The Big Vision: From Industry 4.0 to 5.0 for a New AEC Sector

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Abstract The contribution offers an overview of the key concepts of Industry 4.0 and the application of enabling principles and technologies in the AEC sector. In this sense, the most promising possibilities offered by the fourth industrial revolution are analysed, hinging them inextricably around the theme of sustainability, in the broadest sense of the term. Furthermore, the chapter addresses the issue of the transition towards the emerging Industry 5.0, proposing a refocusing of technological advancement in a human-centred and planet-oriented key. Moreover, the foundations are laid for a broader discussion around the issue of training the professional figures who will be called upon to manage such complex, interrelated, and systemic processes. What is prefigured is a new professional figure capable of managing the entire design process with a systemic vision through which human sciences are merged with technological research, embedded into a holistic vision necessary for guaranteeing a future of prosperity and economic progress while ensuring a sustainable tomorrow for our planet.

Keywords Industry 4.0 · Architecture 4.0 · AEC 4.0 · Sustainable architecture · Industry 5.0

United Nations' Sustainable Development Goals 8. Promote sustained, inclusive, and sustainable economic growth, full and productive employment, and decent work for all · 9. Build resilient infrastructure, promote inclusive and sustainable industrialization, and foster innovation · 12. Ensure sustainable consumption and production patterns

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1 Industry 4.0 Principles

The term Industry 4.0 (I4.0) was first mentioned in 2011, when H. Kagermann, W. Lukas and W. Wahlster presented their strategic proposal to strengthen the competitiveness of the German manufacturing industry at the Hanover Fair, which was subsequently adopted by the German federal government and entitled Industrie 4.0 [1]. However, although there is still no precise definition of what is meant by Industry 4.0, it tends to be generally understood as the set of new technologies and new factors of production and work organisation, which, in addition to changing the way production is carried out, will also profoundly alter relations between economic actors, including consumers, with significant effects on the labour market and social organisation itself [2]. To establish a more technical and in-depth definition of the founding principles of this new technological era, the literature review on I4.0 publications by Hermann et al. in 2015 [3] is very thorough and extensive. In this publication, the following are identified as key founding components of I4.0: Cyber-Physical Systems, the Internet of Things, the Internet of Services, and the Smart Factory.

Cyber-physical systems (CPS) are a fusion of physical and virtual space. It is a continuous cycle of data exchange, between physical processes and computer calculations, which makes it possible for the former to influence the latter and vice versa. Physical processes produce data that are collected, stored, and analysed by sensor-equipped and network-compatible systems. Thus, a physical process is followed by a computing process with a real-time associated response in the physical world. Cyber-physical systems are the elements behind the definition of the Internet of Things and the Internet of Services. Things, the objects incorporating technological devices that create an interface between the physical and digital worlds, can be understood as cyber-physical systems, whereby the **Internet of Things** (IoT) can be defined as a network in which cyber-physical systems interact and cooperate with each other according to pre-defined patterns [4]. The Internet of Things, a concept introduced by Kevin Ashton in 1999, thus refers to a new method of using the virtual network within physical space, i.e., the possibility of making parts of the physical world and objects interact with each other via the computer network.

With the **Internet of Services** (IoS), there is a leap in scale, in which cyber-physical systems no longer consist of individual objects, but of the individual activities of the enterprise value chain. Thus, the development of this technology enables a new mode of business management, characterised by a dynamic distribution of activities [5]. Based on the definitions already provided for the CPS and the IoT, the **Smart Factory** (SF) can be defined as a factory in which cyber-physical systems communicate through the IoT, to assist people and machines in performing their tasks [6]. CPS create a virtual copy of the physical world and its processes, so in the continuous connection and interaction between the physical and virtual worlds, between machines among themselves and with humans, within SFs, it is possible to make decisions remotely and reorganise processes in real-time. This creates the preconditions, for example, for flexible and ‘intelligent’ production, i.e., based on the real demand for a given product at a given time, in real-time. It can be argued, therefore, that the pivotal point of the current revolution is the entry of the virtual world into the real one, through the IoT and the IoS. We are witnessing the progressive fusion of the physical and cyber worlds, in a new concept of a cyber-physical system. Ultimately, it is the combination of these technologies that define the concept of I4.0. Thanks to the introduction of these new technologies, it is possible to gain an insight into the principles that characterise manufacturing in the new industrial era. As mentioned above, the topic is not historicised and the interpretations are multiple, with boundaries that are still very blurred, sometimes contradicting each other. In any case, given the need to make choices, for a clear systematisation of the topic, it was decided to distinguish between:

