Digital Transformation
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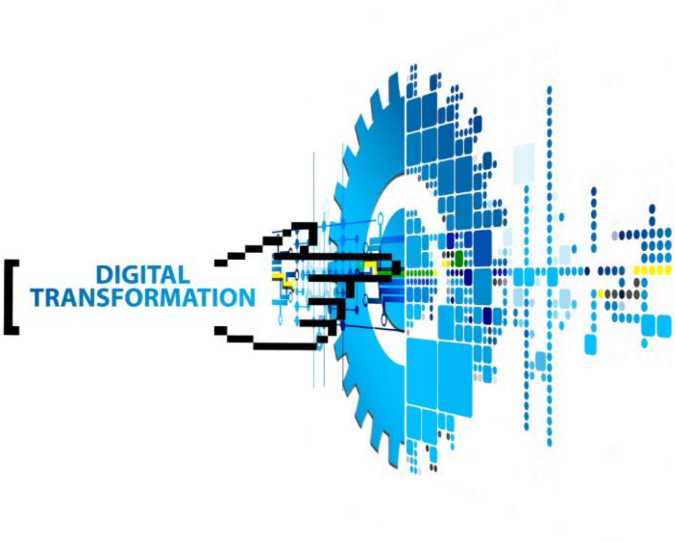

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From Scarcity to Abundance

The Digital Transformation everyone is talking about today is fueled by advances in technology, mostly transducers, i.e., sensors and actuators, and semantics extraction tools, i.e., artificial intelligence supporting data analytics.

The reason why industries and institutions alike are interested in the Digital Transformation, however, is based on economics. The Digital Transformation is shifting the economy of atoms to the economy of bits. The economy of atoms is an economy of scarcity: atoms are limited; if you give an atom away you no longer have it. On the contrary, the economy of bits is an economy of abundance; if you give bits away you still have them (a copy actually, but in the world of bits copies are indistinguishable from the original).

There is more than that, however. The economy of atoms has high transaction cost, i.e., it costs money (and resources) to move atoms along a value chain, while the cost of moving bits is basically zero. This decreases both the capital expenses (CAPEX) required to enter the business of bits and the operating expenses (OPEX), although for support infrastructures (such as communications networks and data centers), CAPEX and OPEX are still huge (hence the small number of companies operating in that space).

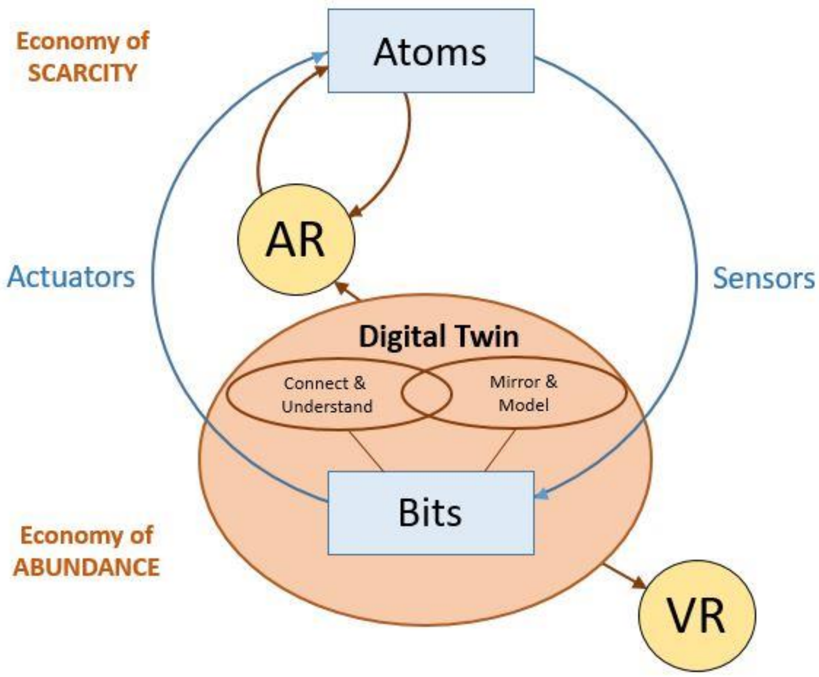


Figure 1. By moving from the economy of atoms to the economy of bits, we are also shifting from the economy of scarcity to the economy of abundance

The diagram shows the loop connecting bits and atoms: bits are created using sensors, forming data. The value of bits is very low, approaching zero, but the value of data can be high if they are meaningful. Hence there is a drive to make sense out of data through mirroring and modeling, and connecting and understanding. Digital Twins, data based entities, are an example of meaningful and actionable data. Through artificial intelligence and data analytics, semantics emerges. Semantics is crucial in the economy of bits because it is delivering value (and the perception thereof): we don't pay for the data but for getting their meaning and for the convenience of getting them. For example, I am not paying for a song's bits, I can get those bits for free through YouTube, as an example, but I prefer to buy them from an online store for the convenience of getting them securely and quickly. Another example: I am not paying for a blood exam to get numbers but to know the meaning of the numbers.

Given the advantages of the economy of bits over the economy of atoms, industries are scrambling to move their atoms operation as much as possible to the bits domain. The two, bits and atoms, get connected by technologies like augmented reality and virtual reality. These two provide an access to the world of bits and more and more through Digital Twins they ensure the connection to the physical twins.

Two currently running IEEE-FDC initiatives have been working on some crucial components of the Digital Transformation, the Digital Reality Initiative (Augmented Reality- AR and Virtual Reality -

VR) and the Symbiotic Autonomous Systems (SAS - Digital Twins). The results they have reached so far and the communities they have aggregated are a perfect starting point for a new initiative that aims at leveraging on the growing interest of industry to exploit the economy of bits. Several industries have already voiced support to a strong initiative in this area, and the most effective way to move ahead quickly is to leverage the results achieved by these initiatives. The new initiative will have the name "*Digital Reality: fostering and leveraging on the ongoing Digital Transformation*".

Digital Twins are at the same time a digital model of some physical entity (object, aggregated objects, processes, etc.) and a digital shadow of the physical entity, mirroring its present situation (hence supporting monitoring and simulation) as well as its history – Digital Threads - (supporting root cause analyses). The Digital Twin can, in some situations, also be used as a proxy of the physical twin, something that is leveraged in Industry 4.0 as well as in other areas.

In a way, AR connects the world of bits to the one of atoms by overlaying bits on atoms. VR, on the other hand, leverages the world of bits.

Flanking bits to atoms

The economy of atoms has existed from the time an "economy" existed. The economy of bits is much more recent, although the immaterial economy has roots that go far back in the past, like the economy of knowledge or the Knowledge Society that was hyped in the last decade.

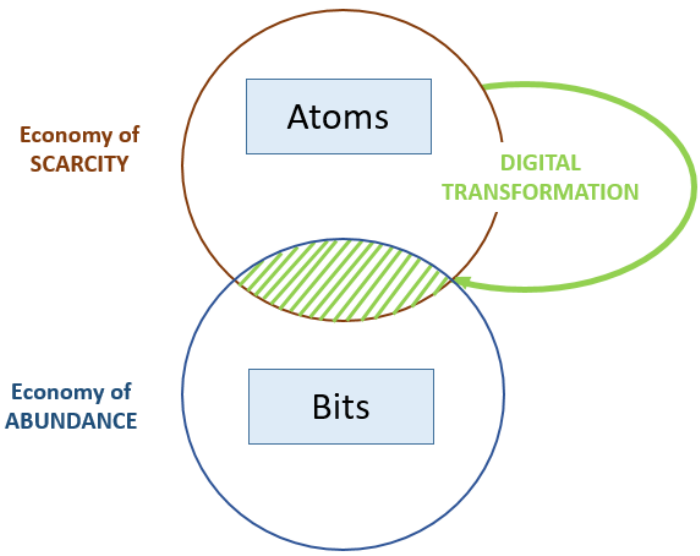


Figure 2. The two worlds of atoms and bits are coexisting and leveraging each other.

Like bits, one can transfer knowledge without losing that knowledge. The problem with the "economy of knowledge", however, is that it takes a long time to transfer knowledge, and the "duplicated" knowledge is seldom like the original one (it can be better or worse, but it is unlikely to be equal). Because of this, an economy of knowledge is not an economy of abundance. Actually, companies often complain of the scarcity of knowledge, notably of the difficulty of finding the skilled people sorely needed to develop the business. In the coming decades we might be seeing the economy of knowledge shifting to the economy of abundance, but that knowledge will not be from humans, rather it will be owned and managed by machines (through artificial intelligence and data analytics).

Today, bits are the only entities in the economy of abundance with:

- an unlimited possibility of duplication (at zero cost)
- absolute fidelity (copies are equivalent to the original)
- very low cost of manipulation (e.g., to create bits out of bits)
- ubiquity (zero cost to move from one place to another)

Some futurists foresee in the coming decades other entities that will become part of the economy of abundance, like energy (such as unlimited energy through fusion and photosynthesis in smart materials) and intelligence, such as Artificial General Intelligence (AGI) and Artificial Superintelligence (ASI). Artificial Intelligence will also bring knowledge into the economy of abundance which will surely lead to a dramatic change in economy and society.

The Digital Transformation is driven by the willingness to reap the benefit of the economy of abundance, hence it focuses on using bits as much as possible. As noted previously, this transformation requires the creation of digital models, transforming atoms into bits by using sensors. It is clearly relevant, as shown in Figure 2, for those businesses that today are operating in the economy of scarcity (most companies today). It is not relevant to those business (a few) that are already operating in the economy of abundance, those that have been born in that economy. Notice that atoms will remain in the digital transformation, and along with them a part of scarcity, but the transformation will leverage bits more and more (denoted by the striped area in the figure).

Also notice that those few businesses that grew in the economy of abundance space need to use a few atoms as well, but these are seen as backstage resources made generally available, like saying that a restaurant needs to use water: this is normally taken for granted, provided by commoditized infrastructures. Likewise, for companies that operate in the economy of abundance: they leverage the existence of digital platforms.

The Digital Transformation allows companies that are operating today in the economy of scarcity to shift part of their business to the economy of abundance. This shift is usually quite complex and the transformation will lead to, and requires, new business models, since the economy of abundance has different rules of the game.

How many bits are needed?

The Digital Transformation eliminates the need to work with some atoms, replacing them by bits. These bits are used along with the remaining atoms, flanking them. Atoms will still be needed, and the question is how many atoms and how many bits? The general recipe is to reduce the atoms in favor of bits as much as possible. The percentage of one over the other depends first on the kind of business and second on the availability of technologies. The increased capability of technologies can increase the bits percentage correspondently decreasing the atoms percentage. As one is planning for a Digital Transformation one should aim at the greatest possible shift from atoms to bits.

Now, let’s clarify what is meant by percentage and number of atoms vs bits. Clearly, we are not counting the atoms, like estimating the number of atoms making up a product, nor we are counting the bytes representing a product during its life cycle. Rather, we are estimating the overall value of the value chain as it is today when operating on atoms, through the product life cycle, from design to use. We then look at the value remaining in the atoms as we move as much as possible to the realm of bits.

One point to notice is that while the overall functionality is kept by the Digital Transition the overall economic value of the parts involving atoms plus the parts involving bits is *lower* than the original value. This is the reason why there is a drive to move from the former to the latter. The lower value results from the increased efficiency of the value chain(s) involved in that product life cycle. Since the increased efficiency translates first into higher competitive advantage and potential higher margins, the players in the value chain are eager to pursue it. Eventually, this increased efficiency translates into lower prices to the end consumer increasing market interest, pulling along the value chain and steering the transformation.

There are businesses where this shift in value can be very high, and others where it is lower, depending on the specific product or sector.

Consider the music industry: atoms are still needed for recording and listening. Everything else, however, can be done using bits. Given this, it is not surprising that the price of music to the consumer has approached zero.

Consider the car industry: there are a lot of atoms that need to be managed through the value chain. Some parts have been converted into bits, namely the design phases, part of retailing and customization (largely using the web) and a small part of the maintenance (where remote maintenance, using sensing and data analytics, can take place). However, most of the value chain is still tied to atoms. In the future, new technology will allow for different manufacturing processes, for example, using 3D printing. Industry 4.0 is addressing these changes, using bits to replace atoms in manufacturing of cars and in other industries.

Taking a broader view

The Digital Transformation affects much more than a single product or industry. It affects the value perception at societal level. Consider the car industry. Cars are part of the larger market sector of transportation. In the transportation sector cars have been a solution to the need for convenience in moving from A to B. If the Digital Transformation is applied not to the car or the car industry but to the need of getting from A to B, a completely different picture emerges.

