1-2015 nanoscale communication systems.

Purpose:

The YANG data model defines a common network management and configuration data model for nanoscale communication systems. In so doing, it fulfils several purposes: it enforces requirements to be compliant with IEEE 1906.1-2015, it describes nanoscale communication systems, it represents the fundamental physics impacting IEEE 1906.1-2015 systems, it defines configuration and management for simulation and analysis, and finally, it defines a self-describing data structure used in repositories of nanoscale communication experimental data.

Need for the Project:

A standard network and management and configuration data model enables efficient understanding and use of IEEE 1906.1-2015 systems and simulations. A standard data model is needed to ensure that systems and simulations are compliant with IEEE 1906.1-2015. A standard data model is needed to serve as human and machine readable documentation of IEEE 1906.1-2015 systems. Because small-scale communication systems interact directly with nanoscale physics, a data model is needed that represents fundamental physics. A common data model is needed to accurately and fairly compare and contrast IEEE 1906.1-2015 systems. Repositories of experimental data from small-scale communication systems require clear and accurate documentation for the data to be meaningful. This common data model will provide a self-describing data model that can address this purpose.

Standards Committee:

IEEE Communications Society/Edge, Fog, Cloud Communications with IOT and Big Data Standards Committee (COM/EdgeCloud-SC).

10.1.3 Augmented and Virtual Reality

10.1.3.1 AR/VR Device Taxonomy and Definitions P2040.1

This standard specifies the taxonomy and definitions for Virtual Reality (VR) and Augmented Reality (AR) devices.

Need for the Project:

Thanks to the recent technology advances and market growth, more and more companies are producing various VR/AR devices, which include but are not limited to head mounted displays, remote controllers, sensor stations, etc. This project is needed to reduce the emerging confusion in many VR/AR devices that have similar or misleading product names but significantly different functions or performance. By

dividing VR/AR devices into different categories and levels, this standard could help end users choose the right devices, facilitate the development of cross-platform content and services, and promote a healthy growth of the VR/AR industry.

Standards Committee:

IEEE Consumer Electronics Society/Virtual Reality and Augmented Reality Standards Committee (CES/VRARSC).

10.1.3.2 Immersive Video Taxonomy and Quality Metrics – P2040.2

This standard specifies the taxonomy and quality metrics for immersive video.

Need for the Project:

Immersive video is an enabling technology behind many Virtual Reality (VR) applications in various vertical industries (e.g., media, entertainment, education, and tourism). Due to the rapid market growth recently, there have been many variants of immersive video which are different in several aspects: 360 degrees or 180 degrees, stereoscopic or not, view point movable or not, focus adjustable or not, etc. This project is needed to reduce the confusion among these variants as they are often simply called "VR video" in today's market. By dividing immersive video into different categories and levels, this standard could help end users choose the right products, facilitate the development of cross-platform content and services, and promote a healthy growth of the VR industry.

Standards Committee:

IEEE Consumer Electronics Society/Virtual Reality and Augmented Reality Standards Committee (CES/VRARSC).

10.1.3.3 AR/VR Immersive Video File and Stream Formats - P2040.3

This standard specifies the formats of immersive video files and streams, and the functions and interactions enabled by the formats.

Need for the Project:

Immersive video is an enabling technology behind many Virtual Reality (VR) applications in various vertical industries (e.g., media, entertainment, education, and tourism). Due to the rapid market growth recently, there have been many variants of immersive video which are different in several aspects: 360 degrees or 180 degrees, stereoscopic or not, view point moveable or not, focus adjustable or not, etc. This project is needed to define the immersive video file and stream formats that support all the variants and facilitate the development of cross-platform content and services. This standard identifies existing applicable video coding standards, and defines the integration of these standards into immersive video.

Standards Committee:

IEEE Consumer Electronics Society/Virtual Reality and Augmented Reality Standards Committee (CES/VRARSC).

10.1.3.4 Virtual Reality and Augmented Reality: Person Identity - P2040.4

The standard specifies the requirements and methods for verifying a person's identity in virtual reality.