- the new technologies (CPS, IoT, IoS, SF)
- the new principles introduced into the world of production (Real-Time Capability, virtualisation, decentralisation, servitisation, interoperability, mass customisation)
- the new IT services underpinning the above innovations (big data, cloud computing, cognitive computing, artificial intelligence, machine learning).

As it is easy to deduce from the description of new technologies, they are based on the collection and analysis of an enormous amount of data. Data is often considered the essential asset of the new era. Therefore, fundamental elements for the establishment of 4.0 are big data and cloud computing, services for storing, processing, and transmitting data, without which, the production and collection of data become essentially useless. Recently, with cognitive computing, we have reached a new level of complexity in data processing, being able to substantially reproduce the functioning of the human brain, to make decisions in the face of a very high quantity and heterogeneity of data and variables. Several principles elevate the factory to '4.0', opening new and innovative scenarios. CPSs monitor physical processes by means of sensors and are at the same time able to analyse and compare the collected data with virtual simulation models. As a result, there is a constant check on the correctness of processes, and any errors or inconsistencies are reported in real-time (**Real-Time Capability**).

Interconnected plants can recalibrate the production plan, restart production on other machines and optimise processes. In this way, humans are supported by the machines themselves in their complex management and, whereas in the past, each change in the production chain required weeks of testing by highly skilled personnel, thanks to virtualisation, i.e., the use of simulation models, pre-production tests take place in the virtual world and the time during which machines are inactive is greatly reduced, resulting in enormous savings in economic terms, making them more sustainable [7].

SPCs are, therefore, able to make decisions and perform their tasks autonomously. Therefore, constant planning and control on site are no longer necessary, making decentralisation of production and decisions possible, which can be managed and controlled remotely. This, of course, means less effort and less time spent by workers on the factory floor, but at the same time more effort in the design of machines and processes. This will lead to a change in the way work is done, increasingly focused on highly skilled intellectual work and less and less on physical work (compensated by machine work). In Factory 4.0, robots and humans may work side by side, thanks to the use of intelligent human-machine interfaces. The use of these new generation robots, called smart robots, will encompass countless functions, from production to logistics to office management [8]. The constant connection between manufactured goods and the manufacturing company (again thanks to the installation of sensors) is leading towards a deep integration between physical goods and services. This process, known as the servitisation of manufacturing (service orientation), will favour entrepreneurial formulas that, in addition to selling a product, will offer constant support services. Customer service will be completely rethought, with an inversion of roles: it will be the company, in fact, that will remotely control the functionality of the product and intervene in the event of anomalies, failures, obsolescence or exhaustion of part of the products. In this way, we will increasingly move towards a market in which the purchase of goods will be replaced by the purchase of services, whereby the manufacturing company will remain the owner of the good and will guarantee its efficiency, maintenance, and eventual replacement. This type of market can only have positive consequences from the point of view of environmental sustainability, since, for example, the disposal of obsolete or end-of-life products will no longer be left to consumers but will hopefully be managed efficiently by the companies themselves. A factor of fundamental importance for the development of the 4.0 vision is interoperability, i.e., ensuring, through compliance with common standards, that all SPCs can communicate with each other, even if they belong to different manufacturers, to create an open network in which everyone speaks the same language [9]. The aforementioned principles describe a highly flexible production model, capable of modifying and reorganising production in a short time, thanks also to the high degree of modularity that will characterise its components. This, together with the ability to collect and process an enormous amount of data, including consumer needs and desires, in real-time, will make it possible to implement customised industrial production. Thus, the specific desires and needs of the individual consumer will once again occupy the central role they played in artisanal production. This scenario is referred to as mass customisation.