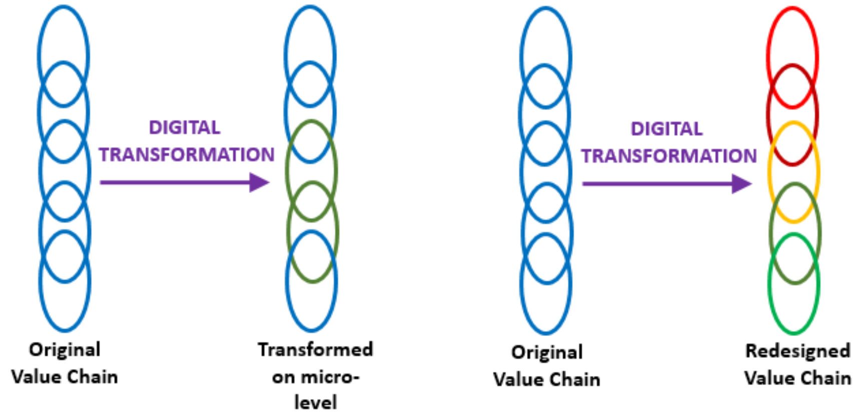


Figure 3. The Digital Transformation may take place at micro level, in a single stop of the value chain, or it may completely redesign the value chain. In this latter case some players may simply disappear while in the former they may be replaced by others more fit to the modified value chain. Using robot to perform certain activities may lead to a reduction in jobs, however a digital transformation that makes irrelevant certain activities is both decreasing jobs and erase the value of those activities, hence making previous business no longer viable.

Cars are clearly a very inefficient way of responding to the transportation need. Our cars remain parked up to 90% of the time, and we spend money “just in case” we need them. Up to know, this model was the only way to meet our needs. However, today we have started to see that companies like Uber and BlaBlaCar are leveraging that inefficient use of cars. By changing part of the value chain to bits they can increase the efficiency and provide the means for people who own a car to share it with other users.

Think about companies that are providing car-sharing services: using bits alone through your phone, a car in your vicinity is displayed, you reserve it and you even open and start its engine. Using bits, the company renting the car knows where it goes, where it is left at the end of the drive and also if it needs maintenance. This is increasing the overall efficiency of those cars, with a usage percentage that can grow to 30%. That is 20% more than the usual car efficiency and is resulting both in a business opportunity for the car sharing services and a decrease in transportation cost thus stimulating the market to drop ownership and move to car sharing.

Fast forward twenty years: self-driving cars will be common, and the societal perception of a car will be dramatically different from today. A car may look much more like public transportation, although it will still offer the convenience of today’s cars. Car sharing efficiency with self-driving cars may well exceed 50%. That will further reduce the cost of transportation and attract even more people.

Notice the important role being played by societal and cultural aspects. Self-driving cars will remove all the “pleasure” of being a “reckless driver”, since you no longer get the opportunity of being reckless. They will be perceived, as mentioned, as public transportation on demand. There will be no more advertisements showing amazing acceleration or breath-taking top speed. From the point of view of driving, all cars will be alike. The value perception will shift to the comfort of the interior, to services (in bits) that can be enjoyed during the trip, and so on. The industry will be profoundly redefined since customers will look at a different set of values, and delivering those values will require different skills.

These are some examples to show that the Digital Transformation can affect those sectors that today seem rooted in the atom economy. By taking a broader view, atoms may be flanked more and more by bits changing the value chains and the entire economic landscape.

The loss of value

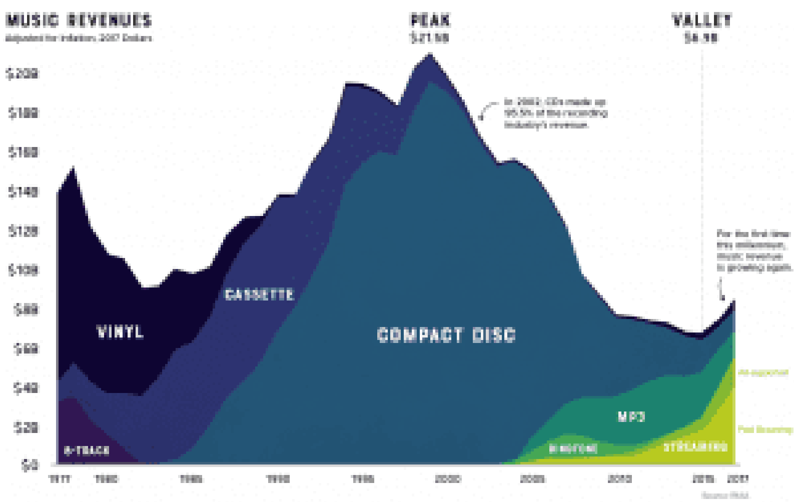


Figure 4. In the music industry, revenue rose as the industry improved the value chain by managing atoms, reaching a broader market, then as the Digital Transformation took over the value chain, the revenues collapsed quite rapidly killing most players in the process and opening the door to new players

As previously mentioned, the Digital Transformation is decreasing the overall value of a value chain, by increasing its efficiency and eventually moving the benefits to the end consumer that will be paying a lower price. Obviously, if the price is lower the total revenue will also be lower as will the value generated by that value chain.

One might think that a lower price will lead to an increased market and that may offset the decrease in price per unit, but it is not true, particularly when the Digital Transformation is applied to a mature market. Take the example of the music industry or the one of the newspaper industry, two areas where the Digital Transformation has occurred (although it is not over yet). Their overall value today is lower than the one they had 20 years ago. Back in 1995 the music market had a value of $21.5B; in 2015 it was down to $6.9B. In these last few years it is slightly increasing but we are well below $10B; over 50% of the value chain value has disappeared. Additionally, by 2017 the old value chain, the one based on atoms (CD, vinyl, cassette), generates less than $1B in revenues, while the rest is generated by the digital representations of music which is basically controlled by new players. Back in 2002 Napster fueled the Digital Transformation. It was fought by the incumbents that eventually won the battle against Napster but lost the war to the Digital Transformation.

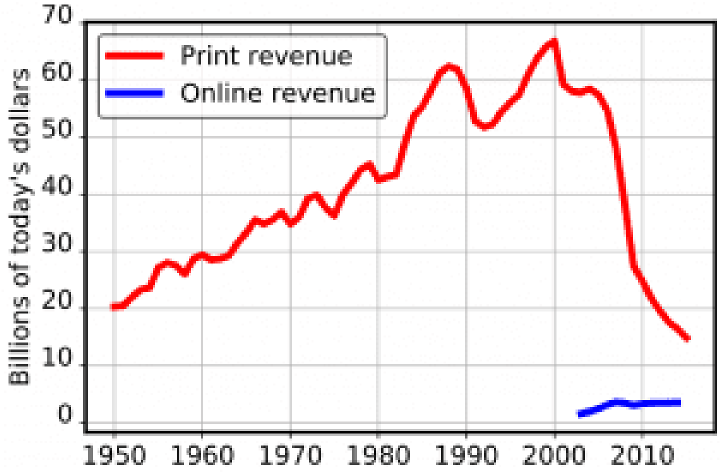


Figure 5. The growth and fall of advertisement value for newspapers in the US. Notice that in the last few years we have seen a growth in the value they generate from their online (bit) services but it is nowhere near enough to make up for the loss of value on the atom based value chain. Source: US Department of Labour

The world of newspapers has been hit hard by the Digital Transformation, with revenues generated by ads in their printed copies falling from over $65B (in the US) to less than $15B (in the US). The uptake of digital advertisement is a drop of water in the ocean of losses generating less than $5B in revenues. Hence the total value of the advertisement on the newspaper value chain went down from the $65B to less than $20B of today.

This is happening fast in many areas, and it usually follows a pattern of growth followed by a plunge that is the result of the Digital Transformation disruption.

Even areas that in theory should benefit from the Digital Transformation are feeling the decreasing value of the atoms-related value chains. For example, the Telecom Operators, even though their networks are carrying more and more bits because of the ongoing shift from atoms to bits, are still tied up with costly infrastructures and heavy labor costs. As the Digital Transformation progresses in their area (with flatter infrastructures based more on software than hardware, as will happen with 5G), we will see a sharper decline of atoms based revenues.

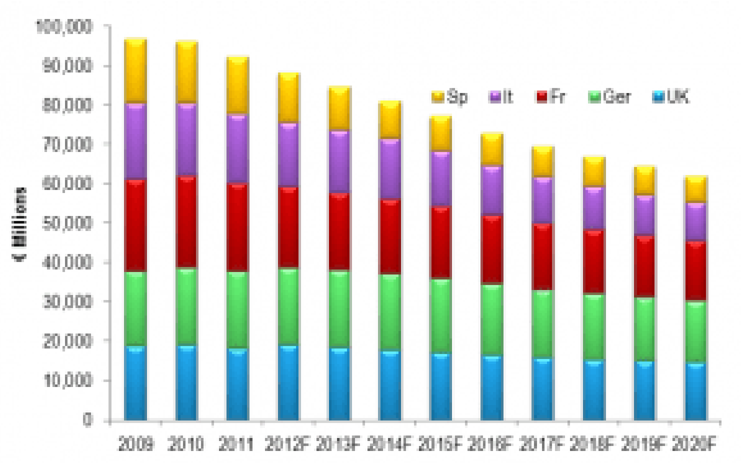


Figure 6. Telecom Incumbent Operators are seeing their revenues shrinking, and it has just begun. Source: IP Carrier

Digital Transformation – Disruptions

The Digital Transformation with its resulting loss of value disrupts businesses, affecting incumbent players and opening the doors to new ones. Disruptions can have different roots that may be difficult to pinpoint. Sometimes it may be clear that a disruption is on the making, and yet established companies may find it difficult to take countermeasures to save their business.

Usually, the problem is that their business is very profitable and moving to a new one would endanger their existing one. As shown, it is typical to see a business increasing revenues and then all of a sudden losing most of them. Predicting where that turning point will be reached is difficult, since it relates to several intertwined aspects, a bit like seeing the stock market rising, and although you know very well that sometime in the future there will be a downward spiral you don't know when to sell your shares. Even by looking back it is sometimes difficult to see why the market changed trends at that particular time although it is easy to explain why.

Figure 7. The drop in Kodak stock value as Digital Transformation took over making film cameras obsolete. Source: CNN

Sometimes, however, the disruption is brought forward by one single cause and is easier to analyze, like in the case of the Digital Transformation sweeping over the photography industry where disruption was a consequence of tech evolution and happened in three phases of transformation:

- Analog to Digital Cameras
- Digital Cameras to Smartphones
- Digital Photography to Computational Photography (ongoing)

Analog to Digital Cameras

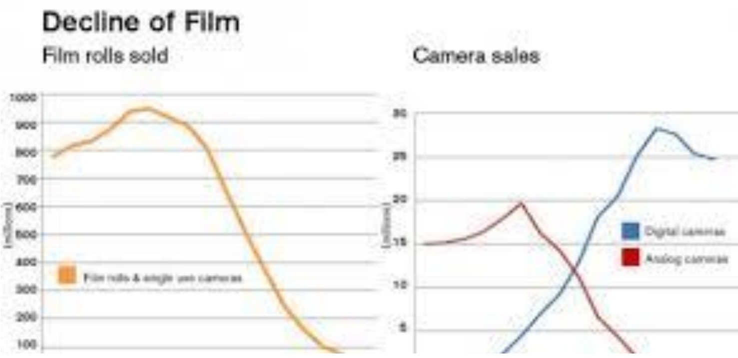


Figure 8. The decline of film based cameras was relatively quick, less than 10 years from the peak to bottom up. Image credit: Technology Review

As shown in Figure 8, the film market increased (surpassing 86B$) until the turn of the century, then all of a sudden it took a plunge leading to its (basic) disappearance in a decade (the marginal market for film photography was sustained by some industrial applications, like medical radiography that is now also disappearing by shifting to digital).

The disruption brought to the companies that produced film, such as Kodak, was the consequence of the uptake of digital photography (see the right side of the figure). Notice how the downslope of film market matches the downslope of the analog camera market and is a mirror image of the uptake of digital cameras.

The uptake of digital photography was fueled by tech evolution in three areas:

1. The improved resolution of digital sensors to capture the image (from 30,000 pixels to over 10 million pixels in the mass market. My current camera has 56 million pixels.)
2. The improved processing capacity that supports the conversion of the data produced by the digital sensor into an image

3. The improved storage memory capacity that has been matching the increased resolution, with the size of a photo moving from some 100kB in the year 2000 to the up to 50 MB currently available (a 500-fold increase).

On the consumer side, the shift to digital meant less expensive photos (no need to buy film nor to print them out. The consumer could decide later what to print or could opt to keep them in a digital form viewable on a screen) and the possibility to look at your photo immediately. It also meant the possibility to duplicate the photos at zero cost and send them to friends immediately.

Some side effects were generated by this analog to digital transformation:

- The possibility to look at your photo immediately made it easier to learn how to take better pictures. You can experiment, change the settings, and immediately see the result.
- The zero cost of taking a photo has multiplied the number of pictures we take and has also helped in making us better photographers.
- The immediateness of taking a photo and looking at it has developed a new culture for images and new habits. Now we take a photo as we would have taken a note in the past. We are moving more and more to a visual world (and we are "visual animals").

The impact on the business was dramatic. On the one hand it displaced those companies that were basing their business on film production (Kodak went bankrupt, Fuji survived because its business was not based on film only). It is particularly interesting to notice the analysis on the survival of Fuji where it was pointed out that shifting the company to only the digital world would not have covered for the loss in the film roll market: the latter generated much more revenues (and margin) than the digital roll (remember: the Digital Transformation *lowers* the value of the market) hence they undertook a business re-engineering that changed the fundamentals of the company, something that is very difficult to do in general. They started this re-engineering when their business in the analog photography was still very strong.