Need for the Project:

Many of the most important long-term applications for virtual reality, like distance education, e-commerce, work meetings, or simulation and training will rely on maintaining a meaningful representation of yourself that can travel across multiple servers. For example, you might be invited to a meeting at another company where you want to both appear as your chosen appearance (your 'avatar') and also be able to authenticate/prove that you are who you say you are. Similarly, you might want to go to school or go shopping as the same visual avatar. Given that VR will be a very 'social' medium, with many experiences depending on the presence of other people. The standard would allow a virtual reality user to; identify themselves to a site or service through a number of identity authorities; authenticate singular pieces of information without needing to trust the site with additional information; present themselves with specific visual assets; while having the visualization of their appearance certified.

Standards Committee:

IEEE Consumer Electronics Society/Virtual Reality and Augmented Reality Standards Committee (CES/VRARSC).

10.1.3.5 Virtual Reality and Augmented Reality: Environment Safety - P2040.5

This standard specifies recommendations for workstation and content consumption environment for Virtual Reality (VR), Augmented Reality (AR), Mixed Reality (MR) and all related devices where a digital overlay might interact with the physical world, potentially impacting users' perception. This standard focuses on setting quality assurance and testing standards for qualifying products in said environments, achieving satisfactory safety levels for creation and consumption environment for all or majority of related products available for consumer and commercial purposes.

Need for the Project:

The rise of popularity of digital/analog reality products in consumer electronics, as well as in commercial / industrial fields is requiring a balanced approach to designing a safe environment for developers and consumers. Virtual Reality and Augmented Reality enable new levels of productivity and speed up the training and content creation, yet standardization is necessary in order to provide a safe zone around the device and its operator. Standardization is viewed as the most efficient way to remove obstacles which operators or consumers might encounter, potentially including mandatory detection of objects in close proximity and releasing a warning if the interaction is deemed potentially hazardous. By providing necessary recommendations, we can reduce or eliminate potentially negative impacts which the industry faces.

Standards Committee:

IEEE Consumer Electronics Society/Virtual Reality and Augmented Reality Standards Committee (CES/VRARSC).

10.1.3.6 Virtual Reality and Augmented Reality: Immersive User Interface - P2040.6

This standard specifies the requirements and methods for enabling the immersive user interface in Virtual Reality (VR) applications, and the functions and interactions provided by the immersive user interface.

Need for the Project:

Most of the Virtual Reality (VR) applications are supposed to provide fully immersive experiences, which could be spoiled by non-immersive user interfaces such as the ones enabled by conventional keyboards, mice, and touchscreens. The industry has recognized the necessity of immersive user interfaces in VR applications, and has put lots of efforts in designing and developing various prototypes or component

technologies. This project is needed to unite these efforts and specify the baselines of immersive user interfaces in order to help facilitate the development of cross-platform content and services, and promote a healthy growth of the VR industry.

Standards Committee:

IEEE Consumer Electronics Society/Virtual Reality and Augmented Reality Standards Committee (CES/VRARSC).

10.1.3.7 Virtual Reality and Augmented Reality: Map for Virtual Objects in the Real World - P2040.7

This standard specifies the requirements, systems, methods, testing and verification for Augmented Reality (AR) and Mixed Reality (MR) applications to create and use a map for virtual objects in the real world.

Need for the Project:

Augmented Reality (AR) and Mixed Reality (MR) applications add virtual objects on top of the real world. In many scenarios, virtual objects are supposed to be perceived as real objects so that they should have their own coordinates and orientations in the real world like real objects do. This project is needed to specify a unified map for various AR and MR applications to assign coordinates, orientations, and other arguments in the real world to virtual objects. The shared use of virtual objects among different users or even among different applications could be enabled by such a map.

Standards Committee:

IEEE Consumer Electronics Society/Virtual Reality and Augmented Reality Standards Committee (CES/VRARSC).

10.1.3.8 Virtual Reality and Augmented Reality: Interoperability between Virtual Objects and the Real World - P2040.8

This standard specifies the requirements, systems, methods, testing and verification for the interoperability between virtual objects and the real world in Augmented Reality (AR) and Mixed Reality (MR) applications.

Need for the Project:

Augmented Reality (AR) and Mixed Reality (MR) applications add virtual objects on top of the real world. In some scenarios, virtual objects are not only perceivable as real objects, but also supposed to interact with real objects and the real world. This project is needed to define different categories and levels of the interoperability between virtual objects and the real world, and specify the systems and methods that enable these categories and levels.