To summarise, besides the change in the role that humans will play in the production cycle, one of the most relevant consequences of the application of IoT and IoS to the industrial world is the profound change in production methods and volumes. Being able to know in real-time the demands and needs of consumers and having at the same time great flexibility of the factory, capable of varying for each production cycle the goods produced, the canonical serial productions with storage of large quantities of products lose their meaning, opening the way to customised and on-demand production, returning to a dimension of production volumes and customisation of the goods produced closer to the artisan world than to that of industrial seriality. Consequently, even if one considers only the changes related to the use of these technologies in industrial production, the benefits derived from them are manifold and of considerable magnitude; there is the possibility of a reduction in waste related to overproduction, the optimisation of energy and materials used, and a reduction in the need for built space for storing products. Unlike previous industrial revolutions, whose main outcome was the improvement of living conditions through increased productivity, this latest industrial revolution has the potential to significantly improve human (and probably planet Earth's) living conditions not through increased production, but through the optimisation of available resources for more conscious, targeted, and customised production. As with all previous technological revolutions involving a radical change in the way we live and relate to each other, but above all in the way we work and produce, its arrival is viewed by many with a mixture of scepticism about its true potential and fear that technology will eventually overwhelm man and replace him in his work, making him useless for productivity. However, this evolutionary process is already underway, and the question should be: how can this enormous potential be harnessed to solve cogent problems and ensure a prosperous future and widespread prosperity for mankind?

2 Industry 4.0 and Architecture

The new scenarios outlined by the advent of the fourth industrial revolution are producing a change in the way of thinking about society and the world of labour, with the definition, for example, of new professional figures; however, the most affected field by the change is the industry, with a rethinking of its management, production methods and the products themselves. Even though, in recent decades, it has been a field of phlegmatic with less technological progress, compared, for example, to the rapid evolution of the automotive industry, we believe that the construction sector and its related professionals are destined to become one of the main fields of application of I4.0 and, later, I5.0. There is no doubt that the most important innovation that has taken place in the last thirty years in the design sector is the spread of CAD (Computer Aided Design) systems first, and CAM (Computer Aided Manufacturing) later. Although several decades have passed, the still predominant use of CAD tools is simply a computerised version (computerisation [10]) of traditional drawing techniques. However, since the early 2000s, a new (perhaps fully digital) digital revolution has begun to take hold: from CAD design, we move to computational design. In fact, as Kostas Terzidis states, while the computerisation that has taken place in recent decades can be traced back to the digitisation of established, defined, and predetermined processes to improve their efficiency, precision, and workflow, in contrast, computational design concerns the algorithmic exploration of indeterminate processes [11]. Why is it important to emphasise this step from our point of view? This shift is necessary because computational design is the only one capable of fruitful dialogue with the virtualisation processes inherent to I4.0. In fact, truly computational creation involves the performance of an exploratory materialisation process, guided by cyber-physical responses, which extends the properties of the design rather than simply realising it [12]. Machines, therefore, are made 'intelligent' and become part of the computational design process, not only performing tasks according to predefined patterns but devising alternative responses to improve the efficiency of processes, consequently reorganising production.