On the other hand, it created the market of digital cameras that went way further than replacing the analog camera market, it actually expanded the market as digital cameras became cheaper (and the cost of developing went down to zero).

Digital Cameras to Smartphones

The second disruption that swept the photographic world was again the result of technology evolution although it was sprinkled with cultural aspects, fueled by flanking value chains, making this an interesting disruption to analyze.

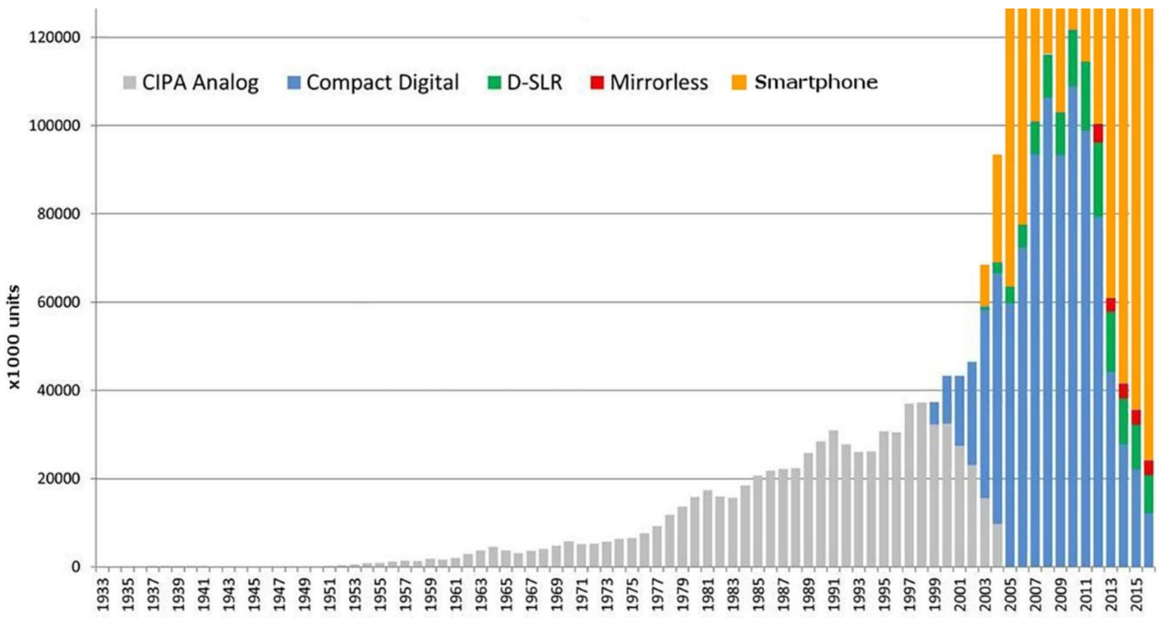


Figure 9. The growth of digital cameras and their downfall as result of the shift to the smartphones. Source: CITA

As shown in the graphic produced by the Camera and Imaging Product Association, the market of digital cameras (both compact and reflex, with the compact ones taking the lion's share) took over analog cameras in just 5 years (1999 to 2004) with a market in 2005 that was double (in terms of number of units) the peak reached by analog (film roll) cameras in 1998.

The quickness in the change is amazing and is a direct consequence of the Digital Transformation: the lowering of cost as result of the shift from atoms to bits. In this case the zero cost was the operation of a digital camera, with an unlimited film roll and the disappearance of the need to develop the film. The printing of a digital image was a decision of the end user; most were and are happy keeping their picture in digital form and viewing them on a screen at zero cost.

The success of digital cameras was such that it pushed smartphones companies to embed them in their product (actually cell phones started to embed a low performance digital camera before the appearance of the smartphone, but it was the latter that eventually disrupted the market).

The problem with embedding a camera in a phone is that it does not fit; a compact camera is too bulky to fit into a phone. To compromise, the size of the image sensor is decreased which lowers the resolution, and the size of the lens is reduced which results in lower luminosity and higher noise. Of course, as technology evolves, some of these constraints are overcome although some of them cannot be overcome because of physical limitations.

In just 5 more years, by 2009, the number of smartphones with an embedded digital camera sold was level with the number of compact cameras sold. Their image quality was not equivalent with the one delivered by a compact camera, but people always had their smartphone with them became used to taking pictures with their smartphone everywhere.

Consider image quality: in 2010 a compact digital camera would deliver better quality than a smartphone but was that a deciding factor for people to buy a compact camera? Actually, less and less because most of the people couldn't tell the difference (which is the case if the image was not printed but viewed on a screen, like a television or the smartphone screen).
Another factor kicked in: the rise of social networks and the sharing of photos. At that point the image quality was limited (in general) by the screen resolution (very few would take a picture from a social network and print it out, they were intended for fruition on the screen). Smartphones are much more convenient than a compact camera to post photos on a social network since they are always connected to the web. The embedding of connectivity in compact camera was too little and came too late.

However, the deciding factor was volume: look at the second graph showing the volume in units of smartphones (orange) vs compact cameras (blue) and digital reflex (green). The difference is not just huge, it is rapidly growing (last year considered in the graph is 2016, now the gap is even bigger). People with a smartphone had no need for a compact camera, and as more and more people got a smartphone less and less people bought a compact camera. By 2015 the game was clearly over. The market for compact cameras is now basically zero and companies that benefitted from the first wave of the Digital Transformation in photography saw their business dying out. From the point of view of the consumer, the Digital Transformation has delivered the same services (better actually) at a lower cost (basically for free). Of course it was not just the increased capability of smartphones that make the difference, it was the concurrent decrease of price in mobile internet access that make the sharing of photos basically free. The Telecom Operators were cut out from the benefit of the digital transformation in this area, and actually they had to pay (in terms of network investment) for it.

The volume of digital reflex has remained roughly stable since those cameras attracted a different market, and until 2017 reflex digital cameras were no match for smartphone cameras.

Another deciding factor, as previously mentioned, was the uptake of social media that started to make large use of digital photos. Instagram (as one example, the same growth is experienced by Snapchat, Twitter, Pinterest, Tumblr, etc) started in 2010 and by 2015 has grown to 400M users. In June 2018 it exceeded 1 billion users active in a month worldwide. Every day some 100 million photos are uploaded and over 40 billion are shared. These numbers are mindboggling and there, in a nutshell, is what Digital Transformation is all about: killing cost and making possible to do (new) things because they become affordable.

And it is not over yet.

Digital Photography to Computational Photography

Figure 10. The L16 has 16 lenses, each time you take a photo you are using several of them, and software takes care of fusing the individual lens output into a single photo. Image credit: Macfilos

The next disruption coming up in photography is going to be computational photography, again the result of technology evolution.

To make better quality photography you needed better equipment: a good camera, a good film roll. This did not change with the shift to digital photography where you still need a good digital camera (with a good sensor and electronics) and a good lens.

By using post processing software (bits) you can improve on your photo, and post processing software has become more and more powerful. Now part of this post processing can take place in the camera making taking high quality photos easier.

We are already starting to see more advanced features that can be performed inside the camera using software (and a lot of processing power) that would not be possible outside of the camera.

Take the L16 camera. After a few years in the making (more than they expected), it hit the market in 2018 as a completely new type of camera, based on computational photography. It leverages bits much more than atoms (although making the atoms comply was really tricky). As shown in Figure 10. The L16 has 16 lenses, each time you take a photo you are using several of them, and software takes care of fusing the individual lens output into a single photo. Image credit: Macfilosit has 16 lenses that come in 3 focal lengths: five 28m wide-angle modules, five midrange 70mm, and six 150mm telephoto ones (equivalent). Yet when you see the image on its screen, you can swipe your finger and decide the focal length you actually want, anything between 28 and 150! Now, notice that the result will be an image taken at the focal length you select, even though there is no optical lens delivering that focal length (unless, of course you select 28 or 70 or 150). Do not confuse this with the electronic zoom you have in your digital camera which is just clipping the area to be used on the sensor making objects appear closer as you zoom further and further. However, in a camera with a real optical zoom, the depth of field and bokeh will change as you change the focal length. Not so if you use the electronic zoom. Also, using an optical zoom (or changing your lens to a longer focal one) causes objects to become compressed, not so with an electronic zoom.

The difference is that an electronic zoom relies on atoms (your camera optical lens and its sensor) while computational photography relies on bits.

Modern smartphones have started to use computational photography providing enhanced capabilities. As an example (see the waterfall photo I took), they can use several snapshots (automatically taken when you push the shutter) and combine them to create the same result you would get by using a long exposure time. Notice that in most cases, with your digital camera, you won't be able to use a long exposure time because there is too much light around and you would end up with an over-exposed photo. You could use filters, but again this is not a solution that could work in many situations.

Figure 11 Photo of the Doi Inthanon Waterfalls, taken with my iPhone.

Figure 12. Photo of the Doi Inthanon Waterfalls, taken with my iPhone simulating a long exposure time.

Take the picture my iPhone generated simulating a long exposure time. Nice effect, isn't it? Well I could have used dark filters (not really practical on an iPhone) to get the same effect exposing for 2 seconds. The problem would have been, however, a sharp increase in noise (because of the long exposure time); I would have needed a tripod to keep the phone absolutely still, and moreover if there was a person in the frame that person would have to remain completely still for those two seconds.

With computational photography the solution is all in the bits (and in the application managing them). There are many things that computational photography can do today, like decreasing noise and increasing sharpness. However, there are even more things that it will be able to do in the coming decade and that will disrupt photography and the related value chains.

First, the requirement of having good atoms to get good photos will no longer be present. This will disrupt the companies whose selling point has been delivering good lenses and always better and better sensors. Of course they will remain a factor (like having the sensor embedding on the processing chip will make computation faster) but it will no longer be a competitive edge. The competitive edge will shift to companies developing software (signal processing) which requires a different set of skills and will no longer require massive capital expenditure. A small company in India may become a leader in some computational photography features, while today it would be impossible for a small company to become a leader in digital imaging chips.

Second, by using computational photography the requirements for atoms decrease, hence the price of the cameras will also decrease (a very interesting proposition to win the consumer market) and likely their bulkiness will decrease letting any object/product, become a potential camera. Any product will be able to "see" how you use it, how you like it and report back. Progress in this image processing may be primarily driven by self driving cars that in the next decade will be relying on it to become aware of their environment.

Third, bits can be analyzed to detect objects, deriving semantics. This is likely to open up a new market for companies like Amazon that might be willing to provide the very best computational photography features completely free aiming to make money from understanding consumer preferences (usually you photograph what you like) and offering related goods.

We are seeing the first steps being taken today with the increased number of cameras on smartphones: there used to be two cameras on a smartphone - one in the front and one in the back. Now there are several phones with three cameras and a few with four. Also, it won't be long before companies will start to use both the front and back camera, with the one facing you helping in determining your mood as you take a picture (or the other way round detecting what is the environment in which you are taking a selfie).

It is likely that the next decade will see the complete shift to computational photography which will become an opportunity for several new businesses (or a reinforcement for several existing businesses). As the focus shifts from atoms to bits, the value lies on what is leveraged from the bits, and several companies will need to reinvent themselves as their business will fade away.

Digital Transformation – Towards the disruption

Consider what may happen, in terms of Digital Transformation, in the area of private transportation (cars). It helps to look back at how the car market evolved. At the very start, cars were an artisanal product; there was no standardization and no rules of operation (the roads were not paved, driving licenses were not required, there were no speeding tickets). That all changed with the birth of assembly lines (Ford in 1913) designed to produce affordable cars that even a blue collar worker could dream of buying. Cars started to become available in the thousands and then hundreds of thousands, and by 1918 most US States enforced a registration plate, started to test the driving abilities (a driving license like the one we have today came later, in the 1930s) and put regulations in place. In other parts of the world the timeline might have been different but the sequence of steps from artisanal car to mass market was the same.

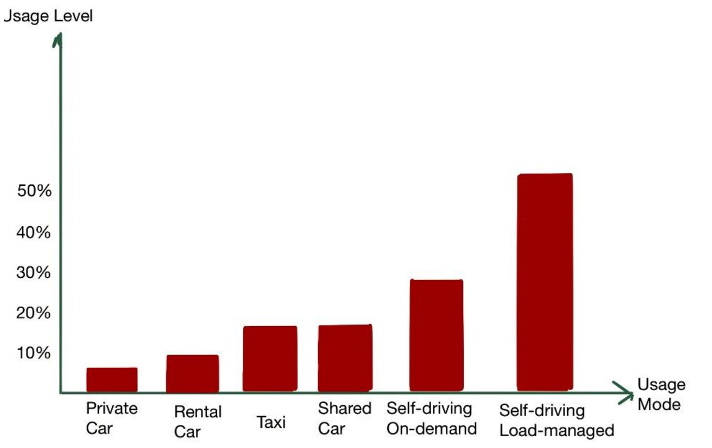


Figure 13. Cars have a very low usage time, being parked most of the time. In the future as they become "services" their usage will increase significantly. Here the Digital Transformation is both the result of a value perception change and enabler for the change.

