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FUTURE TRENDS IN THE CONSULTING ENGINEERING INDUSTRY

May 2019

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"All truth passes through three stages.
First, it is ridiculed.
Second, it is violently opposed.
Third, it is accepted as being self-evident."
Arthur Shopenhauer

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Title: Tunnel of Innovation

"The Tunnel of Innovation is like an open channel towards the world of archetypes, a progressive and exponential illumination which broadens our collective conscience, an unstoppable and necessary connection with the other dimensions of the universe, God's third eye open on the absolute."

Information on the European Federation of Engineering Consultancy Associations can be found on the internet at: www.efcanet.org

Published by the European Federation of Engineering Consultancy Associations, 2018
Publication date: May 2019

ISBN: 9789075085068

Preface

To be successful in today's world it's no longer sufficient to imitate past models. We must innovate and concentrate our efforts on what our competitors are not yet doing.

In this Second Annual EFCA Future Trends Booklet, we further explore the trends that will disrupt the Global AEC Industry. It is irrelevant whether we as a Federation support, embrace or encourage these trends, The future is inevitable. The only constant is change and the rate of that change is increasing uncontrollably. Our goal is to expose the European AEC Community to the possibilities and opportunities that this inevitability will create and the consequence of ignoring it.

These new forms of organisation structure place more trust on the integrity of all those involved in the journey. They can only succeed with the preservation of the core ethical principles which lie at the heart of our profession. Without these failure is inevitable.

EFCA challenge's our Industry to have the courage to transform ourselves, to abandon preconceived frameworks, to embrace new models and try new experiences that will allow us to truly evolve as an industry and society. The transformation won't be easy. There will be many challenges and obstacles as we try to reconcile these future trends with the legal, regulatory and liability precedents which have both constrained and protected us for many years. Shattering the status quo is always disruptive.

Kevin Rudden - EFCA President

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Future Trends Task Force Members

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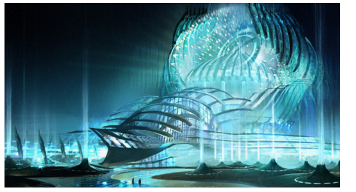
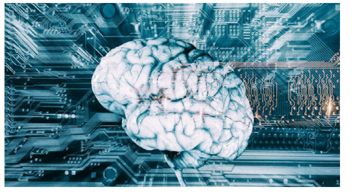
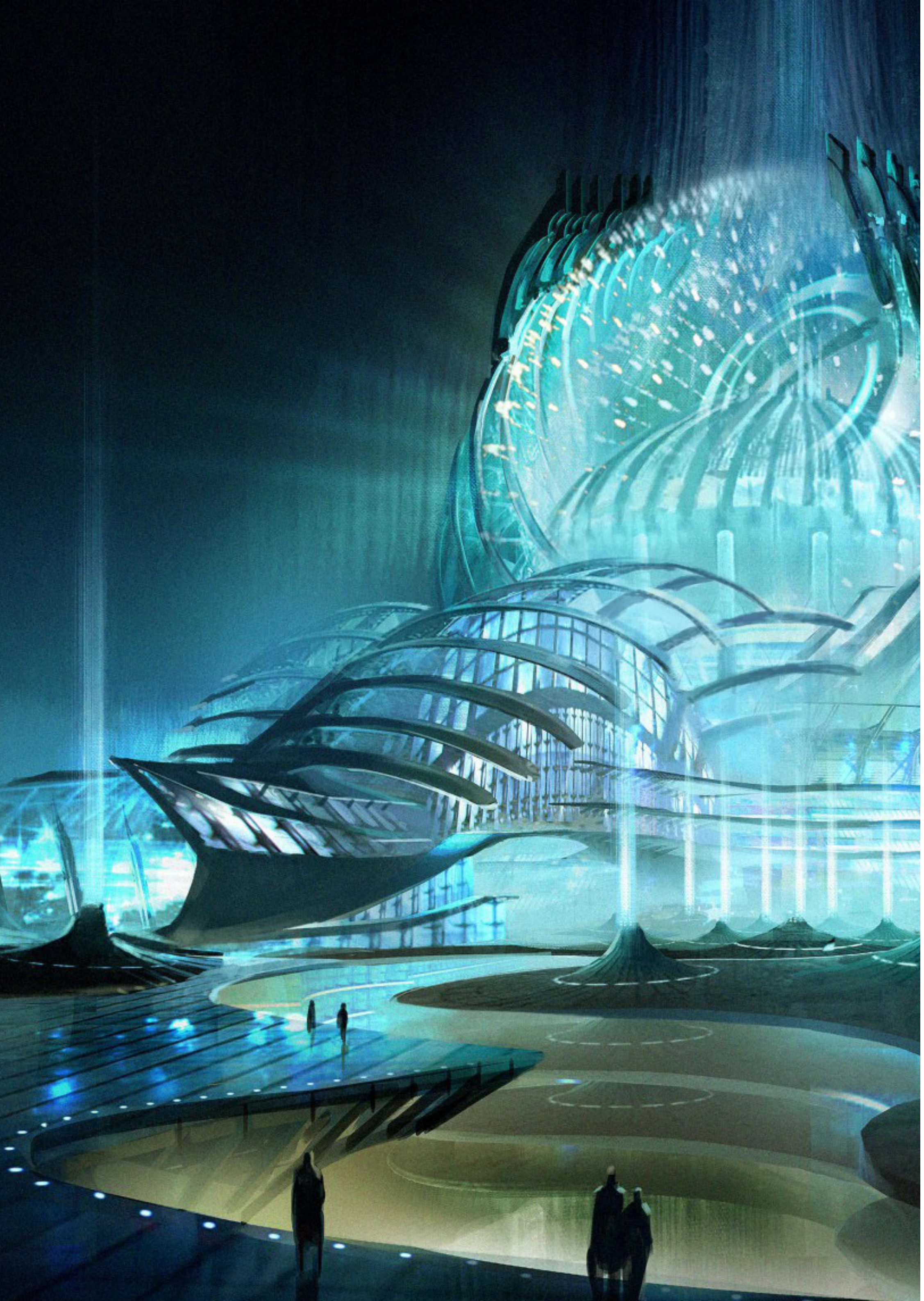




PREMISE

In today's digital era,
"Collaboration is inevitable"
not only necessary.

In the 2018 booklet we looked at the principle trends in the engineering industry. Now let's focus on some operative examples:

- **Collaborative Engineering and Networking**
- **Construction Tech Trends**
- **Blockchain Technology**

The convergence of three digital accelerators:

- **Computing Power**
- **Bandwidth**
- **Digital Storage**

makes what was previously impossible now possible.

To be successful nowadays, rather than imitate past models it's more worthwhile to innovate and concentrate our efforts on achieving what our competitors are not yet doing.

This will involve using the new tools of **Virtual Reality**, **3D Printing and Robotics**, to redefine and reinvent in order to go beyond simple competition between engineering companies.

The exponential speed of these ongoing transformations makes it clear that organisational models based on rapid reactions to these changes **are not enough**.
We need **alternative models** based on **anticipation** to recognize

and interpret foreseeable future trends, both **hard** trends, which are certain to take place, and **soft** trends, which may not necessarily take place.

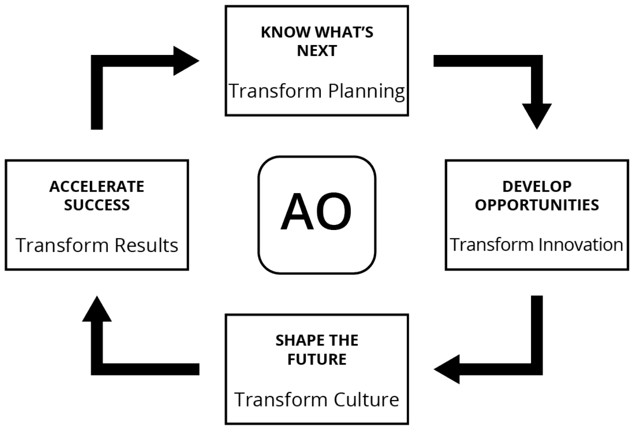
Anticipatory Organisations which obtain disruptive results by means of transformational planning need not only to recognise these new collaborative models and operative tools, but also to make use of **new management models** to enable instant, frictionless, intimate customer value at scale.

"The Anticipatory Organisations Model has the power to shift an organisation's operating mindset from the default of reacting and responding to changes coming from the outside in, to a place of empowerment by anticipating and shaping the future from the inside out."

(Daniel Burrus, The anticipatory organization).

In today's digital era, "*Collaboration is inevitable*" not only necessary.

In order to manage mass collaboration and collective knowledge we need to explore new **tools**, new **talents** and set up a new way of getting the new generation of engineers, architects and leaders on board.

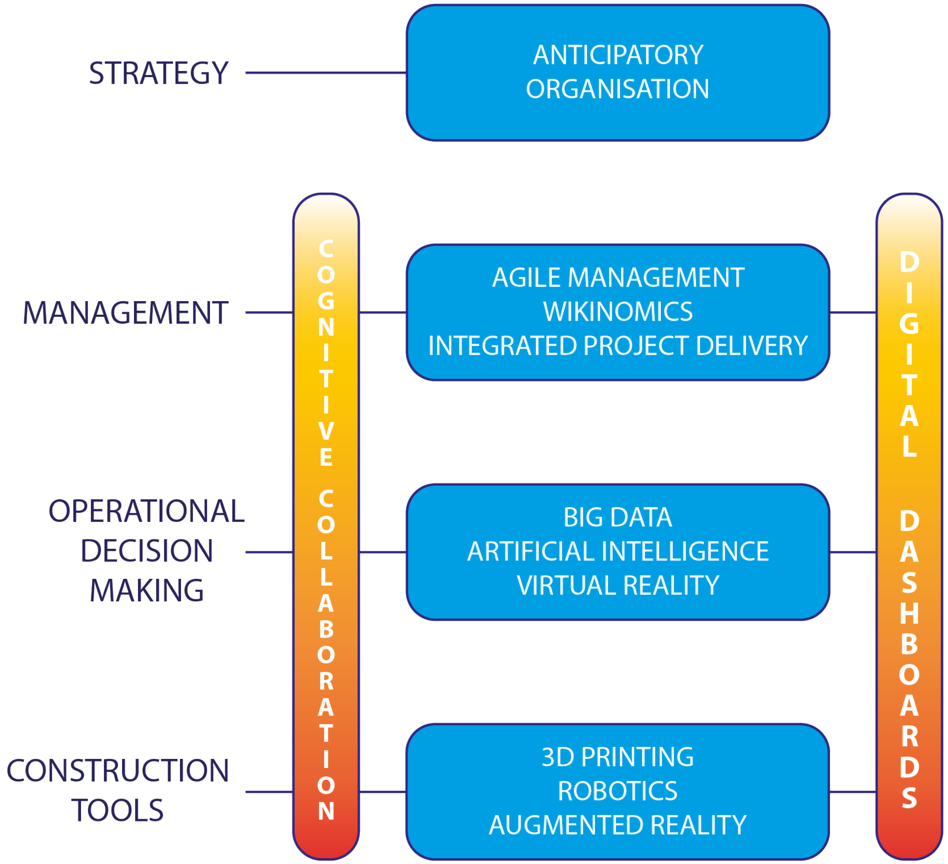


Graphics From "The anticipatory organization" By Daniel Burrus , 2018

The ability to integrate talents of geographically dispersed individuals and organisations is becoming the defining competency for engineering firms. Don Tapscott calls **Wikinomics** "*this new art and science of online collaboration*".