Taking the technologies characterising I4.0 and imagining an application of their principles to the field of architectural design [13], it is possible to outline feasible scenarios that could configure the architecture of the 4.0 era. Starting from the principle of virtualisation, it is, therefore, possible to identify at least six levels of virtualisation:

1. **Virtualisation of conceptual genesis**, i.e., concept generation processes based on the use of artificial intelligence (AI) technologies, through the input of a textual description (prompt) to which correspond a series of outputs (and subsequent variants) expressed in the form of raster images or three-dimensional models or textual scripts [14, 15].
2. **Virtualisation of the design process**, i.e., forecasting processes that can address several factors simultaneously, thanks to the increasingly sophisticated development of three-dimensional and computational modelling programmes. To cite just a few examples, it is possible to virtualise the climatic behaviour of a building, simulating the position of the sun at a given time on a given day in a precise location on the globe and the resulting irradiation (under clear skies); or the phases of the construction process and the entire life cycle of a project, thanks to Building Information Modelling (BIM) software; or able to analyse the structural behaviour of buildings, and so on [16].
3. **Virtualisation of the CAD/CAM and robotic manufacturing process**, i.e., processes of prediction, control, and prior verification of Computer Aided Manufacturing phases, referring both to single machining and to several consequential machining operations [17].
4. **Virtualisation of the production process**, i.e., processes made possible by the advent of I4.0, in which the entire production process of the factory is foreseen and verified in the virtual world [18].
5. **Virtualisation of the maintenance process**, i.e., processes of prediction, control and preventive verification of the global and local behaviour of the building throughout its life [19].
6. **Virtualisation of the demolition process**, i.e., processes of analysis and design for the selective demolition of the building and the recycling or reduction of the impact on the environment of the building components that are no longer suitable for the purpose for which they were designed [20].

The affirmation of **integrated virtualisation** may therefore represent a possible way forward, given that designers are already accustomed to a working approach with an important virtualisation component, which would be a key element in the interaction between the design process and the industrial manufacturing process. In other words, the designer would be allowed to take part in the management of the industrial process, through an integrated design that would be able to contemplate manufacturing and industrial production methods right from the design stages. Vice versa, the computational design becomes the subject of work and 'critical' analysis by the intelligent machines involved in the various phases of the design and construction process, which can elaborate, and signal possible modifications aimed at optimising a process, concerning, example, the optimal use of a material according to its performance, or to reduce waste, etc.

This is an aspect that brings with it a series of critical issues, mainly related to the interchange of data between one process and another, hence the need to be able to work on common software platforms or those that can interface with each other. In a state of interconnection between design tools and manufacturing and construction tools, in a continuous exchange of data and control of physical processes, the entire process would become 'informed'—and not simply computerised—enriched and guided by the 'cloud of data' processed in real time.

In this context, the role of the designer should not be seen as marginal. The 'data cloud' can be a tool of extraordinary potential for the architect who can be a good director of the design and construction process. Imagining the application of the technologies characterising I4.0 to the field of architectural design, the architect's work would naturally be supported by the potential of the new tools, but it would at the same time become more arduous and burdensome in terms of responsibility, as the project becomes increasingly integrated, the result of a holistic conception that could no longer be evaded. It is enough to think of the possibility of designing with the support of a software tool that is always connected, capable of informing and consequently conditioning the project with data relating to the project site, the processes involved, e.g., environmental data (climatic data, seismic risk, presence of electromagnetic fields, etc.), and having to ensure that each condition is part of the project with an appropriate architectural response. At the same time, the designer's work would not be limited to the production of drawings useful for the construction site, but could (and should) allow for the management of manufacturing and construction processes through simulation tools of the processes themselves, which would ultimately also allow for the optimisation of available resources, be they material, energy, economic, etc.

Beyond the design moment, the benefits of 4.0 technologies could be no less fundamental if applied to the actual construction. In fact, the construction resulting from a 4.0 production process can be equipped with sensors and technological devices that make it a smart product, connected to the web and capable of reacting, according to different configurations, to the processing of data received in real time. New technologies could become part of the new generation of buildings, not only through minor elements such as furniture and household appliances, but also through the installation of sensors in structural building components ensuring the monitoring of their performance, in plant components to monitor their integrity and energy efficiency, and likewise ensure the control of values related to health and living comfort. New constructions would thus take advantage of the servitisation principle, whereby there would be the possibility for the manufacturing company to remotely detect wear and tear, malfunctioning, or impending failure of a building component, allowing timely intervention with targeted and less invasive maintenance. The characteristics outlined so far, although probably not described exhaustively given the topicality of the subject, make us realise how fundamental the almost exclusive use of prefabricated dry-assembled components is. Indeed, among the various construction techniques currently available, it is best suited to dialogue with the enabling technologies of the 4.0 era. The use of prefabrication, although ‘advanced‘ and ‘augmented’ by 4.0 technologies, would be indispensable for the following reasons:

- Adequacy with respect to digital and computational design processes.
- Total adherence to digital or robotic fabrication processes, especially with respect to wet or mixed systems, which are known to be inaccurate and uncontrollable fabrication/construction processes.
- Greater accuracy in the fabrication of building components, made in a controlled environment and under consistently optimal conditions.
- Greater precision in the construction/assembly phase of building components.
- Greater adherence between design and actual structural and energy performance, thanks to the precision of all execution phases and the use of certified performance elements.
- Reduced production of waste and scrap material during manufacture and construction.
- Possibility, if appropriately foreseen in the design phase, of being able to replace parts that are no longer suitable for their intended function over time.

3 Advanced Prefabrication as a Tool for Sustainable 4.0 Architecture

Prefabrication, by its very nature, implies the concept of prediction. Envisioning the entire construction process during the design phase, and not a posteriori, means having to conceive the project through a method that cannot be based solely on formal considerations, but must constantly relate the whole and the individual parts, according to a coherent and synergic relationship. Prefabrication intrinsically entails a design methodology that cannot disregard considerations on the efficiency of the construction process, since it entails precise planning of the project, which naturally leads to a rationalisation of all the phases of the construction process, from optimisation of the use of materials to optimisation of construction times and costs, up to making forecasts on the discharge of the same with a view to a circular economy and reduction of the environmental impact at the end of the building’s useful life. Manufacturing construction components in a factory ensures greater efficiency in the use of materials, drastically reducing waste. The quality of these construction components is also improved, with certifiable technical characteristics and performance, because unlike traditional construction sites, they are produced in dedicated factories, by qualified personnel, in a controlled environment, under conditions always maintained optimal and with the appropriate technical instrumentation, like what happens in the industrial production of any technological product. Off-site production allows for energy efficiency in all stages of the construction process, as the production of components is carried out in the factory, according to the company’s energy-saving strategies, while the energy used at the construction site is significantly reduced, as the traditionally designed construction site is transformed into a rapid dry assembly operation of the constituent parts. The dry assembly of parts, typical of prefabricated buildings, also makes it possible to conceive of reversible buildings, which at the end of their useful life allow for the selective recovery of materials and their recycling or reuse, reducing or solving the problems generally associated with the disposal of construction materials.

Prefabrication, in short, is a means of producing buildings in a planned, fast, precise, efficient, and safe manner, as is the case for any other goods produced through an advanced industrial process.

To pursue the goal of building by the principles of sustainability through prefabrication practices, designers should be prepared to manage a more complex design process that is no longer consequential, but oriented towards integrated design. Integrated design is a holistic conception of design, in which all participants in the design process contribute simultaneously so that the design is the result of holistic thinking in which all parts are interdependent and contribute synergistically to the functioning of the entire architectural organism. For example, by ensuring that the building is energy efficient and sustainable, not only because highly efficient systems have been employed, but because environmental well-being is primarily pursued by passive strategies integrated into the building design itself. In this way, the final construction will not be the result of an addition of independent contributions and successive stages of project adaptation that, in most cases, distort the designers' original, albeit valid, conception.