However, affordable is a relative term: because of cost very few people could afford buying a car (until the 1950s) and public cars, or cabs, started to appear in response to the business opportunity (1908 in New York and at the turn of the last century in Europe). Car rental was soon to follow (in 1916 in Omaha later bought by a certain John Hertz, in Germany Sixt started in 1906).

While cabs were the response to the huge cost of owning a car, car rentals leveraged the increased effectiveness of having a car shared by multiple customers, by ensuring the splitting of cost across the customers and increased usage of the car. As computers increased the efficiency in managing rentals and smartphones improved the interface with web services, there has been a growth of car sharing services (such as Uber or BlaBlaCar). They leverage the fact that cars are seldom in use, and it makes sense to exploit their unused time, thus sharing cost.

As you can see from Figure 13. Cars have a very low usage time, being parked most of the time. In the future as they become "services" their usage will increase significantly. Here the Digital Transformation is both the result of a value perception change and enabler for the change., even in the best situation a shared car is not actually used very much (although it may double the usage time of a private car that is estimated in the US to be around 5%[1], 4%[2] in the UK). While this is not a complete Digital Transformation, it has put a dent in the taxi business and is starting to affect public transportation.

Private transportation does not solely depend on technology; it is very much a cultural shaped landscape. People consider car ownership as part of their freedom; it enables them to go where they want when they want. It has been part of the young person's dream for the last 50 years. In these last few years, however, the mood has shifted. In several cities millennials consider the car an unnecessary cost[3], considering it much more effective to use a share-car service whenever you need one. This mood shifting is likely to be accelerated by the coming of self-driving cars. A self driving car will likely be perceived as a public transport, rather than a private one since you lose control of driving.

Some recent studies show that with less than half the number of cars urban dwellers could get the same level of transportation service they get today by owning a car. In addition, the cost will decrease by some 80% (in the long run) as cars are becoming a commodity and their usage time increases significantly, in the range of 30% (see graphic).

This will extend the Digital Transformation and disrupt the car manufacturing companies. They will no longer be able to sell cars by advertising their speed or acceleration. They will no longer be in a business to consumer market, rather in a business to business market. Selling cars as commodities and only selling half the volume is likely to depress the market, and consolidation among car manufacturers will accelerate.

At the same time, a new market may emerge for delivering personalized services, creating sort of personalized cocoons that people will be willing to pay for. There are already some ideas of cars splitting into a commodity moving platform upon which a personalized living shell can be created. This latter may remain in the private ownership domain (and be commercialized by the likes of Gucci and Armani) whilst the former will be a public or large corporation domain.

Still, growing the usage time to 30% is still rather inefficient. Consider the introduction of moving platforms that can reshape themselves to carry (mostly) people during daytime, and carrying goods in night time. That may boost the usage of these movable platforms beyond 50% and would be a disruption in the whole transport value chain. This may occur within the next 30 years, with earlier introduction in certain niches.

Digital Transformation will occur in the transportation sector not necessarily fueled by technology evolution but rather by societal changes. Clearly advanced technology will be needed, but it will not be the deciding point. Regulation and cultural aspects will be the dominating factors. Additionally, the digital transformation in the transportation sector is likely to happen in niches and in phases. In the longer term niches will expand and phases will evolve. Along the way the whole industry and our perception of cars will be changed.

Digital Transformation – Distributed Digital Platforms

The Digital Transformation is made possible by technology advances and is steered by economic and societal factors. It is a whole system transformation that requires the availability of a tremendously complex infrastructure, similar to how the atoms economy has evolved over centuries by creating in parallel tremendously complex and intertwined infrastructures. Logistics value chains have become extremely effective and extremely complex. Computers have boosted

[1] http://fortune.com/2016/03/13/cars-parked-95-percent-of-time/
[2] https://www.racfoundation.org/motoring-faqs/mobility#a5
[3] https://www.fastcompany.com/3027876/millennials-dont-care-about-owning-cars-and-car-makers-cant-figure-out-why

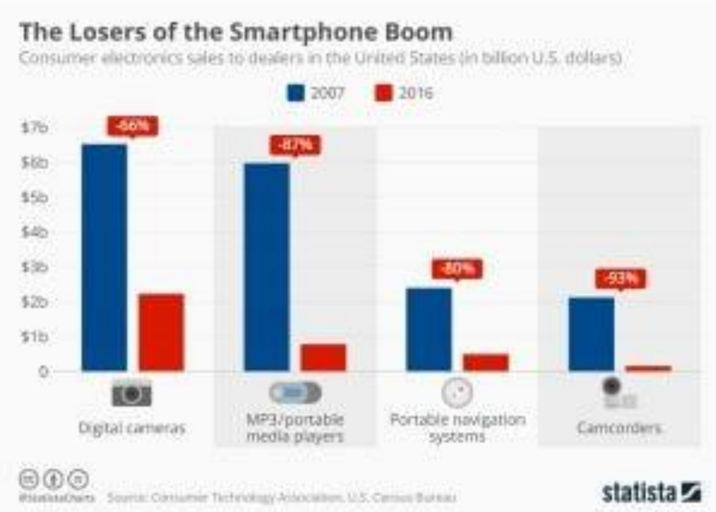
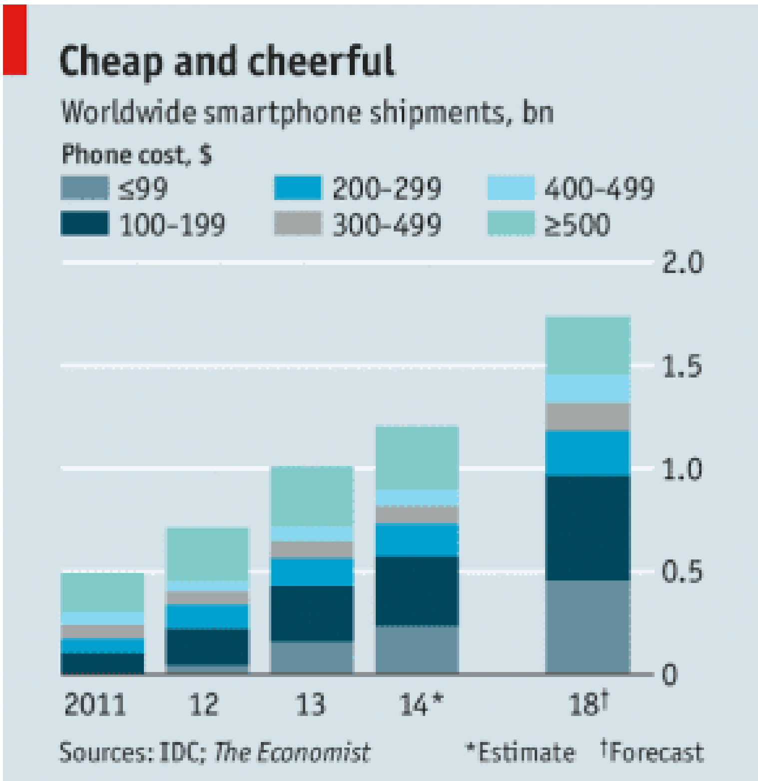


Figure 14. The smartphone has become a digital platform. This chart shows the decline in sales in the US of digital cameras, portable media players, portable navigation systems and digital camcorders as result of the availability of their functions on smartphones.



their efficiencies and made possible the creation and management of even more complex infrastructures. These computers supporting infrastructures are slowly morphing into infrastructures of their own. The large data centers that are supporting shipping of parcels and containers are now managing the shipping of bits in a structured way (e.g. by adopting blockchain).

It is interesting to notice that in many cases we are seeing the transformation of what has been created as a self-standing support to a specific activity into a platform supporting the growth and integration of activities and becoming an infrastructure supporting the digital transformation of one or several sectors.

This is surely the case of the smartphones. As shown in Figure 15. The number of smartphones is rapidly increasing, over 1.5 billion have been sold in 2018. Notice the rapid increase of low cost smartphones, a crucial factor in their global pervasiveness. Source: IDC data, The Economist the number of smartphones sold increases every year, and now almost all new phones being sold are smartphones. In the next decade we can expect that normal cell-phones will fade away, replaced by smartphones. This is enabling a worldwide transformation of many sectors because smartphones are:

- storage and processing units that support a variety of applications
- connected to the web and can be orchestrated
- using just a handful of software platforms (basically just two: Android and IOS) and this stimulates the creation of applications and keeps the cost of porting an application to a different platform reasonably low
- acquired through a distributed investment, basically every end-user pays for the phone and even when they are subsidized the subsidizing companies see a short term return
- creating a digital culture seamlessly changing the behavior of people which is probably one of the most crucial factor in fostering the digital transformation.

Figure 15. The number of smartphones is rapidly increasing, over 1.5 billion have been sold in 2018. Notice the rapid increase of low cost smartphones, a crucial factor in their global pervasiveness. Source: IDC data, The Economist

Smartphones have become a de facto distributed digital platform that is being used in a variety of market segments. Take, just as an example, the bike renting business.

There are a few companies, some operating in many countries, offering bike rental by leveraging smartphones throughout the value chain. The entire process of renting a bike is managed through the smartphone:

- Location of nearest bike
- Reservation of rental
- Unlocking the bike which starts the 'metering'
- Charging of the rental fee
- Relaying of information of final destination of bike to update database for use in next rental process

Mobike[4] is a Chinese company and the largest bike rental in the world, operating (as of end 2018) in over 200 cities, in 19 countries and rapidly expanding. Creating a bike rental in the atom world requires a significant investment in the operation of the business. In addition, the business doesn't scale in terms of operating cost. Every new rental location requires a dedicated operation staff. In the world of bits the operation cost do not increase for a good portion of the value chain (reservation, payment, monitoring, advertisement).

Mobike does not need to train people how to use their smartphone, nor how to use digital payment methods on it. At the same time, users of Mobike get continuously trained in the use of their phone as the digital interface to the digital world.

Figure 16. Smartphones have created a de-facto Digital Platform that industry and institutions are leveraging. Image credit: Space Technologies

The potential of smartphones seen as a distributed digital platform is huge and institutions, like cities' municipalities, need to learn how to leverage them to make cities smarter. Smartphones are an existing digital platform in an existing culture that can be leveraged with very limited investment. Obviously, as with all forms of Digital Transformation, there are a number business that are suffering, to the point of disappearing. As shown in Figure 14, the smartphone has basically killed point and shoot digital cameras, camcorders, portable navigators and MP3 players by moving the functionalities that required atoms to the world of bits. Now software applications, using the smartphone as a digital platform, can deliver them, at lower cost (sometime even for free).

Digital Transformation – Digital Platform Characteristics

The discussion on digital platforms began by considering the one created by smartphones because it was easy to point out the basic characteristics of a digital platform:

- it needs to have storage capabilities
- it needs to have processing capabilities
- it needs to have embedded connectivity
- it needs to be open to let third parties develop on it
- it needs to affirm a standard to decrease the cost of interfacing
- it needs to support scaling to accommodate more users and features
- it needs to aggregate investment creating an attraction point

[4] https://mobike.com/

All of these features are present in the digital platform created by smartphones:

- Each smartphone has GB of storage capacity on board and this capacity keeps growing, thus fueling new applications. Samsung has recently announced 1TB Universal Flash Storage, and its new Galaxy S10 might be offered in a configuration with 1TB. Notice that it took just 4 years to move from 128GB to 1TB which is a doubling of capacity every year, faster than the Moore's law prediction.
- Each smartphone has a processing capacity that far exceed the one of personal computers five years before and the one of supercomputers 20 years before. This processing power keeps growing each year as new generation chips become available. Currently, processing power in a smartphone is no longer an issue, and comparing different smartphones based on processing power is basically meaningless. Smartphones are a delicate engineering tradeoff between various characteristics, like processing capacity, graphic processing capacity, power consumption, screen resolution, thickness, heat dissipation, radio reception, and so on.
- Smartphones have increased their connection capability, actually anticipating 5G in the sense of being able to manage several radio channels and different communications protocols concurrently. A smartphone today can operate on a variety of spectrum frequencies, using GSM, 3G, LTE, Bluetooth, WiFi, NFC protocols. In this respect it is more sophisticated than a radio station of a telecom operator. In addition, it can create and manage local networks (tethering).
- Smartphones have a very limited number of operating systems (with Android and IOS taking the lion's share). This create a consistent and open environment for third parties to develop applications. Third parties see the advantage of developing their apps on this software environment since they are assured of a huge potential market. Additionally, the periodic updates to those OSs take care of backward compatibility (or ensures that an easy path to compatibility is provided) thus preserving the investment in developing applications (notice that the average life cycle of apps is pretty short, so repetitive changes in OS version that eventually lead to incompatibility are not seen as a problem, the investment in developing the apps having been recovered);
- Smartphones, as just pointed out, use a very limited set of OSs that create an aggregation point for third parties. Equally important, the companies behind these OSs have created and made available an application development environment (e.g. Android[5], IOS[6]) that is both facilitating third parties development of applications and provides uniformity (as an example in the user interface), a most crucial aspect to ease users interactions.
- Smartphones' continuous development (and significant backward compatibility of applications) makes scaling possible in terms of delivering ever more complex apps and their intrinsic distribution that is managed collectively by the increased capabilities in network access makes scaling of their number a reality. Possibly no other infrastructure has proven so good at scaling: we have moved from few thousand to several billion phones worldwide, with no issues in service provisioning (occasional downtimes generate surprise in addition to anger, and this is proof of how good the service really is).
- The growth in smartphones is the result of a massively distributed investment, sustained (mostly) by individual users. This investment requires an investment from the network side (roughly in a 70 to 30% ratio, meaning the end users bear 70% of the overall cost and the operators 30%) but this investment is both much lower than the one required by a fixed network and most importantly it scales smoothly with revenues. Operators can invest at the same time as they get returns (this is not the case for a fixed

[5] https://developer.android.com/studio/
[6] https://developer.apple.com/library/archive/referencelibrary/GettingStarted/DevelopiOSAppsSwift/

network). Hence smartphones have created and continue to create a growing business opportunity that attracts more and more business which in turns steers the overall growth.