Finally to understand the consequences and implications of hard trends, and how to leverage soft trends to our advantage, we need an **Agile Management** model which integrates all data and information so that our **big - data** - decision - making is made through specific **dashboards** using **artificial intelligence**.

Cognitive collaboration is essential because humans and computers think better together.



AGILE MANAGEMENT, WIKINOMICS AND IPD

"Agile management is about working smarter rather than harder. It's not about doing more work in less time: It's about generating more value from less work." (Stephen Denning)

Agile Management

Traditional management practice assumes that the world is: ▪ deterministic ▪ predictable ▪ orderly ▪ certain	But in today's digital age we accept that the world is: ▪ probabilistic ▪ unpredictable ▪ disorderly ▪ uncertain
For Stephen Denning traditional management applies detailed command techniques that lead to: ▪ centralization ▪ coercion ▪ formality ▪ tight rein ▪ imposed discipline ▪ obedience ▪ compliance ▪ optimal decisions that take place later ▪ a focus on harnessing ability at the top **In a word, Bureaucracy.**	But in today's accelerated world we need a mission command approach characterized by: ▪ decentralization ▪ spontaneity ▪ informality ▪ loose rein ▪ self discipline ▪ initiative ▪ cooperation ▪ acceptable decisions that are made faster ▪ focus on harnessing ability at all levels **In essence, Agile Management.**

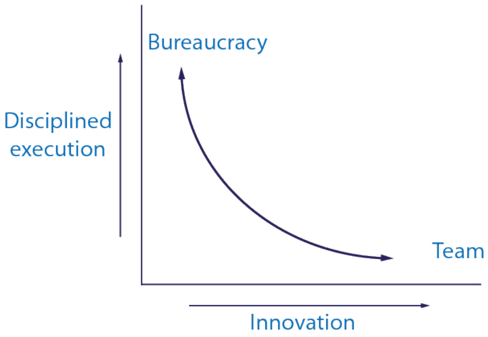
Pia-Maria Thoren, in her book “Agile People” writes:

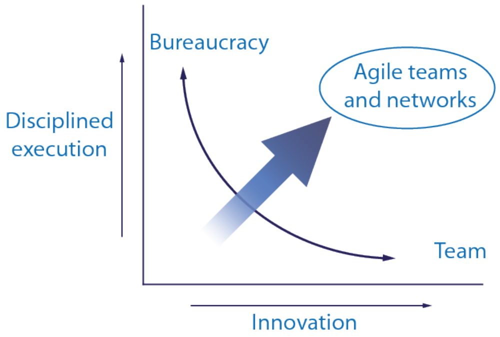
“Agile is a way of moving forward and creating value. It is a mentality that allows people and groups to meet challenges, learn quickly, and respond to change. It is a different and new way of managing teams, individuals, projects, and development.” ...
“Agile, on the other hand, is an incremental approach. Work is completed in small batches or sprints, and then evaluated and tested. The method is collaborative and allows errors to be fixed or feedback to be taken into consideration as you move forward.”

Stephen Denning in his book “The Age of Agile” writes:

“Trying to exploit Technology and data with the management practices that are still pervasive in many big corporations today is like driving a horse and buggy on the freeway. To prosper in the very different world that is emerging, firms need a radically different kind of management.”

“The new management paradigm is a journey, not a destination. It involves never - ending innovation, both in terms of specific innovations that the organization generates for the customer and the steady improvements to the practice of management itself. A firm never “arrives” at a steady state where it can relax because “we are now Agile”. Embracing the new paradigm requires continuous commitment and leadership from management.”...
“Now agile methodologies - which involve new values, principles, practices, and benefits and are a radical alternative to command - and - control – style management - are spreading across a broad range of industries and functions.”





“Becoming an agile organization is an increasingly urgent necessity for companies in today’s digital economy, yet most companies have a deeply embedded command organization architecture and culture.”

Denning recognizes three core characteristics in the organizations that have embraced Agile:

1) The law of the small team
2) The law of the customer
3) The law of the network

1) Agile practitioners share a mindset that work should, in principle, be done in **small**, **autonomous**, **cross-functional teams** working in short cycles on relatively small tasks and getting continuous feedback from the ultimate customer or lender-user.

2) Agile practitioners are **obsessed** with delivering value to the customers.

3) Agile practitioners view the organization as a **fluid** and **transparent network** of players that are collaborating toward a **common goal** of delighting customers.

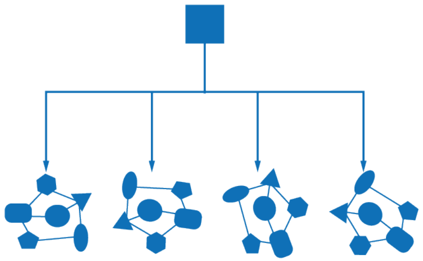
Agile Management is primarily a **hierarchy of competence**, not a hierarchy of authority, and ideas can come from anywhere, including customers.

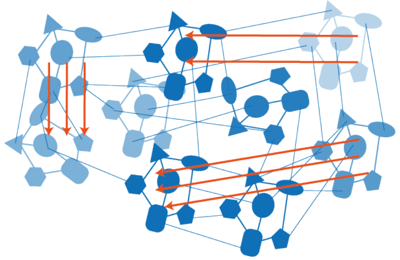
McChrystal’s approach is based on a very simple idea:
Create a team of teams.

This means turning a Task Force from a bureaucracy into a network.

A network is a group or system of interconnected people or things.

An organizational network is a set of teams that interact with and collaborate with other teams with the same connectivity, interaction, and passion as they do within their own small team.



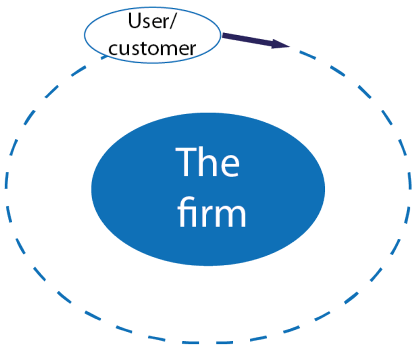


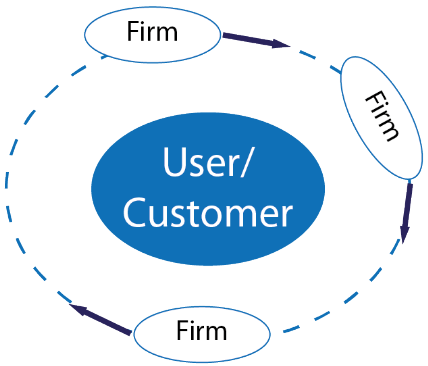
An organizational network is founded on the law of the small team but it requires more. Each team needs to look beyond its own goals and concerns and see its work as **part of the large mission** of the collectivity.

In effect, McChrystal had to transform the preexisting hierarchy of authority into a hierarchy of competence.

Decisions had to be based on **who was best placed** to make the decision, not their position in the formal hierarchy.
This is all about **creating value** for the customer rather than **extracting value** from the customer.

In the digital era, it is necessary to drastically change the way we consider firms' organization. The firm is not at the center anymore . It is the clients who play a core role.





Why is the engineering industry perfectly suited to agile management?

Because:

The industry operates in an **uncertain ecosystem**, in essence in a VUCA* world;

- The purpose of the engineering company is to design single projects perfectly suited to the law of the small team;
- Every single project needs to satisfy the client, in other words to apply the law of the customer;
- The success of the project depends on the ability to manage integrated information, in essence to apply the law of the network;
- The management in an engineering company needs to be primarily a hierarchy of competence, not a hierarchy of authority;
- In today's digital age, engineering companies need to achieve both execution and innovation disciplines.

* **V**olatility, **U**ncertainty, **C**omplexity, **A**mbiguity

Wikinomics

"No matter who you are,
most of the smartest people work for someone else." (Bill Joy)

The profound transformations underway are giving rise to innovative and powerful production models based on **community, collaboration and self-organization rather than hierarchical control.**

As Don Tapscott and Anthony Williams state in their books *Wikinomics: How Mass Collaboration Changes Everything* and *Macrowikinomics – New Solutions for a Connected Planet*, the production chain works more effectively if risks, recognition and the ability to co-develop large projects are spread across global partner networks working on a peer basis, entities operating without hierarchies, overcoming the boundaries typical of traditional organizations and creating what is known as "Wiki workplaces", i.e. sites embracing Wiki work practices.

But what exactly is a Wiki?

According to Kevin Kelly, the author of *The Inevitable*, Wiki denotes "a set of documents that have been produced in a collaborative manner. The relevant text can be easily created, integrated, edited or adapted by anyone and for anyone."

Kelly continues, explaining that the Wiki model, rather than operating like a traditional collective enterprise, envisages working in a collective environment in which **meritocracy** and **doing things properly** are the primary drivers. Vertical production is thus replaced by a horizontal format (without hierarchies), and peer production becomes the norm.

To this end, Tapscott claims that mass collaboration is required in order to create real value among the participants and ensure the greatest probability of success.

"In order to succeed, simply intensifying existing management strategies is not enough. Leaders must start thinking about competition in a new way, and to make the system profitable, they must embrace the new art and science of Wikinomics".

It is not just about open source "ecosystems", or social networking, crowdsourcing, smart mobs, crowd wisdom and so forth.

Instead, we must consider a **radical transformation** of traditional structures and new social and economic operational methods that are based on renewed competitive principles such as **openness, cooperation, sharing, integrity and interdependence.**

Today, depending on the type of project undertaken, we can rent **cloud-based platforms that host all the indispensable specialised software** applications. This allows all team professionals to work simultaneously, remotely and under a unified operational model, with all users employing the same software, which is hosted by the platform itself.