Naturally, this new modus operandi entails a great propulsive thrust in the evolution of the architectural conception against a greater complexity and responsibility on the part of the designer, who with his design choices must succeed in synthesising all the contributing disciplines involved in the project itself. Traditional construction practices, slow and uneconomical, sometimes carried out by unqualified personnel according to an approximate execution, can defeat the effectiveness of design choices. They should therefore be mostly abandoned in favour of a largely industrialised process, even if this means profoundly changing the economic organisation of the construction sector. The affirmation of 4.0 prefabrication, however, in contrast to the widespread vision that imagines it as a means for the mass production of buildings that are all the same, to be reproduced indifferently in any climatic zone and socio-cultural context, should be accompanied by important reflections on the design and technological solutions to be adopted, so that these are integrated and appropriate concerning those of the local architectural tradition. This step is important, not only as a means of visual integration, using materials and forms that belong to the local architectural tradition, but above all as a means of extrapolating from tradition the principles of passive architecture that respond to the place and its climatic characteristics. Combining an industrialised construction practice with architectural solutions linked to the context is not to be considered a forced objective, nor an unrealisable vision. New developments in technology are indeed moving towards total customisation of industrially manufactured products. In light of the considerations outlined so far, it is worth reflecting on one of the most relevant aspects that I4.0 could bring about and which, it is worth pointing out, could lead to overcoming the very limits of prefabrication processes as we have known them until now: mass customisation.

The application of I4.0 principles to architecture will necessarily pass through computational design and subsequent digitally controlled fabrication and construction. About the principles underlying these two technologies, it is possible to identify two possible construction processes that, not surprisingly, are becoming the focus of research and experimentation by academic and non-academic research centres, and of public and private funding and investment. We are talking about a new concept of prefabrication, customised digital prefabrication, and technology that is spreading relatively recently in additive manufacturing. These are the two scenarios within which, in our opinion, the construction of the near future will develop.

Additive manufacturing could play an important role in the transition to a more sustainable construction industry. Through additive manufacturing, it is possible to create elements with an optimised shape obtained through computational strategies, eliminating the waste of material, time and money required for subtractive manufacturing or the creation of necessary formworks and counter-moulds. It even becomes feasible and accessible to make complex shapes that would not even be conceivable using traditional manufacturing methods. Digital fabrication makes it possible of working extensively with non-standard products, conceived and create about a specific project or adapted to it, with the use of the materials most suited to the nature of the project or local availability. In addition, the possibility of manufacturing the building elements on the same site as the construction, transporting only the printers as a sort of mobile factory, or entrusting the manufacture of the components related to a given project to one of the digital manufacturing centres spread throughout the territory, would considerably reduce the energy consumption and pollution produced by the transport of all building components from the respective factories to the construction site. However, the centrality of the manufacturing companies in the transition from the general design to the executive project aimed at construction effectively excludes the designer from having a proactive role in the production part and from entering a relationship with the industry, except in more limited cases. Therefore, it is of fundamental importance that, in the affirmation and diffusion of customised digital prefabrication, as a means of moving towards a more sustainable construction process and life cycle of buildings, the irreplaceable work of the architect, who should assume a pivotal role in the transition to an architecture produced with mass production means but with the individuality of a handcrafted product, is not bypassed. The designer, through computational design, should be at the centre of the new design-production process enabled by the principles of I4.0 and digital fabrication. Thus, the construction of buildings with prefabricated I4.0 components lends itself perfectly to becoming a fully digitised process. The designer develops his or her own (computational) design, which is passed on to the digital fabrication machines, optimising the process for making the components to reduce waste of any kind. All components are manufactured and finally assembled to a precision only possible in an industrialised process, thus reflecting the high-quality standards of the design in the finished construction.

4 From 4.0 to 5.0: Towards a More Sustainable, Resilient, and Human-Centred AEC Industry

The 4.0 revolution introduced several cornerstones for the transformation of several leading industries in Western development models, among which we certainly find AEC. The pillars against which this transformation developed were centred on disruptive technological innovations and interconnected cyber-physical systems in which AI was the driving force for increasing the productivity and efficiency of the industrial system. The focus of this transformation centred on the optimisation of a business model is not entirely consistent with the European Union's Agenda 2030 for Sustainable Development or rather does not appear to be the correct framework for addressing emerging and complex challenges such as climate change, resource scarcity and increasingly acute social tensions. The evolution of such a development model must necessarily contemplate some emerging issues that require actions aimed at:

- Introduce a regenerative dimension, with the circular economy as a key element of the entire production cycle.
- Introducing a social and human-centred dimension, promoting technologies designed to assist the workers and not developed to replace them.
- Introducing an environmental and ecosystem dimension that goes from the exploitation of renewable energies and the restoration of biodiversity, as well as overcoming globalisation and the cultural flattening based on it, towards a new model capable of guaranteeing the preservation and evolution of identities and cultures.