Standards Committee:

IEEE Consumer Electronics Society/Virtual Reality and Augmented Reality Standards Committee (CES/VRARSC).

10.1.3.9 Virtual Reality and Augmented Reality: Immersive Audio Taxonomy and Quality Metrics - P2040.9

This standard specifies the taxonomy and quality metrics for immersive audio.

Need for the Project:

Immersive audio is an enabling technology behind many Virtual Reality (VR) applications in various vertical industries (e.g., media, entertainment, education, and tourism). Due to the rapid market growth recently, there have been many variants of immersive audio. This project is needed to reduce the confusion among these variants. By dividing immersive audio into different categories and levels, this standard will help end users choose the right products, facilitate the development of cross-platform content and services, and promote a healthy growth of the VR industry.

Standards Committee:

IEEE Consumer Electronics Society/Virtual Reality and Augmented Reality Standards Committee (CES/VRARSC).

10.1.3.10 Virtual Reality and Augmented Reality: Immersive Audio File and Stream Formats - P2040.10

This standard specifies the formats of immersive audio files and streams, and the functions and interactions enabled by the formats.

Need for the Project:

Immersive audio is an enabling technology behind many Virtual Reality (VR) applications in various vertical industries (e.g., media, entertainment, education, and tourism). Due to the rapid market growth recently, there have been many variants of immersive audio. This project is needed to define the immersive audio file and stream formats that support all the variants and facilitate the development of cross-platform content and services. This standard identifies existing applicable audio coding standards, and defines the integration of these standards into immersive audio.

Standards Committee:

IEEE Consumer Electronics Society/Virtual Reality and Augmented Reality Standards Committee (CES/VRARSC).

10.1.3.11 Virtual Reality and Augmented Reality: In-Vehicle Augmented Reality - P2040.11

This standard defines an overarching framework for Augmented Reality (AR) systems that assist drivers and/or passengers in vehicles.

Need for the Project:

In-vehicle augmented reality has become a new way of providing driving assistance and other infotainment services in vehicles, and is regarded as a promising vertical application of augmented reality. It can be implemented on various devices: Head Up Displays, Smart Glasses, etc. The common point is to make the user interface more friendly while avoiding or minimizing the risk of distracted driving. This project is needed to specify the requirements and methods for applying augmented reality in vehicles, identify existing applicable standards, and define the integration of these standards into a consistent vehicular environment.

Standards Committee:

IEEE Consumer Electronics Society/Virtual Reality and Augmented Reality Standards Committee (CES/VRARSC).

10.1.3.12 Virtual Reality and Augmented Reality: Content Ratings and Descriptors - P2040.12

This standard defines the content ratings and descriptors for Virtual Reality (VR), Augmented Reality (AR) and Mixed Reality (MR).

Need for the Project:

The immersive and realistic experiences enabled by Virtual Reality (VR), Augmented Reality (AR) and Mixed Reality (MR) enrich people's lives, but some of them have the potential to cause mental or even physical problems (e.g. epileptic seizure). For example, unlike the situation in a theme park in the real world where people could choose not to ride a roller coaster after they see its performance and feel it is too dangerous, usually people are not fully aware of what they are facing before they put on a VR headset and enter a VR game for the first time. Even worse is the fact that people might not have the option to stop or escape when they are forced to ride a virtual roller coaster in a VR game. Hence, in addition to the traditional ratings and descriptors that address the ethical issues such as violence and sexual content, new ratings and descriptors are needed to protect people's health and safety from risky VR/AR/MR content. This project is needed to define a comprehensive set of ratings and descriptors for VR/AR/MR content. Existing applicable standards will be identified and leveraged.

Standards Committee:

IEEE Consumer Electronics Society/Virtual Reality and Augmented Reality Standards Committee (CES/VRARSC).

10.1.3.13 AR/VR - Standards in progress

IEEE VR/AR Working Group is developing **12** standards for virtual reality (VR) and augmented reality (AR). Having attracted participants from more than **200** companies and institutions worldwide, the working group now is one of the largest forces dedicated to VR/AR standardization. The working group participants already include device manufacturers, content providers, service providers, technology developers, government agencies and other parties relevant to VR/AR, constituting an excellent mixture for the standards to be widely adopted.