Recall that in the operational context, work is performed according to Wiki methods – all design documents can be easily created, integrated, edited or adapted by anyone and for anyone (obviously, 'anyone' means previously selected and authorised project participants).

BIM is a highly useful tool as an aid to collaborative working.
It allows professionals working in diverse and distant locations around the world to interface with each other while channelling the results of their work into a unified model.

This also applies when the work corresponds to a micro-task.

The result is that an organisation working in this way is all the more efficient the more it can be automated by means of software, platforms and algorithms. Knowing all these technologies and applying them to engineering is challenging and requires a lot of experimentation.

Also, it was crucial to build an "attention architecture", i.e. a model that would attract interest in the network and thus make it easier to find experts and engage them in the initiative.

Simply creating a network is not enough: it must also be made to work properly, designing **the right ecosystem** that uses dedicated digital platforms that are flexible and adaptable, whatever the size of the project, and obviously automating processes.

These problems were never addressed by those who work in engineering and follow the traditional and no longer competitive approach.

Finally, everyone involved in the system **must commit to work in a modular fashion**, developing a sort of unified language that involves, for example, the use of the same type of dimensional expressions, the same character fonts, and the same symbol sets in graphic renderings and reports: in short, a uniform design language.

This avoids project designs becoming heterogeneous and facilitates their sharing. Moreover, if a number of people working on the same project reference the same BIM model, then modularisation and language unification requirements are effectively resolved as far as graphics issues are concerned.

Wikinomics enables the ethics of sharing as well as the creative recycling and adaptation of previously completed work.

How is this new way of doing business evolving? It is analogous to a group of musicians who, rather than insisting on composing unpublished pieces, rearrange previous creations and succeed in producing a work of art. Essentially, it is a question of re-composing things done by others.

Such an approach can also be adopted in design work. It is a matter of choosing among a certain number of pre-existing and available projects, selecting one that is compatible with the specific needs in question and transforming it to meet the requirements of a given task. If, for example, you were tasked with designing a school, you would not start from scratch.

Instead, you would draw from a set of archived building designs with the same intended use – of course, these designs would have been draughted in a modular fashion to facilitate their sharing.

You would then proceed to extract the designs or partial elements most suited to the project goal. As such, the added value of a designer or an engineering firm is to improve this project design by adapting it to the context and enhancing it with improvements and creative solutions. This is how Wikinomics works.

Learning how to **engage** a team of partners and **co-creating by means of global collaboration** is transforming the fundamental skill set of those pursuing a self-organised business model; this expertise is as essential and important as budgeting, R&D and planning.

This outlook should be compared with the mechanisms of traditional business to allow conventional companies to **innovate** and **differentiate themselves** in order to **compete better** in the "enterprise space" or invent a totally new business founded on a broader human capital base.

The new art and science of Wikinomics – as theorised by Tapscott – is grounded in the five new and powerful ideas previously mentioned: "openness, collaboration, sharing, integrity and interdependence".

Regarding the first of these factors, **openness**, Tapscott again notes that Smart Companies have been focusing on this core idea recently. They are beginning to involve a number of important functions, including human resources, innovation, industry standards, and communications.
Even though it may seem strange, this unexpected openness generated by sudden scientific and technological development is becoming a sort of new imperative for leaders.

It would benefit companies to open their doors more to global talent rather than restricting their horizons to their employees only.

The demands for such innovation have come from a customer base that calls for “open” models, leading many industry professionals to use a wide variety of open software platforms (such as Hyper Ledger of IBM).

The openness factor has encouraged **transparency**, with greater **freedom** in corporate communication and less secrecy around information. Open enterprise organizations foster trust between employees and the company, and this **facilitates innovation** and **reduces costs.**

Regarding the second factor, **collaboration**, Tapscott asserts that enterprises and institutions are increasingly activating collaborative processes, as these represent a new approach to driving innovation, creating goods and services, and solving problems.

Social networking is becoming **social production**, where self-organizing groups are producing everything from software to drones. Sometimes this collaboration occurs globally, involving thousands or even millions of people.

The common thread in Wikinomics is the growing awareness that knowledge, skills and collective resources embedded within broad horizontal networks of participants can sustain much **higher production levels** than can be achieved by a single organization or an individual acting in isolation.

As for the third factor, **sharing**, it was found that investing in common assets allows for shared technology and knowledge resources to be exploited in order to **accelerate growth** and **innovation**.

Bargaining power is not limited to intellectual property but extends to other resources such as co computing power, bandwidth, content, and scientific knowledge.

The fourth factor, **integrity**, is a principle to which companies and other organizations must now adhere, not only because regulators and institutional shareholders demand it, but also because **everyone operating as part of the network insists on transparency**.

All organizations must therefore espouse integrity to ensure a healthy and sustainable environment for enterprises, thus generating a competitive edge.

Honesty, consideration for others and responsibility combined with transparency are the basis of trust and integrity. Once organizations have built a broad base of trust, they are rewarded by the cooperative behaviour of their interconnected networks.

Tapscott closes with the fifth and final factor – **interdependence**. Developed globally, it has become a distinctive feature of our time, involving elements such as people, money, technology, products, services, culture and ideas that are **constantly crossing borders** in a vast network of transactions and social exchanges.

In practice, a common approach adopted in the community is to split complex tasks into a manageable number of secondary activities and to allocate these to various users.

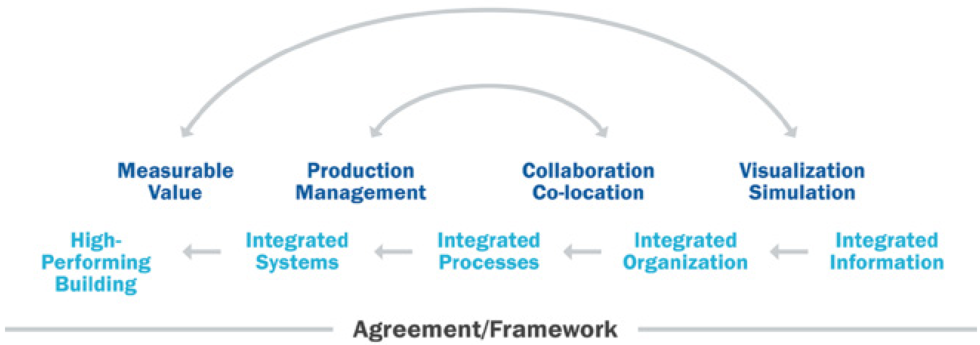
Today, the web offers a feature-rich platform that dramatically **reduces collaboration costs** and, therefore, provides effective access to the global market of ideas, innovations and highly qualified minds at increasingly lower costs.

For example, when discussing sustainable development, we must use the sum of humanity’s knowledge of sustainable technologies and industries, and share it for the good of the planet and the future generations that will inhabit it.

In such a context, with change radically impacting the destiny of all humanity, we must promote a **pre-competitive phase** of cooperation among the world’s most illuminated minds.

Integrated Project Delivery

"Building the right building" and "building the building right"
(Zigmund Rubel)



Graphics from the book **"Integrating Project Delivery"** by Fischer M., Ashcraft H. W.

Simple framework for IPD

Let's start by working backward, from the product, that we have agreed to deliver. Martin Fisher, in his book *Integrating Project Delivery*, writes:

"A **high-performance building** is one that enables its end users to be more effective; it's the right building for their needs, a building usable, buildable, operable and sustainable.

A high-performance building is able to demonstrate that it meets the values and objectives stated by the owner at the beginning of the project, using **specific metrics** developed to evaluate its achievement.
It is composed of **highly integrated systems**, where systems are designed to work together and complement each other.

The nature of these integrated systems means that many people from disparate disciplines and trades must **work together**, **collaborate**, and **exchange information**.

This **integrated organization** brings owners, architects, engineers, and builders together on a daily basis in the same physical space on site, where they are able to jointly solve complex problems.

The owner, design and build team needs an **integrated process** to produce an **integrated building**, and must take time to design ways to work together from the very beginning.

Collaboration and co-location allow an integrated team to perform those integrated process. To work together effectively, the team must have a way of communicating reliably and efficiently.

Integrated information, which supports **simulation and visualization**, and easy access to that information are intensively used to create a transparent process, in which all members of the team understand the work at all times.

Simulations and visualization enable team members to share their knowledge effectively, try out design ideas, separate fact from fiction, contrast good solutions with poor solutions, and communicate with other team members and stakeholders.

No one person or discipline is the gatekeeper of information or interpretation. Integrated information also allows the team to simulate the performance of the building, allowing the design to be **evaluated in terms of performance metrics** before it has been built.

In other words, by building a comprehensive and appropriately detailed **virtual prototype**, the team members are not only able to understand the incredibly complex creature they are dealing with, but they are also able to evaluate whether the building will perform as they intend and make timely adjustments accordingly.

To deliver the building that owners want and users need, project teams must be able to see the design they are creating and its performance vividly, early, and repeatedly.

Integrated information, simulation, and visualization make that possible.

Fundamentally, **IPD** is motivated by the belief that no part of the design, construction, and operation process should be left to chance. Because we do have control over much of the process, we can also track our efficacy. **Meaningful metrics**, not simply data collected, must be used to track both how well team is performing and how closely the building conforms to the goals and values of the owners.

Upholding the entire **IPD** system is a **contractual agreement and framework**, which sets the "ground rules" for the project, and reinforces the idea that decisions can and must be made for the good of the project, not just for individual benefit.

The contract will encourage and enable all integrated delivery systems thereby allowing organizations and individuals to share information, collaborate, innovate, and challenge each other without fear of retribution."

This approach turns the traditional Management Practices upside down. It is based on the concept of **Lean Thinking**, a typical characteristics of the Digital Era and suitable to create innovative solutions.