These characteristics of smartphones, seen as a digital platform, need to be present in other digital platforms to succeed. These are required when both assessing the chances of a digital platform and when designing a digital platform.

Self-driving cars may become a digital platform; they have, at the core, all of the above characteristics, but of course work is needed to develop them and the whole ecosystem. This is a role of institutions, regulators, and industry. It is also a space where neutral organizations like EIT Digital and IEEE may play a significant leading role.

Digital Transformation – Creating an Institutional Digital Platform

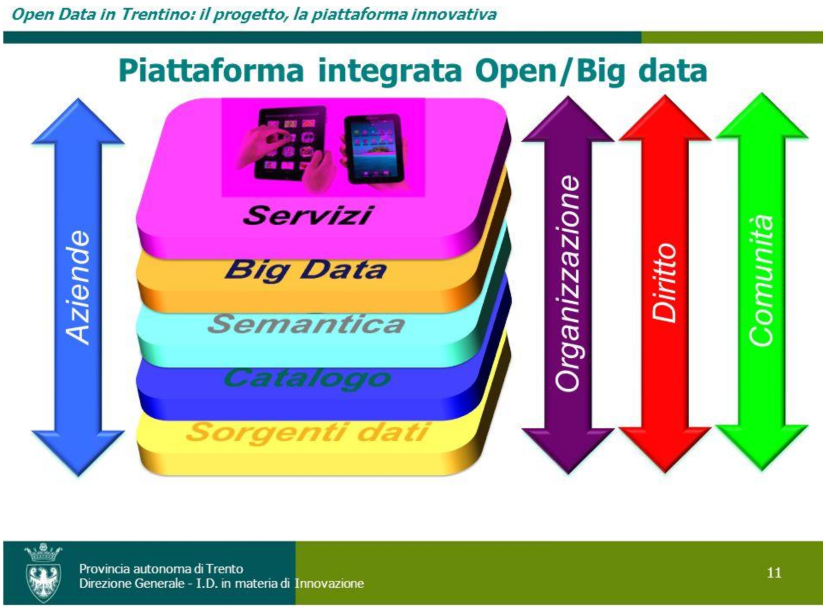


Figure 17. General architecture of the Open Data Trentino. Various data streams, at the bottom, are unified through a common ontology (catalogue) that in turns is interfaced by a semantic layer. This latter, using a variety of software algorithms produces data that are exposed to applications. These latter are both embedded in the platform and provided by industry (aziende). The platforms comply with a set of regulations (Diritto), is structured to support operation processes (Organizzazione) and is intended to serve the whole citizenship (Comunità). Source: Provincia Autonoma di Trento

The Open Data Initiative in Trentino stems from the recognition that data can be leveraged to create value. At the same time, this creation of value requires a structured approach; it needs to be part of a regulatory framework and needs to involve players and users alike.

What about starting from scratch to create a Digital Platform that could succeed? As stated it needs to have the following characteristics:

- it needs to have storage capabilities
- it needs to have processing capabilities
- it needs to have embedded connectivity
- it needs to be open to let third parties develop on it
- it needs to affirm a standard to decrease the cost of interfacing
- it needs to support scaling to accommodate more users and features
- it needs to aggregate investment creating an attraction point

Let's take, as example, the Open Data Initiative[7] set up by the Provincia Autonoma di Trento back in 2013. Six years have now gone by, so we can also see its evolution from the point of view of results (disclaimer: this is a personal take on that initiative and does not necessarily reflect those of the Trento Province).

Over the last 30 years, the Trento Province has accumulated a significant number of databases, recording data on a variety of societal, economical and operational aspects in Trentino. Over 120 databases spanning from agriculture data (apple and strawberry), traffic data (vehicular flow on all Trentino roads, geo-located accidents reports), health care, and so on.

[7] http://www.innovazione.provincia.tn.it/opendata

Each of these databases had different characteristics required different access permission and was designed to meet specific objective. The first step was to recognize that all these data shall be made available. That required the publication of the ontology and the design of a framework of access rules.

This led to the Open Data Trentino: a platform was developed to integrate the access to all of the Province databases, ensuring that use can be tracked, proper ownership maintained and privacy assured. This latter is particularly tricky since individual data may be stripped of identification but by correlating several data identification may emerge. The solution was to open the access to data not as access to the raw data but through date services where a data service function would return the desired (permissible) information emerging from a data set, yet hiding the raw data.

This was the starting step. The next one was to foster an open data mind-set on players, both providers and users. To pursue that the Province required that all service providers under a Province contract would be required to open the data, in accordance to the Trentino Open Data Framework, for the part that was involved in the contract execution. This was a crucial step since the Province is a main player and it is investing on citizens' services. By enforcing their suppliers to adopt an open data framework they not just increased the data pool, they also created a culture.

Furthermore, the Province assured a regulatory framework that protected those commercial enterprises that would open their data on their own, based on the Trentino Open Data Framework. This was a crucial step since it allowed companies to create data ecosystems for their products and services, initiating a Digital Transformation in their sector (and basically forcing others to follow suit).

Notice how these steps fulfilled the set of characteristics I previously listed for a successful digital platform:

- it needs to have storage capabilities
- it needs to have processing capabilities
- it needs to have embedded connectivity

These first three were actually present in the IT infrastructure of the Province, pre-dating the initiative. There was some discussion on setting up a data center for Trentino but the scale was not large enough to make it economically sustainable; it was much better to rely to existing data centers.

- it needs to be open to let third parties develop on it – *achieved by providing the Open Data framework and the regulatory framework;*
- it needs to affirm a standard to decrease the cost of interfacing – *achieved by publishing the ontology and the application interface;*
- it needs to support scaling to accommodate more users and features – *the choice of a mixed architecture with a distributed set of interconnected databases and apps (services) that may be hosted on different servers plus local processing at the edges (smartphones) ensure graceful scalability;*
- it needs to aggregate investment creating an attraction point – *the feature of tracking usage thus protecting ownership is crucial to the establishment of a sustainable business for all parties involved and the development of the regulatory framework created the attraction point.*

It should be noted that the shift towards a Digital Platform is not a downhill path. It requires effort to overcome resistance from incumbent players who have carved their business space and that may see the shift as a loss of control and value (which it is).

Creating momentum is very important, and this requires involving players and creating a critical mass. It requires proving that the creation of services (hence value) on the new platform is possible and attractive to business, both existing and new. Several actions, including hackathons to stimulate service creation leveraging on the Open Data, have been put in place. Main players, like FBK, Engineering and TIM have provided commitment and support.

Digital Transformation – Creating an ad hoc Digital Platform

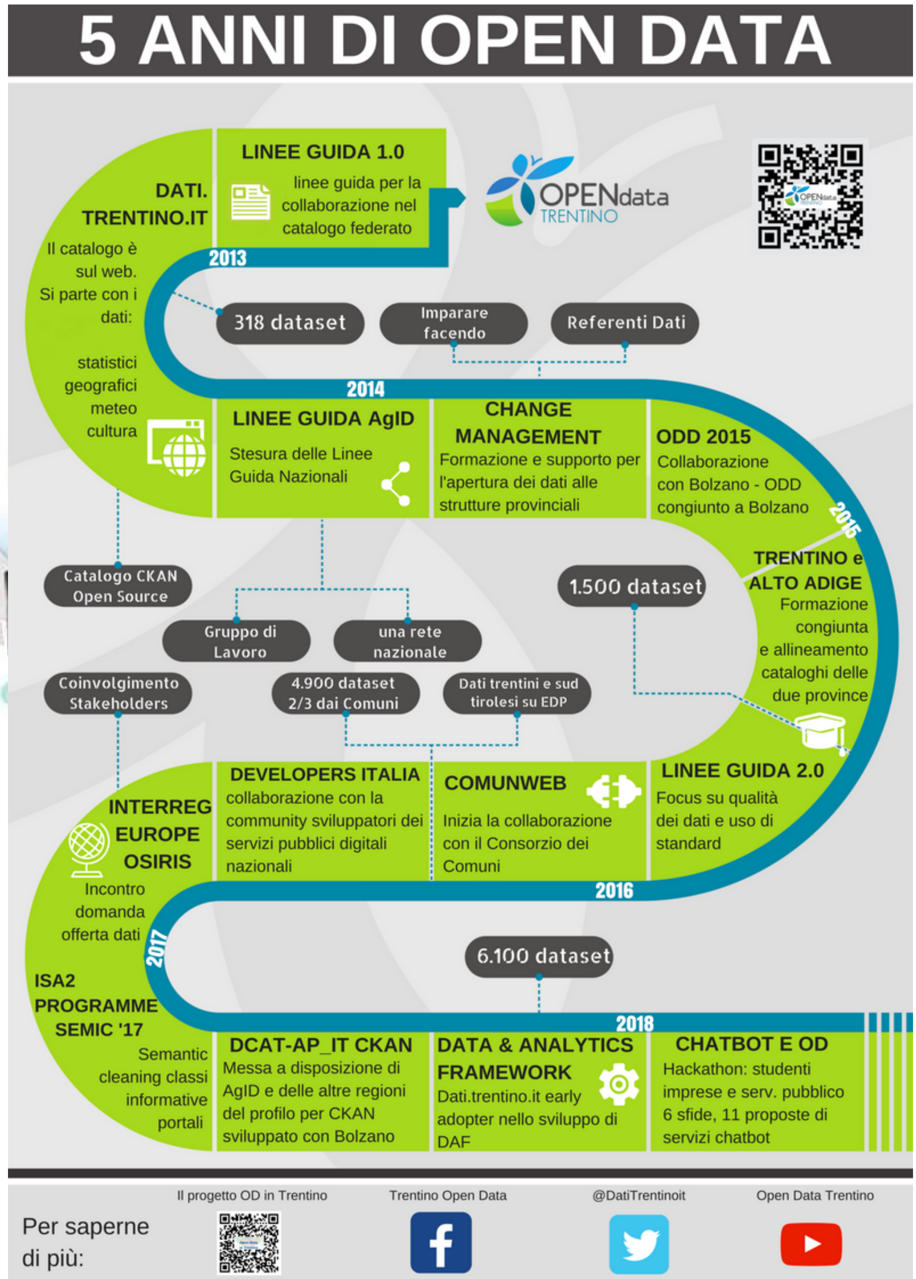


Figure 18. The roadmap followed by Trentino Region in the development of their Digital Platform, starting from the Open Data. Source: Trentino Region

At EXPO 2015 in Milan, Italy, the Municipality of Milan had the objective of creating a digital ecosystem (E015) where all data related to the EXPO could be shared in an open way and leveraged by third parties, in addition to the EXPO 2015 organization. Several streams of data, including private and public transportation, events, restaurants and hotels were available, however each stream had different owner(s) and structure. The task of creating an ad hoc digital platform was given to CEFRIEL, an innovation company active in helping organizations master the Digital Transformation.

The first step was to create a solid and open data infrastructure with a well-defined set of application programming interfaces (API). Once complete, all data were opened to third parties. Training courses were prepared and various forms to attract business interest were put in place.

EIT Digital decided to participate in EXPO and to leverage the E015 data platform focusing on the creation of tourist services leveraging data provided by E015. The result was 3cixty, an advanced recommendation systems able to guide a multitude of tourists in personalized ways. Now 3cixty has become a digital platform to support tourist-oriented service creation. At the same time E015 has evolved, and in 2018 it has been morphed into a digital platform serving as a smart "brain" to aggregate and ease the access to data in the Lombardy Region and is now being managed by the Region IT department.

Some of the lessons learned were:

- Starting with a very focused objective works well but as soon as the platform is used, it is evident that there are other data streams that would be valuable that are not in the platform. 3cixty needed to integrate additional data streams that proved quite complex (for example, tourists going to the EXPO in Milan in 2015 were also interested in visiting nearby towns, like Bologna, Florence, Venice but data about those towns were not part of the E015). Therefore, there was a need to integrate the data streams, moving from a homogeneous to an heterogeneous system.
- The effort required in the buildup of a digital platform is not trivial; it was costly in resources of many kinds. Focus streamlines the effort but also reduces the revenues and the life time of the platform. EXPO 2015 was over after 6 months and clearly the cost of developing the platform was not recouped over that short period of time. Being able to re-use the platform by re-adaptation in a broader context was important. It clearly required some more investment but at the same time it leveraged the culture that was created by the original platform.
- The openness of the platform may backfire. What the end users really like is a consistent look and feel. Openness should not necessarily mean "do whatever you want". A framework that ensures and mandates uniformity in the end can win the users (as happens in the "closed garden" of the Apple development environment and to similar extent with Android).