- ▶ IEEE P2048.1TM Standard for Virtual Reality and Augmented Reality: Device Taxonomy and Definitions
- ▶ IEEE P2048.2TM Standard for Virtual Reality and Augmented Reality: Immersive Video Taxonomy and Quality Metrics
- ▶ IEEE P2048.3TM Standard for Virtual Reality and Augmented Reality: Immersive Video File and Stream Formats
- ▶ IEEE P2048.4TM Standard for Virtual Reality and Augmented Reality: Person Identity
- ▶ IEEE P2048.5TM Standard for Virtual Reality and Augmented Reality: Environment Safety
- ▶ IEEE P2048.6TM Standard for Virtual Reality and Augmented Reality: Immersive User Interface
- ▶ IEEE P2048.7TM Standard for Virtual Reality and Augmented Reality: Map for Virtual Objects in the Real World
- ▶ IEEE P2048.8TM Standard for Virtual Reality and Augmented Reality: Interoperability between Virtual Objects and the Real World
- ▶ IEEE P2048.9TM Standard for Virtual Reality and Augmented Reality: Immersive Audio Taxonomy and Quality Metrics
- ▶ IEEE P2048.10TM Standard for Virtual Reality and Augmented Reality: Immersive Audio File and Stream Formats
- ▶ IEEE P2048.11TM Standard for Virtual Reality and Augmented Reality: In-Vehicle Augmented Reality
- ▶ IEEE P2048.12TM Standard for Virtual Reality and Augmented Reality: Content Ratings and Descriptors

10.1.4 Internet of Things

10.1.4.1 Reference Architecture for Power Distribution IoT (PDIoT) - P2413.2

This standard provides an architectural blueprint for the development of the Power Distribution IoT (PDIoT) engaging various domains and stakeholders, including cloud computing, IoT, legacy grid systems and promoting integration and interoperability among various components of electric power grid. This

standard leverages the IEEE 2413 Standard for an Architectural Framework for Internet of Things. The IEEE 2413 globally recognized IoT Architecture Framework is a foundation for this standard. This standard defines a reference architecture for Power Distribution that includes a Power Distribution Cloud based platform, which supports microservices based rapid development and deployment of distribution grid systems, and migration from legacy monolithic distribution grid operating systems to Internet of Things (IoT) platforms, including descriptions of various IoT services, big data and machine learning driven real-time decision making. The standard defines the four layers of the Power Distribution IoT architecture, terminal layer including terminal units, sensors and actuators, communication network layer, edge computing layer, and the IoT cloud-based application layer to support existing and future distribution grid operation and business services. It also defines interfaces and interactions between the PDIoT cloud operation centers, the edge computing nodes, sensors and actuators, and big data analytics that supports PDIoT. The standard also describes the Power Distribution Grid IoT operation center which aggregates a wide range of applications on a shared software and hardware decoupled cloud platform. The PDIoT operation center supports fast and agile migration from legacy distribution grid operating systems to an IoT cloud. It enables efficient collaboration across renewable energy resources, electric vehicles IoT, smart buildings, supports visualization of distribution grid operational status, and facilitates decision-making and business planning based on knowledge derived from historical, real-time or near-real-time data, and big data. This standard also describes security aspects of the Power Distribution Grid architecture.

Need for the Project:

A standard is needed to reduce the current fragmentation across various verticals in the distribution grid, improve grid operational efficiency, and support integration of renewable energy resources and electric vehicles with the grid. By addressing the need for a Power Distribution IoT architecture, IEEE will fulfill its mission to benefit humanity by increasing the interoperability and portability of Power Distribution IoT solutions. This standard will enable development of a wide variety of applications that will improve distribution grid operational efficiency and reliability, support the evolving power distribution grid ecosystem, help to gain panoramic situational awareness, while adapting to the fast growth of smart terminals, distributed energy sources, and electric vehicles markets connected to the distribution grid.

Standards Committee:

IEEE SA Board of Governors/Corporate Advisory Group (BOG/CAG).

10.1.4.2 Assessment of Blockchain-based Internet of Things (IoT) Data Management - P2144.3

This standard defines the assessment framework for data compliance, governance and risk management in Blockchain-based IoT data management, provides performance metrics such as availability, security, privacy, integrity, continuance, scalability, etc.