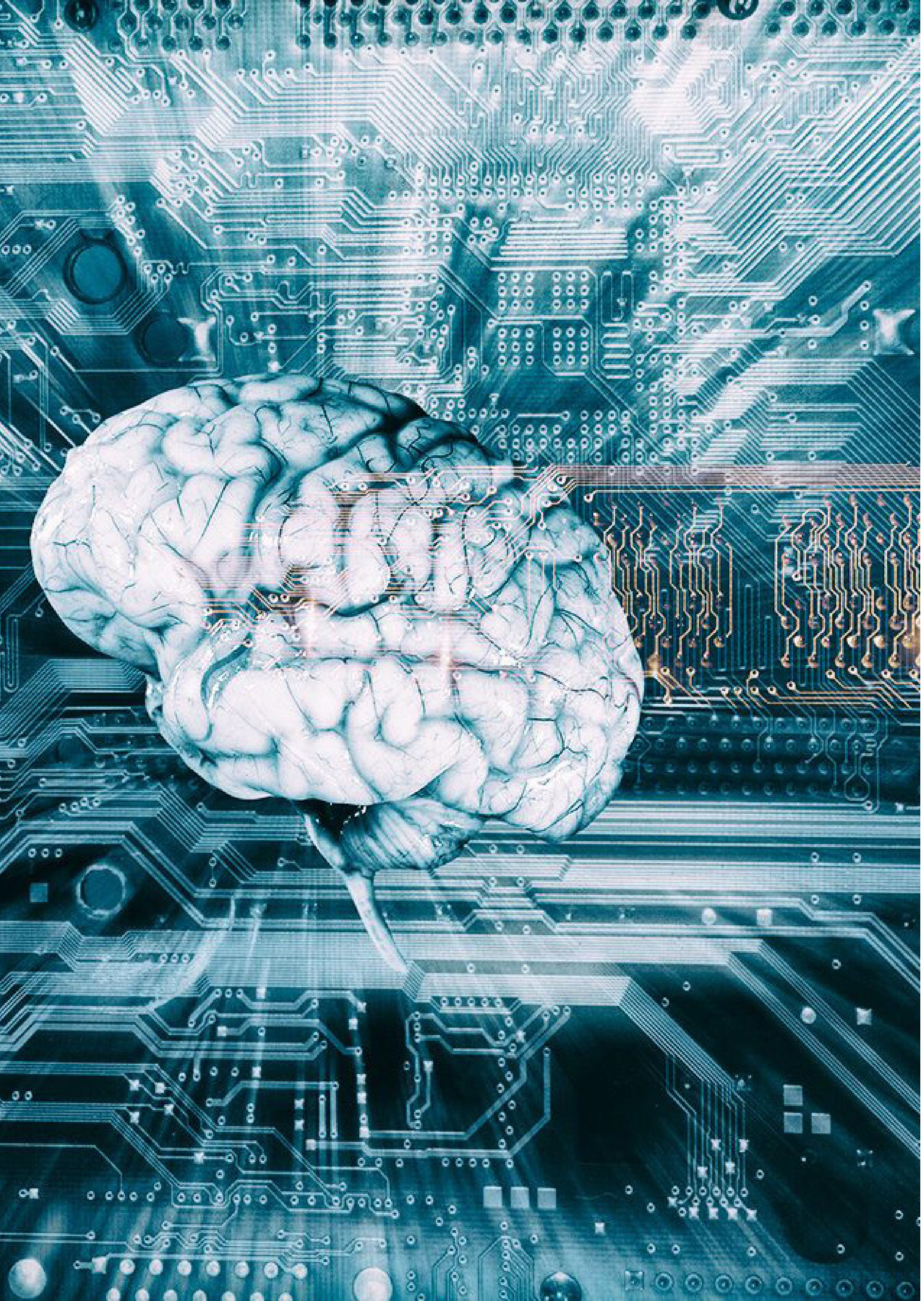
The IPD represents a new design methodology which involves:

- People
- Systems
- Company structure
- Technologies and Techniques

in a collaborative process which exploits the talents and insights of all participants to reduce waste, optimize efficiency in design, manufacturing and construction phases.

According to the IPD Alliance, the IPD guiding principles are:

- Mutual Respect
- Mutual Benefit
- Early goal definition
- Enhanced communication
- Clearly defined open standards
- Appropriate Technology
- High performance
- Leadership



BIG DATA AND ARTIFICIAL INTELLIGENCE

How to use and manage big data and artificial intelligence in the AEC industry.

Big Data is invading the planet, and in the field of engineering, just as in every other area of knowledge, **the volume of data** that is **produced** every day in the world, structured or otherwise, **tends to increase exponentially**.

In 2016 alone, about 4 zettabytes of data were produced (one zettabyte is equal to 1000^7 = 10^21 bytes= 1 sextillion bytes), and it is estimated that by 2020 this number will grow to reach 44 zettabytes (90% of which are not structured).
Given this enormous volume of incumbent data, every company will be obliged to equip itself with hardware and software architectures capable of ensuring its **optimal management**. The engineering sector, in particular, will have to adopt powerful data-capable tools that can analyse, process, interpret and fully harness the power of this information, with the goal of **generating implementable design solutions for every kind of project**.

In professional practice, **various problems must be considered**: firstly, regional and **territory-related restrictions** must be identified; thereafter, the multitude of prevailing **local laws** and regulations must be studied for relevance, as well as any **EU directives** applicable to the project under consideration; finally, a complete reference archive should be compiled comprising material produced with all the most up-to-date **analytic techniques** available (orthographic and stereographic photography, GIS, forecast models, databases, geo-referenced thematic mapping, etc.).

The preceding list should also include any **site-relevant risk** or **environmental analyses** obtained from geological, hydrogeological, climatic, pedologic and vegetation studies. It is also necessary to constantly reference the many technical regulations governing the execution of a worthy design project.

It is important to interpret all these preliminary data in order to verify the feasibility of the work or to identify possible **alternative design solutions**.

Artificial intelligence should therefore prove to be a valid aid in our professional field; it will **accelerate project execution**, offering a competitive advantage to firms that can exploit such an opportunity. The idea of a designer's **Virtual Assistant** was thus born: an artificial dialogue partner capable of managing, interpreting and indicating real-time solutions in relation to the available data and also capable of **supporting the design team** during meetings in order to ease the decision flow.

Indeed, we must acknowledge that we have entered the era of **Cognitive Computing**, and we are aware that there are now cutting-edge tools capable of providing the necessary support as set out by the aforementioned objective. Relevant examples are **Watson** and **iCub** (in its trial commercial version known as R1 - Your Personal Humanoid).

Watson is a supercomputer, an **artificial intelligence system** developed to answer questions expressed in natural language, devised as part of the DeepQA project by a team of researchers headed by David Ferrucci – an IBM technology initiative for the formulation of hypotheses, the massive collection of counter-evidence, analysis and scoring (the ability to reach a goal).
The project was named Watson in honour of the first president of IBM, Thomas J. Watson.

IBM envisioned Watson as a computerised system able to answer questions (a question answering computing system) thanks to algorithms that allow **answers** to be processed in **natural language**, i.e. information retrieval. The application enables the representation of knowledge, automation and automated learning technologies in the field of open domain question answering, i.e. without any restrictions on the topic.

According to Enrico Cereda of IBM, "Watson isn't a computer in the conventional sense; it's a **cognitive system**. Essentially, it **learns** like humans, but it's **much faster**. To understand its potential, just think of one of the things it can do – in a few seconds it can read the equivalent of one million books. [...] **It understands several languages**, including Japanese and Italian, but it doesn't just recognise the words of its dialogue partner [...] When you ask it a question, it t**ries to understand your meaning** by sensing subtle lexical nuances.

"It then processes a number of hypotheses and, in the blink of an eye, presents the plausible answers in a probabilistic manner using natural and comprehensible language"

However, Watson is by no means a technically simple system – it consists of a grid of 90 IBM Power 750 servers, each of which is equipped with a 3.5 GHz eight-core POWER7 processor with four threads per core for a total of 2880 POWER7 processor threads and 16 terabytes of RAM.

Watson devours a huge amount of information and stores it in its immense cloud-based memory – a bank of super-powerful servers housed in IBM centres throughout the world and protected by reinforced concrete walls and sophisticated security systems.
This supercomputer rose to fame in 2011 when it took part in three episodes of the television quiz Jeopardy, providing the **only human-machine clash in the history of entertainment** thus far.

Watson managed to defeat its human opponents in all three televised episodes, outclassing them in terms of buzzer speed, but it did have some difficulty with certain types of questions, especially if they were short and had few words.

Watson could **access 200 million pages of content**, including the entire Wikipedia archive, with four terabytes of disk space, but it was not connected to the internet during the show. In 2011, Watson ran on hardware that would have taken up an average bedroom.

Today, however, the application runs on a machine the size of three pizza boxes, and it is expected that **by 2020 Watson will fit neatly into a smartphone**. The "leap" now required of a system like Watson is the development of a technology applicable to all professions. Never fear, IBM has not been wasting time – they have trained Watson to **learn the terminology of each profession** through the efforts of a group of experts who have taught it subject-specific knowledge in many fields.

In essence, we can say that **today's technologies are already capable of supporting the development of powerful systems that will interact with all professions**.
After the Jeopardy experience and with research constantly advancing, the machine and its machine learning are today being deployed in their first promising applications in several areas, starting with medicine, although **the costs of the technology are still enormous and unquantifiable**.

In health-related matters, Watson's "natural" language makes it suitable as a support system for medical personnel taking clinical decisions regarding patient treatment.

When a doctor asks the system a question, specifying the symptoms and other related factors, Watson first **processes the information** to identify its salient points; it then **processes the patient's data** in order to identify important factors in his/her relevant clinical and genetic history; it then **looks at the available data** to formulate **hypotheses** and **diagnoses**; finally, it provides a list of patient-specific recommendations ranked according to the level of evidence.

IBM's data scientists, engineers and programmers are collaborating with several European organisations to create a new class of cloud-based solutions – a combination of cognitive computing, life sciences and health care. The data typically available to Watson consists of test results, treatment guidelines, electronic medical records, doctors' and nurses' notes, research materials, clinical trials, journals and patient information.

In short, we know that a human brain can contain up to a hundred billion neurons and that each neuron is immersed in a dense network of more than one hundred quintillion synapses [100 x 10^18] (the connections linking the individual brain cells).

What we have, in essence, is a sort of **natural and sophisticated biocomputer** which has often inspired engineers and scientists in the pursuit of artificially intelligent solutions capable of human-like operations. While a normal computer can effectively and effortlessly surpass the computational capabilities of a human being, researchers **have still not succeeded in reproducing** other brain functions such as a **deep understanding of human language** and the ability to satisfactorily **interact** with people.

As such, Watson represents the most advanced artificial intelligence and machine learning project ever conducted by IBM, capable of performing **complex analytic calculations on Big Data** and providing answers that are even comprehensible to non-experts. The purpose of the Watson project is not to "reproduce the brain", according to David Ferrucci. "Rather, it is to build a computer which can be more efficient in understanding humans and interacting through human language, not necessarily at the same level as a living human being".