Even thought to a lesser extent the E015 Digital Platform conforms to the requirements stated previously (the first three –storage, processing connectivity- being ensured by the Lombardy Province servers):

- it needs to be open to let third parties develop on it – *achieved by providing the Open Data framework;*
- it needs to affirm a standard to decrease the cost of interfacing – *achieved by publishing the ontology and the application interface;*
- it needs to support scaling to accommodate more users and features – *the choice of an architecture with apps (services) that may be hosted on different servers plus local processing at the edges (smartphones) ensure graceful scalability;*
- it needs to aggregate investment creating an attraction point – *the drive of the Lombardy Region to aggregate the digital asset and the commitment to the Digital Transformation with two main focus (Citizens' services and Industry 4.0) result in an attraction point for third party business.*

This is a good example of a Digital Platform that was designed to meet a very specific goal (supporting EXPO 2015 service creation) and that has been able to evolve to become a more general Digital Platform. As this evolution has been crucial in moving from a "cost" deemed necessary to support EXPO 2015 to a revenue generator, expanding its scope and its useful life time.

Digital Transformation - A Digital Platform for Smart Cities

Consider Digital Platforms designed for specific application areas, starting with Smart Cities. To determine the interest existing in this area, a search on Google (on February 11th 2019) returned over 200 million references. At the Smart City Expo World Conference[8] (Nov 2018 in Barcelona) the theme was "*Digital Transformation: When Bridging Digital and Physical Means Smarter Living*" a number of companies presented their own Digital Platform tailored to Smart City needs. Among these,

- Huawei presented[9] the result on traffic in Shenzhen (its headquarter city) when its platform was deployed to control city red lights: a decrease of 17% in traffic jams;

[8] http://www.smartcityexpo.com/en/topics/digital-transformation
[9] https://dcnnmagazine.com/infrastructure/huawei-and-the-smart-city/

- The municipality of Singapore assigned[10] ST Engineering with the task of deploying its smart city digital platform to the new green area of Punggol Digital District in Singapore;
- SAP presented its vision of future cities[11], achievable through their flexible digital city platform;
- EIT Digital presented CEDUS[12], the pan-European digital platform for smart cities, developed and deployed by a consortium led by engineering.

There are a large multitude of initiatives, products and companies operating in the digital platform area for smart cities. This should not come as a surprise. There is a huge amount of money being spent for the smartification of cities, and that amount keeps growing year over year to reach some $158B in technology investment[13] in 2022 (according to IDC[14]). Notice that this is just about investment in technology, if you include investment in digging, pouring concrete and the like the investment will be close to $1 trillion.

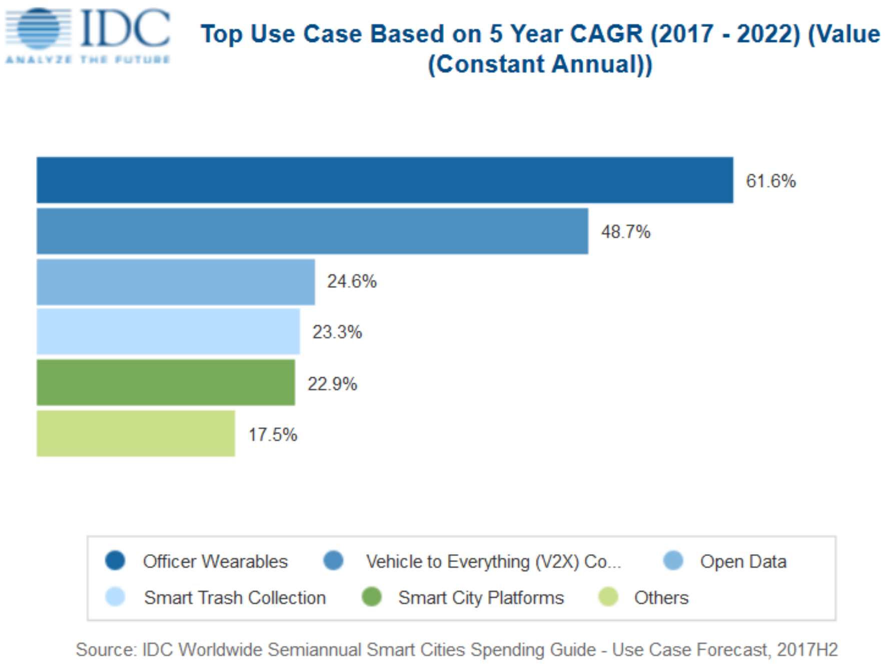


Figure 19. The technology investment in smart cities, globally will keep growing over the next 4 years (in the graphic the CAGR between 2017 and 2022). Although the most impressive CAGR is estimated in personal wearable (for city officers) one should note that the investment today in this areas is basically zero, so any growth will have a significant CAGR. Notable the CAGR expected in Smart City Platforms (22.9) and in Open Data (24.6). A digital platform is actually embedding both and we already have significant investment today, so such a CAGR means big bucks. Source: IDC Worldwide Semiannual Smart Cities Spending Guide

These big numbers are the result of a multiplying factor, i.e., the number of cities around the world committing investment to their smartification. A major part of that investment is not "reusable". If you have to dig to lay optical fiber, the cost of digging (and for optical fiber) is localized and cannot be reused. That is part of the world of atoms and its economy.

However, some 10% of the overall investment around the world is made using bits, in creating applications. This is part of the economy of bits, and it is to a great extent reusable in different contexts. This is where the Digital Platforms play a role: making reuse of applications possible in many cities. This is why there are so many players and initiatives in the Digital Platform space. These platforms are the enabler of the cities' Digital Transformation, and by shifting them into the economy of bits can dramatically decrease cost. The problem, of course, is that today we have too many platforms and they are usually incompatible with one another.

The fact is that while everybody agrees that having a Digital Platform is the way to go no one seems to agree on a single platform. It is as if in the smartphone domain rather than having 2-3 de

[10] https://enterpriseiotinsights.com/20180711/channels/news/singapore-preps-open-digital-platform-tag40
[11] https://www.sap.com/industries/smart-cities.html
[12] https://www.eitdigital.eu/newsroom/news/article/eit-digital-innovation-city-enabler-winner-of-select-for-cities-award-2018/
[13] https://www.idc.com/getdoc.jsp?containerId=prUS44159418
[14] https://www.idc.com/tracker/showproductinfo.jsp?prod_id=1843

facto platforms (Android and IOS having the lion's share) we had millions of platforms. Immediately the potential market for application developers would become fragmented and no longer appealing.

To avoid this fragmentation, the European Commission invested a significant amount of money, over 300 M€, to develop a common, open platform called FIWARE that could be used in several application areas, smart cities being the most obvious one. As in any cooperative project, the result was a set of compromises that although valuable in a scientific perspective required a focused approach to create an industry savvy product.

The FIWARE Foundation[15] consists of over 50 members[16] (at the end of 2018), and it is unclear at this point if in the end it will be attractive to cities around the world. The numbers are good: over 100 cities have expressed interest in using the platform, over 1,000 startups are now developing services for that platform, and there is a very intensive effort by the Foundation to keep growing and spreading the gospel through a variety of events.

The EIT Digital is supporting the effort in making the FIWARE Platform a reality throughout Europe through one of its innovation activities, CEDUS[17].

At the core of all digital platforms is an Open Data Framework, and for each application domain an ontology is required. This part is likely to be standardized, and the evolution of artificial intelligence holds promise to implement these standards at a semantic level.

Digital cities may be a crucial turning point for digital platforms. The application domain and the specific requirements are so broad that standards restricted to the syntax of the data ontology may not be sufficient. Standardization activities, like the ones carried out at ITU SG 20[18] are surely important (they also define a common metrics) but they may not be sufficient. Consideration of the semantic layer may lead to a solution that can aggregate most of the players.

Digital Transformation – A Digital Platform for Industry 4.0

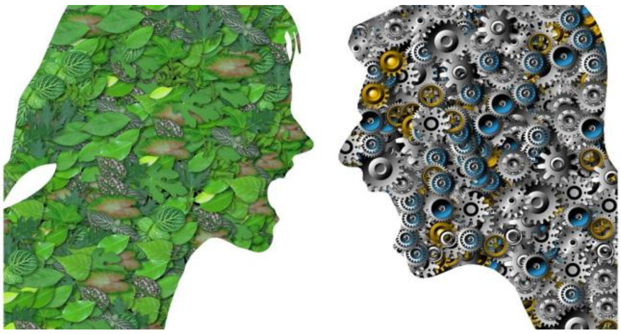


Figure 20. A nice image representing the clash between a green environment and the needs of industry and market leading to its exploitation. The Finnish view of integrating Industry 4.0 with the Circular Economy aims at transforming this clash into a synergistic endeavor made possible by rethinking the whole life cycle. Image credit: Tulevaisuuden tutkimuskeskuksen blog

After considering the abundance of Digital Platforms for Smart Cities (and the need to converge on a limited subset through the adoption of a semantic layer), this section considers the Digital Transformation of the whole production (including supply, distribution and operation chain), what is called –mostly in Europe- Industry 4.0.

The landscape is still fragmented, but it is different from the one of the digital transformation of cites because in Industry 4.0 the major players are industries, mostly private, operating with a different set of constraints, namely a strong quarterly results.

[15] https://www.fiware.org
[16] https://www.fiware.org/about-us/
[17] http://www.cedus.eu
[18] https://www.itu.int/en/ITU-T/ssc/Pages/default.aspx

The landscape is fragmented but one can attempt a classification of approaches in terms of Digital Platforms in four trends:

- End-to-end platforms
- Cloud based platforms
- Connectivity platforms
- Data platforms

End-to-end platforms are looking at the whole set of processes, providing an integrated set of hardware, software, security functions, connectivity fabric and management tools to sustain a new value chain. Their strength is the potential effectiveness since everything is right sized and fits nicely with everything else. Their weakest point is … the same! An industry would require a complete repositioning that is difficult to manage in the transition phase. A government institution, designing a long term vision and plan may well adopt this approach but a single company is unlikely to buy it. Initiatives like the ones in Finland and Germany may be set in this category.

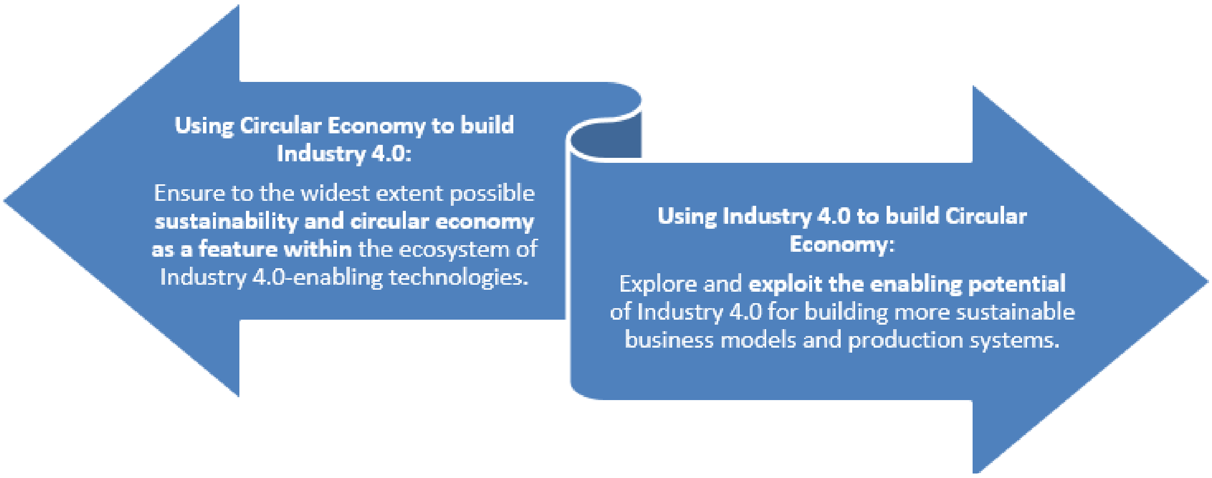


Figure 21. Finland National Initiative on Digital Industry stems from the vision of making the future manufacturing in synch with the Circular Economy. Image credit: Aalto University

Finland has taken a holistic view considering Industry 4.0 and the circular economy[19] (the economy of embedded recycling) as a single goal that can be achieved only by reconsidering whole value chains and related processes. This requires significant investment in research and the Finnish Government is betting on it.

Germany is leveraging its strong position of industrial enabler, (it is usually said, with some simplification but it makes the point, that Germany creates the tools China uses in manufacturing products that the US market consumes) and its government has set the goal of transitioning its industrial capability to leverage cyberspace. The plan is Industrie 4.0[20] and it is targeting 2020 (which may turn out to be an intermediate step towards a full Digital Transformation).