Need for the Project:

The current implementations of IoT devices and systems do not provide means for trusted IoT data management during full data lifecycle. This standard focuses on the assessment of Blockchain-based IoT data management, so that stakeholders can evaluate the quantified performance indicators according to their specific business requirements.

Standards Committee:

IEEE Consumer Electronics Society/Blockchain Standards Committee (CES/BSC).

10.1.4.3 Functional Requirements in Blockchain-based Internet of Things (IoT) Data Management -P2144.2

This standard defines the functional requirements in data compliance, governance and risk management in the operational process for Blockchain-based IoT data management systems.

Need for the Project:

The current implementations of IoT devices and systems do not provide means for trusted IoT data management during full data lifecycle. This standard defines the functional requirements for Blockchain-based trusted IoT data management system, with the goal of providing implementation and evaluation baselines for stakeholders in the IoT ecosystem.

Standards Committee:

IEEE Consumer Electronics Society/Blockchain Standards Committee (CES/BSC).

10.1.4.4 Framework of Blockchain-based Internet of Things (IoT) Data Management - P2144.1

This standard defines a framework of Blockchain-based Internet of Things (IoT) data management. It identifies the common building blocks of the framework that Blockchain enabled during IoT data lifecycle including data acquisition, processing, storage, analyzing, usage/exchange and obsolescence, and the interactions among these building blocks.

Need for the Project:

The current implementations of IoT devices and systems do not provide means for trusted IoT data management during full data lifecycle. This standard will help stakeholders in IoT ecosystem to manage their data and extract most value from it.

10.1.4.5 Clinical Internet of Things (IoT) Data and Device Interoperability with TIPPSS - Trust, Identity, Privacy, Protection, Safety, Security - P2933

This standard establishes the framework with TIPPSS principles (Trust, Identity, Privacy, Protection, Safety, Security) for Clinical Internet of Things (IoT) data and device validation and interoperability. This includes wearable clinical IoT and interoperability with healthcare systems including Electronic Health Records (EHR), Electronic Medical Records (EMR), other clinical IoT devices, in hospital devices, and future devices and connected healthcare systems.

Purpose:

The purpose of this project is to enable secured data sharing in connected healthcare to improve healthcare outcomes and protect patient privacy and security.

Need for the Project:

There needs to be a set of guidelines and standards to standardize use of clinical IoT devices for precision medicine, data sharing, interoperability, and security with a goal of improved and measurable healthcare outcomes.

Standards Committee:

IEEE Engineering in Medicine and Biology Society/Standards Committee (EMB/Std Com).

10.1.4.6 Harmonization of Internet of Things (IoT) Devices and Systems - P1451.99

This standard defines a method for data sharing, interoperability, and security of messages over a network, where sensors, actuators and other devices can interoperate, regardless of underlying

communication technology. The backend of such a globally scalable, secure and interoperable network would be based on the eXtensible Messaging and Presence Protocol (XMPP), and rely on infrastructural components, or bridges, with standardized interfaces that provide real-time conversion of other IoT and M2M protocols, such as those based on CoAP (Constrained Application Protocol), HTTP (Hypertext Transfer Protocol), MQTT (Message Queuing Telemetry Transport Protocol), AMQP (Advanced Message Queuing Protocol), etc., and other interoperability interfaces, such as those provided by the IEEE 1451 Smart Transducer Interface, oneM2M, OMA LWM2M (Open Mobile Alliance Lightweight M2M), OIC (Open Internet Connection), UPnP (Universal Plug and Play), IPSO (Internet Protocol for Smart Objects) Alliance, etc. The standard utilizes the advanced capabilities of the XMPP protocol, such as providing globally authenticated identities, authorization, presence, life cycle management, interoperable communication, IoT discovery and provisioning. Descriptive meta-data about devices and operations will provide sufficient information for infrastructural components, services and end-users to dynamically adapt to a changing environment. Key components and needs of a successful Smart City infrastructure will be identified and addressed. This standard does not develop Application Programming Interfaces (APIs) for existing IoT or legacy protocols.

Purpose:

The purpose of this standard is to define a metadata bridge to facilitate IoT protocol transport for sensors, actuators, and devices. The standard addresses issues of security, scalability, and interoperability. This standard can provide significant cost savings and reduce complexity, and offer a data sharing approach leveraging current instrumentation and devices used in industry.