For example, we know that the "Chinese" supercomputer Tianhe-2 is capable of performing 34 quadrillion [34 x 10^15] computations.
An average human brain stops at 10 quadrillions, but Tianhe-2 occupies an area of 720 m^2 and has so far cost nearly $390 million. And while IBM continues its research to improve the performance of Watson, other researchers around the world are studying how to make computers more "human" and more acceptable to humankind.

Humankind has always perceived this cosmic bond – or simply imagined it – thus sensing the need to engage with artificially intelligent entities which have a similar form, behaviour and ability to hear and perceive others and the world itself, deriving from this a certain sense of warmth.

When humans perceive the need for virtual collaborators, they also yearn for an empathic engagement, imagining them as having souls, emotions and hearts like the Positronic robot "Andrew" – model NDR-114 – bought by the Martin family in April 2005 to serve as a valet-housekeeper in the Chris Columbus film 'Bicentennial Man', adapted from the novel of the same name by Isaac Asimov.

This desire comes from the human heart. Indeed, some have read Asimov's work and then devoted their lives to transforming their dream robots into humanoids with as many human attributes as possible.

As a useful aid for design work, every engineering firm should at least be equipped with a **cloud-connected detachable screen** which can fulfil its necessary support role thanks to leased bandwidth specifically developed for this purpose. It is a question of implementing the storage capacity of R1 and waiting for the prices to drop even lower so that the **Virtual Assistant can truly become available to everyone.**

Indeed, it really does seem that the robotics portrayed in Asimov's science fiction, previously so fantastically removed from reality, is now **converging with the vision of today's scientists**.

This framework needs to exhaustively and exclusively consider the independent variables the project team can and must decide on to create a high-value building.

If we think about what aspects of building projects the project team can, at least of some extent, control, we realize that they fall into three categories: (POP) **P**roducts, **O**rganization, **P**rocess.

The team can decide on the **shape**, **layout**, and **makeup** of the building itself. We call these decisions broadly **product decisions** since they refer to the physical components of a building.
The team can also decide **who** to involve, **when** and **how**. These are **organization decisions**.

Finally, it has to be decided what the different project participants will do, when and in what sequence. These are process decisions.

The POP framework enables the product, organization, and process to align with these multiple goals and be optimized, rather than being bartered against each other in a zero-sum exchange.

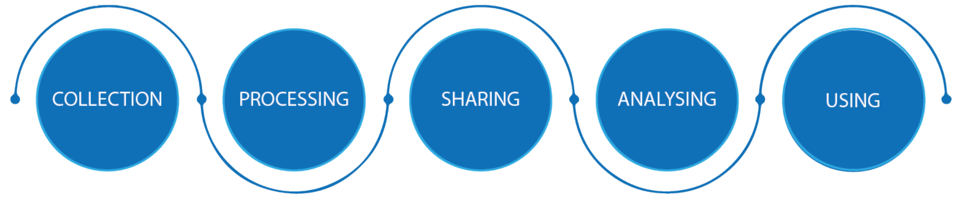
It is critical that these objectives are considered **as early as possible** to avoid suboptimization of the build for a subset of these objectives. It also critical that these objectives are considered in all major decisions, which requires continuity of staffing and definition of methods for predicting and measuring objectives. **POP matrix** is an additional way to align and manage the many **performances**, **objectives** and **metrics**. We need many model-based analyses and simulations to validate predictions and support decision making.

Once again, specific algorithms and artificial intelligence will play a key role. A data analist will assist the client in making the most of the outcoming data, thereby giving them an edge over their competitors.

"Data is the new oil" is the often - quoted mantra these days, and for good reason. Unlike physical assets, data does not get "used up". It can be replicated and used in multiple applications without diminishing its value. In fact, the value of data increases as more data is collected - a sort of "data network effect".

"Artificial intelligence and the internet of things are creating products with the ability to learn and improve the more the products are used, because the more they are used, the more data they collect, the more refined their functioning becomes."
(Sunil Gupta, Driving Digital Strategy)

data life cycle



DIGITAL DASHBOARD

How to organise and manage real time integrated information.

In general, digital dashboards allow managers to monitor the contribution of the various departments in the organization.
To gauge exactly how well an organization is performing overall, digital dashboards allow you to capture and report specific data points from each department within the organization, thus providing at a glance views of key performance indicators (KPIs).

Benefits of using digital dashboards include:

- Visual presentation of performance measures
- Ability to make more informed decisions based on data collected
- Gain total visibility of all systems instantly
- Fast identification of data outliers and correlations

Dashboards are usually a series of graphics, charts, gauges, and other visual indicators that can be monitored and interpreted.
The success of digital dashboards depends on the metrics that are chosen to monitor.

In his book, "*Integrating Project Delivery*" Fischer writes:

"Decisions in a complex design and construction project are made constantly. As the project progresses and conditions change, the owner and the project team must respond swiftly. And the decisions need to be well informed. Team leadership must have ready access to the latest relevant information including cost, scope, schedule, and quality."

"Integrated information coordinates information from all disciplines to provide an accurate representation of project reality"

Integrated information is the neural system of the management process.

For Martin Fischer and others: “Integrated Information has five characteristics:

1. It uses a common language for sharing the information so that it can be understood by all parties. This requires protocol, naming, and interoperability standards;

2. It is readily accessible by all who require the information. Ideally, it is stored in an organized virtual data library;

3. It is unique and reusable. Data reflect the needs of all users and are structured to contain the information required by different parties;

4. It has a source of truth, which allow the users to determine its reliability;

5. It is aggregated into dashboards from cross-functional sources to provide a current and accurate representation of the project. “.

The dashboard is an essential tool for summarizing information which is helpful in taking decisions.

Garcia used the **DEEPAND framework (D**escribe, **E**xplain, **E**valuate, **P**redict, **A**lternative formulation, **N**egotiate, and **D**ecide) to describe what the work teams do in meetings to reach decisions.

One of the goals of integrated information is to remove the waste often associated with the first two DEEPAND tasks.

Building information modeling (BIM) representing all the disciplines in a single model is a good example of integrated information.

This integrated BIM model allows team members from the various disciplines to understand the dependencies of their work on the other disciplines.

For Martin Fischer and others, “ the value of designing an integrated information system at the beginning of the project:

1. Creates a better information environment that creates the transparency needed for the team to do its work;

2. Starts building trust and a collaborative culture;

3. Avoids miscommunication and waste caused by inconsistent and incompatible systems.”

A well-constructed BIM Execution Plan (BEP) reduces waste by bringing clarity to roles and deliverables. It usually describes:

1. The goals of the use of BIM on a project

2. The roles and responsibilities of the players who are involved in the BIM process

3. The level of development (LOD) that the models will develop

4. The naming conventions and interoperability of the various systems incorporated into the BIM.

5. The protocols for model sharing.

Through measurement, a team can **gain control over the objectives** of a project and **how to achieve them**. Measurement and control are directly related.

Choosing and making measurements is a first step towards control. But to be useful, **the information must be aggregated** and **summarized** in an well-designed dashboard to give project management a complete overall picture of project performance.

A team cannot manage production well in any phase of a project without looking at metrics for value-adding work versus waste.

Martin Fisher says:

“In practical way, metrics form the basis of project management and define the actual task that a project manager and project teams undertake.”

“When a project team has enough metrics and collects the data about those metrics in a consistent and low-overhead way, they can be aggregated to provide insight into the process of the job.”

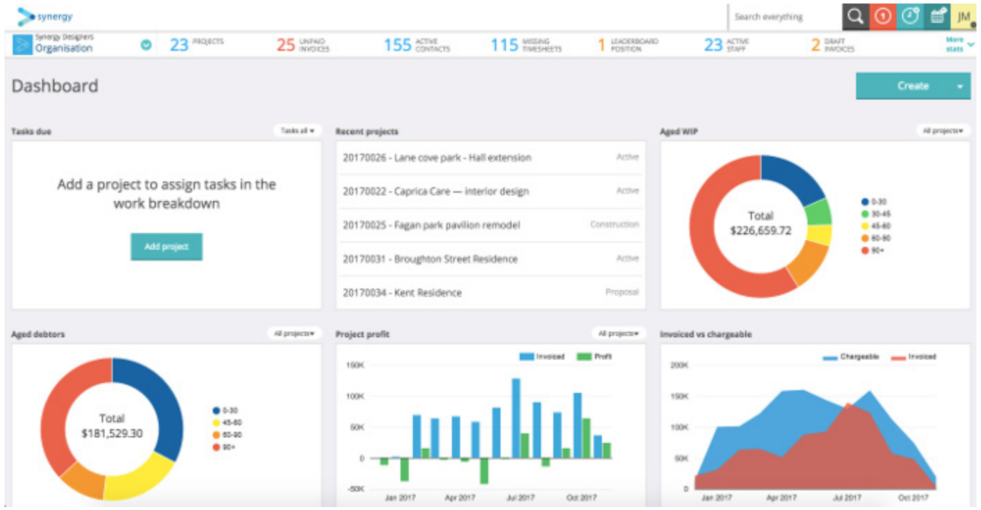
“One way to think of production is like the dashboard of a car.”

“The car’s dashboard gives the driver feedback on the state of his vehicle and, crucially, allows him to change the way he is driving before catastrophe strikes.”

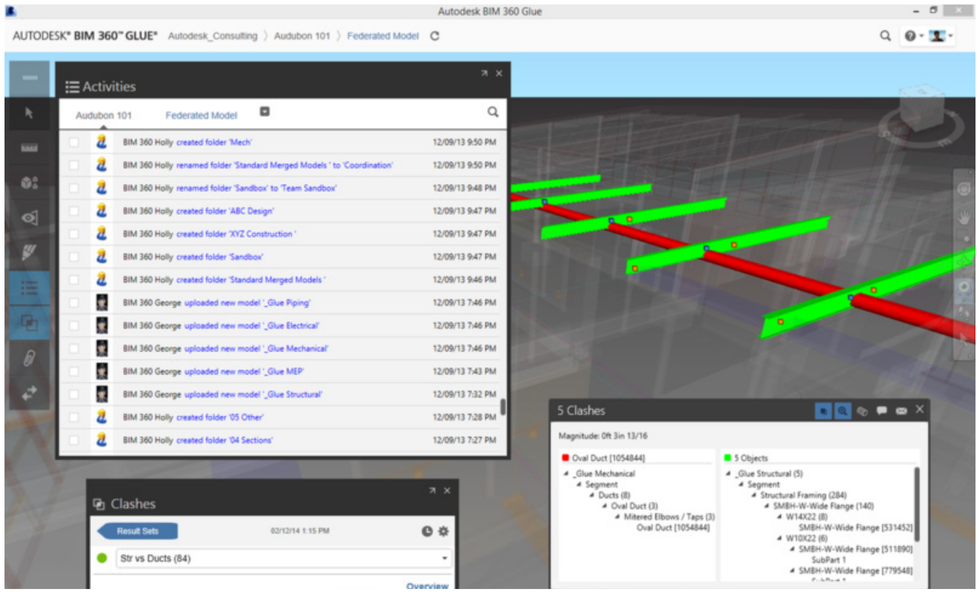
“With no dashboard, the only way a driver can know if he is making a mistake, is after he experiences the disastrous results; he has had no advance warning and no way to adjust his behavior ahead of time. This dashboard analogy is also useful in understanding the development of effective metrics.”