Based on the above, it can be said that there is no need for a new industrial revolution, but rather for proper management of the transition from 4.0 to 5.0, which share the same operational tools, and some methodologies, but certainly not the same aims. From our point of view, it is necessary to distinguish between opportunities and goals. Opportunities should be understood as possible enablers of social and economic development and are essential to ensure prosperity and progress. However, it is not opportunities in themselves that generate progress and prosperity: they must necessarily be driven by a set of goals, which can only relate to the most pressing agendas facing humanity such as:

- Overcoming dependence on economic growth as the sole enabler for development and accelerating the development of effective policies and best practices aimed at the sustainable use of material resources.
- The great acceleration of biodiversity loss, climate change, pollution and loss of natural capital is closely linked to economic activities and economic growth.
- The increase in social and economic inequalities, both between industrialised and developing countries and within industrialised countries themselves, with clear differentiation between metropolitan areas and less urbanised territories.
- The fight against the scarcity of potable water by promoting better exploitation of water resources through the recovery and recycling of used rainwater and potable

water and through the development of technologically advanced and precision agriculture.
- Countering the phenomena of depopulation of entire territories and the consequent concentration of an increasing number of people in urban territories that are increasingly large, polluted, and close to collapse.
- The preservation of the cultural and historical identity of territories, and the activation of virtuous dynamics for their evolution thanks to technology; overcoming cultural globalisation.
- Managing migratory flows and eradicating the political, economic, and social causes that incentivise them, to enable the sustainable development of all territories, even those that currently appear most disadvantaged.

It is precisely the aims that represent the key turning point concerning I4.0: an industrial revolution that is not based solely on economic and technological aspects but rather on a multiplicity of factors that configure a vision of restorative and regenerative sustainable development with an inevitable shift of focus from the 'Internet of Things' to 'Digital for people-planet-prosperity'. This paradigm shift inevitably leads to a transition phase linked to the difficulty of clearly and systematically measuring the impact of this transformation on the social and environmental aspects as opposed to the economic and productivity aspects of the industrial system. Underlying this is the enabling technologies that affect virtually as well as physical space closely interrelated through human-machine interaction and the digital twins.