Need for the Project:

The current implementations of IoT devices and systems do not provide a means to share data and for an owner of devices to authorize who might have the right to access the devices' data including control of these devices.

Standards Committee:

IEEE Instrumentation and Measurement Society/TC9 - Sensor Technology (IM/ST).

10.1.4.7 Assessing the Electromagnetic Fields (EMF) Exposure of Internet of Things (IoT) Technologies/Solutions - P1528.7

This Guide provides a methodology for classifying IoT devices based on RF exposure characteristics. Classification is based on frequency, bandwidth, radiated power, device shape, and typical installation configuration. Links between device class and available measurement/computational standards are provided. A framework criterion for exclusion classes for exposure assessment and criteria for addressing situations where exposure assessment is unavailable are included.

Need for the Project:

In the wireless communication field, 5G and IoT solutions are the main emerging technologies that will draw the borders of the future wireless communication. Concerning 5G technologies, IEEE/ICES TC34 and IEC TC106 has already successfully started two projects which will be jointly developed. Regarding IoT technologies IEEE needs to be at front of standards development.

Standards Committee:

IEEE-SASB Coordinating Committees/SCC39 - International Committee on Electromagnetic Safety (SASB/SCC39).

10.1.4.8 Framework of Blockchain Use in Internet of Things (IoT) - P2418.1

This standard provides a common framework for Blockchain usage, implementation, and interaction in Internet of Things (IoT) applications. The framework addresses scalability, security and privacy challenges with regard to Blockchain in IoT. Blockchain tokens, smart contracts, transaction, asset, credentialed network, permissioned IoT Blockchain, and permission-less IoT Blockchain are included in the framework.

Purpose:

The purpose of this project is to develop definitions and a protocol for Blockchain implementations within an IoT architectural framework.

Need for the Project:

The use of Blockchain technology for IoT enables decentralized, autonomous communication (peer-to-peer, consumer-to-machine, machine-to-machine) without the need for a trusted intermediary. There is an urgent need for standards that will offer a protocol, common vernacular and support interoperability between Blockchain platforms. Standardization of a framework for Blockchain use in IoT will provide a base common understanding enabling innovation in IoT markets.

Standards Committee:

IEEE SA Board of Governors/Corporate Advisory Group (BOG/CAG).

10.1.5 Application areas

10.1.5.1 Standard for a Reference Architecture for Smart City (RASC) - P2413.1

This standard provides an architectural blueprint for Smart City implementation leveraging cross-domain interaction and semantic interoperability among various domains and components of a Smart City. This standard also leverages an architectural framework for the IoT defined in the draft of IEEE P2413 standard, which relies on the international standard ISO/IEC/IEEE 42010. Based on requirements from government bodies, enterprises, and consumers, a variety of applications will be delivered to create social value. The Smart City applications include water management, waste management, smart streetlights, smart parking, environment monitoring, smart community, smart campus, smart buildings, eHealth, eLearning, eGovernment, etc. This standard defines a Reference Architecture for Smart City that includes Smart City Intelligent Operations Center (IoC), Internet of Things (IoT), including descriptions of various IoT vertical applications in Smart City, and identification of commonalities between different vertical applications in Smart City. The standard defines the four layers of the Smart City architecture, device layer, communication network layer, IoT platform layer, and application layer. Relationships with and attributes specific to the cloud computing center, the edge computing technologies, and big data analysis related to IoT for Smart City are also defined in the standard. The standard describes the Intelligent Operations Center (IOC) which aggregates a wide range of data to visualize the city operational status, enables efficient collaboration across agencies and applications, and facilitates decision-making based on knowledge derived from Big Data. This standard also describes unified security aspects of the Smart City architecture.

Purpose:

This Architecture for Smart City is intended to be used by Smart City architects, designers, operators, and users. To support rich and diverse applications that can leverage the cross domain interaction and knowledge is one of the most important enablers of a Smart City. Based on requirements of governments, enterprises and consumers, a variety of Smart City applications will be derived to create great social value. The Smart City Internet of Things (IoT) is predicted to become one of the most

significant drivers of growth in various Smart City technology markets. Most current standardization activities are confined to very specific verticals and represent islands of disjointed and often redundant development. The architecture defined in this standard will promote cross-domain interaction, aid system interoperability and functional compatibility, and further fuel the growth of the Smart City IoT market. The adoption of a unified approach to the development of Smart City IoC and IoT systems will reduce vertical fragmentation and create a critical mass of multi-stakeholder activities around the world.