Both cases, used as slightly different examples, are based on the same approach: a rethinking of the whole manufacturing value chain. They are Government Initiatives that use a variety of levers, from investment in innovation to research coordination at universities to fiscal support for industries buying into the transformation. They include the layout of advanced low latency communications infrastructures (under the 5G banner), the orchestrated deployment of IoT, the creation of a (walled) Open Data Framework and so on. The main issue is setting up an effective orchestration capability, attracting industry and creating a de facto standard.

[19] https://ffrc.wordpress.com/2018/09/12/bridging-industry-4-0-and-circular-economy/
[20] https://www.gtai.de/GTAI/Navigation/EN/Invest/Industries/Industrie-4-0/Industrie-4-0/industrie-4-0-what-is-it.html

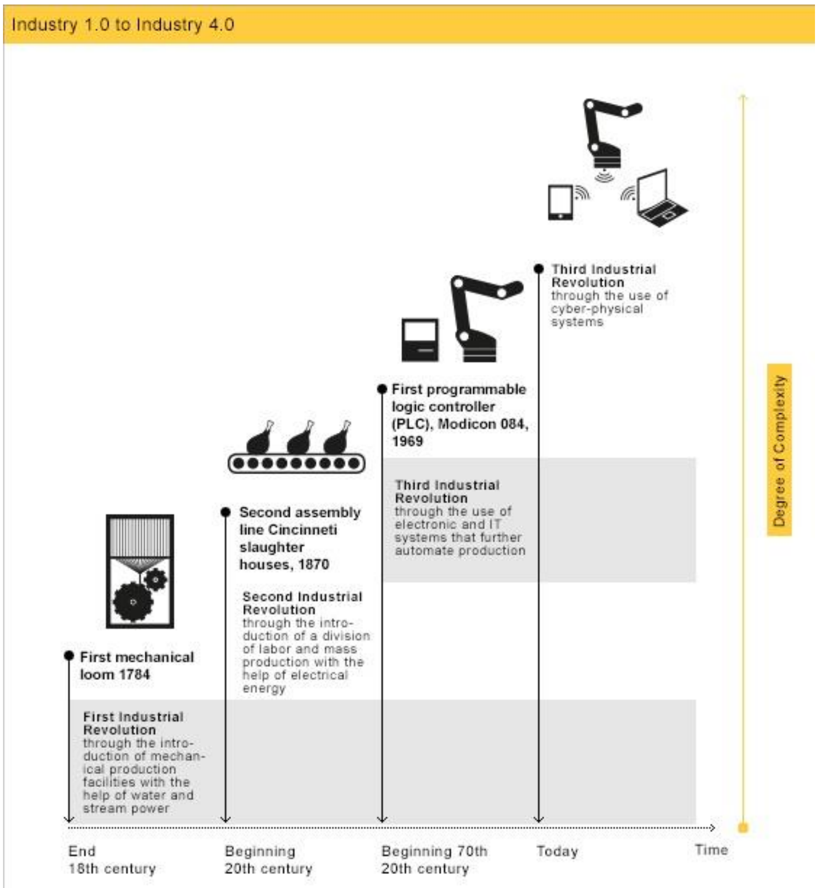


Figure 22. The German Government sees the transition to a Digital Industry has a further evolutionary step of manufacturing. Image credit: GTA

The new EIT Manufacturing[21] was set up exactly in this spirit. The activities of EIT Digital in the Digital Industry area[22], on the contrary, are much more focused and do not pursue this global approach.

Although an end-to-end approach is clearly a theoretically better approach to creating a Digital Industry, its practicality remains debatable and it can only be pursued in a top down approach with the government in the lead.

A much smoother transition to an Industry 4.0 can be pursued by leveraging the clouds that several industrial players are already using. There are clouds that have been and are used as a way to obtain flexible, on demand processing and storage capabilities (basically lowering the total ownership cost), and there are smaller private clouds that companies are using to share data along the supply, distribution chain and that are now progressively used to monitor the usage of their products.

By integrating the various existing clouds, already embedded in the manufacturing processes (extending northbound to the supply chains and southbound to the distribution chains and beyond), a major company may take the lead steering the Digital Transformation from the hub (the company) out (involving its suppliers and distributors). This has been happening in aeronautic manufacturing where Boeing and Airbus are very strong players that can pull their supply and distribution chain in their desired direction.

Other players, like General Electric, delivering high value products (like turbines in the case of General Electric. Notice that the cost of the engines for a 747 or A380 is about one fifth of the cost of the whole plane) can also have the power to steer the supply and delivery chain in their desired direction, and indeed General Electric has its own (private) cloud to keep track of its turbines.

Of course, some industries are already operating in cyberspace (i.e., they are dealing with services that are mostly bit based), and companies operating in this space are already using the cloud as their "manufacturing" infrastructure.

Amazon Web Services is now being offered a digital platform and there are specific guidelines[23] in place to enable the Digital Transformation to these Services.

[21] https://eit.europa.eu/eit-community/eit-manufacturing
[22] https://www.eitdigital.eu/innovation-entrepreneurship/digital-industry/
[23] https://aws.amazon.com/government-education/digital-transformation/

Azure is also offering specific services to manufacturing[24] and support to the Digital Transformation (as well as, obviously, support to all industries already operating part of their business in cyberspace).

System integrators make use of these large clouds and support companies in the Digital Transformation by integrating local clouds and streamlining all processes to operate in the new environment. The Digital Transformation will make significant use of these clouds at the edges and connection providers, like Ericsson, are scrambling to integrate distributed clouds (or fog or edge computing) into their connectivity offer.

Indeed, this view of cloud at the edges represents the transition point from the cloud approach to the connectivity approach. Companies like Cisco are pushing for this approach[25].

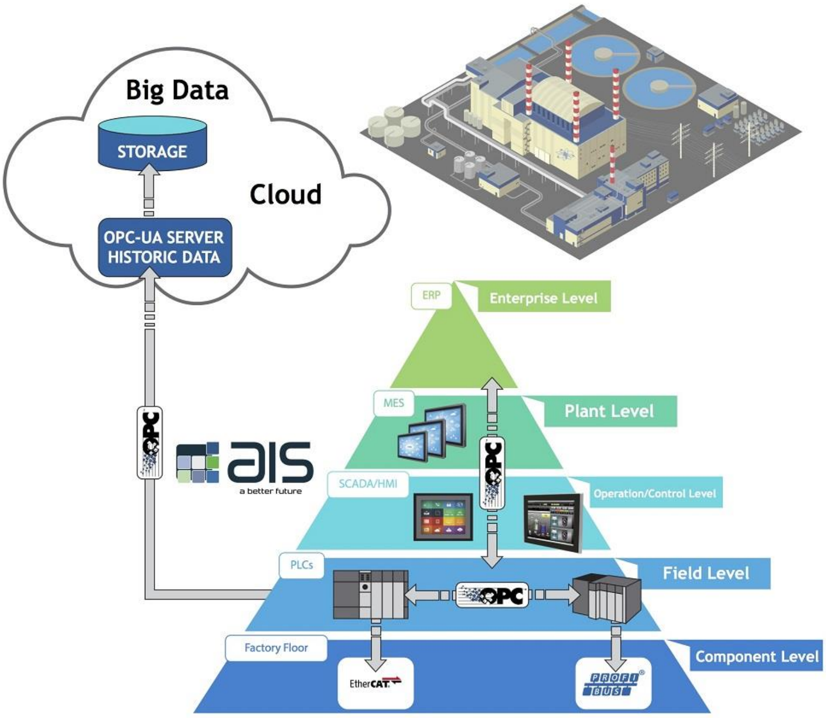


Figure 23. Cloud based solutions, including the major manufacturing protocol standards and integrating IoT and PC industry grade devices, are now becoming available. In the graphic the architecture proposed by the American Industrial SystemsInc. Image credit: AIC

As a matter of fact, the Digital Transformation is flattening hierarchies: all components in a value chain are potentially interconnected with all the others (once industries rely on bits, accessing them in parallel and from any point of the globe is no longer an issue). Interconnection takes place among organizations, enterprises, suppliers, manufacturers, providers and users, among products and products components (IoT), and in the form of feature interoperability among services. Interconnectivity is the name of the game in Industry 4.0, and it is made possible, conceptually by the shift from atoms to bits and practically by the availability of pervasive connectivity infrastructures.

We have continually said that communications infrastructures are just killing distance, everything is here and now, but that is true only at macro level. At the level of robots there is still the perception of difference between local parties and distant ones: this is called latency. Some of this latency is connected to the speed of light (actually the propagation of the electromagnetic field) which cannot be overcome (although by moving manufacturing component in a cloud one could physically co-locate some activities): controlling a robot in London from Turin implies a delay of 2.7 milliseconds per direction so some 5 milliseconds if you need to make decisions based on a response. The only way around this would be to virtualize the robot and its controller and operate them together in close proximity in a cloud, but this can be made only if you can virtualize both, and that is seldom the case.

In practice, however, controlling a robot in London from Turin using a plain vanilla telecommunications network is likely to involve a delay (latency) of some hundreds of milliseconds. A radio system like LTE (4G) may on average add a latency between 50 to 100 ms. A properly designed 5G network may significantly cut this latency below 50ms.

[24] https://azure.microsoft.com/en-us/industries/discrete-manufacturing/
[25] https://www.cisco.com/c/en/us/solutions/enterprise-networks/intelligent-edge.html

Because of this, and the expected penetration of 5G in the long run, many consider it as the ideal communication infrastructure for Industry 4.0.

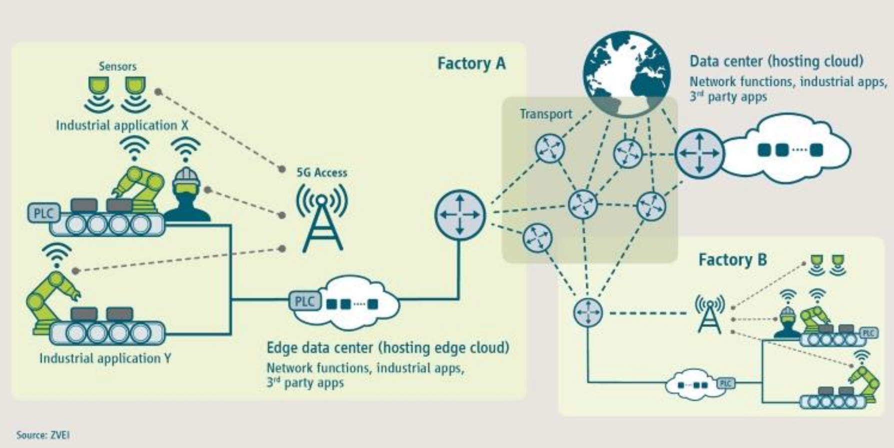


Figure 24. 5G supports communication with unprecedented reliability and very low latencies, as well as massive IoT connectivity. In the graphic the various types of 5G access points relevant to Industry 4.0. Image credit: 5G ACIA

Many CEOs and experts in the space believe 5G will be a welcome bonus to manufacturing, once it is deployed. In the meantime, industry is making the most out of 4G and even 3G. Nevertheless, it makes sense for Telecom Operators to ride the (future) wave of 5G boasting of its low latency that indeed in some niches could make a difference.

5G is coming with a different network architecture where clouds at the edges become an integral component. In this sense a connectivity infrastructure based on an integration of edge computing, multi access capability and micro cells delivering high throughput (5G) will be a most interesting platform for Industry 4.0.

However, a pure communications infrastructure, although highly performant and pervasive is not sufficient to be a digital platform enabling Industry 4.0. As mentioned previously, it must include the cloud part, which in turns makes sense only if you are including data.

In a certain sense data come for free to Industry 4.0. Over the last decade computers aided tools have become the screwdrivers and pliers of the past in manufacturing. Bits are pervasive in product design, prototyping, digital lathe, robots. Additionally, bits are a crucial part of inventory, shipping, quality control, invoicing, payment collection, features delivery, feature updates through new releases, and more. Bits have become an integral part of the manufacturing value chain.

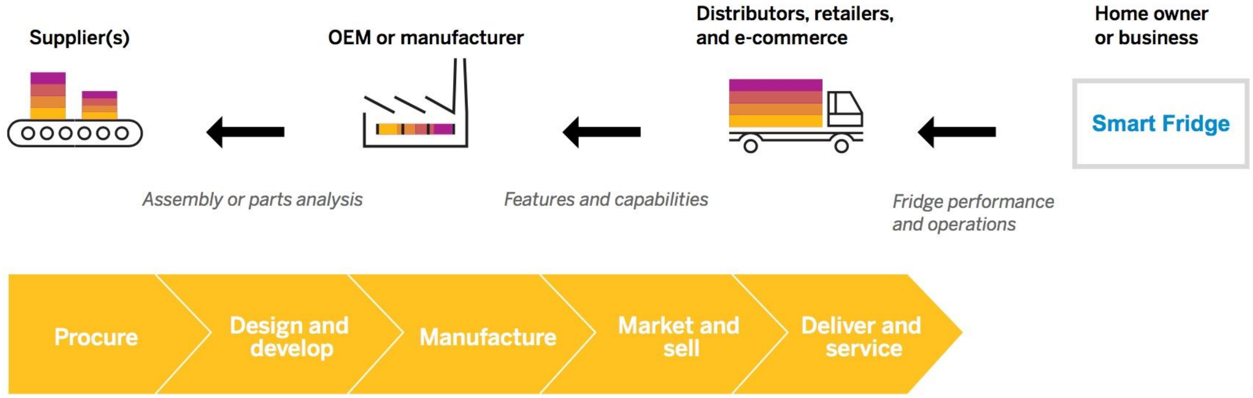


Figure 25. The basic concept of Industry 4.0 is a flattening out of the Value Chain with every player becoming able (potentially) to interact with all the others. This is achieved through the sharing of data and this is why many feel that the digital platform should be focusing on data. Image credit: SAP

In some cases, like when dealing with software creation, bits are almost 100% of the raw material needed. There are computers and clouds to run them on but you can take those for granted, and the packaging of bits is fading away, since by far applications are now downloaded directly from the company "cloud" or from some online store.