“Successful construction projects must also have a useful dashboard that provides real-time information that the team can use to adjust its delivery process midstream.”

“In fact, most modern construction projects already track a variety of metrics. With the widespread adoption of design and construction software at every level of a project, numbers are easily available and can be included in spreadsheets, charts, and graphs.”



Cost control and design progress dashboard - Synergy



BIM clash detection and activities management dashboard - Autodesk BIM 360 Glue

VISUALIZATION AND DEMATERALIZATION

Virtual and augmented reality.

INTRODUCTION

At this point, it is important to explore how the evolution of devices and application techniques related to virtual reality and augmented reality will **impact architecture and engineering** bringing “scalability” to the construction market in various ways. Intuitively, the collective imagination should have a fair appreciation of the immense potential of these extraordinary instruments given that museums all over the world can now portray heritage artefacts as they were in their heyday, with the possibility of virtually walking through ancient buildings and interacting with them, as if a time machine had projected us into the remote past.

To experience such “**journeys**”, it is sufficient to have access to basic devices such as:

- a **viewer**, i.e. technical glasses or a sort of helmet that obscures the wearer’s view of the real world and allows them to watch special screens that project either a completely virtual environment or a real scenario where new elements have been introduced to enhance certain features;
- a **headset** through which the wearer can hear sounds, noises and music;
- a **pair of wired gloves**, which serve to execute movements and type commands on virtual keyboards without the need for a mouse, keyboard, joystick, etc.;
- a **special suit** that envelopes the body (the cyber-suit), through which we can perceive touch and which can perform a 3D scan of our body and then transfer it into the virtual space.

Given the existence of these devices and their potential to make visible what is normally invisible, to hear sounds, smell fragrances and feel barely perceptible tactile sensations, we can be **projected into new or augmented realities**.

Why not consider architects and engineers as **dreamers** capable of incorporating their dreams into the **designs** which they then follow until they are a **reality**?

Dreams live in a completely intangible world, a virtual reality that has not yet materialised and is often distorted and intensified; as such, it is augmented compared to actual reality. We could assert that virtual reality and augmented reality devices do nothing more than **exploit** the **brain's inherent mechanisms** and help us to imagine what we often cannot see, to look at what others can perceive, or to view ancient realities that others have witnessed.

If we consider a client who wants to buy a property or the people who will use a building – or even public administrations and bodies who intend to invest in infrastructure and asset maintenance, railway managers responsible for line repairs, etc. – it is clear that **the availability of these tools could be of the utmost importance**.

Clients could be **guided in their choices** by the ability to "**experience**" the designer's concept as if it were already a reality: the form, dimensions, available spaces, overall visual impact and colour schemes could be optimally assessed at the design stage.

The evaluations and subsequent executive decisions on the part of public administrations would also be easier to implement, since the envisaged design would have **the aspect of the finished structure**. It would be possible to go through the building and assess its functionality using all the senses.

Such devices would be of great help to maintenance staff, who could view **MEP systems which are no longer accessible**, such as underground cables, electrical routing, ducted pipelines and the infinite mechanisms that characterise every project that has multidisciplinary features.

The potential of this technology is vast and much remains to be explored, but in order to gain a realistic understanding of what the future holds in store, we should clarify some concepts.

When talking about technical glasses, suits, headsets, and gloves, we are referring to **immersive virtual reality** (IVR), whereas when we are in front of a personal computer monitor, we are simply in the presence of a **non-immersive virtual reality** in which we observe a three-dimensional space and interact with it by means of dedicated devices – called joysticks in video games – to control what is displayed.

Clearly, the total absorption associated with immersive reality is much more effective at distancing the user from true reality, creating a much stronger engagement with the perceived effects and sensations. Another point which is easily confused is the difference between **virtual reality** and **augmented reality**.

The term virtual reality – metaphorically used to denote a set of lies or **illusions** in which an individual believes or seeks refuge – denotes an actual simulation of true reality where we can navigate in real time in a photorealistic environment and interact with the objects found there.

Augmented reality, on the other hand, evokes a sort of **mix between a perception** of our surrounding reality **and images** generated by a computer, with the aim of providing the user with **additional information** as they move and interact with their actual environment.

Digital tools are never transparent and intangible, and they do affect design work in a pervasive manner: just think of parametric modelling software such as that used in major international architecture firms like Zaha Hadid Architects, or the **CATIA** program designed to join points with smooth curves and used for the first time in architecture by the renowned Frank Gehry to design his complex structures.

The onset of virtual reality and augmented reality is probably destined to play a similarly **decisive role in the transformations** that will impact architecture and engineering practice. Yet, while the way forward is universally acknowledged, the transition has not yet taken place, and we are currently experiencing a rather turbulent phase.

The adoption of *immersive reality tools* requires a careful analysis of **several complementary aspects** on which we should reflect.

Firstly, there is a **quantitative aspect** to be considered, because the world of virtual reality is growing rapidly: for example, in the spring of 2017, Google declared that since 2014 it had sold more than 10 million devices at very affordable prices, leading the company to predict an overall turnover of $120 billion by 2020.

In addition, there is a second factor to be considered: the market is very active and **hundreds of different devices are available**, such as the consumer version of the Oculus Rift viewer, which was launched in 2016.

Industry experts believe that 2019 will mark a sector turnaround, with the "market explosion" settling into a trend of steady widespread diffusion with consistent sales.

In fact, Facebook plans to invest more than **3 billion** in VR over the next decade.

AR stands for augmented reality; it allows real-world perception to be enhanced with superimposed digital content such as sounds, graphics, video or other interfaces.

This category includes devices from **Google Glass** as well as the more recent Hololens and Microsoft's augmented reality viewers.

Even if virtual reality is commonly regarded as the ultimate display technology, in truth, it is augmented reality that is more widespread, with a higher turnover and a superior level of technology.

In terms of interior design, this is certainly the most established system for many giants of the industry.

For example, **Ikea's augmented reality catalogue** can show how the Ektorp sofa will look in the customer's own living room, thus facilitating colour selection and, above all, allowing the item's dimensions to be judged in the context of the space available (14% of Ikea's returns are due to customers wrongly assessing the size of furniture items).

Augmented reality is also used in urban contexts by local administrators to more clearly illustrate to citizens the effects of future transformations that will impact their areas.

The advantage of this participatory approach is the anticipation and reduction of future conflicts. Another example of the creative use of augmented reality was provided by Y.O.U., an education support community based in Brooklyn, which commissioned an architect to design a school building: the "immersive" video in which the students **defined the contents of the virtual spaces** formed the basis for a **Crowdfunding** campaign, thanks to which the building was actually built.

THE CLIENT RELATIONSHIP

Digital tools dominate all aspects of engineering practice. Their use is manifest in the preliminary analysis phases (surveys, GIS); the design phases (CAD, BIM, parametric modelling); project design submission (rendering, video); testing and commissioning, verification and restoration.

As such, it is reductive to consider augmented reality or virtual reality in association with just one of these procedures, although **their main applications do currently apply to the presentation of project design content**.

Indeed, it is abundantly clear, even to those who are not directly involved, that the ability to be immersed in a space that does not truly exist but is perceived as realistic significantly **lowers the communication barriers** between design professionals and their clients.

The success of these immersive reality technologies is mainly due to their ability to immediately **render the perception** of the relationships of **scale between the environment and its objects** – i.e. how small or large a place is – and the "subjective" perspective.

These are precisely the most significant impressions that arise when exploring an architectural space in the real world, and they are also **the most difficult to render with traditional** two-dimensional communication media (floorplans, elevations, sections, axonometric projections, exploded 3D views, etc.), which are very abstract and bear little relation to reality for the untrained eye.

This case demonstrates the mature stage of development that this technology has now reached: it can target the general public, with material costs so low that the relevant devices can be given away free of charge.

The impact of this approach on **property transactions** is evident. Think of how important these technologies could be here, with their ability to allow remote sites to be experienced virtually without the need to travel.

On the other hand, they could also be used to illustrate the outcome of a **transformation project** (restorations, repairs, new constructions) directly at the project site.

The relevance of this approach to design work, however, is not such a foregone conclusion, not withstanding the significant evolution that the sector is currently experiencing.

An online platform, The Construct, has recently introduced the possibility of a number of people sharing the same virtual environment, effectively making it possible to take **virtual group tours** and exchange opinions in **real time**.

Some viewer devices currently on the market are taking an even **more advanced path** (notably HTC Vive and the new Oculus), offering truly interactive exploration through the use of **joysticks** or similar **controls**. Following such a line of development, passive platforms with mere observation features would evolve into "places" where it would be possible to intervene on the model in real time and in a **virtual space**.

Efforts in this direction have been undertaken in the ArchiSpace experiments conducted by Johan Hanegraaf and the architecture firm Studio Associato Meccano. A platform was developed containing CAD drawings of items such as roof skylights and attic staircases inclusive of 3D models, sections, views, descriptions, technical data and photographs.

These solutions ensure that sharing and dialogue can transfer seamlessly **from real to virtual contexts**: in other words, the designer and the client can explore the virtual space **together**, recognising each other as avatars – representations that combine human and virtual characteristics – and commenting on what they see.

Designers can thus **overcome their fears** of not being able to assist their clients while moving through the virtual space, not being able to explain their choices, and not being able to emphasise the strengths and merits of their designs.
Considerable **time can be saved** by such approaches, especially during initial design iterations aimed at refining the client's (frequently vague) ideas. **The benefits for the client are undeniable**, given the possibility of anticipating the potentially agreeable and disagreeable aspects of a design, far more so than could be interpreted from drawings or renderings.

The theme of sharing in architectural contexts arises not only in the relationship between design professionals and their clients, but also between **the various contributors to the project design phase**.

It is normal for many participants to be involved, even at great distances; as a project becomes more complex, it is inevitable that more people will be included.