Need for the Project:

This standard will help to reduce current fragmentation in various verticals in Smart Cities. By addressing the need for a Smart City architecture, IEEE will fulfill its mission to benefit humanity by increasing the interoperability and portability of Smart City solutions.

Standards Committee:

IEEE SA Board of Governors/Corporate Advisory Group (BOG/CAG).

10.2 Acronyms

AI Artificial Intelligence

AGI Artificial General Intelligence

ANI Artificial Narrow Intelligence

API Application Programming Interface

AR Augmented Reality

ASI Artificial Superintelligence

AWS Amazon Web Services

BIM Building Information Modelling

BOG Board of Governors

BYOD Bring Your Own Device

BYOE Bring Your Own Enhancement

CAD Computer Aided Design

CAG Corporate Advisory Group

CAGR Compound Annual Growth Rate

CAM Computer Aided Manufacturing

CAPEX Capital Expenditure

Cas9 CRISPR associated protein 9

Cas13 CRISPR associated protein 13

CDT Cognitive Digital Twin

CEO Chief Executive Officer

CJA Customer Journey Analytica

CJX Customer Journey Experience

CIO Chief Information Officer

CO2 Carbon dioxide

CRISPR Clustered Regularly Interspaced Short Palindromic Repeats

CSP Connectivity Service Providers

CTO Chief Technology Officer

DLP Data Loss Prevention

DLT Distributed Ledger Technologies

DNA Deoxyribonucleic Acid

DNG Digital Negative

DR Digital Reality

DRAM Dynamic Random Access Memory
DRI Digital Reality Initiative
DT Digital Twin
DTO Digital Twin of the Organisation
DX Digital Transformation
EDPB European Data Protection Board
EDPS European Data Protection Supervisor
EEC European Economic Community
EHR Electronic Health Record
EIT European Institute of Innovation and Technology
EPPC European Public Policy Committee
ERP Enterprise Resource Planning
FDA Food and Drug Administration
FDC Future Direction Committee
FRAM Ferroelectric Random Access Memory
GDDR Graphics Double Data Rate
GDP Gross Domestic Product
GDPR General Data Protection Regulation
GE General Electric
GIS Geographical Information System
GNSS Global Navigation Support System
HD High Definition
HMD Head Mounted Display
iBPMS Intelligent business process management software
ICAV Intelligent Connected Autonomous Vehicles
ICOM Independent Core Observer Model
INS Inertial Navigation System
IOS iPhone Operating System
IoT Internet of Things
IT Information Technology
ITU International Telecommunications Union
IVF In-Vitro Fertilisation
JPEG Joint Photographic Experts Group
LHC Large Hadron Collider
LIDAR Light Detection and Ranging
mASI Mediated Artificial Superintelligence
MRAM Magnetic Random Access Memory
NAND One of the two types of flash memory (the other is NOR)
NFV Network Function Virtualisation
NOR One of the two types of flash memory (the other is NAND)
ODD Operational Design Domains
OECD Organisation for Economic Co-operation and Development
OPEX Operational Expenditure
OTT Over the Top
PaaS Platform as a Service
PCM Phase Change Memory
qASI Quantum Computing Artificial Superintelligence
R&D Research and Development

RADAR Radio Detection and Ranging
RNA Ribonucleic Acid
RPA Robotic Process Automation
RRAM Resistive Random Access Memory
SD Standard Definition
SDN Software Defined Network
SDO Standards Developing Organizations
SKA Square Kilometre Array
SIM subscriber identity module
SME Small Medium Enterprise
SPID Sistema Pubblico di Identità Digitale
SRAM Static Random-Access Memory
SSIVA Sapiient Sentient Intelligence Value Argument
STEM Science Technology Economy Math
STT Spin Tunnel Torque
UAV Unmanned Autonomous Vehicles
UBS Union Bank of Switzerland
USD US Dollars
V2V Vehicle to Vehicle
VC Venture Capital
VR Virtual Reality