At the same time the pervasive use of bits over the last decades has happened through waves of digitization. This has resulted in landscape that is not homogeneous, where different tools are not talking to one another and where representations differ in different parts of the value chain and throughout the manufacturing processes. The number of data records and databases has ballooned to the point that one of the big issues facing companies today is achieving interoperability among the different components.

In Industry 4.0 the issue gets even more difficult to manage since the variety of systems that would need to interoperate are no longer within a single company but are owned and operated by different companies.

A further component that has become more and more relevant is the growth of sensors as data generators. IoT, with a continually increasing number of sensors, are amazing data generators but at the same time they cover a very broad spectrum with thousands of ways to generate data (in terms of frequency, volume, characteristics, etc.). People incorrectly talk of IoT as if they were a single "thing", an entity clustering with common characteristics. The variety of the IoT and the different manufacturing and operation landscape (including in this latter the communications paradigms involved) makes the term IoT basically useless if we want to leverage the data they generate (or the ones used in their operation). As a corollary, when someone claims that 5G is great for IoT one should be aware that there is not such a thing as generalized IoT that share common communications requirements such that a single communication paradigm can fit them all.

Companies like SAP are looking at providing integration frameworks[26] (and related tools) to manage this diversity. In case of SAP they are offering their B1iF, Business One Integration Framework, pointing out that Industry 4.0 is about meeting and leveraging four main challenges:

1. Data volume, processing and connectivity
2. Exploiting data beyond manufacturing, using those same data through analytics and AI for business
3. Exploiting data to improve human machine interaction (haptic, augmented reality, virtual reality)
4. Effectively linking bits to atoms

[26] http://blog.asug.com/b1/industry-4.0-and-sap-business-one-how-your-business-can-prepare-for-the-next-industrial-revolution

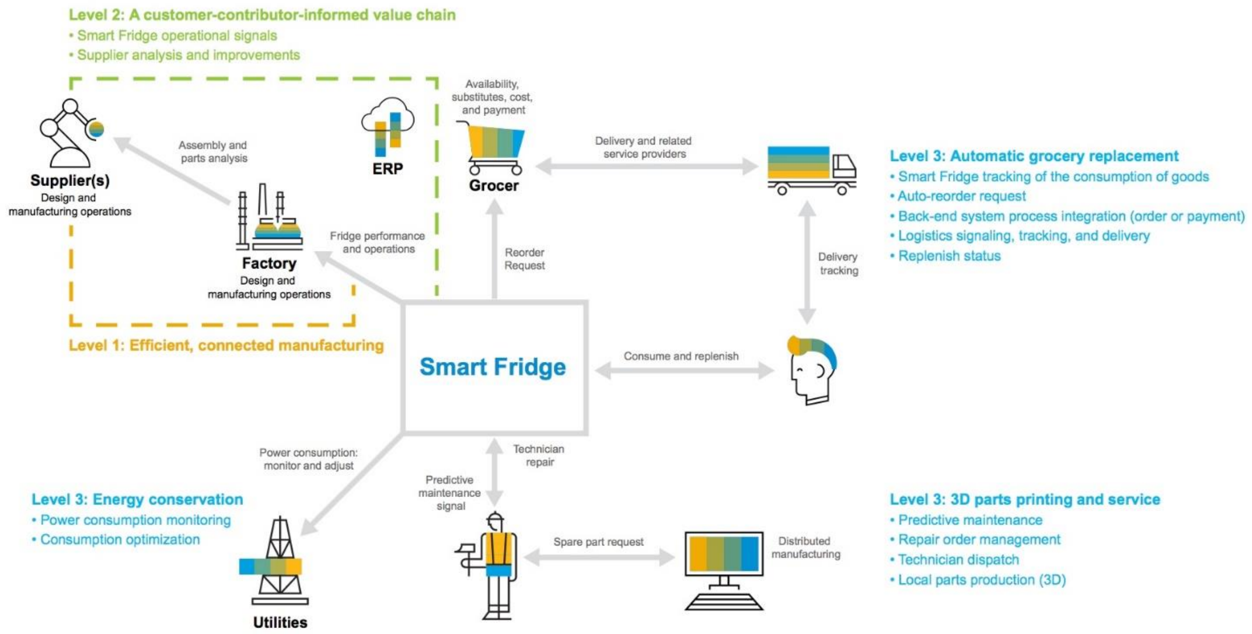


Figure 26. The flattening of the Value Chain in the case of Smart Fridge[28]. Notice the role of IoT t sensing at the customer premises the usage and providing data upstream for analyses. Data analytics, integrating data from thousands of fridges in operation, provide hints to operation problems, allows the provisioning of maintenance services and helps in design of future product These data percolate throughout the Value Chain. Suppliers can be alerted of issues in the compo they provide and continuous re-design is enabled. Image credit: SAP

As noted, any digital platform needs to acquire a strong footprint and SAP is leveraging their presence in the manufacturing industry with their ERP solutions. They are building on those and leveraging the effort they made on creating HANA[27], the platform designed to support IoT in industrial environments. They are actively socializing the value of B1iF[28] by creating an open environment allowing third parties to develop applications and using a common data ontology as the aggregation point. The approach is very similar to the one presented when discussing an institutional driven digital platform, particularly the Province of Trento. Both are using data as their starting point. In case of SAP there is a much stronger integration with the cloud and with several tools that SAP is providing (based on their existing portfolio on ERP applications, well known by the industry).

Digital Transformation – Semantic based Digital Platform

Of the four approaches to Digital Platform for the Digital Transformation of Manufacturing, Industry 4.0, the one based on data is the most convincing. The end-to-end approach is adequate but probably over ambitious and it does not take legacy into account. The communication based approach is just a component that would not help unless there is a parallel shift in a data based approach. The cloud solution, similarly to the communications, is sort of given, is the screwdriver that you need but what is really important is understanding how to use the screwdriver, where are the screws and which one need to be turned (the screws, obviously are the data).

At the same time, there is the huge, overwhelming variety of data, of ontologies and of structure of existing data. Each of them has a purpose, and investment have been put in creating those

[27] https://www.sap.com/products/iot-platform-cloud.html
[28] https://blogs.sap.com/2018/08/14/integration-framework-for-sap-business-one-b1if-central-blog/

structures and relative applications. Although this might be considered a "sunk" investment it creates a huge inertia making any change difficult.

This consideration applies beyond Digital Platform for Industry 4.0; it more generally applies to most verticals, from health care to smart cities, from logistics to construction. The reason for discussing Digital Cities and Industry 4.0 was to show how different verticals may have different requirements and constraints (i.e. Smart Cities are driven by public investment, Industry 4.0 by private investment) but also to show the similarities and the unifying point is surely "data". And, as mentioned, data are heterogeneous, tied to legacy systems, and have issues related to privacy, ownership, reliability.

How can we move forward keeping data at the core of evolution, yet taking into account their variety and the issues related to data?

It makes sense, when planning for the next step to look further down the lane, to understand the direction both in terms of where we would like to go as well as in terms of what directions are enabled by technology evolution (of course taking into account societal and economic implications). This is what the IEEE Future Directions Committee (FDC) is really doing, taking a longer view span, identifying the desirable horizons, and together with IEEE OUs taking the first steps in the desirable direction.

As an example: what is going to happen, or become possible, after Industry 4.0?

SAP have their own ideas and they are surely worth considering. According to SAP (refer to the following graphic), by leveraging the results of Industry 4.0 that make production more efficient from the market viewpoint by including the users in the value chain (getting direct feedback from product/service use through IoT and a flattened value chain), it will be possible to evolve the products/services much more rapidly (and perhaps charging the customer for the evolution). This can be done by dividing the atoms from the bits in the product. The product becomes a combination of hardware with a long life span and software having a much shorter life span. The hardware part may be sold using conventional business models, while the software part may be sold as a service (paying for each subsequent release, paying a subscription fee, paying an on-demand feature evolution, for examples). This will foster an "Incremental Innovation" with a direct customer involvement (empathy).

The subsequent phase fully blurs the boundary between customers and producers leading to an ecosystem driven by innovation (being hinted by the EIT Digital 2020-2022 Strategic Innovation Agenda[29]) which will cause a significant disruption in the market place since the ecosystem takes the lead, at the expense of today's incumbent players (remember the loss of value implied in the shift from atoms to bits). That is why SAP names this phase Disruptive Innovation.

[29] https://www.eitdigital.eu/enhancing-the-global-impact-of-european-innovation/

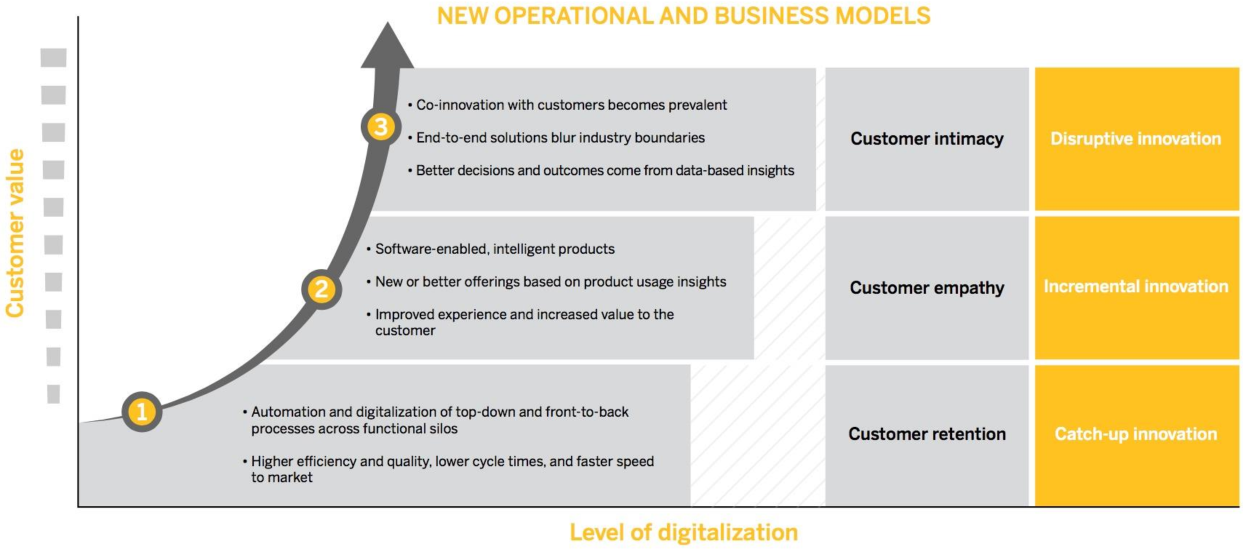


Figure 27. Two phases naturally following Industry 4.0. Industry 4.0 enables a more efficient production in terms of "market efficiency" (the previous industrial phases have basically improved the efficiency from the point of view of the manufacturing industry, increasing in the subsequent phases the efficiency of the supply and distribution chains). Image credit: SAP

How can we take into consideration the diversity in data we have today and move towards an ecosystem where every player can potentially interact, make use, and leverage the data? The answer lies in semantics. By using semantics, the issues related to syntax can be avoided (which does not mean you can get rid of syntax, however), and by operating on semantics alone, different players can interact with one another. Of course semantics need to be extracted from syntax, and this requires in the easiest case some ontology, but in most cases it requires intelligence to correlate data into a context (which means with other data, with a time line, with a purpose). For this we have artificial intelligence in its various forms, with deep learning and machine learning being the crucial ones.

What do you actually get when you start operating on data based on semantics (let me re-iterate: semantics depending on the data-context relation)? You get Digital Twins! Indeed, Digital Twins are semantic representations describing an object, its behavior, its history, and its possible relationships with the context in which it can operate.

Companies like General Electric have started to create and use Digital Twins[30] as a springboard for their Digital Transformation, and the Digital Platforms they have created are based on Digital Twin interactions.

Digital Twins are going to be the future of Digital Platforms, the strong enabler for the Digital Transformation, and their implementation will result in a successful Digital Transformation.

Acknowledgement

The editing and polishing of the text of this article by Theresa Cavrak is gratefully acknowledged.

[30] https://www.ge.com/digital/applications/digital-twin