Gathering all these professionals in one place at the same time is a very difficult, costly and inefficient undertaking.

In these cases, **sharing a virtual work space** can be a very satisfactory solution, more similar to face-to-face interaction than the fragmented communication offered by email. Important engineering firms with offices located around the world (with NBBJ as a prime example) are currently preparing to use virtual reality, primarily as an internal work organisation method.

USEFULNESS IN BUILDING MAINTENANCE

What happens when the structure already exists or has already been built?

Experimentation is still in its early stages, but we can easily foresee some possible developments.

Designers can simultaneously access all the **metadata** that would be typical of a BIM model, with the advantage of direct onsite exploration features. In essence, we can look at a section of a completed structure to obtain information on the distribution of **interior spaces**, **technical plant and structural components**, and also access real data on the state of health of the building, ongoing maintenance work, etc.
In 2014, the company Fujitsu Technology Solutions conducted a research project aimed at producing a glove capable of reading values from certain NFC-enabled sensors (Near-Field Communications, a short-range bidirectional wireless connectivity technology).

The acquired data could then be compared with the contents of a **remote database** capable of updating itself with the sensor readings and directing the maintenance technician in the right direction.

Obviously, the maintenance crew must be issued with the gloves themselves, but they would also employ a stereoscopic augmented reality viewer.

In terms of immersive reality, the potential for effective use by those who deal with structures and technical systems is increasing exponentially. Bentley Systems has developed a prototype for **augmented reality virtual excavations**, an application designed to visualise subsurface utility plant in its real context.
It includes a "slicing tool" that allows the distances between pipes to be measured.

If three-dimensional pipe location data is not available in an existing BIM model, systems can be detected using ground penetrating radar, and layout information can be exported to a 3D platform in order to become an integral part of the augmented reality visualisation.

The wearable market is now an established reality that is seeing increasing investment by manufacturers. Thanks to a patent claim filed in South Korea, it has emerged that Samsung is developing an **intelligent contact lens system**: it consists of a contact lens with a miniature display, a camera, an antenna and various sensors to detect eye movements, especially blinking.

The display incorporated into the lens communicates with an external device, a smartphone, and projects images directly into the wearer's eye, allowing for a **more natural augmented reality visual experience** not limited to a small frontal screen.

Stéphane Côté, an augmented reality researcher at Bentley Systems, has stated that in the future, construction workers will have latest-generation smartphones incorporated into their clothing and a wireless display built into their **digital contact lenses.**

Specifically designed and innovative apps will convey visual and verbal instructions for the coordination of all onsite workers, providing the information relevant to the applicable regulations and steps to be taken.

VIRTUAL COMMISSIONING AND TESTING

One of the functions that new virtual reality and augmented reality technologies may perform is the **commissioning**, via a digital model, of certain **structural characteristics** that can normally be tested only once the construction has been completed, or worse, once the furnishing supplies have arrived. This is known as the "**virtual testing**" of a work that is yet to be handed over.

For example, let us consider the case of a hospital design project where it is essential to **optimise the spaces** in order to ensure an **immediate** and **effective response** to possible medical emergencies.
The need to reconcile the presence of users and flows of people with very different needs, schedules and dedicated spaces is another critical factor that increases the complexity of the architectural solutions and systems to be designed.

In such a dynamic and articulated environment, design elements (exits, furnishings, systems, etc.) **must be positioned effectively**, avoiding even minimal conflict so as not to compromise the handling of emergencies.

Therefore, the ability to test the operation of a bed in a restricted space – such as a ward or operating theatre – thanks to computerised and **virtual reality simulations** will allow for the early detection of errors and considerable time savings.

Thanks to advanced software, the potential scope of **simulations ranges** from the study of ambient **natural lighting** to the **verification of fluid duct capacity**, **ventilation efficiency**, the correctness of the lighting design, etc.

The advantages associated with the opportunities of carrying out "virtual testing" are not only demonstrated in complex cases such as health facilities, but also in the more common situations typical of hotels or retail outlets.

In the first case, the rooms of a hotel can be prototyped down to the smallest detail in a **virtual environment** that will also allow for interaction with the details themselves (opening drawers, reaching shelves, folding movable partitions, etc.).

In the second case, we will be able to simulate customers' **virtual reality visits to a virtual store** and analyse their reactions to the decor and product placement as well as studying their preferred routes and much more. This could help to optimise product placement and display in order to direct customer attention towards specific items or areas of the store.

The challenge in favor of **environmental sustainability** will be considered successful if it takes place through a **dematerialization** of works, the use of **virtual reproduction** for the majority of places dedicated to free time activities in all fields (exhibitions and museums, cinemas and theatres, dance halls and sport facilities, conference, tourism and commercial activities) up to and including assistential and educational facilities which, however, will continue to be designed but **effectively be accessed by means of virtual reality**.

This technology can also **allow the elderly**, **the disabled and the less affluent access to virtual tours** of all kinds, reducing travel frequency and energy consumption.

Restauration will be limited only to situations of real convenience, especially destructive events which require total or almost total reconstruction. In these cases, the **virtual reconstruction** of environments will be preferred in order to **preserve their historical memory**.

Goods and services will be purchased via **architecturally well-finished, virtual exhibition spaces** where holograms can be sent to interact with other holograms, all this without moving from home and living an experience similar to the real one or even more engaging.

The **savings** in terms of **construction materials**, **energy** and land use are evident.

The three digital accelerators already mentioned in the introduction will soon make virtual reality possible in **ways that our imagination can now only hypothesize**.

Martin Fischer writes:
"Through simulation of a building's behaviour, BIM enalbles exploration and optimization across multiple dimensions of cost, quality, and schedule. This results in **better performance predictions**, which are vital to enable productive collaboration among the multiple disciplines and create an optimal workflow.
Not only is the resulting building optimized, the process for creating the building is optimized, as well.
Virtual Design and Construction (VDC) methods can be used to predict the **performance** of buildings for these performance criteria.

Through simulation, the team can **build virtually** before building physically, testing many different prototypes and options to make the right design decisions based on as much hard evidence as possible - not just human judgement alone."

CONCLUSIONS

It is evident that the evolving technological development of immersive reality is **influencing architecture practice**, the **construction sector** and **construction engineering** in a variety of ways. It will accelerate all design and construction phases; moreover, the increasing relevance of virtual and augmented technologies is transforming both design work and the techniques for presenting projects to clients and stakeholders.

While some scepticism does remain among industry operators, we anticipate that these barriers will be overcome as technological advancement fosters general confidence.

Some solutions will become obsolete and will be replaced by other more innovative and effective platforms, while others will consolidate their presence and further refine their capabilities, but we can affirm with conviction that "immersive technology" will play a **strategic** role in the construction sector in the near future.

3D PRINTING AND ROBOTICS

How this new tools impact the future of the AEC industry

Let us begin by looking at how 3D printing works: the first step consists of using a CAD program to draught a detailed image model of the object to be created; this is saved as a CAD file. The file is then sent to the 3D printer, which **"prints" the object** – not on sheets of paper, but using a **specific material** produced especially for this purpose.

With conventional 2D printing using a common inkjet printer, we had a head moving back and forth on a horizontal axis over a paper sheet that was gradually fed forward. The head would spray a thin jet of ink onto the paper and form text symbols or images.
A 3D printer, on the other hand, moves along **three axes** and is therefore not restricted to the two dimensions of a paper sheet. Instead of forming successive rows of ink, it lays down material, depositing it layer by layer. The material can be plastic, metallic or polymeric – in liquid or powder form – and may be used, for example, to simulate the texture of **human tissue**, **ceramics**, **resins**, or construction materials such as **sand**, **stone** and **marble**.

These materials are generally available in the form of spools of **filament** which, when heated by the 3D printer head, become malleable and can be deposited in **successive layers** until the desired object is fully formed. The thinner the deposited layers, the better the resolution. A typical thickness is 0.1 mm, but there are printers capable of thicknesses of the order of 0.02 mm. At these resolution levels, it is necessary to add a precision factor that takes into account the density of the material particles under horizontal alignment.

In recent years, 3D printers have **spread to many industries** thanks to advances in printing technology and the wide variety of materials that can be used. Hence, their **costs are dropping** rapidly and the machines are becoming accessible to both small and medium-sized businesses as well as private individuals.

At present, their operation can be described as **almost perfect**, as opposed to their early days when they were mostly used in industrial applications to make “rudimentary models” of objects destined for production (the so-called prototypes).

3D printing technology has improved to such an extent in the creation of **precisely defined objects** that it has essentially displaced the rapid prototyping sector. The market offers a wide assortment of models that address a variety of applications. From desktop printers which meet a multitude of diverse requirements ranging from teaching, work, hobbies and professional applications to home-grade machines for enthusiasts – often associated with academic activities – and industrial printers.

From an international perspective, testing is underway on materials that can be used to build **concrete structures**. In China, the **WinSun** construction company builds houses and buildings using 3D methods and can “print” 10 houses of about 200 m² in just one day, at a cost of about $5000 each. The company built a very elegant villa of 1100 m² by **separately** “printing” various individual housing **modules**. Four extremely large printing machines – each 10 metres wide and 6.6 metres high – “printed” the structure in sections using special construction materials and a **layer-by-layer** technique to compose each element.

In Italy, Tuscan entrepreneur Enrico Dini, an engineer with a background in the footwear industry, founded his company **D-Shape** and managed to **“print” homes** using a low-cost material – sand.
He has been nicknamed “the man who prints houses”, and he dreams of building large eco-friendly homes with his printers.

He is currently “printing” sections of coral reef to create “fish shelters” i.e. natural fish habitats. This work is being done in Bahrain and in the Larvotto marine reserve (commissioned by the Prince Albert II of Monaco Foundation).

He is also designing a **3D-printed bridge** in Spain, and he is involved in a project to build partially **3D-printed houses** in an African country, along with another which aims to reconstruct the monuments of the Palmyra **archaeological site** destroyed by Isis.

Another interesting project was developed in Barcelona following a study carried out by the Institute for Advanced Architecture of Catalonia (IAAC). This led to the idea of Minibuilders.
Robotics has great potential for the future development of 3D printing in architecture applications, but there is an intrisic limit – robots can print items of **their own size** and no larger. Researchers working on this critical issue came up with the idea of **simultaneously deploying three robots** to overcome the problem. Working as a unit, each compact robot moves on its own tracks.
Theoretically, such a unit could build structures of infinite size, with each robot connected to sensors that control its movements as it deposits layers of quick-setting artificial marble mortar.