5 A Paradigm Shift in Education to Manage the Transition

Time after time, the act of designing and making objects has remained almost unchanged: the human mind comes up with a design, the hand sketches it out and, finally, the hand works to manually transform the concept into reality. Adding digital know-how to the process sets the basis for realising any mass-produced object. In this scenario, AI becomes a disruptive tool because it can assist the designer in the creative phase up to the materialisation of the digital form. While it is true that tools proliferate with disarming speed, what is lacking is an operational methodology capable of systematising the above and opening up new scenarios through which to respond effectively to the concrete problems of the contemporary era. The use of technology for 'educated' and 'creative' entertainment can unfortunately be configured yet another element of mass distraction concerning the concrete problems that humanity is called upon to face. This risk must be concretely stemmed from using solid technical education, which must now start as early as primary school and continue throughout people's lives. A key element of this process is the inter- and trans-disciplinary approach that must be reflected in the development of an operational methodology capable of providing the right know-how to meet the challenges of the current era governed by the exponential growth of 'disruptive technologies'. In this respect, the role of second-level training is crucial as it should foster the development of a holistic vision supported using tools and technologies that learners should at least be familiar with thanks to first-level training courses. Looking at Italy, for example, the Next Generation EU plan has paved the way for the adaptation of technological infrastructures in Italian secondary schools and the introduction of emerging technologies in education. The *'Scuola Digitale'* (Digital School) plan represents a driving force for this, even if what is currently lacking is a teaching methodology capable of integrating tools and technologies into the teaching programmes of the various disciplines, both humanistic and scientific. It is precisely this last aspect that represents a further transition from I4.0 to 5.0: the interdisciplinary approach, which is necessary to govern complex processes and transformations, must favour the inclusion of the humanities in technological research from the earliest stages of education. However, from the point of view of education, the continuous, rapid and relentless race for technological innovation is making it increasingly complex to update and bring up-to-date school and university curricula. Teachers and researchers are called upon to chase innovation and master it at once to be able to disseminate it seamlessly in the community of reference. This process, in any case, can be very difficult to put into practice since the acquisition of knowledge even by the teaching staff requires time and a necessary degree of theoretical and practical depth: it is not possible to teach something that one does not master effectively and that one does not govern morally and philosophically. Therefore, this perspective calls on universities and research centres to change their model and to open up more and more to the corporations that are the protagonists in the development of these technologies, to foster paths of open innovation and technology transfer. In particular, the theme of lifelong learning and the perpetual structuring of courses dedicated to the acquisition of new skills in the field of technological innovation will lead universities to become management hubs of knowledge transfer. No longer, therefore, almost exclusive holders of the highest peaks of knowledge, but actors capable of organising and facilitating the horizontal distribution of knowledge in partnership with technology companies and with institutions and governments. On the other hand, technological innovation can open up many as-yet-unexplored avenues that can foster self-entrepreneurship dynamics, especially among university students. In this sense, universities must play a fundamental role, systematically equipping themselves with business incubators and accelerators, which can provide fundamental support for all those students who are interested in developing their entrepreneurial idea through the launch of a start-up. Nevertheless, this dynamic should also be encouraged and facilitated among researchers, through incentives and career advancement for those who decide to open and run a spin-off company in parallel with their academic activities, perhaps creating new job opportunities for young graduates or PhDs. In this scenario, the university is called upon to become increasingly 'entrepreneurial', i.e., capable of incorporating into ordinary study courses one or more courses aimed at starting up and running a company or developing a business idea. Such a prospect has the potential to detonate the possibility, widely perceived, of an uncontrolled explosion of unemployment resulting from the endemic spread of technological innovations such as robotics and artificial intelligence. In fact, humanity has two roads ahead of it: the first is to stop the incessant development of such technologies because it is potentially too impactful from a social point of view, especially from the employment perspective; the second, making future workers ready, to be able to seize the opportunities that technological innovation can offer, in terms of creating new (albeit different) job profiles and positions or new business ideas. The key to harnessing the opportunities offered by I4.0 from a social point of view lies in how we manage to channel innovation from a socio-occupational point of view. Indeed, being able to utilise technology to significantly reduce repetitive and time-consuming jobs, while significantly increasing the number of creative and knowledge-intensive jobs, could be a hugely valuable achievement for all of humanity.

6 Conclusions

This contribution offered an overview of the key concepts of I4.0 and the application of enabling principles and technologies in the AEC sector. In this sense, the most promising possibilities offered by the fourth industrial revolution have been analysed, hinging them inextricably around the theme of sustainability, in the broadest sense of the term. Furthermore, the chapter addresses the issue of the transition towards the emerging I5.0, proposing a refocusing of technological advancement in a human-centred and planet-oriented key. Moreover, the foundations are laid for a broader discussion around the issue of training the professional figures who will be called upon to manage such complex, interrelated and systemic processes. What is prefigured is a new professional figure capable of managing the entire design process with a systemic vision through which human sciences are merged with technological research. The training process must therefore not only provide adequate knowledge of the enabling technologies but also deal with structuring an operational methodology to be developed concerning a holistic vision necessary for guaranteeing a future of prosperity and economic progress while ensuring a sustainable tomorrow for our planet.

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