The “Foundation Robot”, the leader, “prints” the first 10 layers of material and lays down the foundation footprint; the second machine, the “**Grip Robot**”, moves along what was previously “printed” and deposits a number of shell layers; finally, the last machine, the “Vacuum Robot”, uses vacuum suction to **clamp itself** to the surface and moves in free-form fashion over the newly constructed shell, adding further material to the surface and thus ensuring additional structural strength. The combined action of the three robots therefore solves the limitation in question by means of a **scalable technology** capable of constructing structures using tools with shapes and sizes that are independent of the final dimensions.

Another experiment that is changing the way we conceive construction engineering is underway at the University of Southern California, where a multidisciplinary research group is studying the applications of **Contour Crafting** in the construction of large-scale ceramic sculptures, modern civil structures, and those to be built on the Moon and Mars. This construction technology is capable of assembling large components.

The system comprises robotic arms and **extrusion nozzles** controlled by a computer. The structure is built quickly using the layer-by-layer technique, achieving remarkable energy savings and a superior surface finish quality compared to existing methods.

The striking aspect of this process is that a single house or group of houses, even with different designs, can be **assembled** in a single pass, including the fitting of all electrical, plumbing and HVAC ducts. With this system, it is essentially possible to build a 100 m² house complete with walls, floors and fittings quickly and economically.

As a research project, the goal was to apply Contour Crafting to the construction of **entire villages** on **other planets** - in the pursuit of human colonisation before the end of this century - or to civil structures or emergency housing for events such as earthquakes and floods, with drastic reductions in costs and lead times.

Another interesting project was undertaken near Copenhagen in Denmark – a **sustainable dwelling** named Villa Asserbo, designed by the architecture firm Eentileen, was assembled in just **four weeks**. It was created thanks to a "3D model" which constituted the design specification saved as a computer file and sent to the "printer"– in this case a high-precision computerised milling machine known as a CNC machine – to cut the wooden shapes to the required dimensions.

This cottage is devoid of brick and concrete; it was built with 820 sheets of certified timber harvested in the nearby forests of Finland (where 10 saplings are planted for each tree felled). The eco-home of the future generated very **little raw material waste**, true to its mission of achieving optimal construction economy. The use of steel was kept to a minimum, while photovoltaic and solar thermal panels were incorporated in keeping with the building's "green" ethos.

The structure is not restricted to Denmark; it is a "global" design.
The design file can be sent anywhere in the world – with access to the file, a CNC machine and the assembly information, the house can be "printed" in any country.

Another ambitious project is nearing completion in Gardiner, New York, where architect Adam Kushner is building a 3D-printed residential unit. It consists of a three-bedroom house of approximately 200 m², a Jacuzzi, a 200 m² swimming pool partly covered with a 50 m² gazebo, and a carport.

To realise this dream, Kushner contacted Enrico Dini, who assembled an adapted D-Shape printer capable of making objects in a variety of stone-like materials obtained by combining sand, other inert materials and a magnesium-based binder.

Dini himself said: "The printer to be used on the Kushner estate is the fastest ever built, and it was developed for a multi-year contract with the Italian Ministry of Defence to create camouflaged shelters for military applications, signed in 2010".

The Jacuzzi, the pool and the gazebo will be built first using **rock** and the **magnesium-based binder** as the construction material. The most complex parts will be printed by reinforcing the concrete mix with aluminium filament or steel swarf fibres.

The first step will be a reduced-scale 3D printing of the entire complex, then Dini's printer will be shipped across the Atlantic to the US. In conclusion, 3D printing will be deployed in increasingly important construction engineering applications as printing technologies and the necessary materials evolve. Costs will be driven lower, thus facilitating the widespread adoption of these methods. As we have seen for certain printing contexts, robotics can certainly be of great assistance in this endeavour.

Collaboration between MIT and Wyss has produced a new 3D printing-powered micro fabrication technique, called ImpFab, which produces objects with nanoscale features.
With this process it is possible to shrink objects to 10 times their original size with extreme precision.

Robotics is the branch of **mechatronics** which studies and develops the technologies that enable robots to reproduce human actions, including **intelligent thought**. For this reason, it comprises the most disparate fields, from scientific disciplines – such as mathematics, physics, mechanics, electronics, computing and automation – to areas of the humanities like linguistics, psychology and sociology.

It also includes specialisations such as biology, physiology and medicine. Robots are becoming increasingly sophisticated and intelligent "organisms" capable of **reproducing human behaviour**.

For its part, the study of artificial intelligence (AI) – the design of hardware systems and software programs capable of endowing computers with abilities **similar to those of humans** – is attracting the attention of world-famous scholars who are cooperating in a revolutionary development of the human-machine entity.

Indeed, it is estimated that global spending on robot development will **increase** from $15 billion in 2010 to $67 billion in 2025.

All these examples confirm and clarify that the **future of construction** cannot disregard the use of 3D Printers and Robots; consequently, it raises a series of questions about how these technologies will affect:

- how to design works;
- how to organize construction sites;
- who will manage the two processes;
- how to be constantly updated on the latest available prototypes.

CONCLUSION

It is not easy to answer all questions, but surely it is clear that the method to follow is the one suggested in this booklet:

- to discover, understand and analyze future trends;
- to learn how to use the latest advanced technological tools;
- to implement new management methods that ensure innovation and experimentation through fast feedback cycles with end users;
- to take decisions using simulations, data analysis and information;
- to learn how to organize information on a dashboard designed for each specific project;
- to learn how to implement cognitive collaboration.

By following these principles, The Consulting Engineering Industry, will be able to fully manage the construction processes and become the main actor in the innovation of the AEC industry.

BIBLIOGRAPHY

Bhargava R., **Non-Obvious 2017: How to Think Different, Curate Ideas and Predict the Future**, Ideapress Publishing, 2016

Boi M., Boi P., **Engineering n - Engineering the Future or the Future of Engineering?**, Te.x 2017.

Boi M., Boi P., **Ingegneria elevato n, Ingegneria del Futuro o Futuro dell'Ingegneria?**, Dei Merangoli Editore 2017.

Brunson R., **DotCom Secrets: The Underground Playbook for Growing Your Company Online**, Morgan James Publishing, 2015

Burrus D., **The Anticipatory Organization: Turn Disruption and Change into Opportunity and Advantage**, Greenleaf Book Group, 2017

Dalio R., **Principles**, Simon and Schuster, 2018

Denning S., **The Age of Agile: How Smart Companies Are Transforming the Way Work Gets Done**, AMACOM, 2018

Diamandis P. H., Kotler S., **Bold: How to Go Big, Create Wealth and Impact the World**, Simon and Schuster, 2016

Duhigg C. , **Smarter Faster Better: The Secrets of Being Productive**, Random House, 2016

Fischer M., Ashcraft H. W., **Integrating Project Delivery**, John Wiley & Sons, 2017

Galloway S., **The FourThe Hidden DNA of Amazon, Apple, Facebook and Google**, HOEPLI EDITORE, 2018

Gupta S., **Driving Digital Strategy: A Guide to Reimagining Your Business**, Harvard Business Press, 2018

Harari Y. N. , **Sapiens: A Brief History of Humankind**, Random House, 2014

Harari Y. N., **Homo Deus: A Brief History of Tomorrow**, Random House, 2016

Ismail S., **Exponential Organizations: Why new organizations are ten times better, faster, and cheaper than yours (and what to do about it)**, Diversion Books 2014.

Kelly K., **The Inevitable: Understanding the 12 Technological Forces That Will Shape Our Future**, Penguin 2016.

Ito J., Howe J., **Whiplash: How to Survive Our Faster Future**, Hachette UK, 2016

Libert M. Beck, J. Wind, **The Network Imperative: How to Survive and Grow in the Age of Digital Business Models**, Harvard Business Review Press 2016.

Martini P., **Blockchain Fast and Simple - What It Is, How It Works, Why It Matters: Understand the Basics, Join the Revolutio**n, independently published 2016.

McAfee A. and Brynjolfsson E., **Machine, Platform, Crowd: Harnessing Our Digital Future**, W. W. Norton & Co Inc, 2017.

Mougayar W., Buterin V., **The Business Blockchain: Promise, Practice, and Application of the Next Internet Technology**, John Wiley & Sons 2016.

Nielsen M., **Reinventing Discovery: The New Era of Networked Science**, Princeton University Press 2012.

O'Reilly T., **WTF?:what's the future and why It's up to us**, Cornerstone Digital, 2017.

Parker T., **Smart Contracts: The ultimate guide to Blockchain Smart Contracts – Learn how to use Smart Contracts for cryptocurrency exchange!**, CreateSpace Independent Publishing Platform 2016.

Ramo J. C., **The Seventh Sense: Power, Fortune, and Survival in the Age of Networks**, Hachette UK, 2016

Ramsey S., Blockchain: **Quick start guide to understanding Blockchain, the biggest revolution in financial technology and beyond since the internet**, CreateSpace Independent Publishing Platform 2016.

Raskino M., Waller G., **Digital to the Core: Remastering Leadership for Your Industry, Your Enterprise, and Yourself**, Bibliomotion, Incorporated, 2015.

Raskino M., Waller G., **Digital to the core: Remastering leadership for your industry, your enterprise, and yourself**, Routledge 2016.

Ries E., **The Startup Way: How Modern Companies Use Entrepreneurial Management to Transform Culture and Drive Long-Term Growth**, Currency 2017.

Rifkin J., **The zero marginal cost society: The internet of things, the collaborative commons, and the eclipse of capitalism**, St. Martin's Press 2014.

Rogers D. l., **The digital transformation playbook: Rethink your business for the digital age**, Columbia University Press 2016.

Schwab K., **The Fourth Industrial Revolution**, Crown Publishing Group 2017.

Susskind R., D. Susskind, **The Future of the Professions: How Technology Will Transform the Work of Human Experts**, OUP 2015.

Tapscott D., Tapscott A., **Blockchain revolution: How the technology behind bitcoin is changing money, business, and the world**, Penguin 2016.

Tetlock P., Gardner D. , Superforecasting: The Art and Science of Prediction, Random House, 2015

Thiel P., Masters B., Zero to one: Notes on startups, or how to build the future, Crown Publishing Group 2014.

Thoren P.M., A Radical Approach for HR & Managers (That Leads to Motivated Employees), Lioncrest Publishing, 2017

Williams D., Tapscott D., Wikinomics, Atlantic Books Ltd 2011.

Williams A. D., Tapscott D., Macrowikinomics: New solutions for a connected planet, Atlantic Books Ltd. 2011.

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